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External effects of urban agriculture: an environmental and socio-economic approach

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Contents

Introduction

The interest in issues related to urban food supply is not something new. Major efforts are addressing developing countries, where the main problem is related to increase and improve food security (*Gallaher et al., 2013*). However, the theme is continuously on the rise in Western Countries as well: it emerges in the context of enhancing the productivity of providing high quality food to an increasing number of people (*UNDESA, 2012*), ensuring agricultural production sustainability and respecting the environment.

Dynamics occurring in urban contexts have first been 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. As to be expected, his approach suggests that the urban context is strongly depending on resources coming from surrounding areas. In this sense the city is not meant as an isolate and completely independent system, but rather as a complex system interacting with and within a wider territory (*Zasada et al., 2013*): a metropolitan system. The metropolitan region could be described as a an intermediate transfer space between local and global agricultural system in which coexist and interact two main elements: urban areas with a high density (urban cores) and a mix between peri-urban rural areas, that is defined by its close interaction with the former (*Sali et al., 2014*), whose relative proportions contribute to the description of the metropolitan area itself as being mono- or polycentric.

However, the less dense and more rural areas around the urban cores are increasingly under pressure due to the reciprocal relationship between urbanization processes on agricultural lands on the one hand (*Corsi et al., 2015*) and an increasing food demand by the very people occupying the former agricultural lands on the other hand.

Since global market supply is often not adequately meeting food demand and global market supply not often adequate in meeting food demand, food security, food accessibility (*Alexandratos and Bruinsma, 2012*) and environmental sustainability, new strategies for a more sustainable use of metropolitan food supply in and around highly urbanized areas is needed. In order to ensure this, municipal and regional authorities are starting to develop to new instruments and regulations – all of which being summarised with the emerging term *food planning policies*.

Metropolitan food planning policies

In recent years the "food planning" has become an increasingly important issue. In fact, after a period in which the food system was excluded from the themes of the planners, many political actors all over the world are now paying more attention to it, with focus on issues related to food security in Developing Countries and those related to food sustainability in Developed Countries. In Developed Countries food planning initiatives arise especially in metropolitan areas, because food is an urban issue affecting the local economy, the environment, the public health and the quality of neighbourhoods (*Pothukuchi and Kaufman, 1999*). Managing an urban food system involves *i)* the social aspect, with regard, for instance, to the interventions of aid to poor families through the distribution of free meals, *ii)* the economic aspect, because the preservation of productive agricultural areas in the metropolitan context impacts not only on the local agricultural sector, but also on the sustainable management of green areas, through the services offered by the agricultural activity itself, and finally the maintenance of productive agricultural areas has also an *iii)* environmental impact, through water management and conservation of green areas and biodiversity. For these reasons the multifunctional aspect of the agro-food system cannot be excluded from the planning of a city, just because it has strong effects on a wide range of other sectors (*Morgan, 2009*). In fact the food planning community is a profoundly diverse and multidimensional community, composed as it is of every profession that has a food-related interest and is striving to make food policy-making a more open and democratic process (*Lang et al., 2009*). So far, the food system has not been considered by urban policies, as food planning issues are largely perceived as related to rural areas and agricultural activity, and therefore not covered by the policy urban agendas (*Pothukuchi and Kaufman, 1999*). However, with the spreading of metropolitan areas worldwide (*UNDESA, 2012*) peri-urban and urban-rural fringe areas and their related challenges, such as food supply, have significantly increased (*Mazzocchi et al., 2013*). Today issues concerning rural and urban areas are closely connected and must be considered simultaneously by appropriate policies. Secondly, in the global North, there is not a perception of a lack of food or problems related to food accessibility, as the general urban residents consider food for granted: "*And why not? More and more supermarkets are open all hours of the day […]. If she thinks about hunger at all, she may be comforted to know that a "hunger safety net" exists in her community to keep the needy from falling into the clutches of hunger. Food pantries, free meal sites, and food banks are there along with food stamps, school breakfast and lunch programs, and meal programs for the elderly and for mothers with young children"* (*Pothukuchi and Kaufman, 1999, pp. 214).* However, more recently, problems of malnutrition or obesity as well as the phenomenon of food deserts, urban areas with limited access to fresh and affordable food has been observed also in Western cities (*Choi and Suzuki, 2013: Gordon et al., 2011*). Thus, many food movements have risen up, the most part of population is still not concerned about local food systems and their implications (*Kemp et al., 2010; Aubrun et al., 2005*), although this issue is now known by the public opinion.

Moreover, according to *Morgan* (2009) the new food equation (*Morgan and Sonnino, 2010*) implies that planners deal with food issues principally because of *i)* the food price surge of 2007-08, *ii)* food security has become a national security issue, *iii)* climate change effects, *iv)* land conflicts are escalating, *v)* urbanization is more and more rapid. It must be considered as well the shift of the price transmission mechanism from the "*push and pull*" to the demand-driven systems (*De Treville et al., 2004*), where consumers' preferences prevail denoting their propensity to a demand for local, traceable and, quality food, as well as sympathetic food production denoting the propensity to organic productions, fair trade and productions respecting animal welfare (*Grunert et al., 2007*).

As suggested by *Kerr (1996)*, programs of public investments directed to sustainability in agriculture need to be planned and implemented at different levels (village, district, state). In Europe this kind of interventions are mainly developed at city-level (table 1), but all over the world and especially in the Anglo-Saxon countries several examples of food planning policies and initiatives to manage local agro-food systems and face related themes can be found.

Toronto food security movement has achieved strategic policy commitments from local government, including the adoption by City Council of the Toronto Food Charter in 2001. This includes directives to city departments to serve as a model in food purchasing decisions, to develop partnerships to increase access to healthy foods, to promote composting, and to work with the food industry in order to reduce food packaging and promote reuse and recycling (*Wekerle, 2004*). Also in Europe food planning policies are assuming importance, with examples coming from both large metropolis, such as London (*Morgan, 2009*), and to medium-small cities: the famous Bristol city council in the UK (*Carey, 2011*) or Pisa, in Italy, with its "Urban Food Strategy ", which includes the Food Plan, a planning document coordinated among the participating municipalities of the Pisa Province, whose purposes are to understand and map the related issues at the local level, to ensure an adequate level of coordination among different stakeholders, design and promote aims and principles set out in the Food Charter and Food Strategy (*Di Iacovo et al., 2013*).

Table 1: examples of food planning experiences and strategies in Europe

FOOD PLANNING INITIATIVES AND NETWORKS	
Amsterdam (NL)	*Amsterdam Food Strategy* *Urban Food Policy Pact – partner*
Aubagne (FR)	*Charte pour une agriculture durable*
Barcelona (ES)	*Urban Food Policy Pact – partner*
Bath and North East Somerset (UK)	*B&NES Environmental Sustainability Partnership*
Belfast (UK)	*Belfast Food Network*
Birmingham (UK)	*Birmingham Food Charter*
Bilbao (ES)	*Urban Food Policy Pact – partner*
Bournemouth and Poole (UK)	*Bournemouth and Poole Sustainable Food Partnership*
Bradford (UK)	*Bradford District Food Strategy*
Brighton and Hove (UK)	*Brighton and Hove Food Partnership*
Bristol (UK)	*Bristol Food Network*
Cambridge (UK)	*Cambridge Sustainable Food City*
Cardiff (UK)	*Cardiff Food Council*
Co. Dorset (UK)	*FoodFuture Bridport*
Carlisle (UK)	*Food Carlisle*
Co. Durham (UK)	*Sustainable Local Food Strategy Co. Durham*
Edinburgh (UK)	*Edible Edinburgh*
Frankfurt (DE)	*Urban Food Policy Pact – partner*
Ghent (BE)	*Urban Food Policy Pact – partner*
Gothenburg (SE)	*Urban Food Policy Pact – partner*
Greater Manchester (UK)	*Feeding Manchester*
Herefordshire (UK)	*Sustainable Food Strategy for Herefordshire*
Hull (UK)	*Food4Hull*
Kirklees (UK)	*Kirklees Food Programme*
Lancashire (UK)	*Sustainable Food Lancashire*
Lancaster (UK)	*Sustainable Food City Lancashire*
Leeds (UK)	*Feed Leeds*
Leicester (UK)	*Leicester's Food Plan*
Lyon (FR)	*Urban Food Policy Pact – partner*
Liverpool (UK)	*Liverpool Food People*
London (UK)	*London Food Programme* *Urban Food Policy Pact - partner*
Malmö (SE)	*Malmö policy for sustainable development and food*
Manchester (UK)	*Manchester Food Future*
Marseille (FR)	*Urban Food Policy Pact – partner*
Milan (IT)	*Urban Food Policy Pact – promoter*
Newcastle (UK)	*Food Newcastle*
Paris (FR)	*Urban Food Policy Pact – partner*
Peterborough (UK)	*Peterborough Food Partnership*
Pisa (IT)	*Piano del cibo*
Plymouth (UK)	*Food Plymouth*
Rotterdam (NL)	*Rotterdam Food Council*
Sandwell (UK)	*Sandwell Community Agriculture Programme*
Sheffield (UK)	*Sheffield Food Strategy*
Stockport (UK)	*Stockport Sustainable Food Strategy*
Turin (IT)	*Urban Food Policy Pact – partner*
Tukums (LV)	*Tukums Urban Food Strategy*
Vitoria-Gasteiz (ES)	*Vitoria-Gasteiz Urban Food Network*
West Sussex (UK)	*West Sussex Food Plan*

OTHER FOOD STRATEGIES	
Basel (CH)	Linking different urban food initiatives
Copenhagen (DK)	Facilitate urban gardening
Piacenza (IT)	Facilitate local agriculture
Rennes (FR)	Facilitate local agriculture
Rotterdam (NL)	Rotterdam Food Cluster
Svendborg (SE)	Enhance food literacy of school children
	Facilitate local agriculture and urban gardening
Vienna (AT)	Promote of diversity of food retail
Wageningen (NL)	Food Valley

Sources: *www.sustaianblefoodcities.org; Moraues et al., 2013; www.comune.milano.it; www.cibomilano.org/food-policy-pact; Wascher, 2015*

Analyses supporting food-related policies

As stated in the DOW, the analysis of the metropolitan agro-food systems is based on the setting of "*socio-economic indicators*" related to, among others, "*market structures, accessibility, population, competitiveness, describing the background of agro-food market […] and the environmental indicators (land use, natural resources allocation, etc.)*" allowing the description of "*environmental constraints and values*" (FOODMETRES DOW, page 8).

Any political intervention in the food sector or any food planning initiative cannot therefore ignore the knowledge of the agricultural system it can impact on. It then derives essential preliminary analyses and assessments of the context, with the investigation of the dimensions of both food demand and supply: consequent results undoubtedly play a role as useful tools providing indications on the potentialities of the system and on their strengths and weaknesses, in order to finally shape proper regulations according to the actual conditions and the needs of the territory.

Literature variously provides analyses of demand and supply and their relation, and deepens the role of agriculture in urban / peri-urban contexts in providing food to the city, estimating at what extent it is able to do this. In other words, it is differently expressed the food self-sufficiency of an urban area, as the capacity to produce within its physical boundaries (*Morris, 1987*) and even beyond, enough food for people living there (*Mok et al., 2014*) fulfilling food demand (*Timmons et al., 2008*).

Assessing food demand and supply: state of the art

Nowadays, in the context of Agro-food Systems, consumers are playing an increasing role and their preferences and perceptions have been leading to the emerging of systems alternative to conventional ones, possibly defined by a spatial proximity between producers and consumers, in *"a critical process of reconnection"* (*Ilbery et al., 2005*, p. 117) that involves even sociological and political aspects (*Hinrichs, 2000; Qazi and Selfa, 2005*) and it is well represented by the concepts of Local Agro-food Systems (*Feenstra, 1997; Henderson, 1998; Lacy, 2000; Hinrichs, 2003*) and Alternative Agro-Food Networks (*Murdoch et al. 2000; Renting et al. 2003*). Such dynamics variously contribute to the development and the strengthening of local supply chains and environmental-friendly networks that also pay attention to social inclusion and favor local value added (*Berry, 1977, Barham et al., 2005; Pirog, 2003*).

