Asia Pac J Clin Nutr 2010;19 (3):402-411

Original Article

A recycling index for food and health security: urban Taipei

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The modern food system has evolved into one with highly inefficient activities, producing waste at each step of the food pathway from growing to consumption and disposal. The present challenge is to improve recyclability in the food system as a fundamental need for food and health security. This paper develops a methodological approach for a Food Recycling Index (FRI) as a tool to assess recyclability in the food system, to identify opportunities to reduce waste production and environmental contamination, and to provide a self-assessment tool for participants in the food system. The urban Taipei framework was used to evaluate resource and nutrient flow within the food consumption and waste management processes of the food system. A stepwise approach for a FRI is described: (1) identification of the major inputs and outputs in the food chain; (2) classification of inputs and outputs into modules (energy, water, nutrients, and contaminants); (3) assignment of semi-quantitative scores for each module and food system process using a matrix; (4) assessment for recycling status and recyclability potential; (5) conversion of scores into sub-indices; (6) derivation of an aggregate FRI. A FRI of 1.24 was obtained on the basis of data for kitchen waste management in Taipei, a score which encompasses absolute and relative values for a comprehensive interpretation. It is apparent that a FRI could evolve into a broader ecosystem concept with health relevance. Community end-users and policy planners can adopt this approach to improve food and health security.

Key Words: food system recycling index (FRI), food security, econutrition, food waste, recyclability

INTRODUCTION

There is growing concern about the safety, security, and sustainability of our global food supply.[1] Food systems have evolved from the adoption of agriculture, to the Green Revolution,[2,3] to genetic modification, and finally, overproduction.[4] Technological and agricultural advances have helped diminish famine in recent history. With the population density continuously rising,[5] however, the threat of food insecurity has become reality even in wealthy nations.[6-8] In that respect, the Green Revolution could have been either the cause or effect of population growth. Having impacted mainly staple crops such as wheat and rice, it significantly improved the availability of sustenance to the hungriest. However, critics point out that this development only benefited those with access to irrigation or high-potential rainfall, leaving small farmers unaffected or distressed with costlier inputs and lower product prices.[3] Food producers who did benefit from the Green Revolution provided plentiful foodstuffs at the expense of environmental degradation. Agricultural productivity in some parts of the world has reached a point of surplus in food supply, leading to enormous food wastage.[9] Further, there is a strong imbalance in the distribution and access of food worldwide, especially between developed and developing countries.[10]

It is evident that the high inputs required at each step of the food chain do not yield desirable products only. There are wasteful outputs created in growing, processing, delivery and consumption of food, rendering an inefficient system.[11] Agriculture is the largest consumer of energy through fossil fuel, yet this part of the food system has high energy losses in the form of heat and emissions.[12] Heavy application of nutrient-rich fertilizers and agrochemicals can further impact soil nutrient balance,[13] water and air quality, and biodiversity, all of which can contribute to environmental and health detriments.[9]

Tainting the environment in which we obtain our food creates serious concern for food safety and security. Human health depends on the adequacy and quality of food. Moreover, it is becoming more evident that there are strong links between health, nutrition, and environmental sciences, particularly in how food is produced. *Econutrition* highlights biodiversity as essential for the maintenance of a healthy and varied diet, as well as for environmental buffering against climate change that may affect food supply.[14,15] Thus, the ideal relationship would be: ↑*Environmental health* → ↑*Biodiversity* → ↑*Food diversity* → ↑*Food security* → ↑*Human Health*

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Manuscript received 04 January 2010. Revision accepted 29 January 2010.

The interactions between each factor are complex and require integrative analysis to be well understood. There is general agreement that "as economies expand and populations grow, the need to protect ecosystems in order to maintain the flow of environmental/ecosystem services [upon which the food chain depends] is also increasing".[16]

The current challenge is to improve efficiency in the food system as a fundamental need for sustainability. A Food System Recycling Index (FSRI) would be valuable in assessing current food production methods. This methodological paper proposes a new tool to evaluate recyclability within the food system, to identify opportunities to reduce waste production and environmental contamination, and to provide a self-assessment tool for participants in the food system.

Urban Taipei, Taiwan

Taipei city is one of the most urbanized cities in Asia, with a population density of 9,593 persons per square kilometre.[17] Prior to 2001, municipal waste in Taiwan was disposed mainly through the use of landfills and incinerators. The constructions of garbage disposal facilities were met with strong protest; these were testimony that residents of the small and densely packed island unwelcomed having rubbish in their own backyards. Furthermore, alternatives were needed to prevent harmful environmental and health outcomes within a large population.

Beginning in July 2002, the Taiwan Environmental Protection Administration (EPA) established a waste minimization program, which enforces mandatory garbage sorting and expansion of the scope for waste recycling. Diversified waste management strategies were implemented to achieve the goal of a "Zero Waste" society.[18]

Kitchen waste such as leftover meals, fruit and vegetable peelings, and food scraps, received particular attention in its collection and handling. Currently in Taipei, it is separated by the community as cooked waste for feeding pigs or raw refuse to be composted.[19] This practice has long been used in traditional farming; however its feasibility in the urban setting has seldom been challenged. Taiwan's food waste proportion is about a third of all municipal solid waste (MSW) composition.[20] The collection of kitchen refuse has risen from 167,304 tonnes/year (2.19% MSW) in 2003 to 721,472 tonnes/year (9.21% MSW) in 2009.[21,22] This had decreased the amount of trash weight by 31.4% within six years,[21] alleviating the pressure on landfills and incinerators. In the UK, where there is also major concern towards food waste, only 2% food waste is separately collected for composting.[23] The improvements in waste reuse and recycling have made Taipei City an international exemplar for recycling management in Asia.

