Original Article

Food systems and life expectancy with rapid urbanisation in provincial China

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Background and Objectives: Health outcomes such as survival, minimal disability and well-being are presumptively dependent on food and ecosystems. An integral measure of the critical urban food system linkages to health problems is needed. Much of the current health change in cities could be attributed to short-comings in food systems which can pose threats to food security and food safety. Health problems have needed a reconceptualisation of present medical and nutritional constructs. **Methods and Study Design:** The present study is based on a situational analysis of food and the related ecosystems presumptively affected by rapid urbanisation in China. With an ecological information matrix, an Urban Food System Index with ten indicators which could influence food system outcomes and promote health and well-being has been developed. It uses sixteen data sets from the National Bureau of Statistics for all 31 provinces in China. The indicators were Locality, Climate, Biodiversity, Infrastructure, Transport, Population structure, Livelihood, Recreation and Socialisation, Personal security and Communication. The indicators for each province, scored between 1 (severe) and 5 (best), were used to predict life expectancy for China as a whole by multivariable regression analysis. **Results:** The best model explained 70% of the variance and had significant beta coefficients for population structure (proportion of juveniles) (-0.52, $p<0.0001$) and livelihood (food expenditure) (0.31, $p<0.05$). **Conclusions:** Population characteristics and livelihoods related to food systems can account for much of life expectancy as a health outcome. An index which captured this information is provided and could evaluate concurrently as well as prospectively food system-related health with urbanisation.

Key Words: ecosystem health disorders, urbanisation, rural, food systems, life expectancy

INTRODUCTION

In 2014 China resolved to enable a greater proportion of its population to reside in cities than in rural areas. The aim is that some 70 percent of the country's population, or roughly 900 million people, will be fully integrated into city living by 2025.[1-4] To minimise the impact on existing major metropolises, 2nd and 3rd tier cities will be the focus of this plan and efforts will be made to maintain rural linkages. This development brings with it major food and health system changes for both rural and urban peoples and creates uncertainty over China's ability to feed it's increasing population.[5] People's livelihoods, especially those to do with food and health, will change as will their ecosystems.[6] Dietary consumption patterns have already begun to change. Urban dwellers are already consuming a more varied diet than their rural counterparts; it is richer in animal proteins, fats, dairy and processed staple foods.[7,8] Inevitably, there will be incentives to better connect these urban precincts by road, river, rail and air, which will bring further change and costs to the rural sector.

Food systems in an urbanising China

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.

There are many characteristics of food systems which are affected by urbanisation. To support sustainable and healthy communities, food systems need to have circumscribed ecological dimensions and limited impact in the provision of basic needs, food services and livelihoods. They should be responsive to professional and community critical appraisal (involving risk appreciation), and take

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account of climate change and its mitigation. Food systems should enhance ecological resilience with due regard to questions of equity and ethics and, ultimately, health outcomes. Gibson et al (2015) have attempted to analyse health as it may be ecologically favoured or disordered and enumerate the current situations in urbanising China.[9]

Urban food systems, such as vertical farming and home gardens are gaining popularity.[10] Home gardens in urban areas contribute to health and well-being through improved social and community relationships and can offer a space for retreat in densely populated urban areas.[11] It is an urban reality of many growing cities in China, and elsewhere in Asia, that informal use of un-built land is turned to fruit and, especially, vegetable production by local residents. This is depicted graphically in a recent paper on urban farming and its related market-places in China.[12] Urban agriculture incorporates farming in city areas through mixed land use allowing cultivation to occur on much smaller plots of land. In China, it has become popular across the country as a means to promote urban sustainability and resilience by bringing food production closer to consumers and reducing its environmental footprint; encouraging awareness of food safety in response to major health incidences; and promoting environmental stewardship as urban air and water pollution proliferate in new cities.[13] As urban agriculture becomes more popular, it is actively reshaping urban and peri-urban space, breaking up the monopoly of concrete and strengthening rural and urban links.[13] Town planners are increasingly interested in this as a way of keeping the food system proximate to urban dwellers.

Our hypothesis is that an ecological appreciation of how food systems affect health profiles in cities would enhance food security, including food safety, and improve health and well-being outcomes. In this paper, we develop an urban food system index (U-FSI), which is likely to be associated with an ecosystem health disorder index which we test semi-quantitatively in regard to China as a whole. However, we intend that these be the basis of a participatory and flexible methodology to evaluate and monitor rapid urbanisation in China and elsewhere so that its ecological and food-related health outcomes can be optimised. For developmental and instructive purposes, we make estimates of the likely state of urban food systems and ecosystem-related health disorders for China as a whole, rather than any particular location, mindful of the huge differences on both food and health systems across the country.

The figures we present in this paper show only the most current situation for China, detailed trend analysis over the last decade may allow an understanding of how urbanisation might limit China's future food production - e.g. groundwater depletion, drying up of rivers, and the effect of extreme temperatures on water reserves. Similarly, the success of nutrient recycling through excreta catchment (e.g. urine for phosphorus) and food waste management as livestock feed and fertiliser will be critical. Item by item on the U-FSI, future scenarios can be explored.

METHODOLOGY

Urban Food System Index (U-FSI)

Based on the matrix of fourteen ecosystem characteristics identified in Gibson et al (2015), we have developed an index that could help us to understand the most important elements of urban and rural food systems which presumptively influence health outcomes.[9] The index is based on the requirements for optimal food system outcomes and, in turn, minimal health disorders, at least from an ecological point of view. The index is made up of ten indicators which could influence favourable food system outcomes within each province of China. The indicators have been given an objective score, which range from 1 (severe) to 5 (best), according to data collected from the National Bureau of Statistics of China for each province.[14] Scores were assigned based on how current situations in China contribute to desirable food systems and therefore better health outcomes. For each indicator we have chosen the criteria for best possible outcome on the basis of an extensive matrix published elsewhere.[9]

We hypothesise that, the higher the score for U-FSI, people in urban settings would be less likely to have an urban ecosystem health disorder (U-EHD). Initially, the scores have been formulated to determine and monitor food systems so that health disorders associated with urban ecology are minimised. However, substantiating this association in various urbanisation projects in China must await the accumulation of sufficient data. We intend the index to be applied to existing and newly urbanising communities in order that they can work out how to optimise their ecosystems so that food systems will favour health outcomes.