In reconnecting territorially food production and consumption, the need of analysis tools has risen up. Several studies focus on defined areas and deepen the topic of the relations between demand and supply, in relation to the capacity of the local system in providing required amounts of food, i.e. the assessment of a simplified food balance expressing food self-sufficiency and reliance (*Timmons et al., 2008*). A rich literature concerns this kind of assessment in several contexts according to different, though interrelated, models of analysis. They refer to the assessment of potentialities or the quantification of the current capacities of agro-food systems and can be grouped into three main categories (table 2):

- *(i)* demand-based models: models that evaluate, on the basis of population needs, the theoretic supply in terms of quantities needed or land required (footprint);
- *(ii)* supply-based models: models that, starting from the production capacity of the territory, estimate how many people can be fed (potentialities);
- *(iii)* demand-supply models: in this case, on the basis of the real consumption and the real production of a region, rates of self-sufficiency are obtained.

Table 2: approaches for analysing demand-supply relations

		DEMAND	
		Real	Potential
SUPPLY	Real	*Starting point:* Population food needs and agricultural primary products obtained from agricultural land *Output:* *Requirement coverage by local productions*	*Starting point:* Available land *Output:* Number of people potentially fed by regional agricultural productions
	Potential	*Starting point:* population food needs *Output:* footprint	Not feasible

Demand-based models. These models start their analysis from data and information about food consumption and dietary patterns, either in terms of quantities or nutritional value, and quantify the supply needed to potentially meet food demand.

Concerning this approach, it should be noted the study *Gerbens-Leenes et al. (2002)* carried out for The Netherlands, quantifying specific land requirements per food item, from primary production level to the national one, in a step-by-step approach, finally demonstrating that the higher is the level, the more land is required (*Gerbens-Leenes and Nonhebel 2002)*. On these same bases *Zhen et al. (2010)* then applied the method to two different geographical levels, analysing land requirements per household in a Chinese district.

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. Similarly, the assessment of local supply capacity of Detroit (*Colasanti and Hamm, 2010*) allowed to study in-depth the capability of local urban agriculture and food production to meet recommended dietary intake of fruits and vegetables and estimated how much land, also considering the current extent and distribution of vacant and publicly owned land, is needed to achieve the correspondent productions.

It certainly should be noted the work of *Billen et al. (2009*) in the Parisian area. Authors proposed a methodology to analyse the Paris foodprint through the examination of nitrogen flows to state if city surrounding areas and regions had the ability of meeting the urban demand of nitrogen-containing food products, finally quantifying the respective effective area extent, which, along with the food-orientation approach, makes the analysis different from the concept of ecological footprint (*Wackernagel and Rees, 1996*). A similar analysis was conducted by *Billen et al. (2012),* who estimate the excess production over local consumption and individuated the effective location of areas participating in Paris food supply.

In this group of models studies focused on scenario analysis are included as well. Different nutritional conditions, represented by different total caloric intakes, were considered by *Darrot et al. (2011)* in their investigation of the available land within the city of Rennes, France, and its productive potential to meet food requirements. Authors drew up a simplified food balance, on which basis they calculate and defined the radius of the area around Rennes potentially needed to meet turban food consumptions 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.

A further scenario analysis was made through the ALBIO model (*Wirsenius et al*., 2010) to calculate land area and crop production necessary to provide levels of consumption consistent with dietary changes and increasing livestock productivity in 2030.

Supply-based models indicate the number of people that can be fed with current or future food supply and provision. Realistically, being a city not able to provide resources within its own boundaries, *Porter et al. (2014)* considered the necessity for a city to depend on productions from remote landscapes. In this sense the authors applied and compared in a time series of three years a methodology for the quantification of food balance, based on five single commodity consumption and production patterns but also on imports and exports. 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.

More recently *Cassidy et al. (2013)* re-thought the issue of agricultural productivity, shifting the focus from tonnes per hectare to people fed per hectare, and demonstrated that calories produced by an agriculture exclusively directed to human consumption would potentially increase by 70% and feed additional 4 billion people.

Demand-supply models. These approaches are based on the comparison between actual/current food supply and actual/current demand, expressing this relation either in quantitatively and in relative terms, through an index of self-reliance defined as the ratio between the amounts. Different studies operate in this sense, developing self-sufficiency indexes themselves, as *Ostry and Morrison* did *(2013).* In the work of *Atamanova* (2013) this index is instead defined as "self-efficiency" and, along with other indicators provided, it is only one of the elements for the evaluation of food reliance with dairy products in the Russian region of Bryansk.

Other studies to be taken into account are those of *Giombolini et al. (2011),* who compared offered servings to total recommended dietary requirements for population, providing the percentage of dietary needs met, *Mohanty et al. (2010)*, who proposed the comparison between requirements and actual production of food grains in the Indian district of Orissa, both quantitatively and through a sufficiency factor, as long as the area required to be cropped, and *de Ruiter et al. (2014),* who combined food availability data at household level with country-specific land use data for food items, determining the cropland use associated with dietary patterns of a range of 16 European countries.

Such analyses are also aimed to assess the potentialities and the role of the local agricultural systems. *Sali et al. (2014)* 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 the consumptions of the current dietary pattern into total area of wheat they correspond to, and compared it to total available 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, calculating the food production capacity of the system.

Finally, starting from current policies, available area and the extent of vacant lot, 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 by weight, but the expenditure in total food and beverage consumption has been considered as well, 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 unexplored.

Though evidences in the possibility to differently assess the potentialities of agro-food systems, the issue of food self-sufficiency is mainly tackled from time to time from a single point of view, typically the quantitative or the nutritional aspect, without they are considered together. It then lacks a reproducible methodology that focuses simultaneously on different aspects and can be used as an analysis tool to draw territorial food policies.

Food demand and supply analysis: proposed methodology

In order to overcome this weakness and fill in this gap in the literature, the developed methodology for FOODMETRES aims to characterize the agro-food system of a metropolitan area, aiming at assessing the potentialities for the reconnection of demand and supply in the territory. A multidimensional perspective is used to describe this relation through the simultaneous assessment of different aspects of self-sufficiency expressing the fulfilment of demand in terms of quantities, calories and economic value.

Such an approach is aimed to obtain information that provide the quality of the agro-food system of any region, in relation to:

- the degree of compliance with food habits and food diet;

- the level of food security, meant as the capability of the system in ensuring nutritional and caloric requirements expressed by the population dietary pattern;
- the economic balance of the area and the exposure of the system to global markets.

To each of these aspects is associated a respective index, as the ratio between supplied and demanded amounts, whatever expressed, is associated. Their determination meets the following criteria (fig. 1):

- the comparison between demand and supply is made at level of staple food level, meaning food items considered for the analysis are brought back to their respective primary agricultural product: for instance, the consumed amounts of bread are converted into the quantity of soft wheat needed to produced them or, similarly, consumptions of dairy products are expressed in milk-equivalents, representing the amounts of raw milk needed for their production.;
- the economic value of staple foods, on both demand and supply side, is the production value. This because the role of such simplified economic balance is to evaluate the capabilities of the territory in finding within its own boundaries what it is needed for the fulfilment of food demand expressed by the population;
- still regarding the economic aspect, the calculation of the self-sufficiency level in terms of economic value, it must be specified that all types of products contribute to the supply, since for the measure in monetary terms the aggregated value is to be taken into account, in comparison with the equivalent value of consumed primary products;
- for the calculation of the food security degree through caloric balance, calories are not interchangeable: a surplus of calories deriving from carbohydrates than the demand is not suitable to satisfy a deficit of calories of other origin, if any;
- for evaluating the compliance with food habits (i.e. the level of self-sufficiency through quantities), each staple food group cannot replace another one: for complying with local food diet, each staple food must be produced in sufficient quantities to cover the respective consumption.

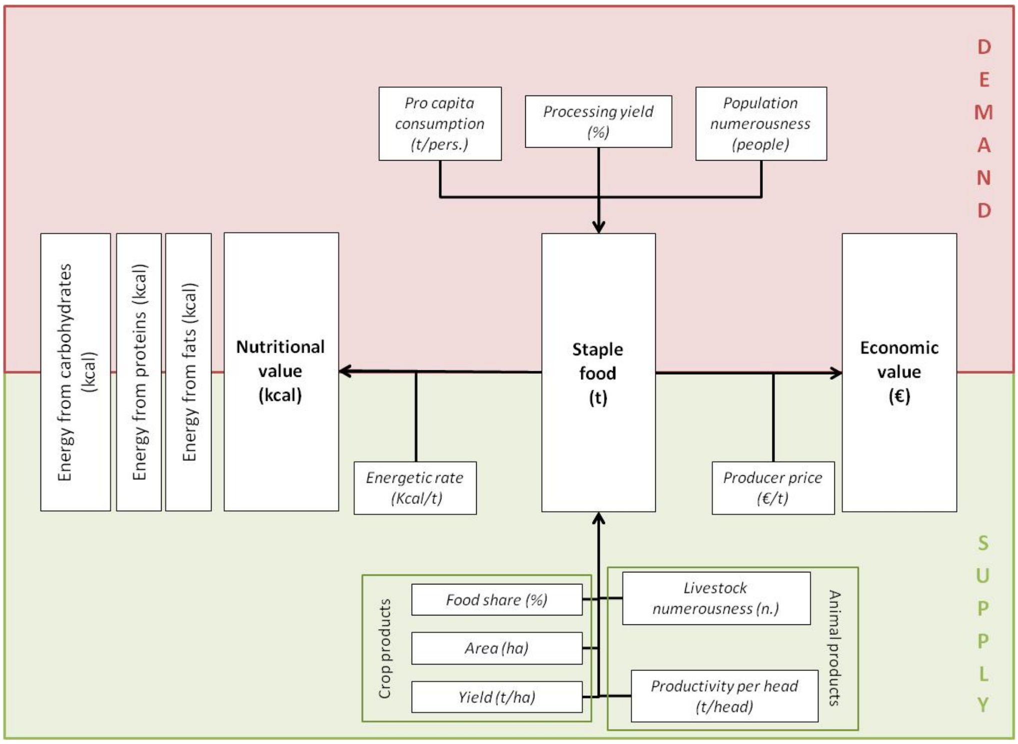


Figure 1: workflow of demand and supply analyses.

Data sources

Data used in the analyses are those provided by international and National datasets.

Concerning dietary habits, the available on line version of EFSA database (EFSA, 2011) and Slovenian National survey (SORS, 2010) were used. The Italian National Institute of Nutrition (INRAN) has been used to associate to each staple food its respective caloric content.

The portals of each Statistical office and other national or regional sources and datasets (LEI, AGRISTAT) collecting several data have been used to extract other data needed, and in particular:

- 2010 Agricultural Census for agricultural area and livestock population (ISTAT, CBS, DEFRA, SORS);
- data on productive yields (AGRISTAT, CBS, DEFRA, SORS).
- producer prices of food commodities and other agricultural and animal productions *(DEFRA; BMELV; ISMEA; LEI; LEI and CBS, 2012; SORS; Tesser, 2007)*.

Definition of case study areas

Metropolitan areas of FOODMETRES case studies. i.e. Berlin, Ljubljana, London, Milan, Rotterdam and Nairobi, mostly refer to their spatial definitions provided by OECD (*OECD, 2006*) (see Annex A1); the international agency does not however provide any definition of Ljubljana metropolitan area: in this case the whole Slovenia has been taken into account to represent the Ljubljana Metropolitan

Region, of which the capital city plays the role of connecting the region into an integral whole, due to its administrative and economic power, traffic ways and daily migration of labour (*Sali et al., 2014*).

However, in order to make OECD regions more homogenous and comparable some adjustments have been made; in fact, though the source is widely recognized and plays a key role as a common criteria for a spatial delineation of regions, the case study areas themselves strongly differ in terms of territorial extent and total utilized agricultural area (UAA), resulting in a high heterogeneity and in a limited chance of comparison (Annex A2, table 8). For this reason, in addition to OECD Metropolitan regions a further area has been considered for Berlin, by proportionally reducing the wider area in order to include a similar extent of UAA.

