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Linking food and land systems for sustainable peri-urban agriculture in Bangkok Metropolitan Region

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HIGHLIGHTS

- A geographic approach helps in a holistic understanding of peri-urban food systems.
- Food-related activities occurred at multiple spatial scales.
- Wet markets served as a hub and spread across wider areas than supermarkets.
- An increase in wet markets and supermarkets was associated with land use change.
- Connection between local farmers and nearby wet markets was limited.

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ABSTRACT

We applied a geographic approach to the analysis of current food-related behaviors in peri-urban Bangkok, Thailand, to better understand potential for building a local food system for sustainable peri-urban agriculture during a period of rapid urbanization. We addressed three main working questions: (1) Do traditional wet markets keep functioning as an important hub for vegetable and fruit food systems under the influence of modern supermarkets? (2) How "local" are the current food-related behaviors of multiple actors? (3) How do the distributions of food-related actors and their environments change in this period of rapid urbanization in peri-urban areas? We combined field based interviews of multiple actors, including farming and non-farming households, wet market retailers, and food shop owners with a GIS analysis of food-related activities and land use changes. We found that the traditional food system played an important role as both a food source for households and a selling destination for farmers. Wet market, a hub in traditional food system, spread across peri-urban areas and kept increasing under urbanization. There was, however, little connection between farmers and nearby wet markets in the same district and it constricted positive feedbacks between producers and consumers in peri-urban areas. Promoting communication between farmers and nearby retailers will contribute to better governance of a local food system and subsequent long-term conservation of peri-urban farmlands.

1. Introduction

Peri-urban farmlands and agricultural activities therein provide food and multiple other functions (e.g., flood mitigation, visual amenity, and recreation) for urban and peri-urban dwellers (Aubry et al., 2012; Zasada, 2011). Peri-urban agriculture is also considered to contribute to a better nutrient status and improved well-being of urban and peri-urban dwellers (De Bon, Parrot, & Moustier, 2010; Midmore & Jansen, 2003). As the global population continues to concentrate in and around cities (United Nations, 2012), the demand for food and the multi-functional roles of peri-urban agriculture are expected to increase (Mawois, Aubry, & Le Bail, 2011; Vermeiren, Adiyia, Loopmans, Tumwine, & Van Rompaey, 2013). The roles are particularly important in growing urban regions in Asia and Africa, where most of the urban population increase and future land development are expected to occur (Seto, Fragkias, Güneralp, & Reilly, 2011). Local governmental authorities and other interested organizations (e.g., non-governmental organizations) in developing countries, however, have only gradually begun to form policies and legislation for enhancing food production and other roles of peri-urban agriculture (FAO, 2007).

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Many previous land-use policies for peri-urban agriculture, which were primarily applied in developed countries, have followed a land protection approach such as zoning or the use of "green belt" policies, which draw a line between urban and rural areas to separate developed areas from so-called green areas (Amati, 2008; Gant, Robinson, & Fazal, 2011; Kühn, 2003). However, land-use planning solely by land protection has often failed to encourage farmers to continue their agricultural activities near urban areas and resulted in the abandonment of agricultural activities and conflicts over land uses both inside and outside the green areas (Darly & Torre, 2013; Yokohari, Takeuchi, Watanabe, & Yokota, 2000). To overcome these issues with peri-urban agriculture, recently proposed land-use and food polices have recommended that local food systems (e.g., direct marketing, farmers' markets, and consumer-supported agriculture) be built to shorten food supply chains at the local level (Aubry & Kebir, 2013; Carey et al., 2011). Localizing the food system is generally considered to be desirable by consumers (Grebitus, Lusk, & Nayga, 2013) and can contribute to the sustainability of agricultural and food systems by strengthening feedback to producers, consumers, and other actors (Sundkvist, Milestad, & Jansson, 2005). Here, localization is not an end in itself (Born & Purcell, 2006) but can be considered to be a measure for sustaining peri-urban agriculture.

A food system can be thought of as "a set of activities ranging from production through to consumption" (Ericksen, 2008). Regardless of the specific form, food systems involve multiple activities and related actors (Ingram, 2011; Sundkvist, Jansson, & Larsson, 2001). In the case of a local food system, the actors include consumers, producers (i.e., local farmers), and various retailers. Integrating the idea of the local food system into peri-urban land-use planning will thus require understanding of how the behaviors and interests of these actors are "local." Although peri-urban areas have a rich potential to form local food systems (Kurita, Yokohari, & Bolthouse, 2009; Paül & McKenzie, 2013), the behaviors of food-related actors may not be "local," particularly in areas where communications between the urban and rural sectors are limited (Sajor & Ongsakul, 2007). Although there is no universal definition of "local" as it relates to local food systems (Martinez et al., 2010), an accurate geographic analysis can provide useful information, including food flow distance from one actor to another as well as the distribution of the system's activities and actors along with their neighboring environments. Previous studies have not, however, fully investigated these points and often only dealt with them abstractly (Feagan, 2007) and had limitations in navigating land-use policies and practices. Several studies on local food systems (Kremer & DeLiberty, 2011; Metcalf & Widener, 2011) and on food "deserts" (Charreire et al., 2010) have investigated food-related behaviors geographically, but the entire complex system of multiple activities and actors were not fully considered. Temporal changes in the behaviors of food-related actors and their environments under urbanization will also affect the potential of, and threats to, food system localization.

In this study, we analyzed the behaviors of food-related actors and their changing environments in peri-urban Bangkok, Thailand, by using the geographic approach to provide detailed information regarding the locations of the relevant activities and actors and how they are linked through the production, distribution, and consumption of local foods. Food systems in developing countries are diverse and range from "traditional" to "modern" (Schipmann & Qaim, 2011). Traditional food systems are characterized by small-scale farmers and wet markets, whereas modern food systems are represented by industrial-scale agriculture and supermarkets (Ericksen, 2008). A wet market is a fresh food market commonly consisting of dozens or hundreds of small retailers. They are commonly found in East and Southeast Asian countries and are considered to be an important hub for vegetable and fruit food systems (Schipmann & Qaim, 2010). Both traditional and modern food systems in developing regions are experiencing dramatic changes under urbanization (Mawois et al., 2011; Vermeiren et al., 2013), but they have not yet been fully addressed geographically in previous studies. We, therefore, discuss the following three main questions, with the aim of providing information about a local food system, which may contribute to the sustainability of peri-urban agriculture. (1) Do traditional wet markets keep functioning as an important hub for vegetable and fruit food systems under the influence of modern supermarkets? (2) How "local" are the current food-related behaviors of multiple actors? (3) How do the distributions of food-related actors and their environments change in this period of rapid urbanization in peri-urban areas? In addressing these questions, we examined the potential contribution of the traditional food system to sustainable peri-urban agriculture and investigated from and to where food system actors (e.g., farmers, consumers, and wet market retailers) buy and sell vegetables and fruits, and what distances they travel to do so. We focused on vegetables and fruits, which are considered to be a vital component of urban and peri-urban agriculture and local food systems (Bon et al., 2010; Martinez et al., 2010).