The *Urban Food System Index* has ten indicators which could influence favourable food system outcomes and promote better health and well-being:

1. Urban locality and its geography are both key factors in food system determination. Presence and proximity to food and water systems, food production in built-up communities and living and working where there are compatible geographical features can determine access to a variety of safe, nutritious food and clean water sources. It can even influence a person's dietary habits, their ability to cook and freedom of choice for hot or cold food, creating "harmony with nature" in changing seasons and weather. Urban gardens help to build community integration in many ways. They provide opportunities for physical activity, recreation and exposure to sunlight and nature. Gardens generate awareness of food safety, discourage waste, and create a healthy food culture, within which agriculture, education, health and nutrition operate.
2. Urban climate and weather patterns play an important role in stability of short-term and long-term food security influencing what is grown according to adaptability and resilience to seasonal changes or climate patterns.
3. Urban biodiversity and recognition of humans as ecological creatures - our biology relies on a diverse and nutritional diet for optimal health which makes us less susceptible to cognitive, homeostatic and immune function disorders. Abundant biodiversity allows for better nutritional variety and encourages human responsibility towards the environment.

4. Environmentally sound infrastructure and energy resources - An important role in the food system is having the correct infrastructure to grow, process and store food. Food growth, specifically non-meat products, relies on rich, fertile soil and safe, clean water for irrigation. Energy resources are a necessity in the cooking of food, therefore using renewable energy resources will maintain ecosystem services.
5. Transport mobility and ready access to public transport to enable transport of food and access to the food chain within an urban setting is important. The food distribution system should be environmentally, energy and cost-effective to deliver food in good (fresh) condition with little or no losses and a reduction in the use of packaging. Having access to public transport enables greater access to food, particularly in areas where supermarkets proliferate on the boundaries of cities.
6. Urban population structure and household differences affected by immigration and emigration can influence dietary habits, human development, child care and survival, obstetric care and ageing, and gender equality. Maintaining household stability and managing rural-urban migration can have positive effects on food choices and use. Women, in particular, benefit. They have more opportunities to learn about healthy food and nutrition, especially in the context of pregnancy, breast-feeding and child-raising.
7. Livelihoods are a major factor in the optimisation of urban food systems and their affordability. Food systems are usually the most resource and time dependent functions of a community and a source of livelihoods for many people. The increasing popularity of urban gardens and the increase in urban hukou transition can ensure rural migrants are able to maintain a source of livelihood and food security.
8. Recreation and Socialisation - The physical acquisition, preparation and consumption of food influences food choices, both within and outside the home. Increasing popularity of urban gardens helps to form community spirit and encourages social behaviour. Involvement in domestic food production promotes physical activity, awareness of the origin of food, and healthy diets. It also fosters a sense of identity with, and responsible behaviour towards, the environment. Exposure to green spaces and parks are also known to have associated physical and mental health benefits. [15]
9. Personal security is a common concern with urbanisation, and this includes food security. A sense of belonging and a source of livelihood can ensure the personal security of families who may have been displaced through urban sprawl.
10. Good communication builds trust among all key players in the food system. It is essential to promote transparency, and environmental and health consciousness throughout society. The more informed society is, the better equipped people are at making decisions and solving problems, providing a sense of control over their food supply and thus avoiding sources of conflict. The use of technology and advertising can connect consumers with producers, enabling them to track the origin of their food and how it was produced. Communication to producers can increase their knowledge about food production and reduction in overuse of chemical pesticides and fertilizers, while improving nutrient recycling, waste minimisation and reduction of antibiotic resistance genes (ARG's) in animal products.

Data inputs (measurement and operationalisation)

Sixteen sets of data were collected from the National Bureau of Statistics (NBS) for all 31 provinces of China for 2013 (Table 1).

These items were chosen based on judgement of possible suitability to each of our ten indicators and most probable influences on life expectancy. The data we have chosen are not uniform and are adjusted based on each province of analysis and availability of data. The 16 selected items are:

- Urban population and Total food production: It is well documented that urban residents are more likely to have better health status as presumptively they have

Table 1. Data sets representative of U-FSI indicators

Location and geography	Urban population (per 10,000) and Total food production (per 10,000 tonnes)
Climate and weather	Total crop area affected by natural disaster (per 1000 hectares)
Biodiversity	Total crop area (per 1000 hectares)
Infrastructure	Total water use by agriculture (per 100 million cubic metres) and Number of users of natural gas (per 10,000 people in private household)
Transport	Number of public buses and Number of private cars (per 10,000)
Population structure	Proportion of juveniles 0-14 (percentage of total population in each province)
Livelihoods	Average income (CNY) and Food expenditure (per person)
Recreation and socialisation	Number of parks and Area of green space per person (per square metre)
Personal security	Proportion of jobless population (percentage of total population in each province)
Communication	Number of households with TV programme coverage and Total users of internet (per 10,000 people)

Source of data: National Bureau of Statistics of China.
Data assessed: (Locality) Urban population and total food production; (Climate) Crop area affected by natural disasters; (Biodiversity) total crop area; (Infrastructure) Water use by agriculture and total users of natural gas; (Transport) Total number of public buses and number of private cars; (Population structure) Proportion of juveniles 0-14 years; (Livelihood) Average income and food expenditure; (Recreation and Socialisation) Number of parks and area of green space per person; (Personal security) Proportion of jobless; (Communication) Access to TV programme coverage and total users of internet.

better access to healthcare and live in areas where sanitation and treatment systems are well established.[16] In addition, levels of food production and proximity to food systems will influence a person's dietary habits and exposure to nutritious food. Generally speaking, relatively greater urban than rural populations are favourable as long as there is a correspondingly workable food system which supports health outcomes. Thus, each of these two variables, urban population and total food production, are scored 1-5.