Analysis of demand

In these contexts, the quantitative dimension of food demand has been traced back to the quantity of food consumed by adult population, according to surveys on dietary habits; EFSA database associates to the age class its respective daily food consumption aggregated per food category (c) and even broken down into subcategories (s) (Annex A2, table 10).

In the subsequent analysis of demand, some food items have been excluded (Annex A2, table 11), due to their scarce consumption, their non-agricultural origin (e.g. fish and water culture products), their non-local origin (coffee, tea, cocoa and similar), their varied composition or because very unspecified foods. Consumptions traceable back to categories then considered correspond to about 90% of total consumed quantities, according to the dietary habit of the specific area (Annex A2, table 12), finally representing the share of demand that local productions can potentially satisfy. This steps certainly represents a quite coarse description, as quantities of very different products are summed together to define the breakdown of consumptions, but this kind of aggregation it is the only way providing us an overview on this aspect.

To each category the respective staple food (p) is associated (Annex A2, table 13), to which demanded quantities for the category itself are traced back, according to specific consumption (C), population numerousness (n) in the region and, where necessary, to a suitable conversion factor (processing yield, ty_s) that express how much of the raw product is contained in the final product:

$$C_p = \sum_s C_s * \ ty_s * n$$

A further aggregation of primary products into staple food categories (Annex A2, table 13) has led to the quantification of their respective food consumptions, by adding consumptions of the same staple food:

$$TC = \sum_{p} C_p$$

Analysis of supply

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

With regard to crop-origin foods, the extent of agricultural area (*a*) devoted to the raw product of each food sub-category (s) has been quantified and then converted into supplied quantities of the raw product itself, where necessary, by multiplying it by an average productive yield (y):

$$S_p = a_p * y_p$$

and then summed to obtain total food supply of crop origin:

$$VS = \sum_{p} S_p$$

Concerning animal production, the amounts of supplied quantities of eggs, dairy products and meat have been quantified according to the numerousness of livestock provided by data sources and productivity per head:

$$S_{c=DAIRY} = dc_m * um$$

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

$$S_{c=MEAT} = su_b * sy_b * w_b * gp_b + \sum_{l} (su_l * sy_l * w_l * gp_l) + \sum_{m} (su_m * sy_m * w_m * gp_m)]$$

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

$$S_{c=EGGS} = ly * w_{EGG} * ue$$

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

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

$$SA = S_{c=EGGS} + S_{c=DAIRY} + S_{c=MEAT}$$

Self-sufficiency and performance indexes

Both supplied and demanded quantities of each staple food category have been converted into caloric dimensions by using the energetic rate of the respective primary product of the category itself (K_p) and considering the percentage of the energetic rate (P) coming from different energy sources (o) (carbohydrates, fats, proteins) (Annex A3, table 14):

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

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

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

$$supplied\ calories: KS = \sum_o KS_o$$

$$demanded\ calories: KC = \sum_o KC_o$$

The economic value demanded and generated in the system has been calculated by summing quantities of each raw products multiplied by their respective average producer price (PP_p) (Annex A3, table 15), with an additional value generated by other agricultural activities operating in the non-food sector (e.g. energy crops, other crops on arable land, flowers cultivation and nurseries):

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

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

Finally, the potentialities of the agricultural system have been described by three indexes, 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

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

for any *p* for which $(C_p - S_p) > 0$

b. Calorie index: it expresses how much the local agricultural system is able to satisfy the dietary caloric intake, both per macronutrient contributing to the total caloric intake itself and per diet

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

for any *o* for which $(KC_o - KS_o) > 0$

c. Value index: it is focused on how much agricultural value is generated, referring to both food and non-food productions, and which is the economic balance of metropolitan agro-food system:

$$IV = \frac{VS}{VC}$$

Categorization of MAS typologies

Results of the calculation and estimation of indexes, both individually and simultaneously, allow defining the quality of MAS, according to the specialization of the productive system, the food security and the economic balance of the territory deriving from the primary sector.

Quantitative dimensions and system specialization

A first characterization of an agro-food system concerns with the quantitative dimension of food demand (i.e. the consumption) and supply (i.e. the primary production), as the steps at the extremes of any food chain.

The amount of per capita consumptions depends on specific dietary pattern and finally affects total consumptions in a region in combination with the population size of the area. It is therefore evident that this latter element is the most driving factor in determining food needs within a territory.

On the other hand, the capability of the system in providing food and meeting demand varies according to the land use of available agricultural area, to the suitability of the territory itself and the specialization of the primary sector, especially under particular agro-climatic conditions it has to operate in. As a result, peculiar features of the “production-consumption” patterns in the different FOODMETRES regions are identifiable at staple food-level (fig. 2), giving preliminary indications on the potentialities of the system in responding to the compliance with diet.

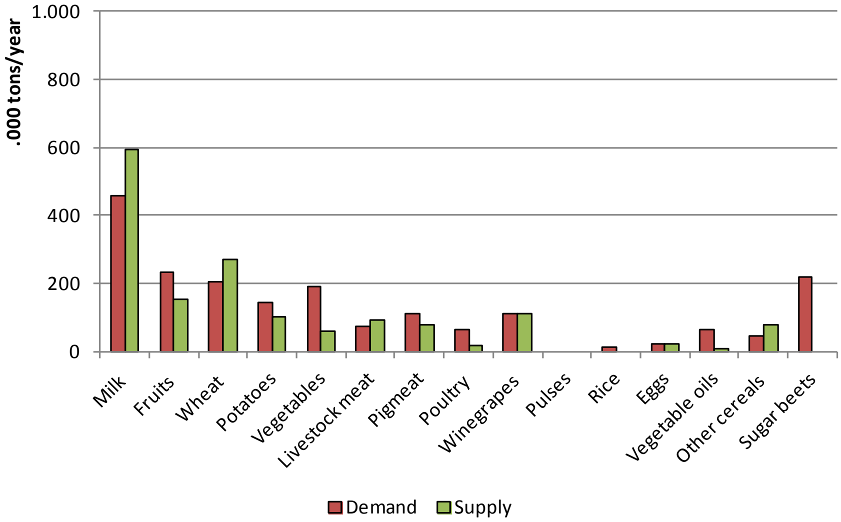


Figure 2: demanded and consumed amounts of staple food in Ljubljana region

In this sense, the aggregation of primary products into wider categories describes the capability in supplying food in a comparative and more comprehensive way, providing further confirmation and information about the specialization of the primary sector and the fulfilment of food requirements. This analysis, through a simple graphical representation (fig. 3), shows the level of self-sufficiency of each macro-category and indicates their different compliances.

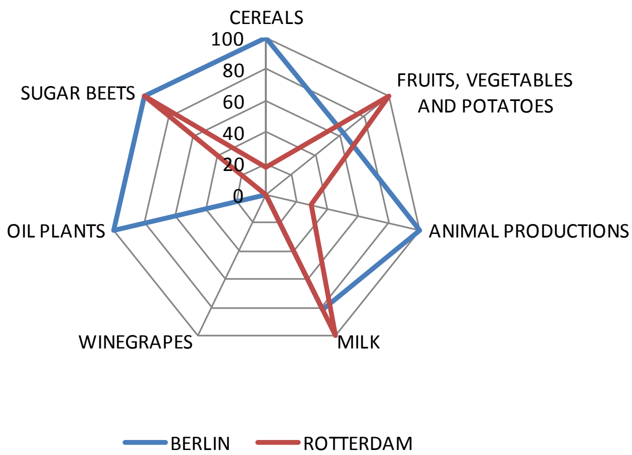


Figure 3: comparison of quantity index of each staple food category in Berlin and Rotterdam. The more regular the shape of the profile, the less specialized the productive system.

The relative distances among the values of the index across all categories, reveals the specialization of the agricultural system, possibly most oriented to those productions supplied in higher quantities than the demand; on the contrary, a more regular shape of the graphical profile (i.e. when the values of the index are quite regular) reveals a higher heterogeneity of productions, regardless their actual extent of self-sufficiency.

Compliance with nutrients and food security

Dietary habits are reflected on total caloric intake provided by the diet itself, while supplied quantities affect the availability of one or more specific energy source. The total energy demand of the specific diets is fairly homogeneous among FOODMETRES European case studies (fig. 4). The differences are attributable not only to the quantity consumed but also to the type of food introduced, which according to its composition, variously contributes to the total caloric intake and can unbalance the relative self-sufficiency to one or another source, due to the prevalence of some productions whose energetic rate is mainly referred to a source. Heterogeneous productions however allow supplying energy intakes from different nutritional sources (carbohydrates, fats, proteins) returning actual condition, while recommended caloric intakes may coincide or be similar to those offered, then indicating that food styles are not consistent with nutritional indications.

It must be specified that in Western or European contexts the "food security" issue scarcely emerges: even if in strongly urbanized contexts the agricultural production is traditionally limited and the city is not able to feed itself with its own resources, an efficient system of accessibility and logistics can ensure the distribution of food across the region, certainly augmented by productions from remote landscapes (*Porter et al., 2014*), with problems of food accessibility and affordability limited to a minority of the population. In these contexts the concept of food security assumes a different acceptation, quite far from the recognized definition of the World Food Summit (*FAO, 1996*), but rather linked to the need of a readjustment of the production-consumption balance, indicating potential food supply in turn including the nutritional quality of food.

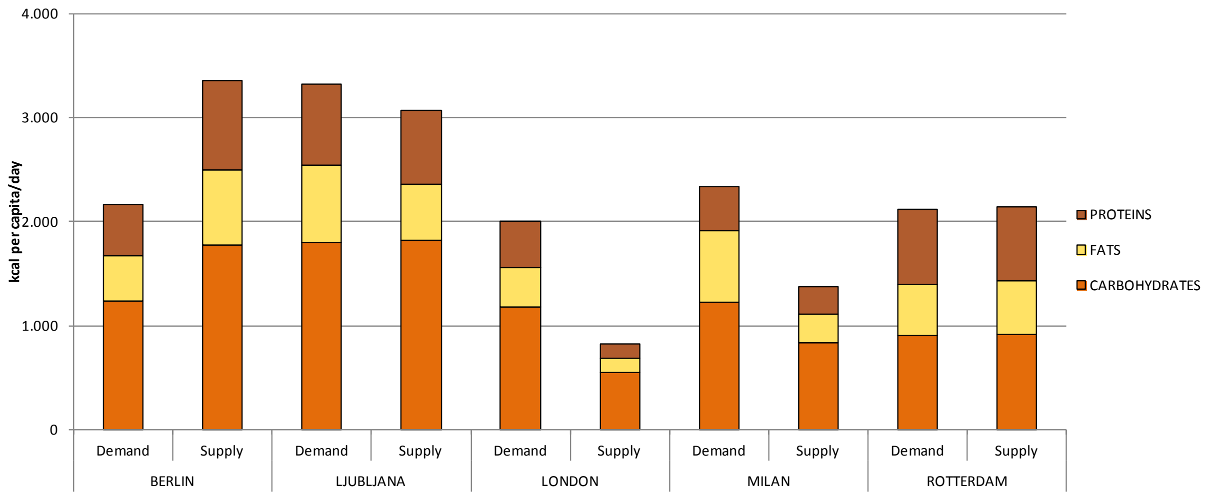


Figure 4: break down of demanded and supplied calories among Energy sources.