2. Study site

We selected the Bang Mae Nang sub-district (BMN), located on the northwestern periphery of the Bangkok Metropolitan Region in Thailand, as a case study site (Fig. 1). Sub-districts are the smallest administrative unit in Thailand, and BMN is located in the Bang Yai district in Nonthaburi Province. BMN is approximately 20 km from central Bangkok and has an area of 21.9 km^2. BMN's population was 7104 in 1993 and had increased to 32,560 by 2011; the number of households increased from 1443 to 17,189 during the same period (Ministry of Interior of Thailand, 2013). The Bangkok Metropolitan Region is mainly located on a fertile back marsh of the extensive continental Chao Phraya delta, where the landform is mostly flat and only 1 to 2 m above sea level (Takaya, 1987). Although the western part of Nonthaburi Province was unpopulated until early nineteenth century, settlement began to spread along with canal development in late nineteenth century (Askew, 2000). The predominant land use in this area before urbanization was vegetable fields and fruit orchards along with a mixture of rice paddy fields and village areas (Thaitakoo, McGrath, Srithanyarat, & Palopakon, 2013). Vegetable fields and fruit orchards commonly have poldered and raised-bed structures (Gajaseni & Gajaseni, 1999), which are adapted for use in the local climate, soil, and water environment (Fig. 2). Major vegetable and fruit products include banana, Chinese convolvulus, Chinese kale, coconut, durian, lettuce, and mango (National Statistical Office of Thailand, 2009). These products are considered to be a vital source of food for the population of the Bangkok Metropolitan Region (Chunnasit, Pages, & Duangngam, 2000). Canal networks, which were extensively developed across the Bangkok Metropolitan Region, are used as an irrigation source in paddy fields, vegetable fields, and orchards. They were also commonly used for transportation, but this is changing because of rapidly growing road networks for automobiles (Hara, Takeuchi, & Okubo, 2005).

Peri-urban areas of the region have experienced massive urban land expansion in the past few decades (Askew, 2000; Murakami, Zain, Tekeuchi, Tsunekawa, & Yokota, 2005). Although the Bangkok Metropolitan Region had already started to grow before the 1950s (Thaitakoo et al., 2013), the current rapid urbanization trend began in the 1970s in terms of both land-use change (Hara et al., 2005) and increasing population (Murakami et al., 2005). This trend has continued to the present. Changes from farmlands to urban land uses were often associated with landowner's expectations for economic

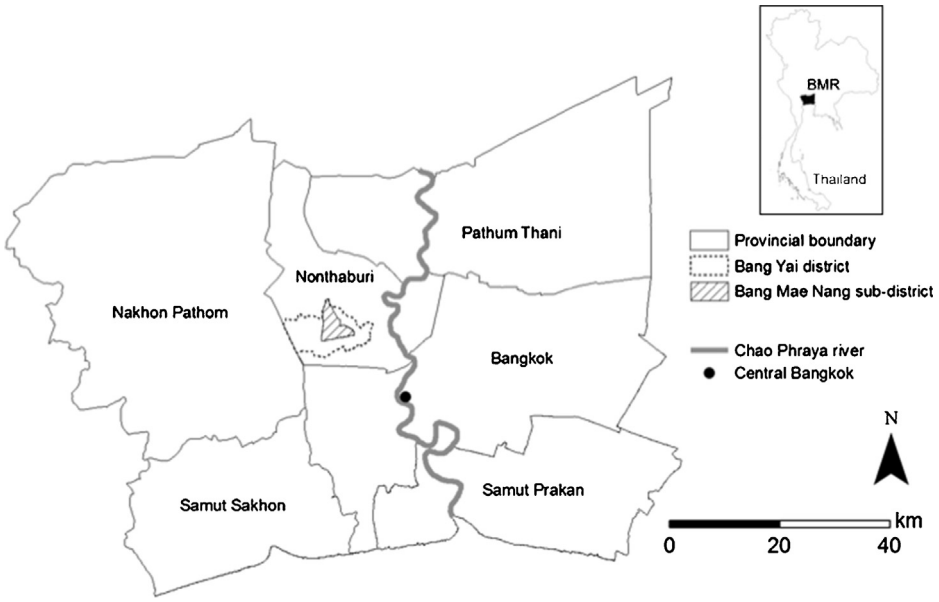

Fig. 1. The location of the Bang Mae Nang sub-district within the Bangkok Metropolitan Region.

returns (Askew, 2000). Rapid urbanization has resulted in a highly heterogeneous landscape with both urban and rural land uses (Thaitakoo et al., 2013). It has also brought about diverse environmental issues both within and beyond the Bangkok Metropolitan Region (Hara, Hiramatsu, Honda, Sekiyama, & Matsuda, 2010). Pollution of canal water by urban waste water is one of the most significant issues (Honda, Hara, Sekiyama, & Hiramatsu, 2010), similar to what has occurred in other developing urban regions (Huang et al., 2006; Khai, Ha, & Öborn, 2007; Mojid, Wyseure, Biswas, & Hossain, 2010). The polluted water flows to nearby farming areas through canal structures, forcing peri-urban farmers to incur water treatment costs (Vagneron, 2007) and potentially threatening consumers of the products from these farms (Lagerkvist, Hess, Okello, Hansson, & Karanja, 2013). Such water-related issues can be partially attributed to the lack of any institution that employs integrated approaches or enhances communication among urban and rural stakeholders (Davivongs, Yokohari, & Hara, 2012; Sajor & Ongsakul, 2007; Sujaritpong & Nitivattananon, 2009). Although a large part of BMN was designated land to be developed in the provincial land-use plan of 2005, the area is still currently dominated by agricultural uses. Urban development in BMN and surrounding areas will be strongly stimulated because a new mass transportation system, which is now under construction, is expected to be placed in operation in the near future. It will directly connect BMN and the surrounding area to central Bangkok (Mass Rapid Transit Authority of Thailand, 2010). Thus, future development must be carefully planned to mitigate potential negative environmental impacts while still gaining the benefits of mixed land uses (Yokohari et al., 2000).

The Bangkok Metropolitan Region has a hybrid food system of traditional wet markets and modern supermarkets (Fig. 3), similar to many other developing countries in East and Southeast Asia (Cadilhon, Moustier, Poole, Tam, & Fearne, 2006; Trappey & Lai, 1997). Supermarkets are rapidly expanding in Asian countries (Reardon, Timmer, & Minten, 2012), and they strongly affect consumers' and farmers' behaviors (Gorton, Sauer, & Supatpongkul, 2011; Mergenthaler, Weinberger, & Qaim, 2009). Even with the expansion of supermarkets, traditional wet markets remain an important place for consumers to buy vegetables and fruits (Goldman, Krider, & Ramaswani, 1999). Traditional wet markets also represent an important market for small-holding farmers who

Fig. 2. An example of vegetable and fruit farmland in the Band Mae Nang sub-district.

are unable to adapt to the huge scale required to supply supermarkets and related intermediate markets (Cadilhon et al., 2006; Schipmann & Qaim, 2010). The wet market system includes both small retail markets and large wholesale markets, and some markets have both retail and wholesale functions. Street food stands, carts, and outdoor restaurants (Fig. 3; hereafter "food shops") are also an important food source for the Thai population, especially in urban areas (Puangkaew & Monma, 2011). Thus, we included supermarkets, wet markets, and food shops as well as farming and non-farming (i.e., urban) households in our analysis.

