THE ROLE OF DIFFERENT TYPOLOGIES OF URBAN AGRICULTURE FOR THE NOURISHMENT OF THE METROPOLIS. THE CASE STUDY OF MILAN

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Abstract. In highly urbanized contexts a strategy for improving food provision and a sustainable use of resources is needed. In order to ensure this, specific interventions should be supported by a background analysis, deepening the potentialities of the local system in responding to urban food demand.
The paper proposes a methodology to describe and assess these capacities in a metropolitan agro-food system from a multidimensional perspective, through an approach combining productive and economic aspects, and describing simultaneously the conformity of productions to food demand, and their contribution to the economic balance of the territory. The methodological approach introduced has been applied to Milan Metropolitan Region.

Keywords: metropolitan area, food balance, food self-sufficiency, self-sufficiency indexes

Introduction

The issue concerning the nourishment of a city is not something new. Major efforts are concentrated in deepening the topic in developing countries, where the main problem is related to increase and improve food security (Gallaher et al., 2013). However, the theme is spreading in developed contexts of Western Countries as well, where it emerges the need to enhance productivity in order to nourish more and more people (UNDESA, 2012), ensuring a sustainable agricultural production and respecting the environment.

Dynamics occurring in urban contexts were firstly investigated by Wolman (1965) who introduced the concept of “metabolism of cities”, basing his theory on the quantification of overall fluxes of a North-American urban region. His approach suggests and underlines that urban contexts mostly depend on resources coming from surrounding areas and in this sense the city is not meant as an isolate and completely independent system, but rather as a complex one, interacting with and within a wider territory (Zasada et al., 2013): the metropolitan system. The metropolitan region could be described as a global system in which coexist and interact two main elements: high-dense urban areas (urban cores) and less dense areas, strictly related to the former (Sali et al., 2014a), whose proportions and relationships define the monocentric or polycentric structure. However, the less dense and more rural areas around the city core are more and more threatened by occurring and expected demographic dynamics, pressing on them in terms of both land consumption and in a parallel increase of food requirements, trends occurring in a context with limited natural resources, as a metropolitan area is. A higher soil consumption, due to the conversion of agricultural into built-up land to meet the needs in residential and economic settlements, is much more intense in peri-urban areas (Piorr et al., 2011), leading to a higher urban sprawl, conflicts in land use, decrease of arable land (Oldeman et al., 1999) and the productive potential of a specific territory, further altering the metabolism of a city (Wolman, 1965; Kennedy et al., 2007).

In highly urbanized and metropolitan areas a strategy for a sustainable use of resources is then needed, as global market supply is not often adequate in meeting food demand, food security, food accessibility (Alexandratos and Bruinsma, 2012) and environmental sustainability.

In order to ensure this, specific interventions are needed. Based on the analyses of potentialities and performances of a metropolitan context in feeding people there living, the paper proposes a food balance analysis tool, also useful to give indications and improve food planning policies in such a context. The first paragraph focuses on literature about food balance models, the second and the third explain respectively methodology and results. Finally, some conclusions are drawn.

Assessing food demand and supply: state of the art

The role of urban agriculture in providing food to the city and estimate at what extent it is able to do this, has been widely investigating by quantifying the capacity of an urban area of producing within its physical boundaries (Morris, 1987) enough food for people living there (Mok, 2014), fulfilling food demand (Timmons et al., 2008).

Studies on food balance follow three main approaches: i) models based on different dietary habits and their potential changes; ii) models based on potential changes in the agricultural production technology; iii) models based on a territorial approach, considering the different features of the area.

Concerning the first approach, Desjardin et al. (2010), in their study for Waterloo Region, Canada, estimated the amount of locally grown products needed to meet population nutritional requirements and expressed it with land that potentially supplies these productions. Giombolini et al. (2011) in a similar analysis for Willamette Valley, Oregon, U.S.A, compared offered servings to total recommended dietary requirements. Food consumption patterns and diet are important elements to be considered in order to get results towards sustainability in agriculture (White, 2000), as some diets in favour of the welfare and human health have lower environmental impacts (Duchin, 2005). A scenario analysis was made through ALBIO model (Wirsenius et al., 2010) to calculate land area and crop production necessary to provide levels of consumption according to dietary changes and an increase in livestock productivity in 2030. The model returned an average decrease of the requested area from 19% to 39%, depending on the case study region, and its decrease according to higher livestock productivity and lower animal protein content in the diet. More recently, Menconi et al. (2013) provided a model for determining the area needed in a central Italian context to ensure food self-sufficiency, according to a variable number of components, represented by the annual quantities needed to satisfy nutritional requirements of individuals. Finally, de Ruiter et al. (2014), starting from consumptions at household level, calculated and compared among 16 European Countries the land required to provide the caloric intake corresponding to the respective dietary pattern.