The food security issue as internationally defined and recognized is instead much more relevant in Developing countries. The interest towards such argument in African contexts particularly suits with the project and the case study area of Nairobi. Demographic dynamics and projections for African cities reveal rapid population increase and urbanization (*UN-Habitat, 2014*) that would lead to a continuously rising of urban poor on one hand (*Gallaher et al., 2013*) and to the emerging need of providing food to an increased number of people (*Olielo, 2013*) on the other. This obviously concerns with Kenya as well, and with both Nairobi county and Nairobi city, as the most populated and dense administrative units of the country (*CRA, 2011*). At the same time the per capita food production shows a declining trend (*Abdulai et al., 2004*) and in addition the largest proportion of agricultural production coming from smallholders farmers suggest this will remain unchanged in the next future (*Thornton and Herrero, 2001*). In these conditions, food shortages and undernourishment occur, with a large part of the population dealing with problems of food access to basic dietary requirements (*Luan et al., 2013*). Kenyan current food habits in fact mainly relies on a small basket of foodstuffs, which lacks in dietary quality and variety and affects nutritional problems. Though an average person consumes daily 2,155 kcal of food (*FAO Stat, 2009*), such a caloric intake is mainly due to the wide consumption of maize, wheat, rice (*Klaver and Mwadime, 1998*) and other cereals, such as sorghum; dietary pattern is also based on consumption of milk, different kinds of meat (beef meat, sheep and goat meat, poultry, camel and pig meat) (Annex 2, table 12), beans, potatoes, plantains and cassava. All these staple foods are local productions, but in most cases they mostly need to be imported because not kept up with national consumption requirements (*Ariga et al., 2010*): as demonstrated by *Luan et al. (2013)* with the assessment of production-consumption balance in Africa during time, the food self-sufficiency ratio in Kenya has progressively decreased, in turn exacerbated by demographic trends, having repercussions on the economic balance at country-level.

Economic dimension

Concerning the economic aspect, the value produced by the agro-food system at producer-level and corresponding to the diet, varies across different regions (fig. 5), according to their demographic dimension, the productivity, the prices paid to farmers in such areas.

The analysis carried out at production level aims to deepen the potentialities of the system in reconnecting demand and supply, apart from the actual trade balance, import/export flows and value added. In this case, whenever an incomplete self-reliance and consequently a negative economic balance occurs, the value generated in the territory is potentially retained there, balancing the equivalent amount of the economic dimension required through the diet.

On the supply side, it must be considered that agricultural productions set in a territory are destined not only to human consumption, but they include further activities and existing specialization of the agricultural system (nursery gardening, floriculture, cultivation of energy crops) (the dark green portion in fig. 5), possibly increasing the total producer value generated by the primary sector. This can result in a potential net surplus and in a positive economic balance for a specific territory, as evident in Berlin and even more in Rotterdam area.

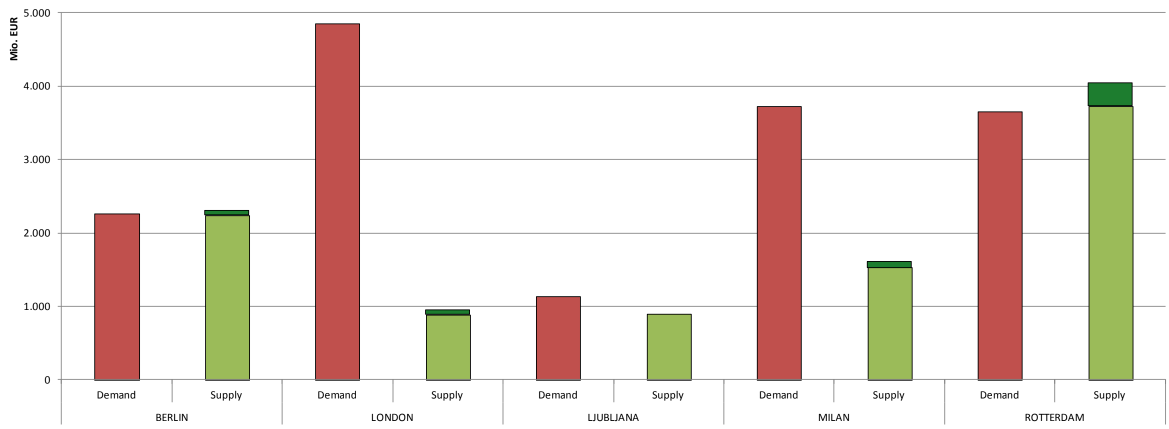


Figure 5: elements of the economic balance in case study areas. Dark green represents the share of value generated by no-food productions.

This kind of analysis cannot be easily applied to contexts such as the city of Nairobi. In this case in fact, the possibility to assess the production value of its agro-food system has to tackle with some difficulties arising from the site specific area and the structural features of the system itself. It must be taken into account that the marketing of livestock and agricultural products are more often done through informal channels and that a substantial proportion of agricultural production is from smallholder subsistence agriculture, even scarcely supported by accurate and available data, finally affecting the whole analysis and limiting the chances of comparison among case study areas.

System performances

The relationships between three indexes at diet-level and their simultaneous analysis finally allow defining the peculiar profiles of a metropolitan area and the performances of its agro-food system. Graphically comparing the quantity and the value index it is possible to distinguish three different regions (fig. 6). In the region 1 are located metropolitan areas in which agricultural systems are able to meet food habits better in quantity than in value. This means that the most produced goods have a lower value compared with those most consumed.

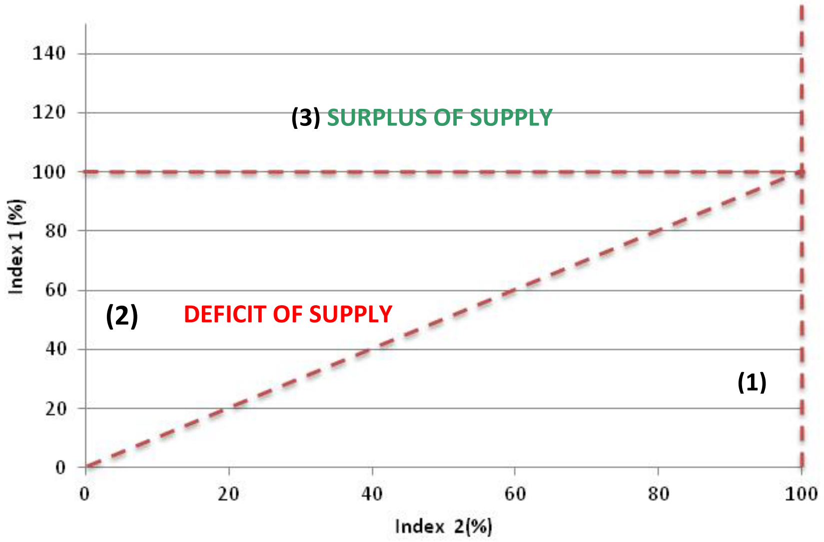


Figure 6: comparison between couples of indicators – different performances

Opposite situation occurs in the region 2. In this case the agricultural system generally produces goods with a higher value compared to those constituting the local diet. Usually, in this region are located very specialized agricultural systems, which therefore are not able to shape their productions to the variety of commodities, demanded by consumers.

An agro-food system is located in the region 3 whenever an economic surplus occurs, namely, the value of staple foods produced is higher than that consumed. It is this the case of Rotterdam (fig. 7), where the positive balance is related to the excess of supply (e.g. for milk and vegetables): high quantities produced, also possibly deriving from a strongly specialized system, contributes in increasing the overall value, while in the other cases a more scarce production differentiation does not allow meeting more than 80% of agricultural products demanded by consumers.

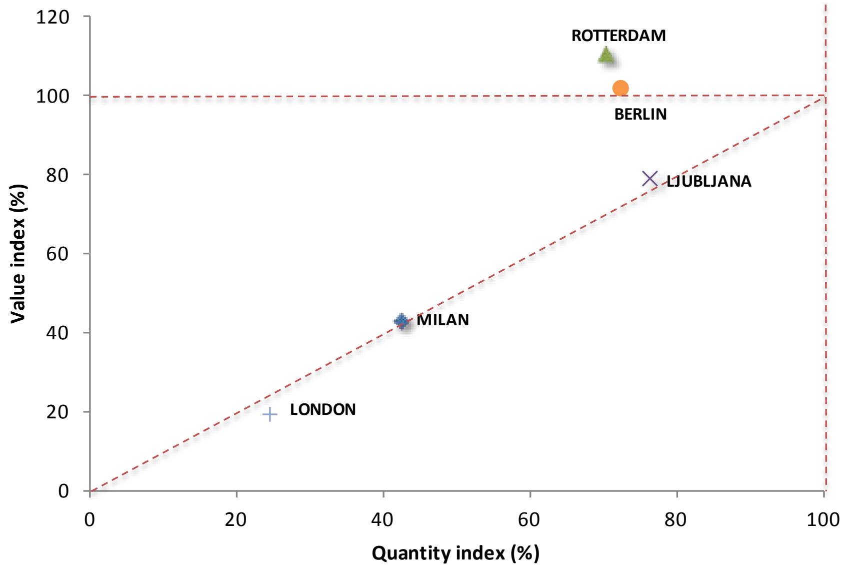


Figure 7: productions and values - performances of metropolitan regions

A similar trend is to be found in the relationship between caloric and value indexes (fig. 8). It shows, for the same value of the previous distribution, a higher capability in meeting the need of total caloric intake, according to the conditions that the index itself is subject to. Several productions, also belonging to different food categories and with repercussions on the final total value, in fact contribute to the fulfilment of the caloric demand from the same source of energy.

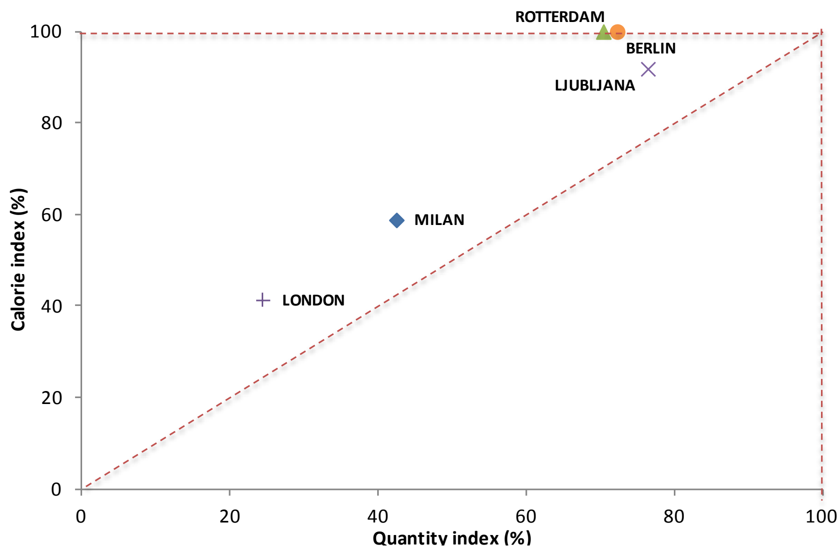


Figure 8: relationship between caloric and value index

The comparison between productions and caloric intake (fig. 9) only refers to food production, as it shows simultaneously the compliance with food patterns and with the caloric intake: such a relation summarizes the main features of the dietary patterns. In this case all metropolitan regions show a better ability to meet the caloric needs rather than food habits as a whole. This identifies the main features of the diet. On one hand, whereas an insufficient fulfilment of caloric needs, even more energetic intakes are needed; on the other hand this describes a productive system whereby supplied products, although in insufficient quantities to meet the overall demand, allows providing more caloric products, with a consequent relative higher compliance with energy needs. Then a more closely orientation of diet towards ability to meet caloric needs, also considering the supply profile, would lead to the consumption of fewer quantities with a higher energy content.

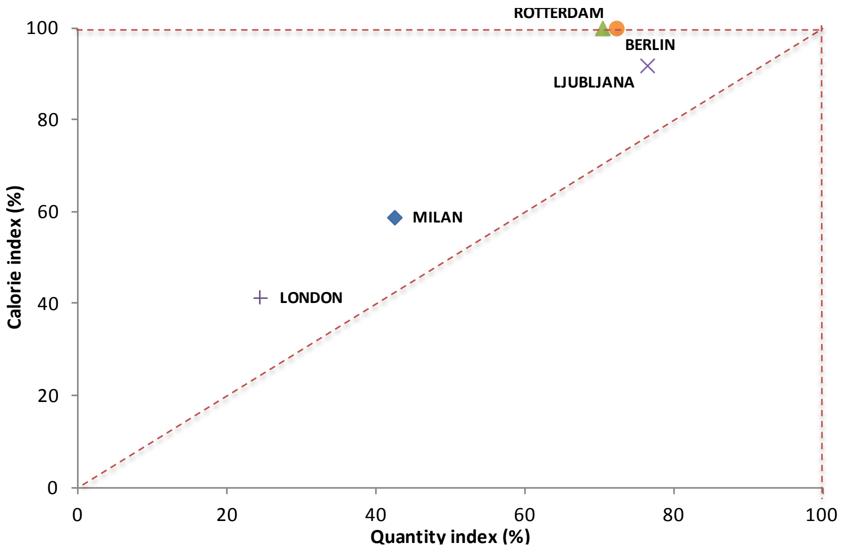


Figure 9: food production performances

Finally, the simultaneous combination of the indexes (fig. 10) helps describing MAS on a more complex and comprehensive basis, returning an overall indication on the quality of the agro-food system as a whole.