- Total crop area affected by natural disaster: Although China has reduced poverty, hunger and malnutrition in accordance with the 2015 Millennium Development Goals, it needs to ensure food supply and food security remains constant as population increases. As urban climate and weather patterns can affect food production by influencing what is grown, resilience to seasonal changes and adaptability remain a priority. Maintaining a stable food supply is paramount in addressing the nutritional needs of a growing population. Thus, the less crop area affected by natural disasters, the better should be the health outcome. In this case, crop area affected is scored 1-5.
- Total crop area: Agricultural areas are generally assumed to be more influenced by human activity than are forested areas. Also, highly developed economies substantially reduce the amount of land under cultivation for more efficient, but ecologically risky agricultural technologies. Together, these phenomena tend to compromise biodiversity and the potential for dietary diversity. Our biology, however, still relies on a diverse and nutritious diet, sourced from both rural and urban areas, in order for us to have optimal health. Thus, total crop area is scored 1-5.
- Total water use by agriculture and Number of users of natural gas (as utilities and infrastructure): Environmentally sound infrastructure plays an important role in the food system. Food growth relies on the use and availability of water for irrigation. While many people in China eat out, traditionally people cook and eat most of their meals at home. A lack of cooking facilities can create a barrier to healthy living.[17] On this basis, users of natural gas were assessed only by household. Greater water use and more users of natural gas are each scored 1-5.
- Number of public buses and Number of private cars: Proximity and accessibility to food will contribute to food security. A healthy diet may be more difficult to obtain where public and private transport are limited in a community. Thus, greater access to transportation, represented by each of these two variables, number of public buses and number of private cars, are scored 1-5.
- Population structure (Proportion of juveniles 0-14): Urban population structure and household differences can influence inter-alia dietary habits, human development, child care and survival. The food system is vital for a number of factors contributing to population structure. These include healthy growth and development of children and adolescents, wellbeing, disease prevention, and life expectancy. To some extent, the proportion of juveniles is indicative of this food and health system relationship. Thus, a higher proportion of juveniles (0-14) are scored 1-5.
- Average income and Food expenditure: Regions with higher incomes are more likely to be food secure and experience better health assessed through morbidity and mortality statistics.[18] Poverty and food insecurity are associated with lower food expenditures, low fruit and vegetable consumption, and lower-quality diets which may result in higher consumption of energy-dense foods that contribute to ill health, like obesity.[19] In particular, it generally costs more to achieve a diverse diet, especially with fruit and vegetables, and this, in turn, is associated with life expectancy.[20-22] Average income and food expenditure are each scored 1-5.
- Number of parks and Area of green space per person: Exposure to green space has been associated with better physical and mental health.[15] Among the various ways in which this linkage might be achieved are ecological pathways and social activity.[23,24] The number of parks and the area of green space per person are scored 1-5.
- Proportion of jobless population: Social stability is, in part, dependent on earning a livelihood. Without a livelihood, personal security and social stability may be compromised. A key element of livelihood is food security with its relevance to health. Thus, the proportion of jobless population is scored 1-5.
- Number of households with TV programme coverage and Total users of internet: Two of the most common forms of communication technology are TV and the internet. The use of technology for advertising can promote an environmental and health consciousness. Access to a TV or the internet does not necessarily equate a longer life, it can be considered of influence in educating people about food-related health risks. The number of households with access to TV programme coverage and the number of internet users are each scored 1-5.

All corresponding data were standardised using the formula:

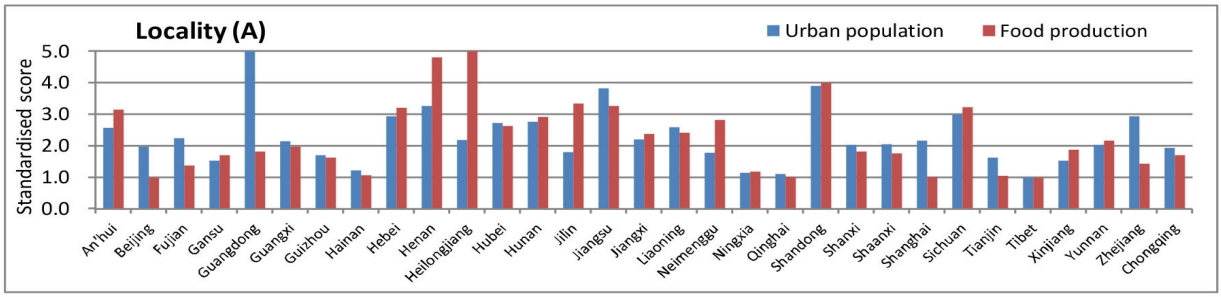
$$(5-1)\times\frac{x-\min}{\max-\min}+1$$

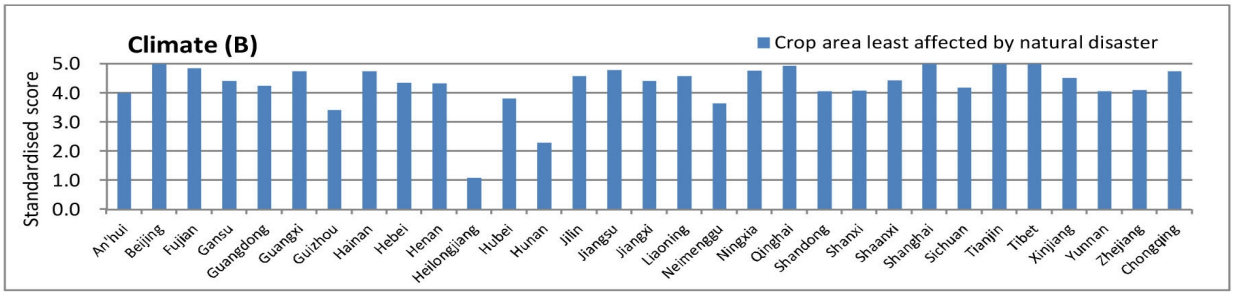
This gave a value between one and five. We determined that a value of 5 represented the best possible outcome while a value of 1 represented the worst possible outcome for each province. All scores were then plotted into histograms which correspond with each U-FSI indicator (Figure 1 (A-J)).

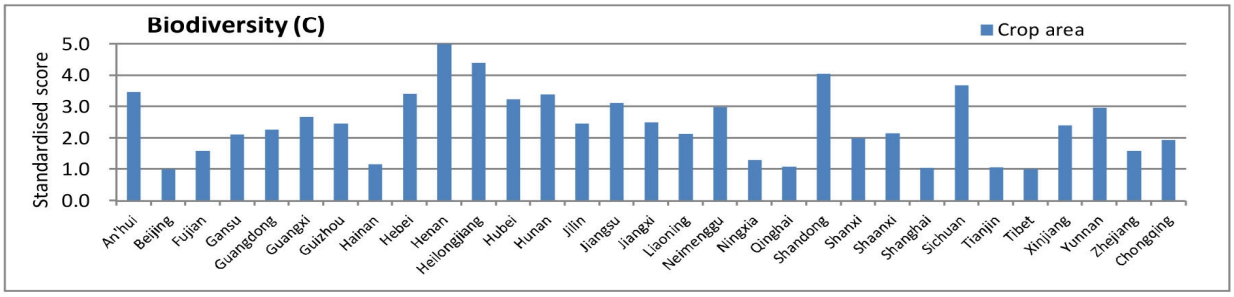
Data were also collected from NBS (2013) for life expectancy in all 31 provinces (Figure 2). The data were chosen so that we could perform multivariable linear regression (MLR) on the U-FSI indicators and life expectancy.