The second approach was investigated for instance by Gerbens-Leenes et al. (2002) who quantified specific land requirements per food item in The Netherlands, from primary production level to the national one, in a step-by-step approach, using information on yields, imports, food industry recipes and proportions of open-air and protected crops. In its further development (Gerbens-Leenes and Nonhebel, 2002), the method demonstrated that the higher is the level, the more is land required. On these bases Zhen et al. (2010) applied the method to two different scales, analyzing land requirements per household in a Chinese district.

With regard to the latest approach, it must be noted the work of Billen et al. (2009) in the Parisian area. Authors proposed a methodology to analyze Paris foodprint through the examination of nitrogen flows to state if rural and surrounding areas and regions were able to meet the demand of nitrogen-containing food products that come from the city. Most of analyses are however focused on quantitative aspect of food balance, rather than a micro component of food itself, as nitrogen is. More realistically being a city not able to provide resources within its own boundaries, Porter et al. (2014) considered the necessity for a city to increase its food security through productions from remote landscapes. In this sense they applied and compared in three years a methodology to quantify food balance, based on consumption and production of five single commodities and also on import and export flows. The analysis finally resulted in the comparison of food self-provisioning across capital regions of Tokyo, Canberra and Copenhagen and in the quantification of total land area required to ensure local consumption of wheat from local sources. A similar analysis also based on wheat is that of Sali et al. (2014b), who proposed a simplified food balance in the metropolitan region of Ljubljana, Slovenia, to determine the possibility for the city to be fed by proximity agriculture. Starting from data provided by national statistics, they converted dietary consumptions into total area of wheat they correspond to, and compared it to total arable land if it would be entirely devoted to wheat. Even more recently Filippini et al. (2014) analyzed the role of peri-urban livestock farms in the urban region of Pisa in fulfilling urban demand for meat, according to potential, current and actual supply and results of on-farm surveys. On the bases of supplied and demanded quantities they calculated food production capacity of the system.

Different studies focus on developing tools to assess the degree of self-sufficiency of a metropolitan area rather than a city, developing self sufficiency indexes (FSI), as Ostry and Morrison did (2013) for six major food categories, by calculating them as the ratio between production and consumption.

In the work of Atamanova (2013) this index is instead defined "self-efficiency" and, along with other indicators provided, it is only one of the elements for the evaluation of food sufficiency with dairy products in the Russian region of Bryansk. Finally, starting from current policies, available area and the extent of vacant lots, crop yield and food consumption, Grewal and Grewal (2012) developed three scenarios to estimate the potential level of self-sufficiency of Cleveland, U.S.A. This capacity is not only expressed in weight, but also the expenditure in total food and beverage consumption was considered, leading to economically quantifying the annual retain in Cleveland due to self-reliance. This study represents one of few works considering the economic dimension of self-sufficiency, as this aspect still remains quite unexplored.

However it lacks a simple and reproducible methodology focusing on metropolitan contexts that can be used as an analysis tool to characterized them and help in drawing territorial food policies.

Methodology

In order to characterize metropolitan agrofood systems and derive useful information to support food planning initiatives, it is proposed an analysis tool for a territorial food balance assessment. In this sense, the identified approach aims to characterize a metropolitan area through a multidimensional indicator of food self-sufficiency.

The methodology proposed firstly includes the quantification of food dimensions, with food demand and supply assessment, and then the calculation of self-sufficiency indexes, as the ratios between food supply and demand, expressed by quantities, calorie and economic value. The simultaneous assessment of these three ratios provides, like an "identity card", the quality of the agri-food system of any region.

The methodology has been applied to the case study area of OECD Milan (*OECD, 2006*) (fig.1): it has a territorial extent of more than 13,000 km^2, built-up for almost 25%, where 7.8 Mio. people live; these conditions have strong repercussions on the availability of agricultural area, as its amount in the region is nearly 490,000 ha (equal to 618 m^2 per capita).