3. Materials and methods

3.1. Preliminary survey and GIS data acquisition

We first conducted a preliminary survey in BMN and surrounding areas in July 2011 to collect basic information on food production, consumption, and flow, and used the information to develop both the questionnaire items and to select interviewees for our later semi-structured interviews. In this preliminary phase, we performed open-ended interviews with wet market retailers, food shop owners, and farming and non-farming households about food-related behaviors (e.g., where purchases of vegetables and

Fig. 3. Photographs of a wet market (upper left), supermarket (upper right), food shop (lower left), and mobile vendor (lower right).

fruits were made, where farmers planned to sell vegetables and fruits). We randomly selected a total of 12 interviewees and tried to select them from various places within BMN. Through this preliminary interview process, we were able to confirm the types of food-related behaviors to be surveyed in our later interviews, including visits to wet markets or supermarkets, cooking or eating outdoors (i.e., at food shops), subsistence farming, provision from neighbors or relatives, and the use of mobile vendors who carry vegetables, fruits and other goods for sale by cars or motorbikes (Fig. 3). Although the food-related behaviors were diverse, we were able to confirm that the respondents could easily identify their major food source and selling destinations, questions that were asked in the semi-structured interviews.

Along with the open-ended interviews, we also obtained locally produced geographic datasets for 2008 at Or Bor Chor, the Provincial Administrative Organization for the Province of Nonthaburi, to assist in the selection of respondents in the semi-structured interviews and confirm the locations of wet markets and supermarkets in and around BMN. Although the dataset covered multiple topics, we primarily used the following data for this study: land-use maps, maps of wet markets and supermarkets, and ortho-rectified aerial photos (50-cm resolution). We also used land-use maps and maps of wet markets and supermarkets from 2003; these maps had been used in previous studies and were confirmed to be sufficiently accurate for the purposes of this study (Hara et al., 2010; Hiramatsu, Hara, Sekiyama, Honda, & Chiemchaisri, 2009; Honda et al., 2010). We double-checked the extent of the residential and agricultural areas across the study site as well as the names and locations of wet markets and supermarkets by comparing the datasets and by our own field-based observations in the preliminary survey. Although there was a 3- to 4-year gap between the most recent datasets and our field-based interviews, we considered that the datasets were sufficiently reliable to represent the current food-related market environment because all wet markets and supermarkets open in 2008 were still open in 2011 and only one new wet market had opened inside BMN after 2008. According to Nonthaburi municipal officials, land-use data for 2008 were produced on the basis of a photographic interpretation of ortho-rectified photos. The land-use map and the map of the markets were prepared in the ESRI shapefile format, and the aerial photos were prepared in the Geotiff format. These datasets represent a snapshot of the then current conditions and were made for local governmental use (e.g., land-use planning). We also conducted supplemental open-ended interviews of municipal officials in August 2012 to learn more about the current state of urban planning and rural development programs as well as the current state of supermarket regulations. We interviewed a total of 6 officials from the departments of agriculture, natural resource management, planning, and social cooperation. Although we also collected statistical reports about agricultural production (e.g., an agricultural census in 2003), we did not use them in our analyses because the numbers did not appear to be reliable (i.e., the production numbers differed in the various reports) and were mostly aggregated at the provincial level.

3.2. Interviews of food-related actors

Following the preliminary survey, we conducted semi-structured interviews of the actors related to the BMN food system in August 2011 and May 2012. Face-to-face interviews were conducted because this was the only way to contact multiple food-related actors in our study site because accurate address and telephone data were not available. Although this method is not cost-effective in terms of collecting samples, it enabled us to confirm whether the respondents clearly understood the questions. A total of 124 actors were interviewed, including 31 wet market vendors, 24 food shop owners, 26 farming household members, and 43 non-farming household members. We adopted a spatial sampling method to represent the larger population for the household and food shop selections. We first roughly divided BMN into 11 areas based on the spatial distribution of houses in the 2008 land-use map and then visited the areas and randomly selected about 4–8 households and 2–3 food shops in each area. We also visited the 6 wet markets in and around BMN, based on the land-use map and preliminary survey, and randomly sampled 4–8 vendors in each market. The location of wet markets, food shops, and households were recorded by using GPS (Global Positioning System) digital cameras (EXILIM EX-H20G, Casio) and later mapped on GIS software (ESRI ArcGIS 10.0). Because some parts of the agricultural

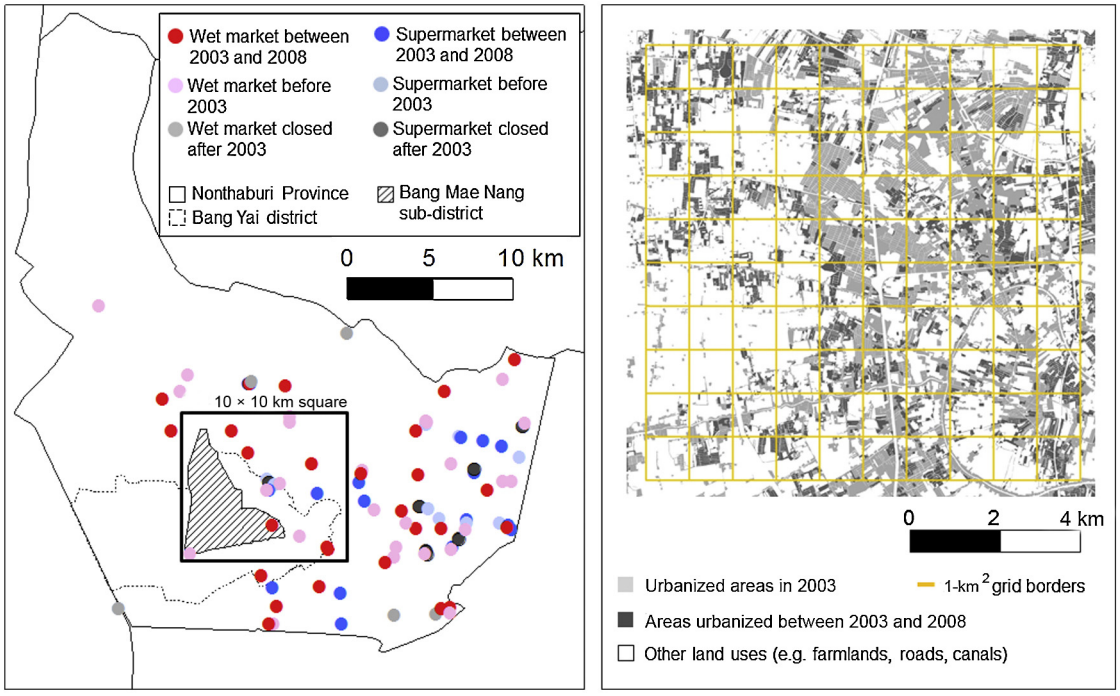

Fig. 4. Distribution of supermarkets and wet markets in Nonthaburi Province. The left panel shows the location of wet markets and supermarkets in Nonthaburi Province, whereas the right panel shows urban land uses in and around the 10 × 10 km square area shown in the left panel.

fields in our study site, especially orchards, were severely affected by flooding from September to December 2011 (Shinya, Tsuchiya, Hara, & Thaitakoo, 2013) and some farmers were still recovering from the flooding in May 2012, we asked the farmers to report on the pre-flooding situation. The wet market and food shop structures incurred less damage and operations were more or less the same after the flooding, so we were able to combine the results from August 2011 and May 2012.