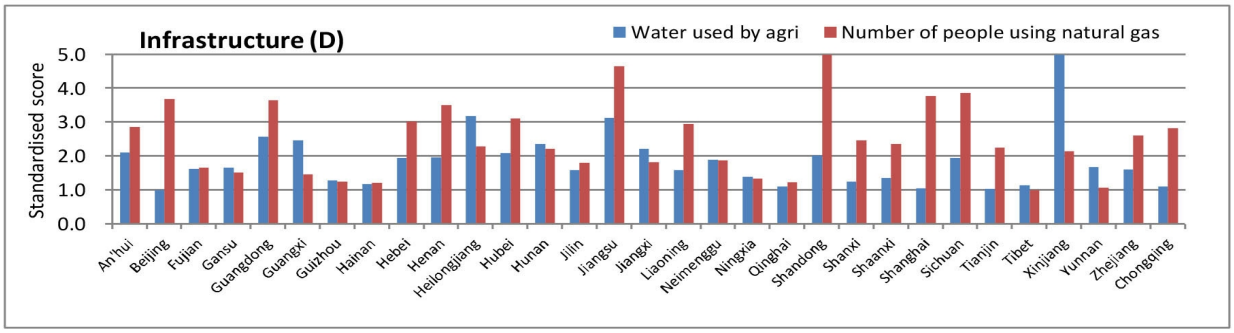
Figure 1 shows a number of items which have been chosen to represent the ten indicators which make up our U-FSI. In some cases, we have chosen two rather than one item per indicator.

While we do not show aggregates of the items as a histogram because of the differences between them in underlying methodology, we do consider that a simple









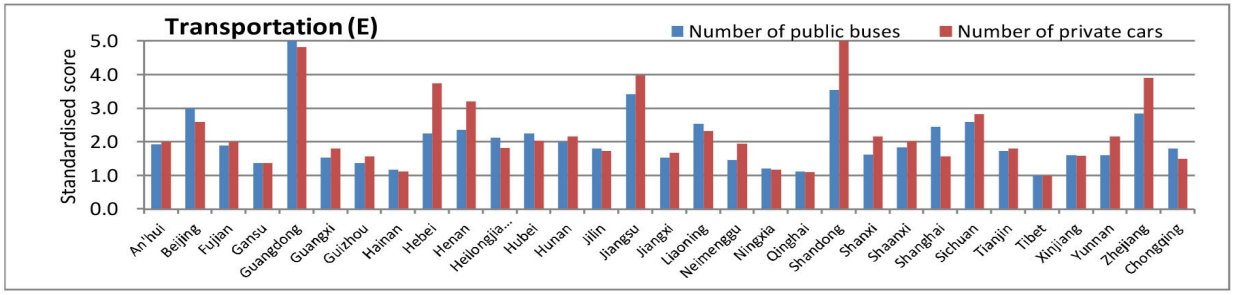


Figure 1. Urban Food System Indicators and their contributory items for China: Situation as at 2013. Source of data: (A-E) National Bureau of Statistics of China. Data assessed: (A) Urban population and total food production; (B) Crop area least affected by natural disasters; (C) Total crop area; (D) Water use by agriculture and total users of natural gas; (E) Total number of public buses and number of private cars.

addition of the standardised scores has validity for an U-FSI. These additions (with an average of 2 items within an indicator where that applies), shown in Figure 3a (Total score for each province) and 3b (Total score for whole nation), show the provinces less affected by urbanisation in terms of indicators within our U-FSI and also how the whole of China ranks according to our U-FSI. This allows for some insight into those localities which might be most amenable or least vulnerable to rapid urbanisation.