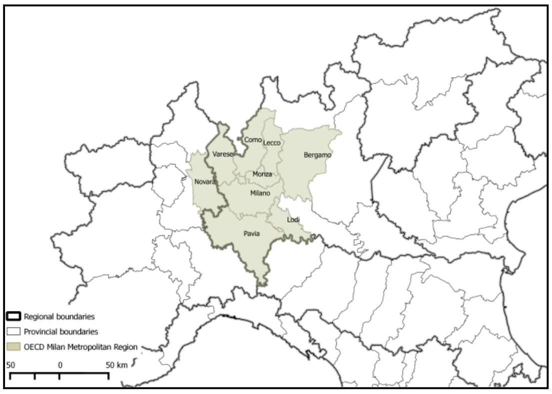

Figure 1. OECD Milan Metropolitan Region

Analysis of demand

The quantitative dimension of food demand has been traced back to the quantity of food annually consumed by population, according to EFSA Chronic food consumption statistics (*EFSA, 2011*), which associates to different age classes (index *age* in eq. 1) the respective daily food consumption aggregated per food category (*c*) and even broken down into subcategories (*s*) (table 1).

Table 1. Food categories considered in the analysis

Food category	Food subcategory	Base product
Milk and dairy products	Liquid milk Butter Cheese	*Milk*
Fruits	Various	*Equivalent*
Grain products	Bread Pasta Milling products	*Wheat*
	Rice	*Paddy rice*
Vegetables	*Various*	
Pulses	*Various*	
Roots and tubers	*Potatoes*	
Meat	*Poultry meat* *Livestock meat* *Pig meat*	
Vegetable oil	Olive oil	*Oil olives*
Alcoholic beverages	Wine	*Wine grapes*
Eggs	*Eggs*	

Demand per base product (p) depends on specific consumption, population numerousness (*n*) in a single municipality (*m*), as provided by National Statistics (*ISTAT, 2011*) and, where necessary, on a suitable conversion factor (*ty*) (table 2), expressing how much of raw product is contained in the final product (AGRISTAT, 2014; CIA Lombardia, CLAL, 2014; ENR, Lucisano and Pagani, 1997):

$$C_p = \sum_s \sum_m \sum_{age} C_{s,m,age} * n_{m,age} * ty_s \tag{1}$$

Then, total food consumption has been quantified by adding consumptions of each category:

$$TC = \sum_p C_p \tag{2}$$

Table 2. Food subcategories, base products and processing yields

From...	To...	Conversion factor
Rice	*Paddy rice*	Processing yield
Bread	*Wheat*	Baking yield
Pasta		Yield to pasta
Milling products		Yield to flour
Olive oil	*Oil olives*	Production yield
Drinking milk	*Milk*	1
Butter		Yield to butter
Cheese		Yield to cheese
Wine	*Wine grapes*	Wine making
Fruits, Vegetables, Pulses, Potatoes, Bovine meat Pigmeat, Poultry meat, eggs		1

Analysis of supply

Two different approaches have been adopted to quantify the supply from products of crop origin (VS) and animal productions (AS), and then to estimate total supplied quantities TS.

In the first case, data from regional database SIARL (2012), collecting information on farming activities at cadastral level, have been used to quantify at municipal level the extent of agricultural area (a) devoted to the base product of each food category p (see table 1). These extensions have been converted into supplied quantities of raw product, where necessary, by multiplying them by an average productive yield (AGRISTAT, 2014) and then summed to obtain total food supply of plant origin:

$$VS = \sum_m \sum_p a_{m,p} * y_p \tag{3}$$

With regard to animal productions, the amounts of supplied quantities of eggs, dairy products and meat have been quantified according to the numerousness of livestock provided by National Agricultural Census (ISTAT, 2010) and productivity per head (AGRISTAT, 2014):

$$S_{p=EGGS} = \sum_m ly_m * w_{EGG} * ue \tag{4}$$

where *ly* number of laying hens, w_{EGG} the weight of an egg and *ue* the number of eggs per hen;

$$S_{p=DAIRY} = \sum_m dc_m * um \tag{5}$$

where *dc* number of dairy cows and *um* the average yearly production of milk per head;

$$S_{p=MEAT} = \sum_m [su_m * sy * gp_b + \sum_l (su_{l,m} * sy_l * w_l * gp_l) + \sum_p (su_{w,m} * sy_w * w_w * gp_w)] \quad (6)$$

where *su* number of animals for slaughter or fattening, with *b* broilers, *l* meat cattles (e.g. calves, bullocks, bulls, cows) and *w* swine (e.g. piglets, fattening pigs); *sy* is the average yield at slaughter, *w* average weight per head and *gp* growth periods number per year.