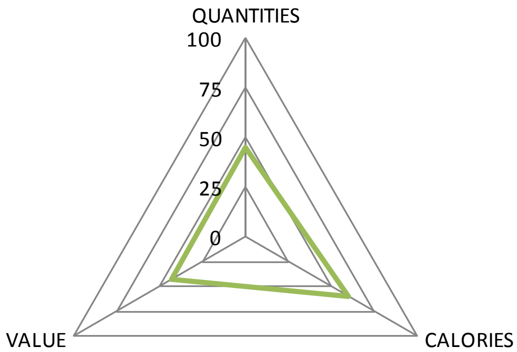


Figure 10: multidimensional profile of a MAS, example of Milan Region.

The more the shape of the profile is irregular, the more productions are differently unbalanced in satisfying needs from any point of view: regularity in fact expresses the capacity of supply in providing enough quality and value food in the same proportion. Where an incomplete self-reliance occurs, whatever the dimension, the gap between actual and optimal capacity corresponds to food non producible in the local context, determining a net deficit compared to demanded quantities: this lack must come from a wider area where a different, wider and more complex agro-food system operates.

Depending on the combination of values and according to the proposed evaluation criteria (fig. 11), the single performances of any systems summarized and the ability to provide larger or smaller productions with a higher or lower economic and/or nutritional value defined, resulting in different levels of system productivity, security and profitability.

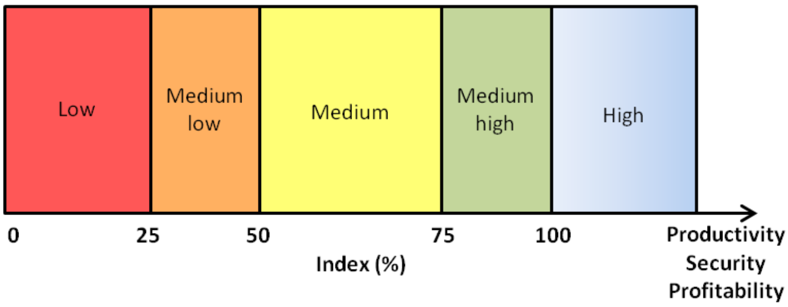


Figure 11: indexes evaluation criteria

On these bases in figure 12 are shown the compliances of the metropolitan regions with each considered aspect. The results set out here are affected by the spatial dimension of the regions taken into account; the potentialities of the system and the indications of its performances are therefore strongly related to the territorial extent of the metropolitan area, leading to different but peculiar results across case study regions. In general terms, the fulfilment of caloric needs is higher than the compliance with diet, due to higher caloric content of produced foods; on the contrary with regard to the economic value an univocal trend is not identifiable, as in some cases it is higher and in others lower than food self-sufficiency.

Figure 12: system performances of case study areas, colour coded according to evaluation criteria

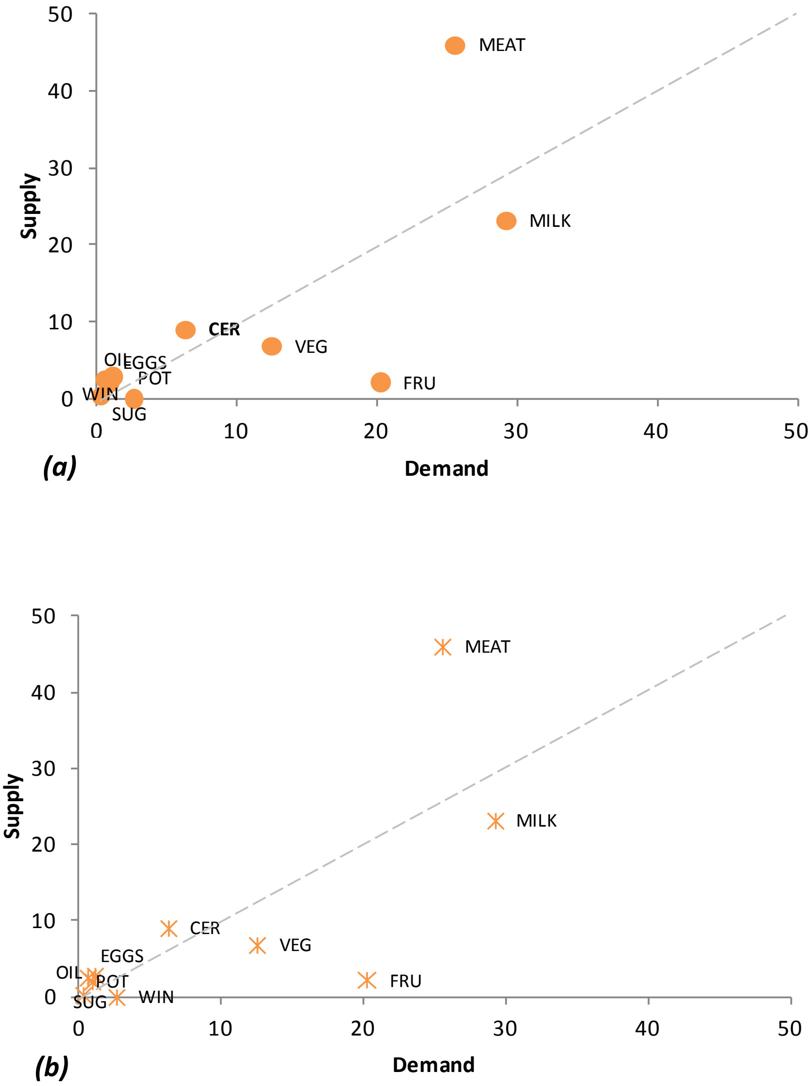
	Food habits compliance	Caloric needs	Economic balance
BERLIN OECD	*72*	*100*	*102*
BERLIN RED	*62*	*100*	*78*
LJUBLJANA	*68*	*92*	*79*
LONDON	*25*	*41*	*20*
MILAN	*42*	*59*	*43*
ROTTERDAM	*73*	*100*	*111*

The absolute values related to the different aspects, since based on actual and current situation of each agricultural system, reflect the actual potentialities of the metropolitan contexts. The comparison among them thus shows the actual features and differences in reconnecting demand and supply. This allows a sort of classification of an agro-food system according to its "quality", variously declined in productive and economic terms. In this sense it is then evident that the scarce potentialities of the Milan region, and even more those of the London area, reveal the necessity to depend on other and wider systems, with an exposure to other than local or regional markets. The reconnection between demand and supply is instead more stimulated whereas systems show better potentialities, as in the Ljubljana region; with regard to Berlin and Rotterdam, quite similar performances under the different points view are returned. This does not necessarily mean their systems are completely self-reliant or closed systems without interaction with other areas; consistently with the focus of the analysis the potentialities in reconnecting production and consumption within a territory are assessed, without taking into account, for this same reason, the actual import and export flows.

Quite similar assessments are possible also focusing on single products or groups of products. In this case, it is interesting deepening their relative economic importance, both from the demand and the supply side. Either dimension, compared to its respective total value, allow overcoming the limitations that arise from the size of the considered areas, as evident from the comparison between the two different spatial boundaries of the Berlin metropolitan area (fig. 13*a* and *b*). In this sense, therefore, the analysis at primary product level is not affected by the shape and the size of the region, finally giving the chance to compare areas possibly very different for demographic and/or productive features.

Figure 13: relative importance of staple food groups in
(a) REDUCED BERLIN Metropolitan Area and
(b) BERLIN OECD Metropolitan Area

MEAT = meat
MILK = milk
FRU = fruits
VEG = vegetables
CER =cereals
EGGS = eggs
POT =potatoes
OIL = oil plants
WIN = wine grapes
SUG = sugar beets



Analysis of staple food categories

The analysis at commodity-level firstly refers to a grouping of different products into wider categories (see Annex A2, table 13). This choice has been made as an explicit recall, though not a complete overlapping, to commodities each FOODMETRES case study identified and chose to analyse, as already pointed out in D3.1.

Such an analysis provides information about the position of the groups themselves on the market, emphasizing the chance to be locally consumed or mainly commercialized on and through global markets. This latter condition particularly occurs when the relative importance of a product in the respective sector is higher than the role it plays in the local consumption. Otherwise productions are mainly addressed to the local context.

This approach confirms the specialization of the primary sector, the position on the market of different products or food groups in a same territory (see Annex A6) and also the possible different orientation to the market they may have according to their production in a specific area, defining which case study areas are characterized by a positive (negative) balance and then are potentially net exporters (importers) of such food products. In fact, as *Billen et al. (2009)* pointed out, the potential for the commercial export of any agricultural product emerges with its productive surplus over its requirements, resulting in an autotrophic system.

In figure 14 are scattered the relative importance of commodities in each FOODMETRES case study area. The scatter cloud can be divided into two main groups corresponding to the main different market orientations, reflecting different proportional relations between values, also pointed out quantitatively by the equation and the correlation coefficient (r) of the linear trends. As more evident in figure 15, a large part of these products are however dispersed in the region close to the origin or along the demarcation line between two different markets. This underlines in the former case the scarce importance of these products, and in the latter the undefined market orientation, revealing a possible commercialization through both global and local channels and systems.

In any case, whatever considered, each cluster is made of a set of heterogeneous products (table 3). Similarly, in most cases it is not possible to precisely associate to a staple food group a precise market orientation, but rather a main orientation (table 3) and the presence of some common features must be noted. Despite different territorial contexts, milk-based and cereals-based products are mostly oriented to global markets, while, on the contrary, meat has a lower export potential; finally It must be noted that the tendency to be exposed to an undefined market is associated with a more industrialized and intensive productive system, such as that of eggs production and processed foods (e.g. vegetable oils, wines and sugars).

Figure 14: global or local market orientation of staple food categories. Plotted elements (n = f x r = 50) are the staple food categories (f = 10) in all the metropolitan regions considered (r = 5)

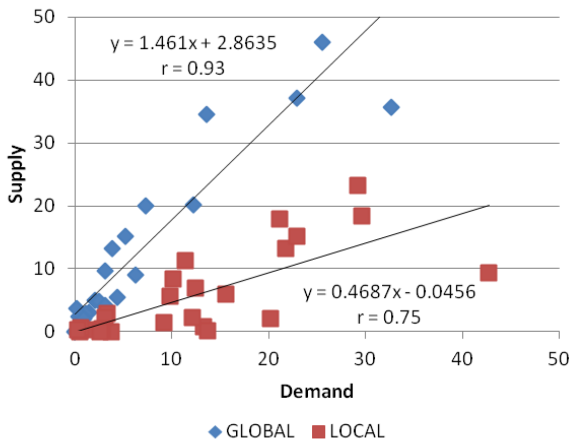


Figure 15: main market orientation of staple food categories. As the figure above, plotted elements (n = f x r = 50) are the staple food categories (f = 10) in all the metropolitan regions considered (r = 5).

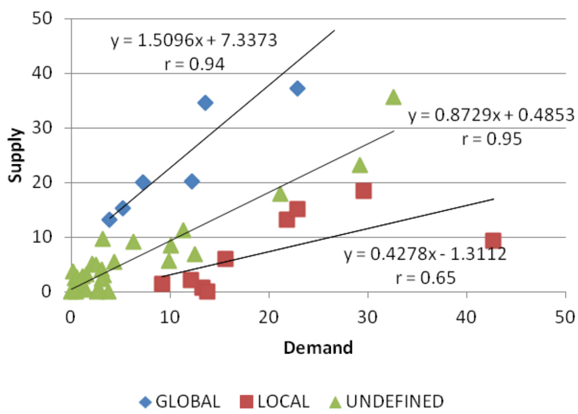


Table 3: market orientation of staple food groups

STAPLE FOOD GROUP	MARKET ORIENTATION (n.)		
	Global	**Local**	**Undefined**
Cereals	3		2
Eggs		1	4
Fruits		2	3
Meat	1	3	1
Milk	3	1	1
Oil plants		2	3
Potatoes			5
Sugar beets			5
Vegetables	1	1	3
Wine grapes			5
Total (n.)	*8*	*10*	*32*
Total (%)	*16*	*20*	*64*

A similar heterogeneity can be also found when analysing relative importance of commodities on both the demand and the supply side, according to specific ranges set *ad hoc* (figs. 16 and 17). In general terms, a correspondence exists between demand and supply, as products less required are also those less offered: the type of products and their numerousness within the range 0-25% of both dimensions are almost exactly the same (table 4), except for meat and vegetables.