Statistical methods

Pearson correlation and VIF values assessed the associa-

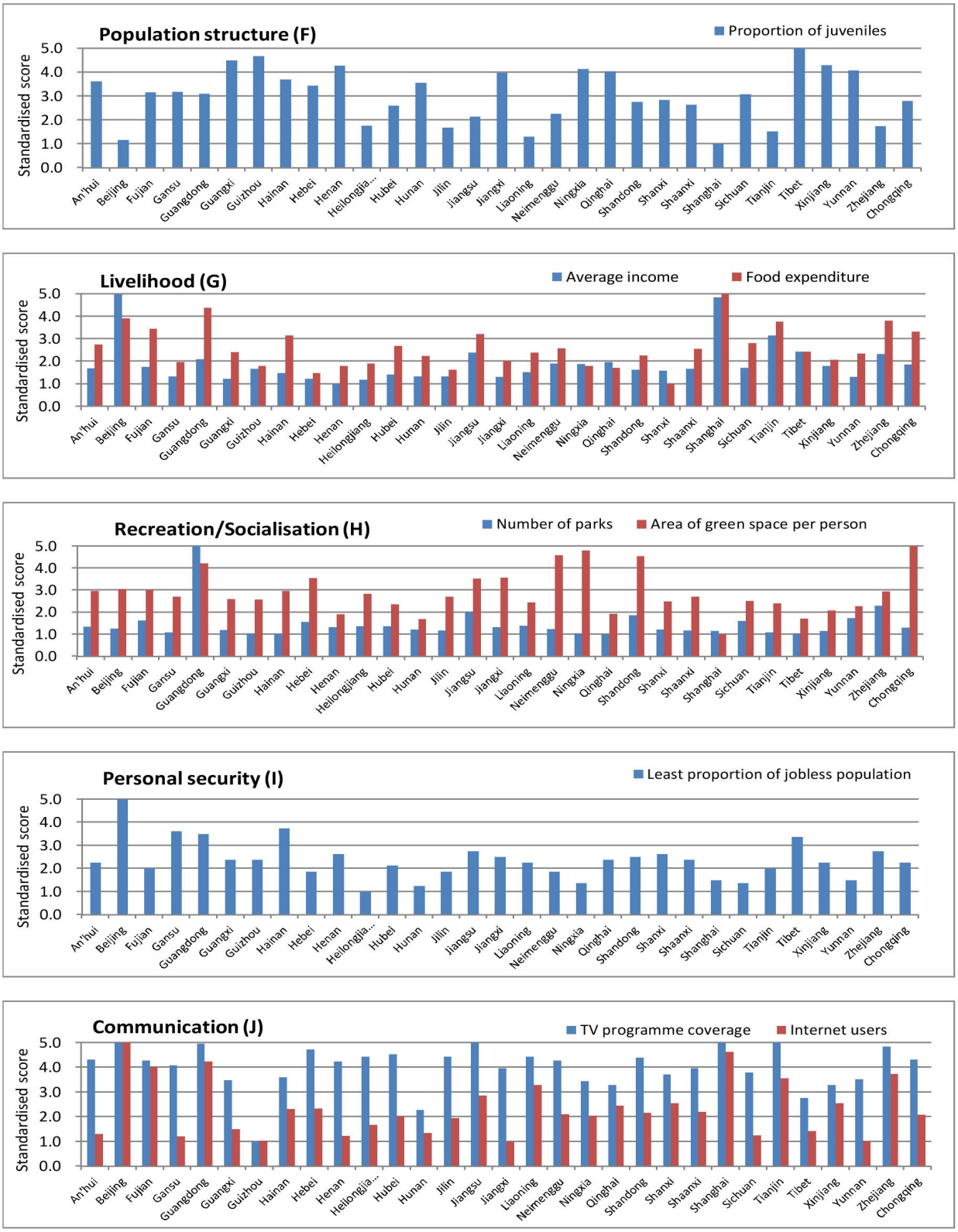


Figure 1. Urban Food System Indicators and their contributory items for China: Situation as at 2013 (cont.). Source of data: (F-J) National Bureau of Statistics of China. Data assessed: (F) Proportion of juveniles 0-14 years; (G) Average income and food expenditure; (H) Number of parks and area of green space per person; (I) Proportion of jobless; (J) Access to TV programme coverage and total users of internet.

tion between all sixteen items of our U-FSI. All data sets were taken as the independent variables and life expectancy as the dependent variable (Table 2). Among all of the variables, urban, number of users of natural gas, number of buses, number of private cars, proportion of juveniles, food expenditure, number of parks, number of households with TV program coverage, and total users of internet showed a significant relationship with life expectancy. Correlation analysis and VIF values for multicollinearity between independent variables were undertaken prior to multivariable regression and further analysis (Table 2). The absolute data were used for each independent

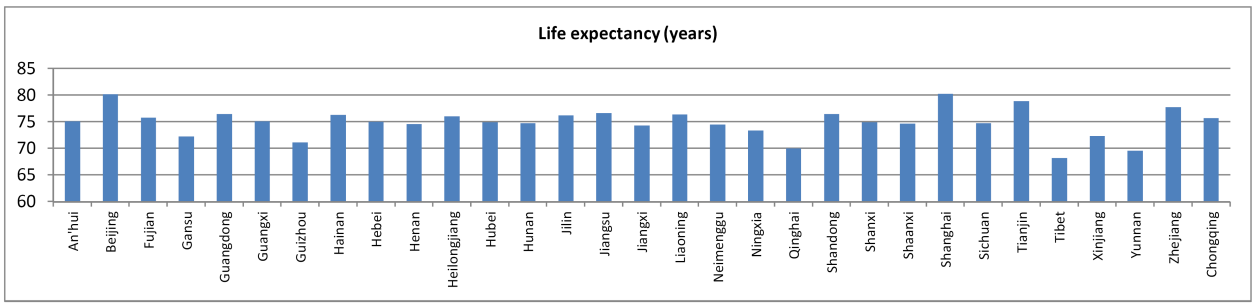
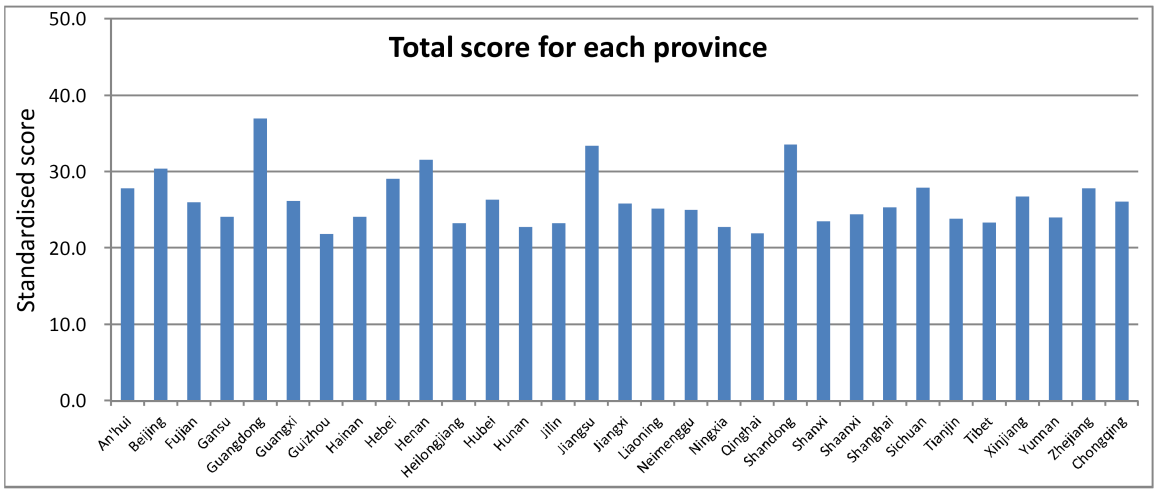
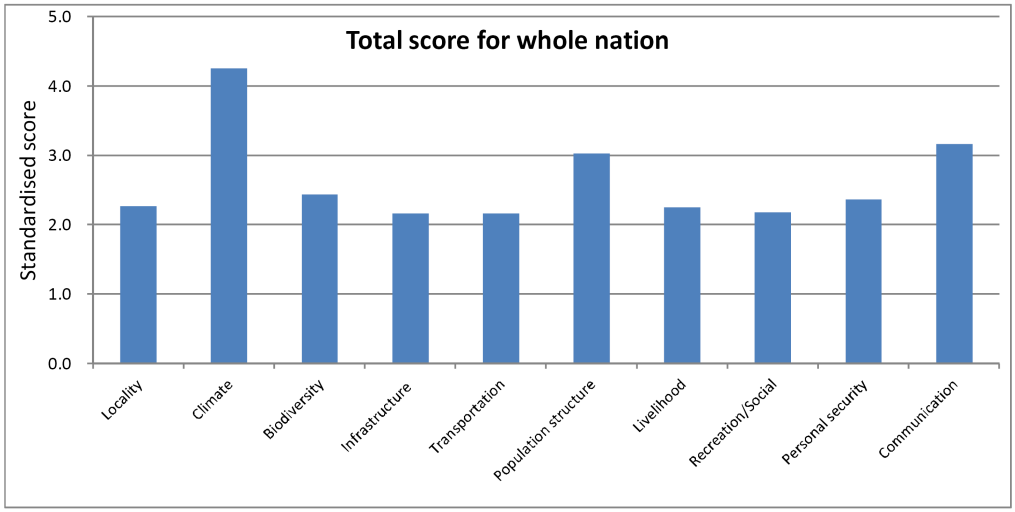