Kitchen waste recycling is important because of the high organic content which can be returned to the food system.[22] The continuous flow of energy and nutrient in the food system demands a renewal of waste back to its source. Recyclability ensures that the food cycle does not stop at the hands of consumers. In Taipei City, the household and commercial end-users of food products are particularly involved as participants of waste management. Using government-authorized trash bags, residents wait with their rubbish at a designated gathering point by the street, where the garbage truck arrives playing well-known classical tunes (e.g., Beethoven's "Für Elise", or Badarzewska's "The Maiden's Prayer").[24] Rather than leaving the bags to be picked up by garbage collectors or automatic waste collection vehicles, as is the case in most countries, residents toss the bags onto the trucks themselves.[24,25] With the responsibility of garbage sorting in their own hands (improper disposal results in fines), in addition to the societal pressure to conform, community awareness and ownership for environmental protection has been promoted.

The successful implementation and positive results in Taiwan provide evidence that integrated waste management must become a policy priority. On this basis, there appears to be an opportunity to evaluate the possibility of recyclability in Taipei. There are indicators that can be used to monitor the progress of Taipei's goals. For example, the city employs the Resource Recycling Rate (RRR):[19]

$$[(\text{Compost Quantity} + \text{Resource Recovery Quantity}) / (\text{Garbage Output including Resource Recycling Quantity})] \times 100$$

Different methods have been adopted to evaluate environmental friendliness and sustainability of products and processes. Perhaps most commonly used, the Life Cycle Assessment (LCA) follows production processes to evaluate broader environmental impacts, including materials and energy consumed. While there are variations of LCA (e.g., economic based LCA, hybrid LCA), the method has four components: Goal and Scope Definition, Life Cycle Inventory, Impact Assessment, and Improvement Analysis.[26,27] Because of the difficulty to address different energy forms, arbitrary value ratios or a hierarchy of metrics are used to derive an aggregate value. When quantifiable data are unavailable, such as for many ecosystem services, these factors may be ignored since they cannot be represented through a common unit.[27]

The research community is realizing the need for holistic assessment methods that address both qualitative and quantitative relationships in the ecosystem.[28] With respect to the food ecosystem framework, it is imperative to take into account the recyclability of resources. To explore this approach and possible methodology for a Food Recycling Index (FRI), urban Taipei has been used as a case study.

Food Recycling Index (FRI): Approach and Framework Setting

Recycling indices usually refer to the changing market price of recyclable commodities, such as textiles, rubber, plastic, and metal. The assignment of economic worth to recyclable items may not reflect underlying environmental costs and benefits. Instead, those reflected tend to be ones associated with the collection and processing of recyclable materials,[29,30] rather than the costs and benefits in the provision of what are likely to be valuable ecosystem services.

Using a food system framework for a recycling index, the impact of food waste handling on the efficiency of the whole food system could be elucidated. On the basis of data for kitchen waste management in Taipei, it is apparent that a Food Recycling Index (FRI) could evolve into a broader ecosystem concept with health relevance. The overall framework for a FRI would address energy, resource and nutrient flow, specifically in the food pathway, from production to utilisation or disposal.

The generic phases of the food cycle, which would be the basis of a food systems framework, are:

Agricultural Production → Processing → Distribution → Consumption → Waste management

In order for a FRI to encompass all the major processes involved in each phase, quantitative and qualitative relationships will need to be understood. Using a participatory approach, FRI may involve active participants in the food system – agriculturalists, manufacturers, and community end-users – to contribute to the formation of this index. With a closer understanding of underlying procedures in their own ecosystem, participants could provide valuable insight and ensure that important and complex relationships between the processes are not overlooked. These may include factors associated with food culture, historical values, and local economy.

Against this background, the eligibility of food consumption and food waste management for a place in a FRI for urban Taipei has been evaluated.

MATERIALS AND METHODS

A stepwise approach for the development of a FRI is described in this section. Following these steps, estimates relevant to the Urban Taipei framework were systematically explored, providing applicable information for this preliminary assessment.

Methodological Steps for a FRI

Identification of the major inputs and outputs in the food chain

Inputs are the additions or resources required in order to carry out each process in the food cycle (See 'generic food pathway' in previous section). These may include, although are not limited to, energy (e.g., electricity, food calories), natural resources (e.g., water, fossil fuel, biogas, wood), nutrients (e.g., fertilizer, animal feed), and agrochemicals (pesticides, herbicides, veterinary chemicals). Outputs are the products or by-products that result from each process in the food cycle. For example energy (e.g., calories, heat), nutrients (e.g., food, animal feed, fertilizer), and waste (e.g., water, excreta, contaminants, pollutants, packaging).