The variety of products encompassed in lower ranges is higher, but it progressively decreases with the increase of the importance, resulting in the same products when the importance is higher than 25%: vegetables, meat and milk. In these cases however, their respective numerousness is exiguous, reflecting their site-specific production profile.

Figure 16: grouping of staple food categories based on importance ranges in relation to demand

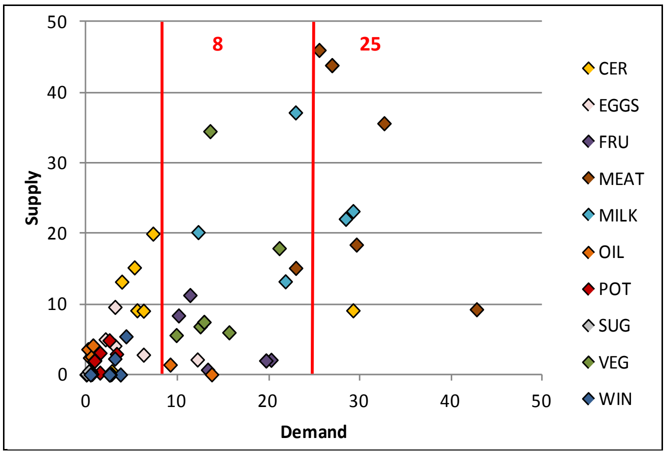


Figure 17: grouping of staple food categories based on importance ranges in relation to supply.

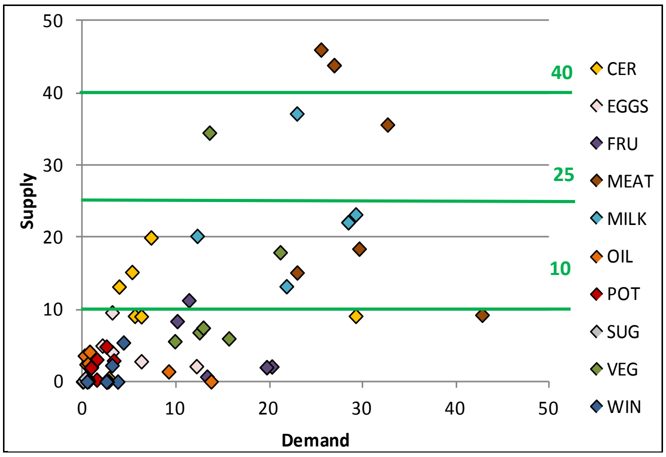


Table 4: numerousness of food categories in importance ranges

STAPLE FOOD GROUP		DEMAND ID AND RANGE			SUPPLY ID AND RANGE			
		D1 (0-8%)	***D2 (8-25%)***	***D3 (>25%)***	***S1 (0-10%)***	***S2 (10-25%)***	***S3 (25-40%)***	***S4 (> 40%)***
NUMEROUSNESS (n.)	Cereals	4	1		2	3		
	Eggs	4	1		5			
	Fruits	1	4		4	1		
	Meat		1	4	1	2	1	1
	Milk		3	2		3	1	1
	Oil plants	3	2		5			
	Potatoes	5			5			
	Sugar beets	5			5			
	Vegetables		5		3	1	1	
	Wine grapes	5			5			
	Total	*27*	*17*	*6*	*35*	*10*	*3*	*2*
	Total (%)	*54*	*32*	*12*	*70*	*20*	*6*	*4*

Combining the positions of the groups with respect to the range of supply and demand in which they are located (table 4), this relation is pointed out once again. Along with the scarce importance of most products across regions, progressively higher orientations of demand for meat emerge (respectively in Rotterdam, London, Ljubljana, Berlin) and, from the supply side, among the most important productions both milk and vegetables refer to Rotterdam area (see Annex A7).

Table 5: combination of relative importance – commodities distribution

DEMAND ID RANGE	SUPPLY ID RANGE			
	S1	**S2**	**S3**	**S4**
D1	CER X 2 EGGS X 4 FRU X 1 OIL X 3 POT X 5 SUG X 5 WIN X 5	CER X 2		
D2	EGGS X 1 FRU X 3 OIL X 2 VEG X 3	CER X 1 FRU X 1 MEAT X 1 MILK X 2 VEG X 1	MILK X 1 VEG X 1	
D3	MEAT X 1	MEAT X 1 MILK X 1	MEAT X 1	MEAT X 1 MILK X 1

Cost and benefits of improving self-sufficiency indexes

Indications from food balance assessment

Looking at quantity and value indexes normalized on population numerousness and hectares of UAA (table 5) further implications of *pros* and *cons* of self-sufficiency arise.

Concerning the quantitative aspect of production, food supply available to individuals is insufficient to meet their needs. In this sense the system cannot sustain the demand expressed by the population neither comply the diet; this scarce capacity is consistent with the analysed contexts that are metropolitan and urban systems where most of the population and a small amount of agricultural area are concentrated. The quantities potentially produced in these areas are not enough to feed the local population, but the corresponding productive activity can provide such amounts through a lower intensive agriculture, with a difference in yield (t/ha) ranging from -14% in Berlin to -57% in London. This means that a more intensive agriculture is required to totally meet food demand, but such a scenario would lead to repercussions on the system itself, and in particular on its environmental sustainability. A higher production can in fact be obtained by increasing yield (according to an “intensive approach”) or agricultural area (“extensive approach”). It is mostly in the former case that consequences and impacts on the environment would occur: among them, for instance, a higher impact of livestock breeding, a higher soil or water pollution due to a stronger use of fertilizers and pesticides, the exploitation of natural resources in general, the specialization in some particular crops only (e.g. monoculture) leading to a deficit in other food categories, the specialization in protected crops allowing high-valued productions all over year.

With regard to the increase of agricultural land, it must be noted that it is not always a possible alternative, due to land availability and constraints, soil consumption and urban sprawl. In this case the spreading experiences of urban gardening (as agriculture in the inner city) can enhance the local production, even not suitable to obtain large amounts of products, and thus improve the sustainability of the urban environment, also leading to several socio-economic benefits.

Similarly, with regard to the economic aspect, the value equivalent to the expressed food demand is in general higher than the value the system is able to generate; this is not valid for the metropolitan area of Berlin and even more for Rotterdam region, for which the existing agricultural system are potentially more profitable than it is actually required by food habits. This is partly due to the fact that the creation of value combines all the agricultural activities and not only food and feed related ones; thus in these two contexts other activities, such as the cultivation of energy crops or, as in Rotterdam area the strong specialization in floriculture, determine the overall potentialities of the agricultural system. In fact, as previously described, it is this share from still agriculture but not related to food production that can play a decisive role in the economic balance, at production level, of the territory.

Table 6: performances of the agricultural systems in considered metropolitan regions

METROPOLITAN REGION	QUANTITIES (t/year)				VALUE (.000€/year)			
	Per capita		Per hectare		Per capita		Per hectare	
	Demand	*Supply*	*Demand*	*Supply*	*Demand*	*Supply*	*Demand*	*Supply*
BERLIN	0.62	0.53	2.01	1.72	0.37	0.38	1.22	1.24
LJUBLJANA	0.84	0.64	3.63	2.77	0.56	0.44	2.41	1.90
LONDON	0.53	0.15	10.94	2.97	0.31	0.06	6.38	1.25
MILAN	0.78	0.33	12.55	5.36	0.47	0.20	7.60	3.29
ROTTERDAM	0.59	0.47	11.04	8.76	0.47	0.52	8.68	9.62

A demographic descending trend is not expected to occur and, unless changes in eating and dietary habits that can vary the amount of food required thus determining a lower overall demand, it is reasonable to assume that an increasing level of self-sufficiency in urban contexts can derive from higher supplied amounts, according to the approaches already described. Up to now, the value generated in the systems analyzed can mostly economically sustain, even not entirely, their own demand, as the correspondent self-reliance is in general lower than the optimal value.

Simulation with a linear programming model

In terms of sustainability of agro-food systems, different tools could be used in assessing different potential scenarios. For an economic evaluation in terms of both structural changes, as land use changes and use of resources, and in a productive way, for instance the modification of productive orientation or different farming techniques, assessment and simulation tools can easily be used, and in this sense the Linear Programming (LP) represents a valid option.

This kind of model is typically used for the optimization of scarce resources that means allocating them in the most efficient way. A linear programming problem may be defined as the problem of maximizing or minimizing a linear function subject to linear constraints, whether equalities or inequalities. A typical example of this would be considering the limitations of materials and labour, and then determining the "best" production levels for maximal profits under those conditions.

The theoretical framework of these programming can be expressed in the form:

maximize $c1^{M} x$

subject to $Ax \leq c2$

and $x \geq 0$

where *x* represents the vector of the variables that will be determined through the model, *c1* and *c2* are the coefficients vectors that we choose to use in the function, *A* is the (known) matrix of coefficients, and M is the matrix transpose. The objective function ($c1^{M}x$) is the expression to be maximized or minimized. The inequalities $Ax \leq b$ and $x \geq 0$ are the constraints that specify a convex polytope over which the objective function must be optimized.

With regards to the structural changes in the local agro-food systems in reconnecting territory, food and policy, the LP can become useful for analysing the agricultural potential of an area in relation to the food demand.

Different scenarios of sustainability

The LP could be used not only to hypothesize scenarios of internal resources redistribution in order to optimize the food supply in response to food demand, but with a recalibration of the imposed constraints on the system could become a model for providing information. For example, considering the current policies and proposed agribusiness policies to support the local agricultural system, it would be possible to produce plausible scenarios that could become useful tools to support policy-makers in order to improve sustainability of an agro-food system.

With a particular focus on the Milan OECD area, scenarios simulated are related to some different ways to improve sustainability, understood as the increased reconnection between local demand and local supply. In this sense the optimization problem concerns with a productive structure able to satisfy population food demand according to possible modifications on both the demand and the supply side. The relationship between supply and demand (de facto) has been formalized by a multi-objective model that measures the gap between the amounts consumed and the quantities produced of each staple food category, in order to simulate the adaptations of the agricultural productive system by getting a closer compliance with demand.

In particular, the objective function of the model aims at minimizing the sum of the differences showed by each staple food category between the level of production and the level of consumption. In this way, given D_i and S_i the demand and supply respectively for each base product i, the production $S_i = S_i(x)$ is defined as a function of the factor of production *x* (land extent or animal numerousness) devoted to it, while the function $S_i(x)$ depends on relation between crop production and processing needed to obtain staple food i.

The multi-objective model is expressed in the form:

Minimize $\sum_i w_i |D_i - S_i(x)|$

subject to $Ax \le c$

and $x \ge 0$

where *x* represents the vector of the variables that will be determined through the model, *c* is the coefficients vector chosen to be used in the function, *A* is the (known) matrix of coefficients and the weight *w* is the importance given to each raw product to meet the food demand.

The baseline scenario (scenario 0) gives an overview about the current agro-food system and it is useful for making comparison with other scenarios. It represents the features of the agricultural system in the region, in terms of cultivated crops and livestock numerousness. It returns the distance of each food quantity (or value) supplied from quantity (or value) demanded.

- The first scenario (scenario 1) focuses on the minimization of the productive gap, returning how the production system could adapt in order to satisfy as much as possible the demand expressed for each food category.
- The strong presence of livestock requires a large amount of fodder, which is only partly supplied (30%). It is therefore possible to determine which consequences could have the hypothesis of producing locally the whole fodder need on the capability of the production system in meeting food demand (scenario 2).