Figure 2. Life expectancy by province. Source of data: National Bureau of Statistics of China.



(A)



(B)

Figure 3. Total scores of urban food system indicators for each province and for whole nation. (A) Data assessed: total of each indicator expressed as a total for China. (B) Data assessed: total of each provinces score

variable in the regressions. $p<0.05$ was considered as statistically significant. All statistical analyses were performed using SPSS software version 19.0 for Windows.

In this paper we take a narrative approach to how and to what extent the U-FSI might account for the U-EHDI in China - and what may eventuate if the associations are or are not addressed. As this is a first attempt at producing an U-FSI scoring system, detailed relevant data have not been thoroughly collected or assessed, meaning that there is a degree of uncertainty associated with the results. The score of each indicator in relation to its current situation in each province in China is shown.

RESULTS

Urban Food System Index (U-FSI)

It can be seen that Guangdong, Jiangsu, Shandong and Henan province scored the best among all provinces, suggesting they are least affected by urbanisation in terms of our U-FSI indicators. On the other hand, Guizhou, Qinghai and Hunan and Tibet scored the worst, suggesting they are more vulnerable to rapid urbanisation. The indicators showing the best scores for the whole nation were climate, communication and population structure, while the worst scores were seen for infrastructure, transport, and recreation and socialisation.

Table 2. Multivariable **r**egression analysis for life expectancy using all ten indicators with VIF values for collinearity

Model	Coefficients†			t-statistics	*p*-values	Collinearity statistics‡	
	Unstandardised Coefficients		Standardised Coefficients				
	B	SE	β			Tolerance	VIF
(Constant)	1.08	1.78		0.61	0.55		
Urban population	-0.01	1.14	-0.01	-0.00	0.10	0.01	103
Food production	0.24	0.46	0.29	0.53	0.61	0.04	24.8
Crop affected by natural disaster	0.10	0.25	0.10	0.41	0.69	0.21	4.75
Crop area	-0.31	0.53	-0.37	-0.59	0.56	0.03	31.5
Water used by agriculture	0.04	0.16	0.04	0.27	0.79	0.57	1.76
Number of people using natural gas	-0.45	0.39	-0.53	-1.13	0.28	0.06	17.7
Number of buses	0.55	0.88	0.52	0.63	0.54	0.02	55.6
Number of private cars	-0.31	0.33	-0.36	-0.94	0.36	0.08	12.1
Proportion of juveniles	-0.30	0.26	-0.37	-1.12	0.28	0.12	8.60
Average income	0.21	0.31	0.22	0.68	0.51	0.12	8.22
Food expenditure	0.31	0.26	0.31	1.20	0.25	0.19	5.41
Number of parks	-1.50	0.67	-1.20	-2.24	0.04	0.04	23.6
Area of green space per person	0.22	0.14	0.24	1.62	0.13	0.58	1.71
Proportion of jobless	0.04	0.15	0.04	0.27	0.79	0.69	1.45
TV programme coverage	0.21	0.29	0.20	0.70	0.49	0.16	6.42
Internet users	1.48	1.34	1.35	1.11	0.29	0.01	121

Source of data: National Bureau of Statistics of China.
Data assessed: (Locality) Urban population and total food production; (Climate) Crop area affected by natural disasters; (Biodiversity) Total crop area; (Infrastructure) Water used by agriculture and total users of natural gas; (Transport) Total number of public buses and number of private cars; (Population structure) Proportion of juveniles 0-14 years; (Livelihood) Average income and food expenditure; (Recreation and Socialisation) Number of parks and area of green space per person; (Personal security) Proportion of jobless; (Communication) Access to TV programme coverage and total users of internet.
†Dependent variable: Life expectancy
‡Any variable with a VIF >10 was regarded as eligible for multivariable regression analysis
B indicates the values for the regression equation for predicting the dependent variable from the independent variable.
SE: standard errors; β: standardised coefficients; VIF: variance inflation factor.

Table 3. Prediction of life expectancy by food related indicators of the components of the Urban Food System Index (U-FSI) by multivariable linear regression analysis

	Model 1		Model 2	
	β	*p* value	β	*p* value
Constant	5.19	<0.001	4.01	<0.001
Proportion of juveniles	-0.65	<0.001	-0.52	<0.001
Food expenditure	-	-	0.31	<0.05
R^2	0.63		0.70	
xβ Regression coefficients for U-FSI components				

Source of data: National Bureau of Statistics of China.
Data assessed: (Locality) Urban population and total food production; (Climate) Crop area affected by natural disasters; (Biodiversity) Total crop area; (Infrastructure) Water used by agriculture and total users of natural gas; (Transport) Total number of public buses and number of private cars; (Population structure) Proportion of juveniles 0-14 years; (Livelihood) Average income and food expenditure; (Recreation and Socialisation) Number of parks and area of green space per person; (Personal security) Proportion of jobless; (Communication) Access to TV programme coverage and total users of internet.

The most notable results indicated that Guangdong scored 5 for four of the ten indicators, namely locality (urban population), transport (number of public buses), recreation and socialisation (number of parks), and communication (access to TV programme coverage). While Tibet scored 1 for six of the ten indicators, namely locality, climate, biodiversity, infrastructure (number of users of natural gas), transport, and recreation and socialisation (number of parks).

Stepwise regression analysis showed that the best model (Table 3) explained 70% of the variance and had significant beta coefficients for population structure (proportion of juveniles) (-0.52, $p<0.0001$) and livelihood (food expenditure) (0.31, $p<0.05$) Thus, there are provincial ecological characteristics related to food which can account for much of life expectancy as a health outcome.