Classification

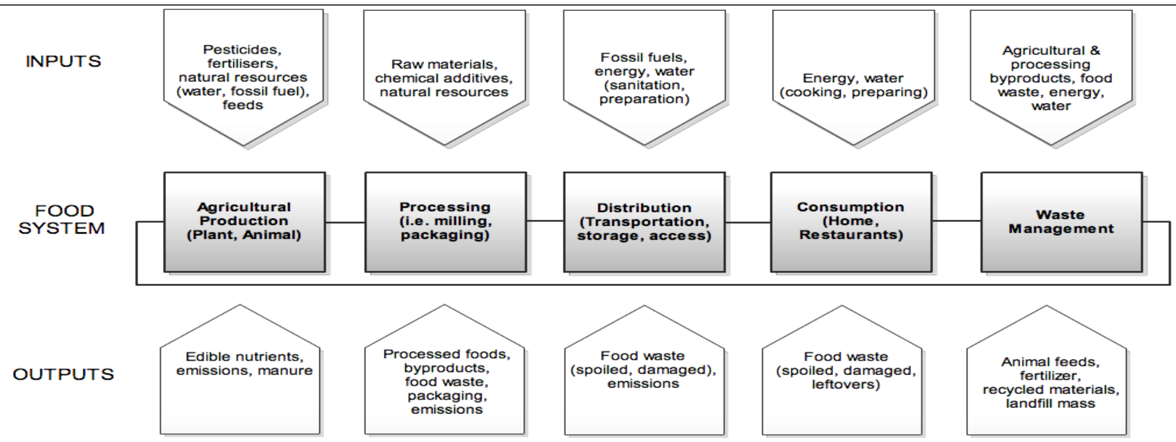
The inputs and outputs are allocated to modules, classified as energy, water, nutrients, and contaminants. These components were selected for their relevance to health and food security, particularly in terms of econutrition.

Scoring

Using available data for inputs and outputs (quantitative or qualitative), an estimate score is given for each cell in a matrix (Figure 1). The relative rating scale ranged from 1 to 5. That is, a semi-quantitative score representing none/minimal (1), low (2), moderate (3), high (4), or very high (5) input required/output produced.

Figure 1. Overall food cycle and the inputs and outputs at each intermediate step. Estimated FRI scores were given for the penultimate and ultimate steps of the food system, using the Urban Taipei framework

Inputs	FRI Score Matrix				
	Agricultural Production	*Processing*	*Distribution*	*Consumption*	*Waste Management*
Energy	NA	NA	NA	4	3
Water	NA	NA	NA	3	1
Nutrients	NA	NA	NA	4	2
Contaminants	NA	NA	NA	2	2



Outputs	FRI Score Matrix				
	Agricultural Production	*Processing*	*Distribution*	*Consumption*	*Waste Management*
Energy	NA	NA	NA	3	2
Water	NA	NA	NA	2	1
Nutrients	NA	NA	NA	3	3
Contaminants	NA	NA	NA	2	2

NA indicates Not Available at present
Rating scale: none/minimal (1), low (2), moderate (3), high (4), or very high (5) input required/output produced.

Recyclability Assessment

Recyclability was assessed by identifying outputs that were reused, perhaps after processing, in a subsequent or antecedent phase of the food system. Consideration was given to the possibility of recycling certain outputs, although it may not have been actively done in the system being assessed; this would be referred to as 'potential recyclability'. Depending on the objectives of the FRI, either may be used. Thus, the recycling ratio should reflect the absolute fraction of recycling achieved, as well as the relative proportion of the total recyclability potential.

Recyclability conversion to create sub-indices

Standardization was performed for each module (i.e., energy, water, nutrients and contaminants). This was obtained in a similar way to the Resource Recycling Rate:[19] i.e., (input value/output value)×100. Its semi-quantitative nature implies the existence of relative and absolute values to be gained from this index.

Derivation of Food Recycling Index

The sub-indices were converted to an aggregate index score, FRI, for the pre-defined framework.

Estimates for Urban Taipei

In examining the urban Taipei framework in this paper, the focus was that of the penultimate and ultimate steps in the food system, *consumption* and *waste management*, which have high potential for recycling.

Publicly available data from the EPA and municipal government websites in Taiwan were used. National estimates were used in addition to those for Taipei where data sets were incomplete or unavailable (e.g., in the same year for a particular measurement); this is indicated where it applies. Interpretations were based on the most recently available data, with due regard for comparability (Tables 1 and 2). The primary purpose of this paper is to demonstrate how a step-wise approach can be used to obtain a Recycling Index.

Consumption inputs and outputs

Energy

The available food per capita per year in Taiwan in 2008 was 2672.63 kcal/d.[31,32] This is 1.2 times the recommended daily intake (2,200 kcal/d) for an adult. Although this is the projected availability, actual consumption is unlikely to reach the estimate. The most recent Nutrition and Health Survey in Taiwan (NAHSIT) 2005-2008 provides Taiwan-wide representative values for dietary intakes and, when made available, will allow a more accurate picture of energy throughput in the food system. In addition to food ingredients and personal exertion, cooking requires energy in the form of electricity, gas, wood or kerosene, depending on the appliances used. These inputs at home and by way of restaurant usage are not taken into account in this paper, which offers an approximation (and small under-statement) for the energy inputs into the latter end of the food system. The energy

Table 1. Estimated inputs for food Consumption and Waste Management in Taipei City. The scale and year for which the values represent are placed in parentheses

Inputs	Taipei City Estimates	
	Consumption	*Waste Management*
Energy	2,673 kcal/d available per capita (Taiwan 2008)[31] *Gas and energy used for cooking; home and restaurant usage*	81,310 tonnes food waste (Taipei 2009)[33] 721,472 tonnes food waste (Taiwan 2009)[21] *Collection vehicles and processing machinery*
Water	*Household water usage for cooking and kitchen cookware cleanliness*	*Facility and machinery sanitation*
Nutrients	Macro- and micronutrients available per capita[32]	*Kitchen waste nutrient composition* 30.56% food waste in MSW (Taiwan 2008)[20]
Contaminants	*Agrochemicals and non-food additives*	*Waste oil, non-food additives*