In the semi-structured and face-to-face interviews, interviewers used a common list of questions that had been developed based on information gathered in the preliminary survey. Members of both farming and non-farming households were asked about their major source of vegetables and fruits (i.e., where they were usually purchased); amount of vegetables and fruits that were self-grown (more than half of total household consumption, less than half, or none); provision of vegetables and fruits from neighbors or relatives (yes or no); where they usually eat breakfast, lunch, and dinner (home or not); preference for local products from Nonthaburi Province (yes or no); reasons for preferring Nonthaburi products (safety, price, convenience, local preference, or other); and major criteria for purchasing vegetables and fruits (price, product origin, freshness, organic, or looks) along with personal attributes (e.g., age of the household head). In addition to these questions, farming households were also asked about where they regularly sell their products (e.g., the name of the wet markets) and the types of agricultural products they grow. Wet market vendors and food shop owners were asked about their major source of vegetables and fruits, where they usually purchase the products they sell, types of agricultural products they sell, and other personal attributes (e.g., home location).

3.3. Analysis

We then carried out three analyses: (1) collecting every type of food-related behavior of multiple actors in BMN and identifying major food flows, (2) analyzing the spatial scales and distances travelled in the local food flows in BMN and the surrounding area, and (3) comparing the geographic distribution of wet markets and supermarkets with the degree of urbanization.

In the first analysis, we listed all types of "major source of vegetables and fruits" responses from wet market retailers, food shop owners, and households. We also listed all types of the farming households' responses on "where they sell products regularly" and summarized the responses from farming and non-farming households on food-related behaviors to identify food flows.

In the second analysis, we focused on the food flows related to wet markets because they were confirmed to be the major food source and destination for multiple actors in our first analysis. To do this, we calculated Euclidean distances of food flows (1) from wet markets to farming and non-farming households, (2) from wet markets to food shops, (3) between wet markets, and (4) from farming households to wet markets. We then conducted pairwise Wilcoxon rank-sum tests with Bonferroni's correction to examine these categories to better understand how the food flow distances differed among the actors. Although the Euclidean distances do not precisely represent the actual flow distances between related actors, we considered the Euclidean distance to sufficiently represent the relative differences in distances for the behaviors of food-related actors (Charreire et al., 2010; Kremer & DeLiberty, 2011). In addition, we were unable to obtain complete road network data matching the distribution of the wet markets, and the respondents were not always able to clearly illustrate the directions from the point of departure to the destination because they sometimes take different routes.

For the third analysis, we used the market and land-use datasets obtained from the Nonthaburi municipality. We conducted this analysis for 10 × 10 km square area at the center of Nonthaburi Province (Fig. 4), which covered the location of all interviewees in and around BMN. We selected this area because the second analysis revealed that food flows related to BMN often involve wet markets at a larger spatial scale, particularly in the eastern part of Nonthaburi (as we explain in Section 4). This area setting also enabled

Table 1
Major vegetable and fruit sources for households, food shops, and markets and major sales destinations of vegetables and fruits for farmers. Each cell shows the number of respondents (percentage) in each group.

Source/destination	Purchase					Sell
	Households			Food shops	Wet markets	Farmers
	All	Non-farming	Farming			
Wet markets	46 (66.7%)	34 (79.1%)	12 (46.2%)	21 (87.5%)	26 (83.9%)	10 (50.0%)
Mobile vendors	15 (21.7%)	2 (4.7%)	13 (50.0%)	1 (4.2%)	0	–
Supermarkets /retail shops	5 (7.3%)	4 (9.3%)	1 (3.9%)	0	0	0
Farms	1 (1.5%)	1 (2.3%)	0	1 (4.2%)	4 (12/9%)	–
Others	1 (1.5%)	1 (2.3%)	0	1 (4.2%)	0	2 (10.0%)
Middle-men	–	–	–	–	–	8 (40.0%)
No answer	1 (1.5%)	1 (2.3%)	0	0	1 (3.2%)	0
Total	69	43	26	24	31	20

us to eliminate areas near the boundary of Nonthaburi Province, where residents potentially have good access to wet markets and supermarkets outside Nonthaburi. Bang Yai City market, which is one of the biggest wet markets in Nonthaburi Province, was set as the center of the square area. The square area was divided into 1-km^2 grids for the following spatial analyses; this grid size is often used in food accessibility analyses as a daily travel distance for food purchasing purposes (Charreire et al., 2010).

The land-use dataset included urban, agricultural, and other land uses as land-use categories. Although the agricultural land uses were also divided into sub-categories, such as paddy field and orchards, a comparison with the aerial photos and data obtained through field observations revealed that the data for the sub-categories were not of sufficient quality to be used in the analysis. We also confirmed that the classifications of urban and agricultural lands were of sufficient quality. Most urban development from 2003 to 2008 occurred in previous agricultural areas; thus, an increase in the urban land-use ratio can be understood as a decrease in the agricultural land-use ratio. We therefore used the urban land-use category for the grid analysis as an indicator for both urban and agricultural land-use changes. Although vacant lots have also been considered in some previous urban agricultural investigations (e.g., Hara, Murakami, Tsuchiya, Palijon, & Yokohari, 2013b), we did not include them in our analyses because very few exist in and around BMN. The urban land-use area included residential, commercial, and industrial land uses but did not include roads and water bodies (e.g., canals). We also manually edited some of the urban land-use areas within the 10 × 10 km square area based on our field observations and ortho-rectified aerial photos to ensure the quality of the grid analysis. We calculated urban land-use areas within each 1-km^2 grid for both 2003 and 2008. For each 1-km^2 grid, we then calculated the Euclidean distance from the grid center to the nearest wet markets or supermarkets for both 2003 and 2008 by using the "Spatial Analyst" function in GIS software (ESRI ArcGIS 10.0). We then compared the changes in distances to wet markets and supermarkets by using the Wilcoxon rank-sum test to understand differences in the spatial distributions of the wet markets and supermarkets.

Finally, we applied a linear regression model to understand the effect of urbanization on the distances from the grids to the wet markets and supermarkets. We analyzed relationships between the ratios of urban land-use areas in the grids and the distances to wet markets or supermarkets. We conducted this analysis for both the 2003 and 2008 datasets; thus, the total number of linear regression models was 4. We selected the land-use ratios as explanatory variables and the distances as response variables. The number of observations was 100 for each model, and we used the ordinary the least squares method to estimate the parameters in these models. By comparing these linear regression models, we were able to identify changes in the agricultural and food environments for farmers and other food-related actors.