Other two scenarios simulate the effects of the compliance with consumers' preferences on the productive system. In this case it is firstly hypothesized (scenario 3) its conversion towards practices satisfying vegetarian consumers: this returns the most cost effective solution able to replace meat proteins with those producible from legumes, milk and eggs, still providing the same overall amount of proteins. Similarly, a vegan dietary pattern (scenario 4) has been simulated as well, with the total substitution of animal products with proteins of plant origin. Results of these simulations are shown in table 7.

Table 7: scenarios of simulation

Categories	Scenario 0 Current	Scenario 1 Minimum gap	Scenario 2 100% fodder	Scenario 3 Vegetarian	Scenario 4 Vegan
			Crop area (ha)		
Total available land	*458.518*	*458.518*	*458.518*	*458.518*	*458.518*
Fruits	1.596	40.053	40.053	40.053	40.053
Wheat	44.446	122.661	122.661	122.661	13.096
Barley	2.294	5.708	5.708	5.708	
Oats	77	478	478	478	
Maize	2.153	155	155	155	155
Rice	140.190	10.297	10.297	10.297	10.297
Vegetables open field	3.668	13.658	13.658	13.658	13.658
Protected vegetables	865	3.221	3.221	3.221	3.221
Pulses	1.042	9.134	9.134	90.122	250.223
Potatoes	380	5.201	5.201	5.201	5.201
Olives for oil	425	425	425	425	425
Oil plants	3.341	4.633	4.633	4.633	
Wine grapes	15.024	15.024	15.024	15.024	15.024
Sugar beet	6.895	9.432	9.432	9.432	9.432
Maize for feed	109.362	67.443	130.706	49.718	
Temporary grassland	39.030	63.264			
Permanent grassland	87.732	87.732	87.732	87.732	87.732
			Animal numerousness (heads)		
Dairy cows	172.644	278.583	278.583	278.583	
Beef cattle	786.060	602.646			
Pigs	2.279.849	241.930	201.510		
Broilers	1.322.993	13.248.520	4.319.331		
Layers	2.756.754	3.154.211	3.154.211	22.959.140	
Value of production (Mio. EUR)	***3.015***	***2.813***	***2.289***	***3.362***	***2.081***

The *baseline* scenario (0) represents an overview of the current agricultural system in terms of cultivated crops and livestock numerousness, revealing that in the metropolitan area agriculture is mainly based on cereal cultivation (especially rice), fodder crops and animal breeding, for both dairy and meat production. This situation describes a local supply that only partially meets the food demand expressed, with an actual value of production that is about 3 billion Euro. The multi-objective analyses all return similar breakdowns among food crops, with different combinations of agricultural area intended for feed and animals bred.

The first scenario shows potentialities in increasing the productions of all the crops, except rice and maize for food, revealing that an augmentation in their land extent is needed to completely meet their respective food consumption. Similarly, but with more pronounced modifications, in comparison to the current situation, an increase in the number of dairy cattle, broilers and layers occurs, as long as a marked reduction in pigs, sustained by productions granted by both grasslands and maize for feed. Such a condition still returns a potential positive economic balance, which is however the 93% of the current one, due to the strong reduction in animal production.
In the "*fodder* scenario" (scenario 3) the land extent intended for food crops show the same trend of the previous one, ensuring productions sufficient to meet the demand; with regard to fodder crops, the cultivation of temporary grassland is not encouraged at all, in favour of permanent grassland and maize for feed. At the same time this situation reveals the capability of the system to sustain animal breeding in general, except beef cattle, with a higher number of dairy cattle, broilers and layers and a reduced amount of pig heads; this allows obtaining optimal levels of compliance with also animal products, which increase from 62% and 87% of the scenario 0 to 100% for milk and eggs respectively, and from 9% to 29% for poultry meat. As a result of this simulation, the production value decreases by nearly 726 million Euro (-24% compared to scenario 0 and -23% to scenario 1).
If the current system would adapt to a vegetarian system, an increased production of almost all staple foods would occur, except for some cereals that already show a productive surplus (e.g. rice and grain maize for food): among them the highest augmentation is related to pulses, which cultivation can rely on more than 90.000. This ensures a fairly good overall correspondence with the food demand: an optimal compliance (100%) is for all staple foods, but olives for oil and wine grapes, whose self-sufficiency still remains around 0.2% and 55% respectively. Even the extent of fodder crops is overall diminished by a half, animal heads sustainable by these productions increase: a twofold augmentation in the number of dairy cows occurs, while layers are subjected to an increase of an order of magnitude, finally resulting in a complete self-sufficiency for animal products. Thus, the lower income provided by food crops than by feed or animal products would cause a quite strong decrease in the total economic value generated, but in this case, due to the large amounts of milk and eggs, it is higher than the current one (+ 122%).
With the vegan scenario, areas of temporary forages for feed are redistributed among other land uses in order to provide food productions. The cultivation of minor cereals, such as barley and oats, and oil plants is not favoured, while, as long as the strong reduction in rice cultivation, the most part of agricultural area for food (70%) is devoted to pulses. In this condition the compliance with food demand is on an optimal level: on one hand food crop productions allow quantitative surplus, except

in the case of olives for oil and wine grapes, on the other the system adapts itself to the demand, not returning any area devoted to feed crops and consequently not permitting animal breeding. This situation leads to a reduction in the value generated: in comparison to the current potentialities it decreases from 3 billion Euro to 2 billion Euro (- 69%). Such a trend is shown also if compared to the vegetarian scenario, with a reduction of 38%, mostly due to the absence of products of animal origin.
The differences in the production value between the first three scenarios and the latter two can have implications not immediately evident from the comparison of the values themselves. In fact, though the economic balances of scenario 0, 1 and 2 are lower than the other situations, it must be considered that their production patterns include products not destined to direct consumption, such as animal products, but rather needed to be processed. In this way the processing itself can contribute in increasing the agricultural value generated in the territory, by providing value added; it then derives that in these cases the economic balance returned by simulations can potentially increase due to this condition. Conversely, more limited amounts of foods to be processed, or even their total lack, as in the vegetarian and in the vegan productive system respectively, would scarcely generate further value, finally resulting in the actual potentialities of the system.

Conclusions

It is certainly not a coincidence that scenarios show an economic value of production lower than the baseline scenario: actual production is the result of a laborious process of adaptation to global economic environment in order to take advantage of those competitive factors of which the Lombard agricultural system is equipped. This has led to a production specialization which modification necessarily leads to a reduction of the value generated.
Still, the renunciation to produce meat would considerably increase the possibility of producing other goods such as fruits, vegetables, legumes and cereals, thus improving the self-sufficiency level of metropolitan areas. On the contrary, the attempt to increase the self-sufficiency of food for livestock leads to an impoverishment of productive variety, given the known low energetic and environmental efficiency of livestock production.
From a methodological point of view, the assessment tools of metropolitan agro-food systems described in this report allow to set lines of food policy useful to improve the sustainability of the system. The descriptive model of the system can also be used as a multi-objective model to analyse jointly mutually conflicting objectives, such as those that occur when you need to satisfy both

economic and environmental objectives. The follow-up of research will use this type of simulation tools to produce decision support tools for food policy, at regional and local level.

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Annexes

A1. Metropolitan Regions

Figure 18: BERLIN Metropolitan Region

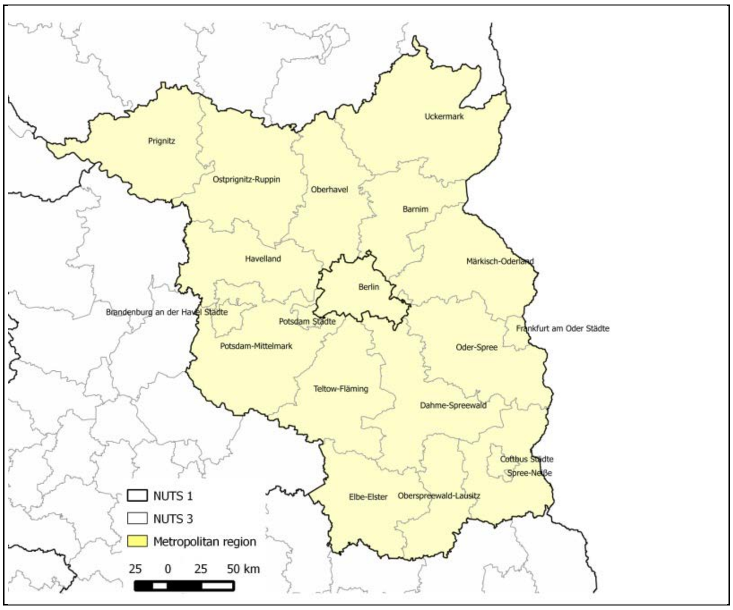


Figure 19: REDIMENSIONED BERLIN Metropolitan Region (in violet)