Italics are used where there is limited confidence in the evidence, or numerical data is inaccessible.
MSW: Municipal Solid Waste

Table 2. Estimated outputs from food Consumption and Waste Management in Taipei City. The scale and year for which the values represent are placed in parentheses

Outputs	Taipei City Estimates	
	Consumption	*Waste Management*
Energy	1%[†]-13%[‡] unconsumed calories *Waste oil*	21,899 tonnes pig feed (27% kitchen waste); 59,411 tonnes compost (73% kitchen waste) (Taipei 2009)[33,34]
Water	72% Household sewage treatment rate[§] (Taipei 2004)[35]	*Facility sewage treatment[†]: 22% (Taipei 2004)[35]*
Nutrients	30.56% food waste in MSW (Taiwan 2008)[20] *Additional loss due to denaturing*	*Pig feed nutrient composition* *Compost nutrient composition*
Contaminants	*Waste oil, non-food additives*	*Leachate and emissions*

Italics are used where there is limited confidence in the evidence, or numerical data is inaccessible.
[†](81,310 tonnes food waste in Taipei[33])/(5,623,700 tonnes gross food supply in Taiwan[32])*100=1% output
[‡](721,472 tonnes food waste in Taiwan[21])/(5,623,700 tonnes gross food supply in Taiwan[32])*100=13% output
[§]Percentage of water pollutants removed from total sewage produced.

outputs resulting from consumption taken into account relate to the discarded excess food, which ranged up to 13% of the available food supply. While fat is high in energy (9 calories per gram of fat), used cooking oil is generally not included in food waste estimates, although this oil may be captured illegally or legally with separative technology for use as biofuel or, illegally, recycled into food.[36,37]

Water

Household water usage includes activities such as bathing, washing, cooking, and drinking. It is difficult to estimate the volume related to food consumption (e.g., washing, cooking, cleaning cookware), especially since there is variation within populations. Surveys have been developed for individuals or households to perform self-evaluation.[38] Such tools could be adapted or expanded to fit a FRI. Sewage treatment rates could be used to estimate water output from obtained input volume. Again, these kinds of information have been used with the required caveats.

Nutrients

Taiwan's macro- and micronutrients availabilities per capita are listed in Table 3. Just as with available energy per capita, these values are likely overestimates of actual dietary intake. The NAHSIT data will also be valuable in improving accuracy for this assessment step. As for outputs, kitchen waste accounts for 30.6 % of MSW mass,[20] although nutrient composition will vary appreciably. Further, there are additional nutrient losses due to water solubility or heat lability depending on the cooking method and time.

Contaminants

Agrochemicals (e.g., pesticides, herbicides, fungicides) and veterinary chemicals (e.g., growth hormones, antibiotics) used in food production can be non-biodegradable or toxic.[13] Non-food additives are also often incorporated for specific functional benefit, such as prolonged shelf lifetime. These can each vary greatly depending on the production method and origin of the foods. Prolonged and careless use of cooking oil can also make it less chemically safe, most seriously in regard to toxic lipid derivatives with potential carcinogenicity;[39,40] it is a significant discard in Asian cooking.

Table 3. Macro- and micronutrients availability and consumption in Taiwan

Nutrient	Availability per caput per day	Recommended Dietary Allowance (Adult)	
		Male	Female
Protein (mg/d)	85	56	46
Fat (mg/d)	110	65	65
Carbohydrate (mg/d)	330	130	130
Calcium (mg/d)	516	1000	1000
Phosphorus (mg/d)	1,115	700	700
Iron (mg/d)	13	8	18
Vitamin A (IU/d)	7,886	3000	2333
Thiamine (mg/d)	1.4	1.2	1.1
Riboflavin (mg/d)	1.3	1.3	1.1
Niacin (mg/d)	15	16	14
Ascorbic Acid (mg/d)	140	90	75

Source: Taiwan Council of Agriculture.[32]

Waste Management inputs and outputs

Energy

Kitchen waste collection is a determinant of how much food-derived energy goes towards waste management. In 2009, approximately 81,310 tonnes food waste was collected in Taipei City, and 721,472 tonnes nationwide. Kitchen waste recycling has reached a rate of 1,900 tonnes/d.[34] Energy is also required to maintain collection vehicles and machinery in the recycling facilities, such as automatic rollers and pressers.[19] Kitchen waste in Taiwan is used to produce pig feed (~25%) or fertilizer (~75%).[33,34]

Water

For sanitary reasons, water is currently required in waste management facilities; however, this should be minimisable.

Nutrients

As mentioned previously, nutrient composition in kitchen waste will have intrinsic variation. This will affect the nutritional value in compost (which will affect it further in any case), as well as swine feed. Due to this variation, food waste is often used to supplement livestock, rather than used as the main feed.

Contaminants

Discarded cooking oil poses environmental and health risks, particularly if it is handled unhygienically. Poorly managed waste facilities can also threaten environmental safety through toxic leachate (liquid drained from garbage) or emissions. In the case of gaseous outputs, there is growing potential to convert this to energy with more advanced technologies.[41]

RESULTS

Recyclability Assessment – Urban Taipei

The estimates for Urban Taipei were evaluated to assign scores for each input and output (Figure 1, upper and lower Tables). Table 4 presents the derivation of the FRI using recyclability ratios for each module; that is, the ratios of input to output scores for energy, water, nutrients and contaminants. Since consumption outputs were reused as inputs for the waste management process, this ratio was also incorporated as 'Consumption output/ Waste Management input'. Greater recyclability ratios represented higher inputs used to produce the resulting outputs for each module. The rate of inefficiency, or wasteful products created, is the proportion over 1.00 multiplied by 100 (i.e., average ratio for energy is 1.28, hence its usage was 28% inefficient). Since a ratio less than 1.00, meaning output is greater than input for the same process, may be invalid or unlikely unless, for example, there was energy capture by the process, the FRIs retained have been those equal to or greater than 1. Only the contaminants module had an average ratio of 1.00, which reflects "optimal" efficiency; in other words, just enough input was used to produce output without excess by-product.