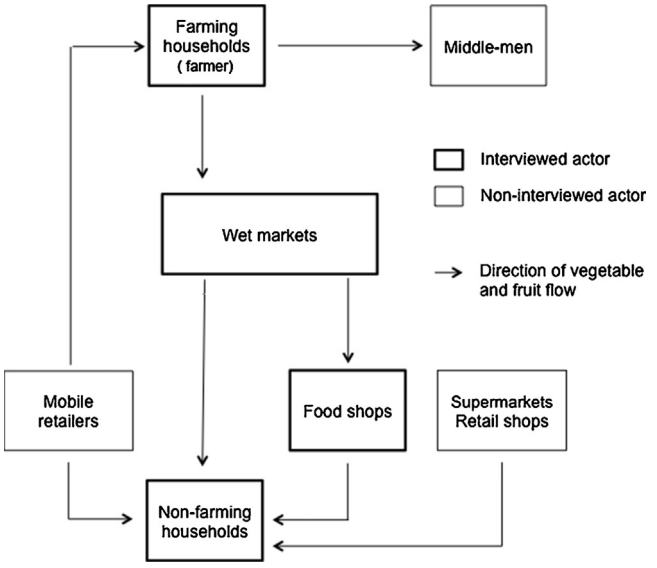

Fig. 5. Major food flows in and around the Bang Mae Nang sub-district.

4. Results

4.1. Food-related behaviors of multiple actors

Wet markets generally functioned as the most important hub in the food system in and around BMN (Fig. 5). Non-farming households (79.1%), farming households (46.2%), food shop owners (87.5%), and wet market retailers (83.9%) strongly depended on local or regional wet markets (Table 1). Farmers (50.0%) also stated that wet markets are an important sales destination, followed by middle-men (40.0%). Only a small number of wet market retailers (12.9%) obtained vegetables and fruits directly from local farmers. This number includes both the case where farmers sold their own products at wet markets and when wet market retailers purchased products directly from nearby farmers. Supermarkets and other small retail shops (e.g., convenience stores) were rarely (7.3%) used as a source of vegetables and fruits for the group overall and even less so by farming households (3.9%). Mobile vendors were an important source of vegetables and fruits for farming households (50.0%) but not for non-farming households (4.7%). Trading in vegetables and fruits among wet markets frequently occurred, generally from larger markets to smaller ones (i.e., regional to local). We also confirmed that wet markets are usually owned by a private company, from whom small retailers rent space for their operations at the markets. Most small retailers were local and lived in BMN or the surrounding sub-districts.

Table 2 presents a summary of the responses for farming and non-farming households on their vegetable and fruit purchasing

Table 2
Vegetable and fruit purchasing behaviors of surveyed households. Each cell shows the number of respondents (percentage) in each group.

Question in interview	Response	Non-farming households (n = 43)	Farming households (n = 26)	Total (n = 69)
Subsistence farming	Yes	24 (55.8%)	24 (92.3%)	48 (69.6%)
	More than half	11 (25.9%)	11 (42.3%)	22 (31.9%)
	Less than half	13 (30.2%)	13 (50.0%)	26 (37.7%)
	None	17 (39.5%)	2 (7.7%)	19 (27.5%)
	No answer	2 (4.7%)	0	2 (2.9%)
Provision from neighbors or relatives	Yes	15 (34.9%)	18 (69.2%)	33 (47.8%)
	No	18 (41.9%)	8 (30.8%)	26 (37.7%)
	No answer	10 (23.6%)	0	10 (14.5%)
Cooking behavior	Morning at home	12 (28.0%)	25 (96.2%)	37 (53.6%)
	Lunch at home	13 (30.2%)	9 (34.6%)	22 (31.9%)
	Dinner at home	27 (62.8%)	20 (77.0%)	47 (68.1%)
Major criteria for purchasing vegetable and fruits	Price	3 (7.0%)	2 (7.7%)	5 (7.2%)
	Location	3 (7.0%)	6 (23.1%)	9 (13.0%)
	Fresh	19 (44.2%)	12 (46.2%)	31 (45.0%)
	Organic	7 (16.3%)	1 (3.9%)	8 (11.6%)
	Looks	5 (11.6%)	3 (11.5%)	8 (11.6%)
	No answer	6 (14.0%)	2 (7.7%)	8 (11.6%)

behaviors. Basic household characteristics (e.g., age of head and number of household members) were similar. Subsistence farming and provision of food from neighbors were relatively common in farming households (92.3% and 69.2%, respectively), with 42.3% of respondents reporting that they fulfilled more than half of their household vegetable and fruit consumption from their own farms. Relatively smaller numbers of non-farming households also practiced subsistence farming or had food provided by a neighbor (55.8% and 34.9%, respectively), and self-grown foods generally included only herbs and spices and thus did not greatly contribute to consumption overall. Farming households consumed meals at home more frequently than non-farming households. Cars and motorbikes were the most common modes of transportation used for purchasing vegetables and fruits for both farming and non-farming households (69.2% and 60.5%, respectively). Both farming and non-farming households expressed a preference for products from Nonthaburi (92.3% and 86.0%, respectively). The most common reason for this preference was "convenience" for both farming and non-farming households (80.8% and 48.8%, respectively). Freshness was the most commonly cited purchasing criterion for both farming and non-farming households (46.2% and 44.2%, respectively, Table 2). Among the 43 non-farming household heads, 13 (30.2%) were originally from within Nonthaburi, 12 (27.9%) moved from Bangkok, 15 (34.9%) moved from other provinces, and 3 did not answer. Most of farming household heads (21 households, 80.8%) were from Nonthaburi, while the others came from Bangkok (1, 3.8%) or other provinces (4, 15.4%). We did not find any clear relationship between the original hometown of the household heads and their food-related behaviors and preferences.

4.2. Geographic analysis of spatial scales and distances of local food flows

The results of the flow distance analysis showed notable differences among the actors. Fig. 6 presents a visual interpretation of observed vegetable and fruits flows related to wet markets. The most commonly used wet market by all 124 respondents was the Bang Yai City market, which is located in the central commercial area of Bang Yai district and has relatively larger facilities as compared with other wet markets in Bang Yai. The flows related to households and food shops were mainly on the BMN sub-district and Bang Yai district scales, whereas the flows of farmers' sales to wet markets were often on a larger scale (Nonthaburi Province and the Bangkok Metropolitan Region; Fig. 6). Wet market retailers often chose large wholesale wet markets outside of Nonthaburi Province (e.g., Talad Thai in Pathum Thani Province) as a food source. Fig. 7 shows the median and range of distances of vegetable and fruit inflows from wet markets to households, food shops, and wet markets and outflows from farms to wet markets. As shown in Fig. 7, the distance from households to wet markets was relatively shorter (2.67 km for farming and 2.52 km for non-farming households, on average), whereas distances from wet markets to wet markets and from farmers (for selling) to wet markets were relatively longer (17.10 and 8.96 km on average, respectively).