DISCUSSION

Health problems are often not seen as food-related even though the more recent appraisal of the global burden of disease, and that for China in particular, rank dietary factors as first and foremost.[25] Across China's provinces at widely different stages of development and urbanisation, we have found that the food-related characteristics of population structure and livelihood together as an index can account for 70% of the variance in life expectancy (Table 3). There is scope for a deeper understanding of these relationships through a

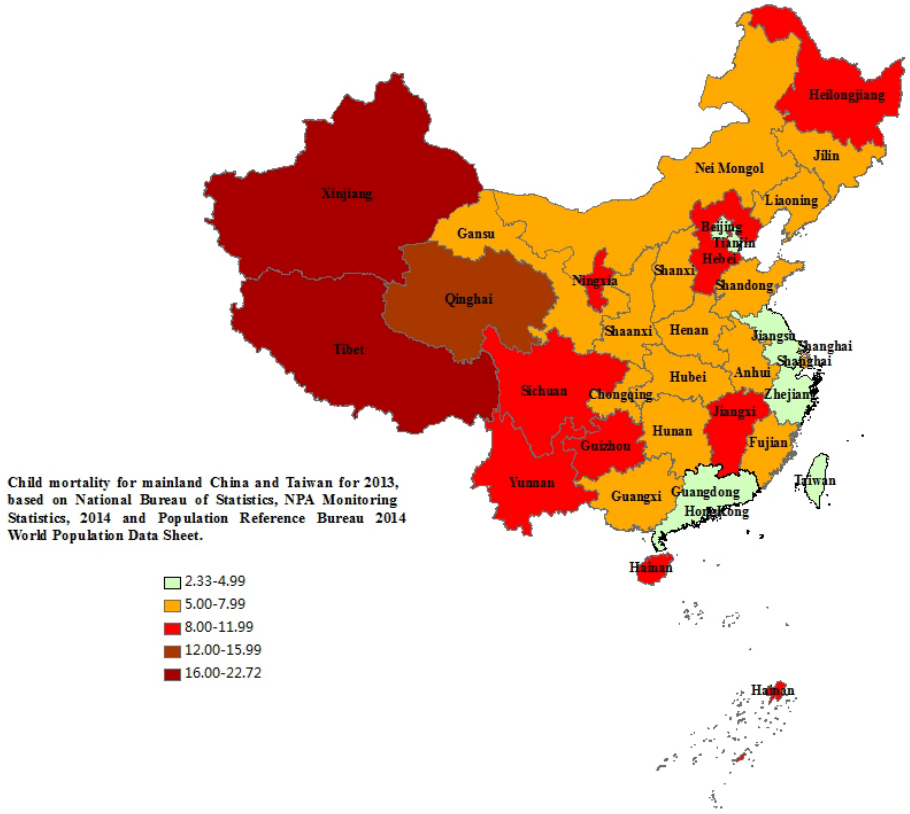


Figure 4. Infant mortality for mainland China and Taiwan for 2013, based on National Bureau of Statistics, NPA Monitoring Statistics 2014 and Population Reference Bureau 2014, World Population Data Sheet.

consideration of more health characteristics by province and then urbanisation precinct. The scope for this can be seen in the disparate infant mortalities across China (Figure 4).

The present approach sits well with the World Health Organisation-Food Agriculture Organisation (WHO-FAO) United Nations system food based dietary guidelines of 1995 which are intended to be regionalised and localised.[26] It has also been argued that these guidelines can be the basis of development strategy.[27] This paper also contributes to highlighting the importance that food and ecosystems have on health outcomes and future sustainable development, an issue the United Nations have recently addressed with the launch of Global Goals for Sustainable Development.[28] We now see how they are relevant to major population shifts and ecological transformations, like the envisaged acceleration of urbanisation in China.

Presently, the various dimensions of infrastructure, transport and recreation and social space are considered to be the three major ecological threats to food system security in China as a whole and as it urbanises rapidly. On the other hand, climate, communication and population structure are considered to provide the three best opportunities for life expectancy in China.

Insofar as we have gone, with a simple stratification of the population into children and youth 14 years or younger, we see this as a large determinant of ultimate life expectancy. If confirmed, this draws attention to the importance of intra-population and intergenerational dynamics in food-health relationships. It is consistent with the findings in the Taiwanese population question of dominantly Chinese ancestry, that the grandparental and grandchild generations co-share food habits.[22] This implies that a future population with limited inter-generational food system collaboration may be health disadvantaged. The question is to what extent these conventional indicators as used for international monitoring and comparison are associated with our U-FSIs. Among all variables considered, two were selected by multivariable regression (Table 3) with population structure as the most significant influence on life expectancy.

Likewise, the livelihood indicator, food expenditure, has a significant influence on life expectancy, in accord with the analysis in Gibson et al (2015).[9] Any livelihood factor is likely to be susceptible to exaggerated change with urbanisation. It can be argued that these associations might be bidirectional when, for example, average income and food expenditure contribute to our U-FSI, and feeds back on livelihood. In the meantime, the more money spent on food, the better the life expectancy, as found in Taiwan–wide studies of nutritional economics.[21]

An important item which we have not included in our U-FSI index due to a lack of data is Governance. Without solid data it is difficult to accurately assess here, however where data are available they should be included in the assessment. Good governance is recognised as a major influential factor in the food system.[29] Reliable and transparent governance should ensure the development of robust, secure and efficient urban food systems, conducive to public health. Adequate overall management of food and health systems at international, national and local levels ensures food is safe and secure for all.

Government investment in food waste facilities, recyclable packaging, and education on nutrient and fertiliser flows in cities should be fully utilised.[30] Emergency preparedness programmes should be developed and subsidy programmes to maintain food price levels should be encouraged.

It is somewhat surprising to us that two of our presumptive indicators in the U-FSI, climate and biodiversity, were not significantly associated with life expectancy. This may be because they are subsumed in the population indicator, along with that to do with food expenditure. The evidence for profound effects of ecosystems on human health, leading to survival prospects, is substantial.[9,23] Again, the importance of climate change for health has been articulated across several dimensions by Butler.[31] At present, we are limited in the information available in China to document the links between food systems, biodiversity, climate and health including morbidity and mortality at all ages. It is worth noting that this type of analysis, which considers climate and biodiversity, is still relatively new. Its future development with a broader range of inputs and outputs may provide a clearer picture of how food and health systems could be better integrated with rapid urbanisation.