Total supplied quantities of animal products derives from the sum of previous elements

$$SA = S_{p=EGGS} + S_{p=DAIRY} + S_{p=MEAT} \quad (7)$$

while total food supply is

$$TS = AS + VS \quad (8)$$

Self-sufficiency and performance indexes

Both supplied and demanded quantities of each food category have been converted into caloric dimensions by using the energetic rate of the respective raw product of the category itself (K_p) and considering the percentage of the energetic rate (P) coming from different sources (o) (carbohydrates, fats, proteins) (INRAN, 2014)

$$KS_o = \sum_p (S_p * K_p * P_o) \quad (9)$$

$$KC_o = \sum_p (C_p * K_p * P_o) \quad (10)$$

Then, total caloric supply and demand have been calculated by summing the calories relevant to each source:

$$supplied\ calories: KS = \sum_o KS_o \quad (11)$$

$$demanded\ calories: KC = \sum_o KC_o \quad (12)$$

Similarly, the economic value of supply and demand has been obtained by summing quantities of each base product multiplied by their respective producer prices (PP_p) (ISMEA, 2014):

$$produced\ value: VS = \sum_p (S_p * PP_p) \quad (13)$$

$$consumed\ value: VC = \sum_p (C_p * PP_p) \quad (14)$$

Finally, the potentialities of the agricultural system have been described by three indexes, expressing the extent to which total food supply can meet total food demand, as the ratio between supplied and demanded amounts. More in details:

a. Quantity index: it reveals how much the local production pattern fits with local food habits, without exceeding quantities of a food product compensate lacking quantities of another one

$$1 - \frac{\sum_p (C_p - S_p)}{TC} \quad (15)$$

subject to $(C_p - S_p) > 0$

b. Calorie index: it expresses how much the local agricultural system is able to satisfy the dietary caloric intake, both per macronutrient contributing to total caloric intake itself (eq. 16), and per diet (eq. 17), avoiding that exceeding calories from an origin compensate lacking calories from another one

$$1 - \frac{KC_o - KS_o}{KC_o} \quad (16)$$

subject to $(KC_o - KS_o) > 0$

$$1 - \frac{\sum_o (KC_o - KS_o)}{KC} \quad (17)$$

subject to $(KC_o - KS_o) > 0$

c. Value index: it is focused on how much of the production agricultural value is generated and which is the economic balance of metropolitan agro-food system

$$IV = \frac{VS}{VC} \quad (18)$$

Results and discussion

Food categories taken into account and their relative proportion on the national average diet, reflect dietary habits of population. They count for almost three quarters of total consumed quantities (74%), with fruits and vegetables ranking first (33%), milk and dairy products second (16%) and then cereals (11%).

Regarding self-sufficiency capacities per category, it is particularly evident the large amount of rice provided over the demanded quantity (fig. 2), result consistent with the case study area, encompassing the province of Novara where most of Italian and Northern Italian rice is cultivated. Surplus values surely imply flows of products towards other areas or regions, but this is not necessarily valid where a deficit occurs. In these latter cases in fact it would be possible that part of or total quantities are anyway exported and then the index may be overestimated; then the final value is to be rather interpreted as a net balance and a general indication for the potentialities of the system, or, in other words, the maximum contribution of local productions to the fulfilment of specific food demand.

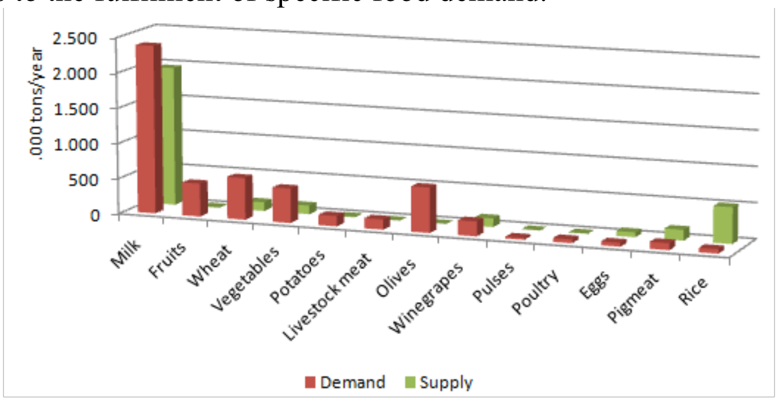

Figure 2. Raw products: demanded and supplied quantities.

A further aggregation of food product into wider categories, allows getting to an overview of the main features of the agricultural system in the region, by estimating supplying capacities in a comparative way. With regard to quantities supplied by each category, the quantification of the respective indexes (fig. 3) reveals the agricultural specialization of the area in cereal cultivation and products of animal origin, without however, leading to a complete self-sufficiency for these same categories.