4.3. Comparison of the distribution of wet markets, supermarkets, and urban land uses

Fig. 8 shows the maps of urban land-use ratios and the distances from the various grids to wet markets and supermarkets. Urban land use in the overall area increased from 24.5% to 37.8% from 2003 to 2008. The ratios in the smaller 1-km^2 grids showed a great deal of variation, ranging from 0.1% to 59.5% in 2003 and from 1.6% to 71.2% in 2008. The number of supermarkets in Nonthaburi Province increased from 10 to 20 as the urbanized area expanded (7 closed and 17 opened). The number of wet markets also increased from 31 to 53 (5 closed and 27 opened). As shown in Fig. 8, urban development from 2003 and 2008 mainly occurred in the eastern side of the study area, which is closer to the urban center of Nonthaburi Province. Supermarkets tended to be concentrated in the more urbanized areas in the central and eastern parts of the area, whereas wet markets were distributed across a wider area that included relatively rural areas in the western part. Distances from the grids to wet markets were significantly lower than distances from the grids to supermarkets ($P < 0.001$, the Wilcoxon rank-sum test) in both 2003 and 2008. All grids had improved accessibility (i.e., shorter travel distances) to wet markets and supermarkets in 2008 than in 2003. The average distance from the grids changed from 2.0 to 1.4 km for wet markets and from 3.8 to 2.8 km for supermarkets.

The results from the regression analysis between the distance from the grids to wet markets and supermarkets and urban land-use ratio showed that highly urbanized areas have good access to both wet markets and supermarkets (Table 3, Fig. 9) Although all of the models showed a very strong relationship between urban land-use ratio and distance to wet markets or supermarkets ($P < 0.001$), supermarkets were more strongly related to urban land-use ratio than wet markets (Table 3). As shown in Fig. 9, distances to wet markets were shorter than distances to supermarkets. This was true even in the grids with high urban land-use ratios. Changes

Fig. 6. Visualization of vegetable and fruit inflows to households, food shops, and markets and outflows from farms. The left panels show larger scale maps beyond Nonthaburi Province, whereas the right panels focus on the Bang Mae Nang sub-district.

Table 3
Estimated linear regression model values for 1-km^2 grids based on ordinary linear squares. Explanatory variables are urban land-use ratios of the 1-km^2 grids and response variables are distances from the grids to wet markets and supermarkets in 2003 and 2008.

Response variable	Explanatory variable	Intercept	Coefficient	*P*-value	R^2
Distance to wet market in 2003 (m)	Urban land-use ratio in 2003	2.55×10^3	-2.40×10^3	<0.001	0.19
Distance to wet market in 2008 (m)	Urban land-use ratio in 2008	2.00×10^3	-1.63×10^3	<0.001	0.15
Distance to supermarket in 2003 (m)	Urban land-use ratio in 2003	4.97×10^3	-4.66×10^3	<0.001	0.26
Distance to supermarket in 2008 (m)	Urban land-use ratio in 2008	4.34×10^3	-4.21×10^3	<0.001	0.33

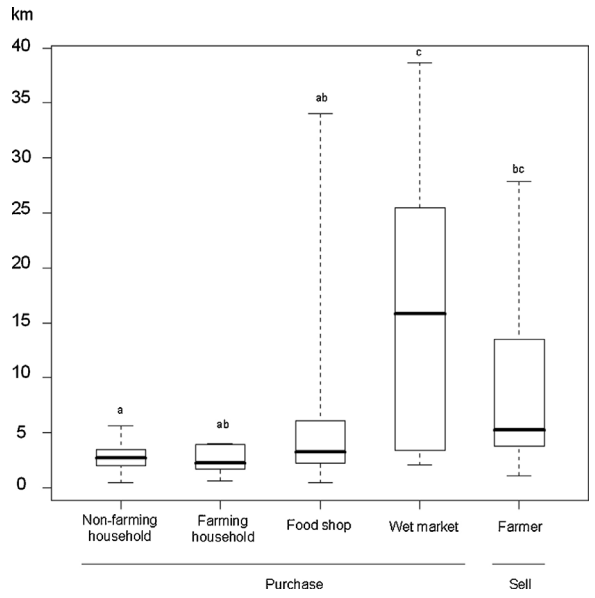

Fig. 7. Distances of vegetable and fruit inflows from wet markets to households, food shops, and wet markets and outflows from farms to wet markets. Values are medians (horizontal lines), the central 50th percentile (boxes), and the range between the maximum and minimum values (range bars). Values labeled with different letters differ significantly (pairwise Wilcoxon rank-sum tests with Bonferroni's correction, $P < 0.05$).

in the distances to wet markets from 2003 to 2008 were not clearly observed in the grids with high urban land-use ratios. On the other hand, distances to supermarkets decreased during the same period even in the grids with high urban land-use ratios.

5. Discussion

5.1. Changes in traditional and modern food systems under urbanization

Our results showed that traditional food retailing systems remain vital even during this period of rapid urbanization in a peri-urban area. Wet markets generally functioned as the most important hub for both producers and consumers of vegetables and fruits in and around BMN (Fig. 5, Table 1). Our study results (Table 1) did not clearly show the importance of the modern food system, possibly because the process of urbanization is still in its initial stages in the BMN area and the purchase of vegetables and fruits at supermarkets is not yet common. Our geographic analysis (Fig. 9) also supported the advantage of wet markets over supermarkets in terms of accessibility across a wide range of urbanized areas. Even though supermarkets are located in the relatively more urbanized areas in BMN (Figs. 4 and 8), households still primarily chose wet markets as a source of vegetables and fruits. The continuing importance of the traditional wet market system has been mentioned in previous studies (Cadilhon et al., 2006; Goldman et al., 1999; Shepherd, 2005), and our findings showed that a similar trend can be observed in this dynamically changing peri-urban area of the Bangkok Metropolitan Region. The reasons to choose wet markets as a source of vegetables and fruits include low price, product quality (Gorton, Sauer, & Supatpongkul, 2009), convenient location (Trappey & Lai, 1997), and cultural habits (Goldman et al., 1999). The importance of wet markets for local farmers in rural areas has been noted (Schipmann & Qaim, 2010), but our results indicate that the same is also true in peri-urban areas (Table 1).

Our household interviews showed that non-farming households tended to depend more heavily on nearby wet markets and meals eaten outside of the home, whereas farming households depended on self-grown products, provision from neighbors, and mobile vendors (Tables 1 and 2). These differences imply that the urbanization has brought about various changes in food purchasing behaviors and even fostered a greater dependence on wet markets among non-farming households. Several studies have revealed the importance of wet markets as a source of vegetable and fruit consumption in developing urban regions in East and Southeast Asia (Goldman et al., 1999; Gorton et al., 2009; Trappey & Lai, 1997), and our results suggest that this trend was partly because urban households replaced food sourced from their own farms and neighbors to food from wet markets and food shops. Although previous studies (e.g., Cadilhon et al., 2006; Shepherd, 2005) have often considered wet markets to be part of the "traditional" food system, our results imply that wet markets remain a part of the expanding food system during periods of urbanization. Our interviews of farming households also showed that the "traditional" food system included vegetable and fruits sources other than wet markets (e.g., self-grown products, provision from neighbors, and mobile vendors), and those other sources are gradually disappearing under urbanization in contrast to the growth seen in wet markets.