The ratios were also averaged for the food system processes. For consumption, recycling inefficiency was at approximately 29%. More inputs, including food ingredients, energy, and resources were used than actually re-

Table 4. Recyclability assessment using scores ratios to generate an aggregate FRI, based on processes and modules for Urban Taipei

Modules	Consumption Input/Output	Consumption Output/ Waste Mgt Input	Waste Management Input/Output	*Average Ratio per Module*
Energy	4/3 (1.33)	3/3 (1.00)	3/2 (1.50)	1.28
Water	3/2 (1.50)	2/1 (2.00)	1/1 (1.00)	1.50
Nutrient	4/3 (1.33)	3/2 (1.50)	2/3 (0.67)	1.17
Contaminants	2/2 (1.00)	2/2 (1.00)	2/2 (1.00)	1.00
Average Ratio per Process	1.29	1.38	1.04	***FRI =1.24***

Consumption input includes things that eventually end up as waste, while waste management input comprises food waste as a fraction of actual waste that becomes recycled.
FRI: An index that reflects both module and process.

quired to prepare a meal, resulting in food waste mass. The ratio of this food waste to waste management inputs was similarly high (1.38), whereas the recyclability ratio for waste management was relatively low (1.04).

The aggregate FRI for Urban Taipei was 1.24, which was derived by taking the mean of all average ratios per module and per process. As described, the recyclability ratios as well as the FRI index encompass absolute and relative values for a comprehensive interpretation.

DISCUSSION

Waste minimisation is at the core of environmental sustainability, an area that is pertinent to health and food security. The FRI developed in this paper is a methodological approach to assess recyclability within a food system, which is a vital strategy before a Zero Waste society is achieved. Food consumption and waste management patterns in Taipei were investigated as a case framework, concentrating on recyclability in an urban ecosystem. Although there was limited accessibility or confidence in some of the evidence, an ex ante recyclability evaluation was made provisionally.

The overall FRI for Taipei was 1.24, indicating a moderate level of inefficiency to be the case. Relative to outputs produced, the process of consumption expended inputs with 29% wastefulness, which appeared to be congruous with the 30% food waste proportion observed in Taiwan.[20] Household food waste collection has increased substantially since Taiwan began subsidizing kitchen waste recycling programs in 2001. While Taiwan has been surpassing the set goals for kitchen waste collection and recycling in recent years,[22] a gap remains between food waste that is produced vs. what is effectively recovered for reuse (Consumption Output/Waste Management ratio =1.38). This may be related to economic development and higher household incomes leading to changes in eating habits. Consumer demand for convenient meals and 'superior' foods, such as animal products, contributed to the emergence of a nutrition transition.[42] The low waste management ratio of 1.04 may be indication that most of the inputs expended in this process were used up efficiently; minimal waste was created from waste itself. Thus, waste management is a vital process that ensures recyclability of excess products and by-products, returning valuable resources back to the food chain as feedstock for animals and fertilizer. In the case of contaminants (Average ratio=1.00), which may involve non-biodegradable or toxic chemicals, the persistence of these substances in the food system is not favourable. Moreover, recycling of contaminants can be deliberate or unintentional (e.g., sewage collected waste oil).[37]

Taipei city's food pattern is one with considerable vegetable consumption by national comparison. Higher vegetable consumption is desirable from a nutrition and health point of view, although it also creates a greater potential for food waste, for example by way of vegetable leaves and peels. On the other hand, Chinese cuisine is remarkable in allowing the use of most every part of plants and animals; fish head, pig innards and even its blood are used as ingredients in some traditional dishes. This prudent approach has encouraged creativity and extensive variety in Chinese cooking. In addition, the ubiquity of local farmers selling fruits and vegetables in Taipei city, often by the road directly from the back of a truck, presents another manner of food packaging minimization. For the most urbanized city in Taiwan, it seems as though the residents have adapted their behaviours with considerable mindfulness for the environment. While it may not be obviously so from the surface, Taipei's commitment towards conservation and recycling of resources makes it one of the 'greenest' in the region.[43]

This paper focused on the latter parts of the food system, leaving the preceding phases – agricultural production, food processing, and food distribution – outside the scope of this assessment. That is not to imply respective unimportance; in fact, the agricultural sector is often regarded as the main culprit of high energy and resource consumption, as well as high emission levels.[44] The current assessment of Taipei was demonstrative of how a FRI could be expanded to develop a FSRI (Food System Recycling Index), which would encompass the whole food system. This systems approach has valuable utility to help decision makers establish sound policies for food and health security. For instance, in using decision making models such as the ZOPP approach (Goal Oriented Project Planning),[45,46] the FSRI methodology serves as a tool for a holistic appraisal of the food ecosystem. The Problem Analysis phase of a decision-making model (Figure 2), including all the actions involved (expanded in flow chart), are prerequisite for the establishment of realistically achievable goals. Following the participation of community end-users and expert panel review for a FSRI assessment, goals and strategies can be planned to target high input users.