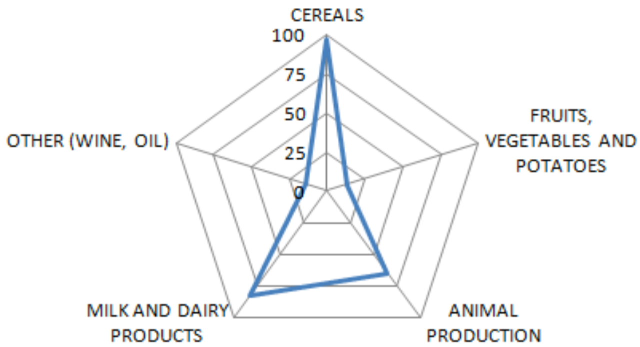

Figure 3. Quantity index for aggregated food categories.

Also due to the nature of the main productions, caloric amounts offered for all the categories of nutrients considered cover most part of requirements expressed by population (fig. 4); however, overall agricultural productions of the metropolitan region generate a low production value, in comparison to a high demand (fig. 5). Even if profitable in absolute terms, the economic performances of the agriculture in the region result in a negative economic balance for the entire system: the generated value is retained in the territory (local and metropolitan contexts) and totally consumed there, but it is not able to fulfil the demand, finally leading to no outflows of value from the region.

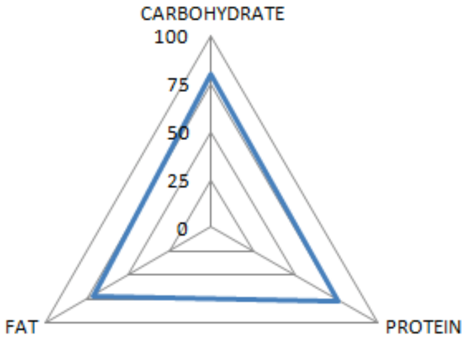

Figure 4. Fulfilment of caloric demand, according to the source of caloric intake.

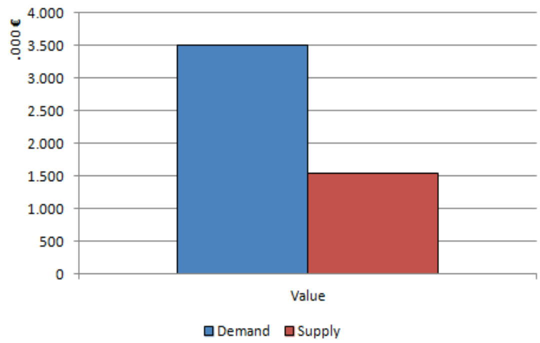

Figure 5. Requirement and retaining value in the case study area.

In figure 6 it is shown the combination of different overall indexes; this representation helps describing the entire agricultural systems on a more complex and comprehensive basis, indicating its capacity to fulfil different requirements expressed by population diet. The multidimensional description expresses once again the features of the agricultural system there operating: the scarce fulfilment of demanded quantities reflects the specialization of the production, which is oriented to caloric products with a (relatively) scarce economic value, like cereals or animal products are. It also means that this system must search for the lacking parts in external systems, leading to import foods from elsewhere, linking the agro-food system of OECD region with global markets.

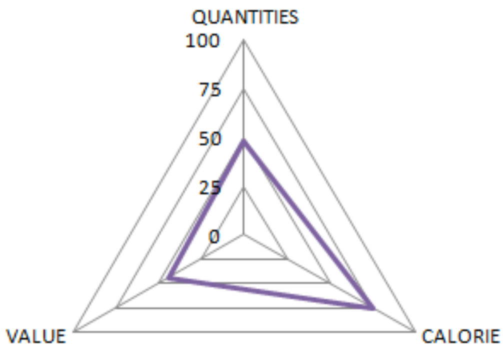

Figure 5. Multidimensional indicators for Milan OECD Region

Conclusions

The proposed methodology allows combining multiple aspects of both the agricultural system and the demographic component, in term of dietary habits, finally obtaining an overall description of the agricultural sector under different profiles; indications are given, not only on the potentialities of agricultural systems, but also on their own characteristics.

While food security remains an important, and well deepened, issue for developing countries, results from adopted approach can be useful to understand the aspects of availability and affordability of food products also in well developed contexts, such as the case study is. In this sense it may be applied for comparison among regions in different countries, both according to the same diet or a specific consumption pattern. However, it must be remarked that these results are to be taken into account as indications on the system's potentialities only, as complete food self-reliance would also have some implications in terms of practical feasibility. The analysis carried out per municipality and the availability of statistics at cadastral level has allowed to estimate food balance at a very detailed level, which finally ensures the possibility to differently aggregate municipalities themselves into regions considered interesting from time to time. The availability of data across regions and Countries allows adopting this methodology to make comparison among different contexts, also in order to provide indications for policy instruments and interventions (e.g. basis for a Food Planning).

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