Differences in the spatial distributions between wet markets and supermarkets suggest that the two types of markets use different strategies to cope with urbanization. Wet markets were located across the peri-urban area (Figs. 4 and 8), and they particularly were located closer to consumers in less urbanized areas as compared to supermarkets (Fig. 9). Supermarkets, however, tended to be concentrated in highly urbanized areas. These results imply that wet markets spread in the early stages of urbanization and are targeted at a relatively smaller population in newly developed residential areas, whereas supermarkets open in the later stages of urbanization after the population has increased. Several studies have reported the differences in customers and products between wet markets and supermarkets in urban areas (Gorton et al., 2009; Schipmann & Qaim, 2011), and our results showed the markets also differ in their store location strategies, which may have an effect on the relationships between peri-urban land uses and food systems.

Our geographic analysis also indicated the increasing presence of supermarkets in highly urbanized areas. Distances from grids to wet markets in highly urbanized areas did not change from 2003 to 2008 (Fig. 9); the average was about 1 km, which is a common travel distance for food purchasing (Charreire et al., 2010). These results imply that wet markets were already saturated in highly urbanized areas. Conversely, distances from grids to supermarkets in highly urbanized areas decreased during the same period, and there was a greater abundance of supermarkets in highly urbanized areas in eastern Nonthaburi (Fig. 4). Although the Thai government is considering implementation of regulations to slow the rapid expansion of supermarkets (Shannon, 2008), our interviews with municipal officials confirmed that these regulations have not yet been implemented. These results, together with the potential of huge urban development and increasing land values subsequent to the opening of a mass transportation system in the study area (Hara et al., 2010; Mass Rapid Transit Authority of Thailand, 2010), indicate an increasing dependence on supermarkets as a source of vegetables and fruits in the not-too-distant future.

5.2. Potential contribution of the "traditional" food system to sustainable peri-urban agriculture

Our results suggest that policymakers and planners in rapidly developing urban regions can take advantage of the "traditional" food system in expanding markets to maintain a localized food system and sustain peri-urban agriculture. The results of our survey of household purchasing behavior support this conclusion (Table 1) because many households preferred vegetables and fruits grown in

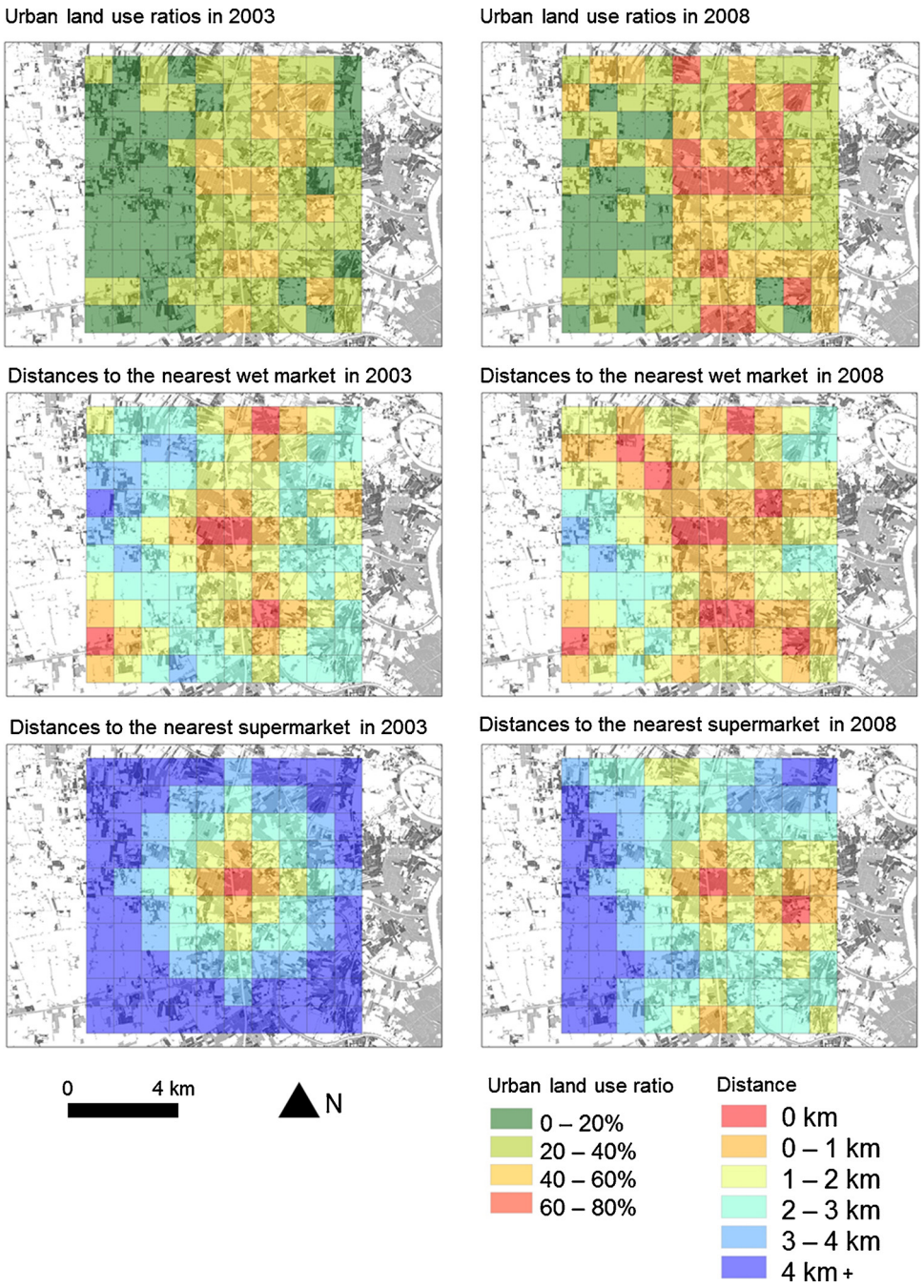

Fig. 8. Urban land-use ratios of and distances to wet markets and supermarkets from the 1-km^2 grids inside the 10 × 10 km square area. The left panels show the land-use ratios and distances in 2003, and the right panels show them in 2008.

Nonthaburi because they are easier to obtain and are fresher than other fruits and vegetables. If local farmers were to maintain their own spaces at nearby wet markets similar to the way that farmers' markets are managed in developed countries (Hara, Tsuchiya, Matsuda, Yamamoto, & Sampei, 2013a; Kremer & DeLiberty, 2011), they could directly sell their products, minimize transportation costs, offer the freshest products, and potentially gain higher margins than they do by selling produce to middle-men or wet market retailers. Although farmers can receive benefits from modern food systems in some cases (Reardon, Barrett, & Swinnen, 2009), the minor contribution of supermarkets as a source of vegetable and fruit purchases in our study indicates the advantages of wet markets as a means for food system localization.

Peri-urban farmers suffer from the effects of water pollution caused by urban development and, as a result, incur increased costs in their farming operations (Honda et al., 2010; Sajor & Ongsakul, 2007; Vagneron, 2007). Fostering direct communication with non-farming households could improve recognition of this issue among farmers and consumers (Sundkvist et al., 2005). Such feedback could also benefit consumers if farmers were to gain a greater recognition of the importance of offering safer or reduced-fertilizer products to non-farming households. Promoting their locally grown products in nearby wet markets may be difficult for a single farmer and may therefore require the establishment of local farmer organizations (FAO, 2007) or a local food certification scheme (Hara et al., 2013a).