Community involvement and ownership would be a key component in developing a FSRI. Household and

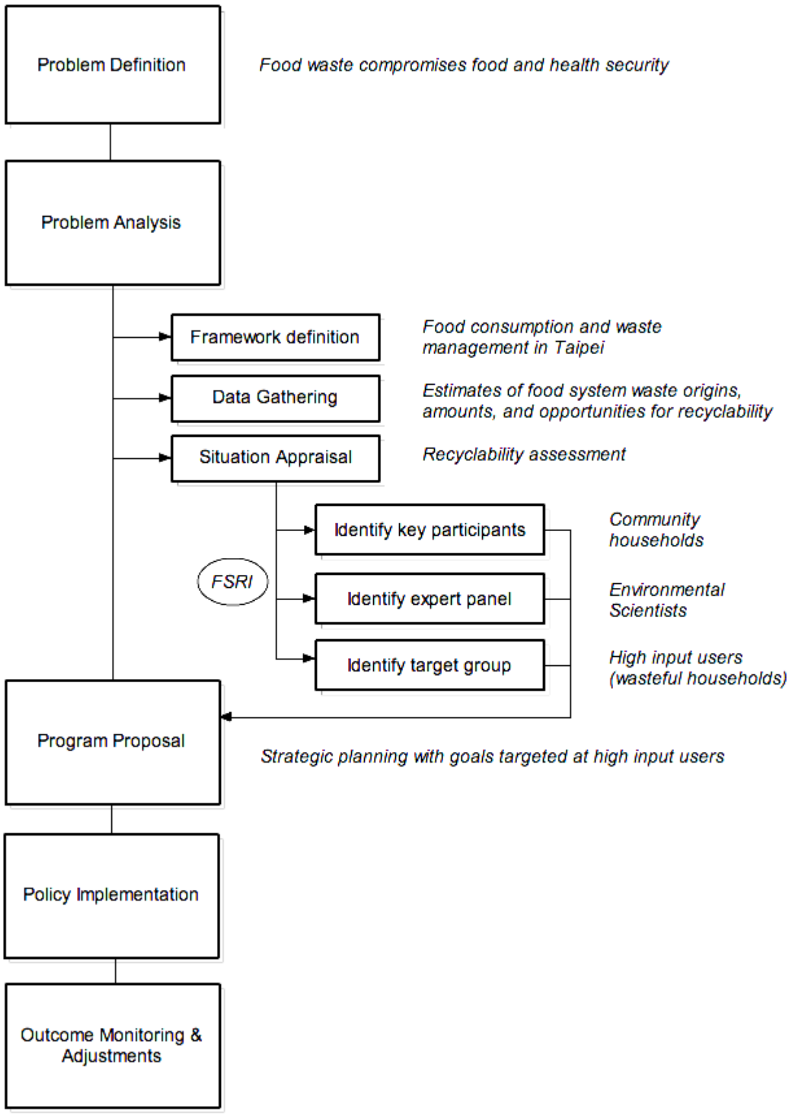


Figure 2. Decision making flow chart illustrating the utility of a Food System Recycling Index (FSRI). Examples applicable to this paper's framework are italicized on the right-hand side.

community end-users, as well as farmers, food producers and waste collectors are invaluable for developing a comprehensive FSRI. Further, as a novel method to evaluate recyclability within the food system, different communities can use it as a self-assessment tool to identify opportunities to reduce waste production and environmental contamination. Comparisons can also be made between different systems using the holistic approach in the FSRI method.

In addition, a baseline reference will need to be established, possibly through empirical studies to further develop a FSRI. Although the reference model needs not be an ideal setting characterized by perfect recyclability, Taipei could be a candidate where recyclability is nearly optimized; the diversified waste management efforts are recognized for good implementation as well as acceptance by the public. Taiwan has become an exemplar for recycling in the Asia Pacific region, as evidenced by investigative teams sent by countries including Japan, China, Germany, and the Netherlands to survey the recycling system in place.[47] Whatever scenario is utilised, a FSRI baseline can be analysed against to develop strategies to further improve management of the food system, including the waste handling aspects within it, by identifying and minimizing information gaps, maximizing community capabilities in terms of economic, social, environmental, and sustainability dimensions.[48]

There are limitations in the FRI methodology that can be developed as it evolves with application. For example, it can be difficult to obtain measurements for the same time periods, or those with enough recency, especially since measurement practices and food system processes change over time. A challenge that will perhaps always be present is the existence of different measurement units; interpretation of arbitrary conversions must be made with care. Utilizing the FSRI will also expose major information gaps or areas that are currently neglected by policy planners. Further research may show that custom adaptations are needed for different systems, although a generic FSRI with wide range of applicability would be quite beneficial. The FSRI may, for example, incorporate additional indices that are relevant to food system recyclability.

Furthermore, the FRI may expose limitations to recyclability itself. Special attention must be paid to toxic or harmful wastes. In the case of cooking oil, health concerns tend to encourage consumers to 'waste' more oil by not overusing during cooking. Fortunately, these situations may stimulate innovations such as using waste oil as biofuel.[36] It also promotes the use of biodegradable inputs into the food system, such as organic fertilizers and pesticides.