While we have tried to gather and assess data which are applicable and relevant to our indicators, many data were unavailable. Ideally, the total number of senior citizens (65+) would be included in our assessment for population structure as would dietary habits of juveniles (0-14) as a large young population could be very poor and undernourished or it could be better off and well nourished. This would presumably show a greater correlation of this indicator with life expectancy than does our current assessment. Additionally, we chose the number of public buses and of private cars as transport indicators. A poor transportation system reduces access to food outlets-especially for those who are not car owners or have limited access to reliable and affordable public transportation. While income plays a key role in food access and shopping behaviour, transportation and access are also factors. Therefore, while ours may be considered tenuous indicators of food access, they nevertheless develop an understanding of how transport and access to food contribute to food system functionality and, in turn, promote health and well-being.

Similarly, since the number of parks and area of green space per person probably applies to urban areas, in some cases, as with large national parks distant from population centres, there may be less effect on health than with small parks within an urban precinct.

When we scored water use in agriculture, we presumed that this access to water source would contribute to food production and therefore to food security. However, with rapid urbanisation, it is not uncommon for such water to be diverted to non-food producing industrial activities.

Towards an Urban Ecosystem Health Disorder Index (U-EHDI)

An *Urban Ecosystem Health Disorder Index* could enumerate health disorders, known as ecosystem health disorders (EHDs), which may arise on account of ecological problems, including those responsible for difficulties with the components of the U-FSIs. In the case of U-EHDI, where we live, its biodiversity and whether the food system delivers a biodiverse diet would be among the most critical environmental associations.

Limitations

Generalisability

We argue that any urbanisation endeavour, especially one that is accelerated, requires a systematic analysis of its environmental and health consequences, including those mediated by the related food systems. China has improved the food security and health status of its peoples with astonishing speed, but at environmental cost. This has not happened uniformly across the country and the differences may become sharper with the planned rapid urbanisation in the years ahead. We have made an assessment of the risks by calculating objective scores in a semi-qualitative way from a collection of available data sets sourced from the National Bureau of Statistics of China, by which, by its nature, are incomplete and subject to misinterpretation.[14] Nevertheless, it serves to demonstrate the way in which disparate data may be required to understand the more fundamental ecosystem basis of health disorders than is allowed by the conventional biomedical model. The biomedical model usually starts with clinical or public health epidemiology as the framework, an international classification of disease (WHO International Classification of Disease), and operationalised in clinical practice by way of diagnosis and management.

The model we present, with its connections between ecosystems and food systems during urbanisation and as pathways to overall health outcomes could be the basis of program evaluation and management. While we have considered China (as provinces and as a whole), we expect our approach to be more robust local setting-by-setting. That said, county and global factors will always play an important, even over-riding, role in the analysis.

It must be emphasised that we have looked at life expectancy on a regional rather than an individual basis. It is inevitable that, within each region, there will be a range of food and food system associations. Some of these will depend on local ecology, culture and socio-economic status. An important candidate for consideration in future work would be the relative contributions of plant and animal-orientated food systems for incorporation into evolving urban environments and how they might affect health outcomes.

In this paper, we have focussed on a range of indicators which might be associated with life expectancy, but also with economic development and ecosystem sustainability. It must be acknowledged that competing pathways may operate in such associations. It is likely that our methodology both underestimates and overestimates food and health system interaction.

WHO health concepts

In the present paper, we have not pursued by way of multivariable regression, health dimensions other than life expectancy, presently the most available health data base by province in China. There will be considerable merit in applying hype methodology to infant mortality rates, maternal mortality rates and to disability adjusted life years

(DALYS). Extensive data of this kind and in detail have been adduced for the whole country.[25]

Present & future

The tempo of ecosystem change and urbanisation is such that an approach, like the one advanced here, needs earnest attention, for all its imperfections.

Risk communication

The risk analysis which emerges from this and related work needs ownership and input at the population level. This will enable more effective risk communication and management.

Conclusions

Common health issues related to food availability are scarcity, quality, and food and nutrition disorders.[32,33] Lack of well-being occurs if people are food insecure. There are changing patterns of food and nutrition related diseases (FNRD) largely attributable to ecosystem loss and change (which also contributes to other health domains). The ultimate measures of health to which the WHO subscribes remain those of well-being, child and maternal health, disability and mortality, although the threats to these outcomes are increasingly ecological. Our study supports the view that population structure and livelihood can predict life expectancy in China. Although biodiversity and climate were not demonstrably linked to life expectancy in the present analysis, better data and more sophisticated pathway analysis would very likely provide this evidence given the collateral findings available from other studies. Future work with the more complete WHO health criteria should be worthwhile. In addition, we expect to further systematise EHDs so that they may serve as dependent variables in similar analyses.

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AUTHOR DISCLOSURES

The authors declare no conflict of interest.

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Original Article

Food systems and life expectancy with rapid urbanisation in provincial China

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快速都市化下的中國各省糧食系統及平均餘命

背景與目的：健康指標如存活狀況、失能極小化及安適，被認為與糧食及生態系統有關。都會糧食系統與健康問題的關連需要一個關鍵且整體的措施。多數城市目前的健康轉變可歸因於糧食安全及食品安全的糧食系統缺失。健康問題需要重新建構醫療及營養的概念。**方法與研究設計：**本研究是基於糧食與相關生態系統受中國快速都市化影響所推斷的狀況分析。使用一個生態資訊矩，發展出一個可影響糧食系統結果與促進健康及安適的城市糧食系統十個指標。資料來源為 16 個涵蓋中國 31 省的國家統計局資料庫。這些指標包含區域、氣候、生物多樣性、基礎建設、交通、人口結構、生計、娛樂及社會化、個人安全及溝通。各省的指標計分為 1（嚴重）到 5（最佳），將此分數代入複迴歸分析，以預測中國整體的平均餘命。**結果：**最佳模式解釋 70%的變異，其中人口結構（未成年人口的比例，-0.52，p<0.0001）及生計（糧食支出，0.31，p<0.05）的迴歸係數達統計顯著水準。**結論：**人口特性及生計與糧食安全的相關，可以大幅解釋平均餘命這個健康指標。提供一個涵蓋這些資訊的指標，能評估隨著都市化現階段及前瞻糧食系統相關的健康議題。

關鍵字：生態健康失調、都市化、鄉村、糧食系統、平均餘命