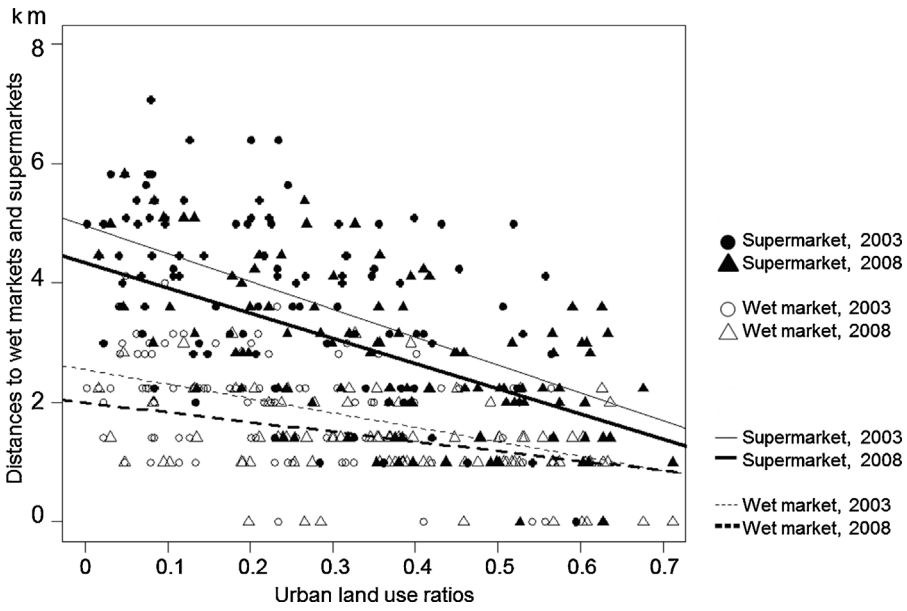

Fig. 9. Relationships between urban land-use ratio of the 1-km^2 grids and distance from the grids to wet markets and supermarkets in 2003 and 2008. The lines show the estimated linear regression models (OLS; also see Table 3).

The importance of close (i.e., within the same district) wet markets, however, is currently lower for farming households than for non-farming households. Our geographic approach showed that consumers and producers often did not choose the closest wet markets as their food source or selling destinations (Figs. 6 and 7). This indicates that distances are not the only criteria when choosing food-related behaviors. As shown in Tables 1 and 2, farming households were less dependent on wet markets as a source of vegetables and fruits and more dependent on the products from their own gardens and from mobile vendors. Farming households also did not choose nearby wet markets as a sales destination for their products; rather, they sold to wet markets that were farther away (Figs. 6 and 7) or directly to on-site middle-men (Table 1). These findings indicate a weak relationship between farmers in peri-urban areas and nearby wet markets. Our interviews of wet market retailers support this argument in that only a small number of the retailers reported acquiring vegetables and fruits from local farmers (Table 1). The expansion of new wet markets in our study area may have been driven by consumer demand rather than a producer strategy to sell products locally. Although the wet market system has recently drawn attention as an alternative to modern market systems (i.e., supermarkets) for small farmers (Cadilhon et al., 2006; Schipmann & Qaim, 2011; Shepherd, 2005), our geographic analysis indicated that the development of a wet market system alone is not enough to create a local food system in peri-urban areas. Considering the relatively long history of agriculture at our study site (Askew, 2000), several local farmers may continue to depend on the traditional food system and sell to relatively old wet markets that are not located in or around the BMN area (Fig. 6). Sajor and Ongsakul (2007) and Davivongs et al. (2012) demonstrated the exclusion of farmers from growing peri-urban communities in their water management studies, and our results showed the same phenomenon can be observed in the food system.

5.3. *Need for geographic approach in studying complex food system*

Our GIS-based analyses enabled us to better understand the linkage between land use and food system change in an urbanizing area. The spatially explicit and quantitative information provided in this type of analysis can help address the core questions related to local food systems, such as the following. First, what spatial scale does the term "local" refer to (Born & Purcell, 2006; Martinez et al., 2010)? Our food flow analysis (Figs. 6 and 7) revealed that the travel distances for purchasing foods were 2.67 km for farming households and 2.52 km for non-farming households, which were significantly longer than the assumptions in previous research (e.g., 1 km, Charreire et al., 2010) and indicated the need to consider regional and geographical characteristics in developing local food systems. Second, what is the relationship between local food systems and agricultural and urban land uses (Hara et al., 2013a)? Our spatial analysis (Figs. 8 and 9) showed that a geographic approach can partly answer this question by visualizing their spatial distributions. We believe that the application of geographic techniques in food system research will significantly advance our quantitative and objective understanding of the patterns of food production, delivery, and consumption (Kremer & DeLiberty, 2011) and cities as complex and networked systems (Seto et al., 2012). It will also help researchers and policymakers to better understand whether or not localizing food systems will reduce environmental impacts (Edwards-Jones et al., 2008; Kulak, Graves, & Chatterton, 2013).

6. Conclusion

Our findings can be summarized as follows. First, traditional food retail systems were still vital even during a period of urbanization, and wet markets were an important source of vegetables and fruits for consumers as well as an important sales destination for producers. Urbanization in peri-urban area even fostered the importance of wet markets as the sources of vegetables and fruits for local households. This strongly indicated the potential of wet markets as hubs of local food systems to tighten feedback loops between consumers and producers in peri-urban areas and to sustain peri-urban agriculture. Second, peri-urban farmers lack connections to nearby (i.e., in the same district) wet markets as a sales destination, and this was one of the most significant obstacles preventing positive feedback between local consumers and producers. Local governments and other actors may be able to overcome this obstacle by promoting communication among farmers, wet market retailers, and non-farming households.

This study had several limitations. First, the focus of our survey was to ascertain the general behavior of multiple actors when buying and selling food, but we were not able to gain a deeper understanding of why people chose certain types of sources or destinations (e.g., relationships between food-related behaviors and household incomes). A better understanding of the actors' behaviors, especially those of farmers, is critically important to gain a better understanding of the food system in peri-urban Bangkok. Detailed socio-economic information of farming households will help to examine the sustainability of farming activities under urbanization (Vagneron, 2007). In addition, we were unable to collect quantitative information of food production and consumption per household, which would have contributed to understand the relationships between peri-urban agriculture and nutritional status (Bon et al., 2010; Midmore & Jansen, 2003) but required extensive monitoring of a certain number of household samples. Second, our estimates of travel distance were based on Euclidean distances. The use of a complete road network dataset to measure actual distances travelled would improve the quality of the geographic analysis, although this type of dataset was not readily available. Third, we could not obtain a geographic dataset for wet markets and supermarkets before 2003 and after 2008. These limitations hampered our understanding of the impact of urbanization on food systems, although obtaining these types of datasets in developing countries is often difficult because of severe limitations on data availability and accessibility (Hara et al., 2013b). Long-term monitoring of multiple food types (e.g. rice and meat) and the combined use of a remote sensing approach with field-based surveys will be needed to capture the dynamics of food systems in peri-urban areas undergoing urbanization. Despite these drawbacks, we believe that our methodology is applicable in many peri-urban agricultural areas.

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