More work is needed to evaluate and incorporate the initial phases of the food system. It is likely that significant inefficiencies exist in that area, as well as high recyclability potential. The agricultural sector has a significant impact on environmental degradation, in particular due to the large contributions towards resource requirements, emissions and waste production. There is increasing interest, as well as pressure, to modify our existing food system. This provides sufficient reason to adopt a systems approach for food security and global health. While helping to identify recycling inefficiency in food systems, the FSRI can serve as an indicator of systemic sustainability, safety and adequacy. The demonstrated approach for a Taipei FRI incorporated the concept of econutrition throughout the assessment process. Evidently, food and health security is not only concerned with lack of food availability. More than ever, environmental health and our wellbeing depend on how we produce our food and handle the associated wastes.

ACKNOWLEDGEMENTS
The author wishes to thank Professors Mark L. Wahlqvist, Duo Li, Yong Guan Zhu and Angela Yu Chen Lin for their expert advice, and Yuan Ting Luo for constructive suggestions and translation of the Chinese abstract.

AUTHOR DISCLOSURES
The author declares no conflicts of interest.

REFERENCES
1. Wahlqvist ML, Keatinge JDH, Butler CD, Friel S, Mckay J, Easdown W, et al. A Food in Health Security (FIHS) platform in the Asia-Pacific Region: the way forward. Asia Pac J Clin Nutr. 2009;18:688-702.
2. Borlaug NE. Contributions of Conventional Plant Breeding to Food Production. Science. 1983;219:689-93.
3. IFPRI. Green Revolution: Curse or Blessing? International Food Policy Research Institute. Washington, DC: 2002.
4. Schafer-Elinder L. Obesity, hunger, and agriculture: the damaging role of subsidies. BMJ. 2005;331:1333-6.
5. Short RV. Population growth in retrospect and prospect. Phil Trans R Soc B. 2009;364:2971-74.
6. Butler CD. Food security in the Asia-Pacific: Malthus, limits and environmental challenges. Asia Pac J Clin Nutr. 2009;18:577-84.
7. Freedman DA, Bell BA. Access to Healthful Foods among an Urban Food Insecure Population: Perceptions versus Reality. J Urban Health. 2009;86:825-38.
8. Kirkpatrick SI, Tarasuk V. Food insecurity in Canada: considerations for monitoring. Can J Public Health. 2008;99: 324-7.
9. Goulding K, Jarvis S, Whitmore A. Optimizing nutrient management for farm systems. Phil Trans R Soc B. 2008; 363:667-80.
10. Friel S, Baker PI. Equity, food security and health equity in the Asia Pacific region. Asia Pac J Clin Nutr. 2009;18:620-32.
11. Lin AY, Huang ST, Wahlqvist ML. Waste management to improve food safety and security for health advancement. Asia Pac J Clin Nutr. 2009;18:538-45.
12. Wang Y-W. Sustainable agricultural practices: energy inputs and outputs, pesticide, fertilizer and greenhouse gas management. Asia Pac J Clin Nutr. 2009;18:498-500.
13. IUPAC. IUPAC - Global availability of information on agrochemicals. 2008/07/15 [cited 2010/01/22]; Available from: http://agrochemicals.iupac.org
14. Wahlqvist ML, Specht RL. Food variety and biodiversity: Econutrition. Asia Pac J Clin Nutr. 1998;7:314-19.
15. Deckelbaum RJ, Palm C, Mutuo P, DeClerck F. Econutrition: Implementation models from the Millennium Villages Project in Africa. Food Nutr Bull. 2006;27:335-42.
16. UN ESCAP. Ecosystem Services. United Nations Economic and Social Commission for Asia and the Pacific. 2009/03/11 [cited 2010/01/25]; Available from: http://www.unescap.org /esd/environment/services/
17. Department of Statistics. 1.7 Population for Township and District and by Urban Area. Monthly Bulletin: Taiwan Ministry of the Interior, 2009.
18. Taiwan EPA. Management of General Waste. 2009/08/04 [cited 2010/01/25]; Available from: http://www.epa.gov.tw/ en/epashow.aspx?list=112&path=163&guid=fbbb159b-a668-45c6-90bf-aa0d7f5115b2&lang=en-us
19. SongShan Healthy City Taipei. E3 Household Waste Collection Quality (Resource Recycling Rate). [cited 2010/01/26]; Available from: http://www.songshan-healthy city-taipei.org.tw/e3_eng.asp?eng=1
20. Taiwan EPA. Table 4-2 Properties of Municipal Solid Waste Taiwan Environmental Protection Administration, 2008.
21. Taiwan EPA. Table 4-1 Clearance of Municipal Solid Waste by All Organizations Taiwan Environmental Protection Administration, 2009.
22. Taiwan EPA. The Current Status for Kitchen Waste Recycling and Reuse. 2010/05/05 [cited 2010/01/25]; Available from: http://www.epa.gov.tw/en/epashow.aspx?list=125&pa th=9105&guid=2d105564-911d-4536-ae70-798eb75b345c &lang=en-us
23. Hogg D, Barth J, Favoino E, Schleiss K. Dealing with Food Waste in the UK. Report for WRAP. Eunomia Research & Consulting; 2007.
24. Taiwan Culture Portal. Waiting for the garbage truck. 2008/11/28 [cited 2010/01/26]; Available from: http://www. culture.tw/index.php?option=com_content&task=view&id= 1011&Itemid=157
25. Ross J. What I Picked Up About Trash in Taipei. The Washington Post. 2007/12/02 [cited 2010/01/26]; Available from: http://www.washingtonpost.com/wp-dyn/content/article/200 7/11/29/AR2007112901887.html
26. Scientific Applications International Corporation. Life Cycle Assessment: Principles and Practice. Reston, VA: U.S. Environmental Protection Agency, 2006.
27. Zhang Y, Singh S, Bakshi BR. Accounting for Ecosystem Services in Life Cycle Assessment, Part I: A Critical Review. Environ Sci Technol. 2010;44:2232-42.
28. Zhang Y, Baral A, Bakshi BR. Accounting for Ecosystem Services in Life Cycle Assessment, Part II: Toward a Ecologically Based LCA. Environ Sci Technol. 2010;44:2624-31.
29. Ministry for the Environment. Guidance Principles: Best Practice for Recycling and Waste Management Contracts: Working Draft. New Zealand Government. Wellington, New Zealand: 2007.

30. Villalba G, Segarra M, Chimenos JM, Espiell F. Using the recyclability index of materials as a tool for design for disassembly. Ecol Econ. 2004;50:195-200.
31. Taiwan Council of Agriculture. Per Caput Per Day Energy Supply. Food Supply & Utilization Annual Report 2008.
32. Taiwan Council of Agriculture. Food Balance Sheet. Food Supply & Utilization Annual Report 2008.
33. Taiwan EPA. Clearance of Municipal Solid Waste by Implementing Agencies. 2009.
34. Taiwan EPA. The Feasibility Evaluation Plan for Promoting Centralized Sludge Treatment and Biomass Energy from Recycled Kitchen Waste, Sewage, Pig Farming Wastewater and Domestic Wastewater. 2009.
35. Taipei Healthy City. Taipei Healthy City Profile & Project. Taipei City Government: 2005.
36. Liu Y. Used Cooking Oil Promises to Fuel China's Rapidly Expanding Car Fleet. World Watch Institute. 2006/10/12 [cited 2010/01/26]; Available from: http://www.worldwatch.org/node/4656
37. Barboza D. Recycled Cooking Oil Found to be Latest Hazard in China. The New York Times 2010.
38. U.S. Geological Survey. Water Science Questionnaire #3: How much water do you use at home? US Department of the Interior. 2010/04/01 [cited 2010/04/26]; Available from: http://ga.water.usgs.gov/edu/sq3.html
39. Ehling S, Hengel M, Shibamoto T. Formation of Acrylamide from Lipids. Adv Exp Med Biol. 2005;561:223-33.
40. Totani N, Burenjargal M, Yawata M, Ojiri Y. Chemical Properties and Cytotoxicity of Thermally Oxidized Oil. J Oleo Sci. 2008;57:153-60.
41. Rosenthal E. Europe Finds Clean Energy in Trash, but U.S. Lags. The New York Times 2010.
42. Zhai F, Wang H, Du S, He Y, Wang Z, Ge K, Popkin BM. Prospective study on nutrition transition in China. Nutr Rev. 2009;67:S56-S61.
43. Scully J. Is Taipei the greenest city in Asia? Creative Cities 2.0. 2010/01/21 [cited 2010/01/26]; Available from: http://www.creativecities.org.uk/is-taipei-the-greenest-city-in-asia/
44. Lal R. Carbon emission from farm operations. Environ Int. 2004;30:981-90.
45. Goethert R, Beamish A, Little K. ZOPP: Goal Oriented Project Planning. The World Bank Group. 2001 [cited 2010/01/26]; Available from: http://web.mit.edu/urbanupgrading/upgrading/issues-tools/tools/ZOPP.html
46. Helming S, Göbel M. ZOPP Objectives-oriented Project Planning: A planning guide for new and ongoing projects and programmes. Strategic Corporate Development Unit 04. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH; 1997.
47. Taiwan Review. Recycling: Taiwan’s Way of Life. 2010/03/01 [cited 2010/04/26]; Available from: http://taiwanreview.nat.gov.tw/ct.asp?xItem=93434&CtNode=1337
48. Herrera-Ulloa ÁF, Charles AT, Lluch-Cota SE, Ramirez-Aguirre H, Hernández-Vázquez S, Ortega-Rubio A. A regional-scale sustainable development index: the case of Baja California Sur, Mexico. Int J Sustain Dev World Ecol. 2003;10:353-60.

Original Article

A recycling index for food and health security: urban Taipei

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糧食與衛生安全攸關之食物回收指數－以台北市為例

現今的食物體系已經逐漸形成一個高度缺乏效率的系統，從生產、消費到廢棄的每個過程中不斷地產生浪費。目前所面臨到的挑戰是改善食物體系內的回收再利用率，這也是糧食與衛生安全的根基。本文為方法學的研究，主要是發展一個食物回收再利用指數(FRI)，藉由此指數來評估食物體系內的回收再利用情形，及發掘可以降低廢棄物產生與環境污染的機會，並且提供參與食物體系過程者一個自我評量的方式。利用台北市的架構來評估食物體系的食物消費和廢棄物管理過程中資源與營養素的流動。FRI 的分段步驟為 1.判定食物鏈中最主要的輸入與產出 2. 將輸入與產出分類並放入模組(能量、水、營養素和汙染物) 3. 為每個模組給一個半定量的分數並使用食物消費和廢棄物管理兩者來訂定群組分數 4. 評估回收狀態和潛在的可回收與再利用率 5. 將分數轉換為次級指數 6. 產生一個 FRI 總分。從台北市廚餘回收之資料，產生的 FRI 為 1.24，該指數之絕對值與相對值，可供詳盡的闡釋。FRI 可以推廣至與衛生相關之生態體系概念。家戶消費者和政策計劃者可以使用 FRI 以增進糧食與衛生安全。

關鍵字: 食物回收再利用指數、糧食安全、生態營養、食物廢棄物、回收再利用