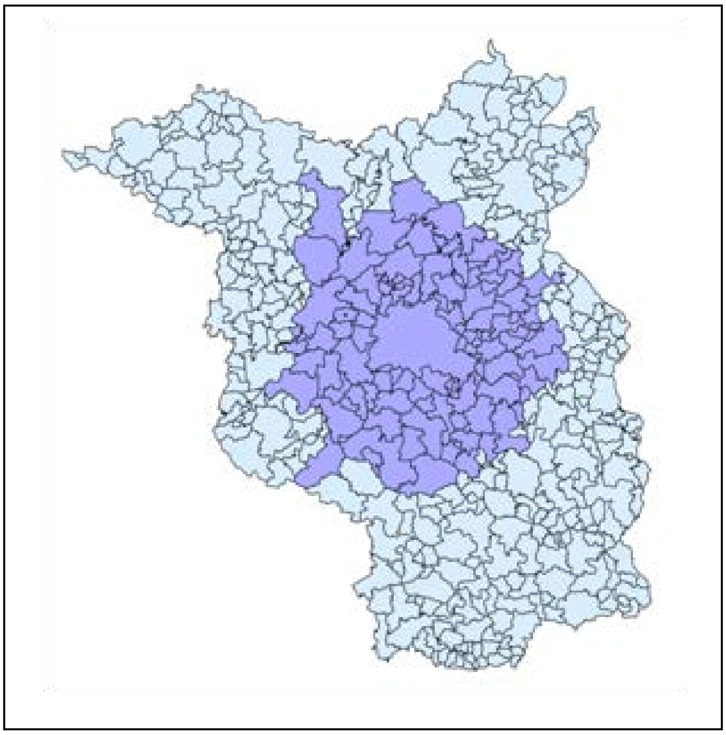


Figure 20: LJUBLJANA Metropolitan Region

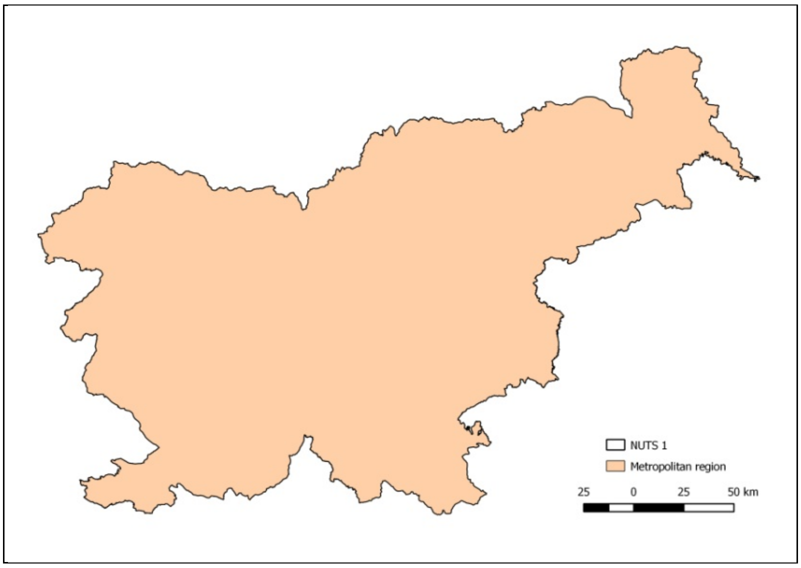


Figure 21: LONDON Metropolitan Region

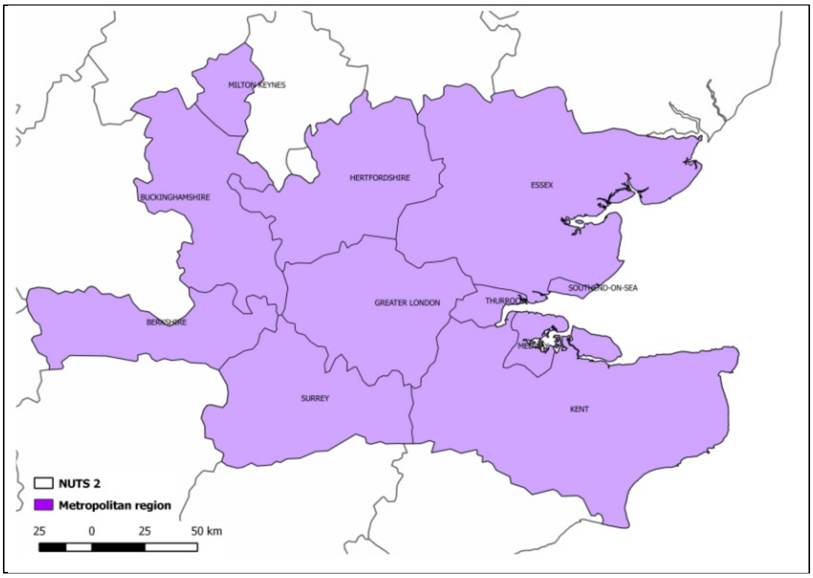


Figure 22: MILAN Metropolitan Region

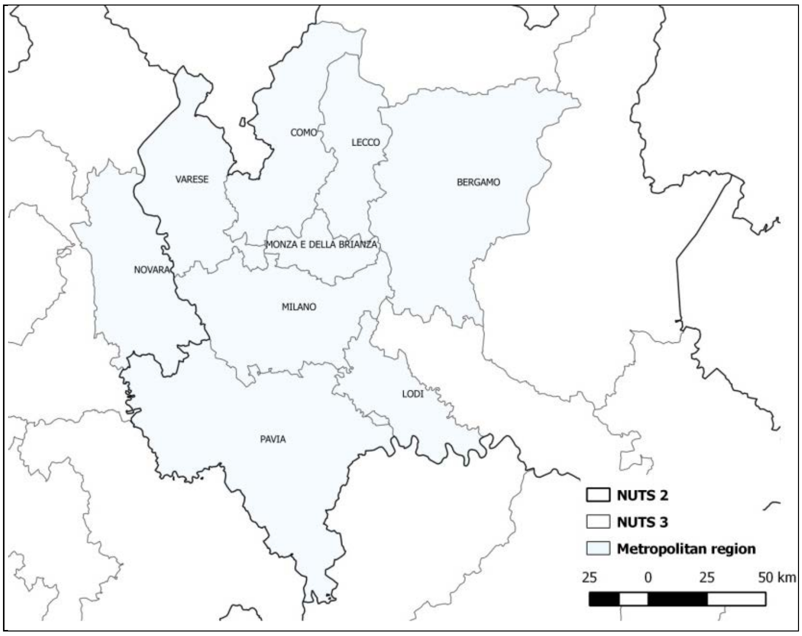
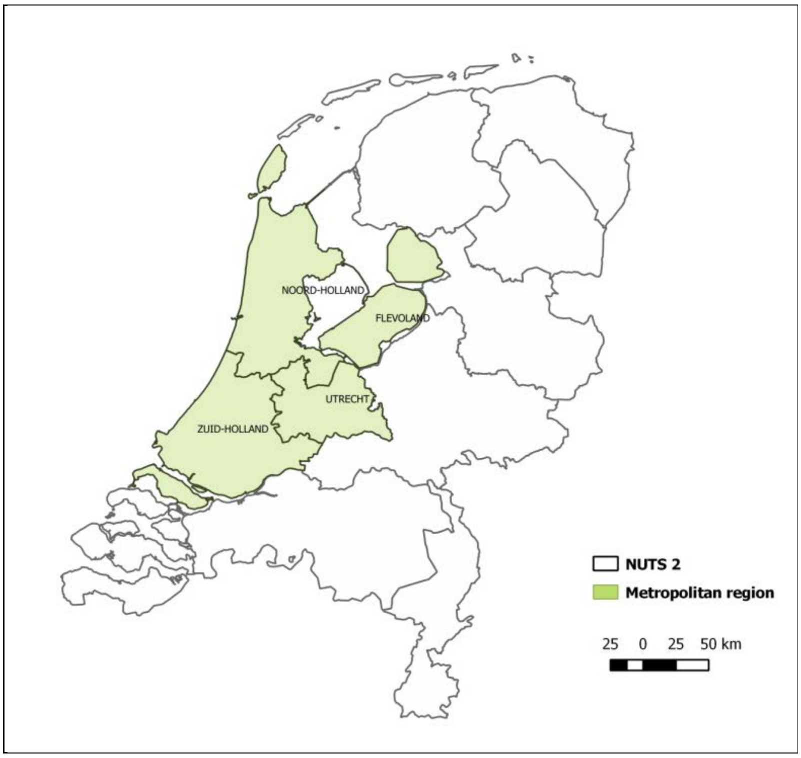


Figure 23: ROTTERDAM Metropolitan Region



A2. Methodology – figures and tables

Table 8: overview of case study areas

METROPOLITAN REGION	AREA (.000 km^2)	POPULATION (Mio. people)	DENSITY (people/ km^2)	UTILIZED AGRICULTURAL AREA (UAA)		
				TOTAL (ha)	TOTAL (% territorial area)	PER CAPITA (ha/person)
BERLIN OECD	31.50	6.04	198	1.860.951	59	0.31
BERLIN (redim.)	9.60	4.76	496	566,282	59	0.12
LJUBLJANA	20.20	2.05	102	474,432	23	0.23
LONDON	16.12	15.57	966	761,384	47	0.05
MILAN	13.10	7.89	602	489,668	37	0.06
ROTTERDAM	11.37	7.84	690	420,850	37	0.05

Table 9: breakdown of Utilized Agricultural Area in major crops and uses. In brackets the percentage on total UAA

METROPOLITAN REGION	UTILIZED AGRICULTURAL AREA								
	Cereals	Potatoes	Total vegetables and legumes	Fruits	Vineyards and olive yards	Sugar beets and other industrial crops	Other crops on arable land	Forages	Permanent grassland and pastures
BERLIN OECD	509,900 *(27.4)*	9,400 *(0.5)*	20,452 *(1.1)*	3,399 *(0.2)*	- *(-)*	140,500 *(8.2)*	n/a	367,000 *(19.7)*	279,600 *(15.0)*
BERLIN (redim.)	155,161 *(27.4)*	2,860 *(0.5)*	6,223 *(1.1)*	1,034 *(0.2)*	- *(-)*	46,754 *(8.2)*	n/a	111,677 *(19.7)*	85,081 *(15.0)*
LJUBLJANA	93,941 *(19.8)*	4,076 *(0.9)*	2,646 *(0.6)*	9,190 *(1.9)*	17,243 *(3.6)*	11,787 *(2.5)*	437 *(0.1)*	54,727 *(11.5)*	277,492 *(58.5)*
LONDON	284,761 *(37.4)*	5,505 *(0.7)*	42,856 *(5.6)*	11,868 *(1.6)*	- *(-)*	76,066 *(10.0)*	23,923 *(3.1)*	34,487 *(4.5)*	208,730 *(27.4)*
MILAN	280,394 *(57.3)*	*370* *(0.1)*	4,533 *(0.9)*	1,464 *(0.3)*	15,448 *(3.2)*	3,920 *(0.8)*	58 *(0.01)*	64,481 *(13.2)*	93,213 *(19.0)*
ROTTERDAM	45,774 *(10.9)*	14,437 *(3.4)*	27,008 *(6.4)*	10 *(0.002)*	- *(-)*	20,094 *(4.8)*	1,917 *(0.5)*	58,813 *(14.0)*	181,442 *(43.1)*

Table 10: food categories and subcategories as listed in the EFSA database.

FOOD CATEGORY (c)		FOOD SUB-CATEGORY (s)	
(I)	**Alcoholic beverages**	*(1)*	*Beer and beer-like beverages*
		(2)	*Fortified wines and liqueur wines*
		(3)	*Liqueurs*
		(4)	*Spirits*
		(5)	*Wine*
(II)	**Animal and vegetable fats and oils**	*(6)*	*Animal fat*
		(7)	*Margarine and similar products*
		(8)	*Vegetable fat*
		(9)	*Vegetable oil*
(III)	**Composite food (incl. frozen products)**	*(10)*	*Cereal-based dishes*
		(11)	*Composite food (incl. frozen products) (unspecified)*
		(12)	*Meat-based meals*
		(13)	*Prepared salads*
		(14)	*Ready-to-eat meal for infants and young children*
		(15)	*Vegetable-based meals*
		(16)	*Ready to eat soups*
		(17)	*Rice-based meals*
(IV)	**Drinking water**	*(18)*	*Bottled water*
		(19)	*Tap water*
(V)	**Eggs and eggs products**	*(20)*	*Eggs, fresh*
(VI)	**Fish and other seafood**	*(21)*	*Amphibians, reptiles, snails, insects*
		(22)	*Crustaceans*
		(23)	*Fish meat*
		(24)	*Fish offal*
		(25)	*Fish products*
		(26)	*Water molluscs*
(VII)	**Food for infants and small children**	*(27)*	*Cereal-based food for infants and young children*
		(28)	*Follow-on formulae, powder*
		(29)	*Follow-on formulae, liquid*
		(30)	*Food for infants and small children (unspecified)*
		(31)	*Infant formulae, powder*
		(32)	*Fruit juice and herbal tea for infants and young children*
		(33)	*Yoghurt, cheese and milk-based dessert for infants and young children*
(VIII)	**Fruits and fruit products**	*(34)*	*Berries and small fruits*
		(35)	*Citrus fruits*
		(36)	*Dried fruits*
		(37)	*Fruit juice*

		(38)	*Fruit nectar*
		(39)	*Jam, marmalade and other fruit spreads*
		(40)	*Miscellaneous fruits*
		(41)	*Mixed fruit and vegetable juice*
		(42)	*Mixed fruit juice*
		(43)	*Other fruit products (excl. beverages)*
		(44)	*Pome fruits*
		(45)	*Stone fruits*
		(46)	*Vegetable juice*
(IX)	**Grains and grain-based products**	*(47)*	*Bread and rolls*
		(48)	*Fine bakery wares*
		(49)	*Grains for human consumption*
		(50)	*Pasta (raw)*
		(51)	*Breakfast cereals*
		(52)	*Grain milling products*
(X)	**Herbs, spices and condiments**	*(53)*	*Baking ingredients*
		(54)	*Condiment*
		(55)	*Dressing*
		(56)	*Herb and spice mixture*
		(57)	*Herbs*
		(58)	*Seasoning or extracts*
		(59)	*Spices*
(XI)	**Legumes, nuts and oilseeds**	*(60)*	*Legumes, beans, dried*
		(61)	*Legumes, beans, green, without pods*
		(62)	*Oilseeds*
		(63)	*Tree nuts*
(XII)	**Meat and meat products**	*(64)*	*Edible offal, farmed animals*
		(65)	*Game birds*
		(66)	*Game mammals*
		(67)	*Livestock meat*
		(68)	*Meat imitates*
		(69)	*Poultry*
		(70)	*Sausages*
		(71)	*Preserved meat*
(XIII)	**Milk and dairy products**	*(72)*	*Cheese*
		(73)	*Concentrated milk*
		(74)	*Fermented milk products*
		(75)	*Milk and milk product imitates*
		(76)	*Liquid milk*
		(77)	*Cream and cream products*
(XIV)	**Non-alcoholic beverages (exc. milk based beverages)**	*(78)*	*Coffee (Beverage)*
		(79)	*Coffee imitates beverage*
		(80)	*Soft drinks*
		(81)	*Tea (Infusion)*

(XV)	**Products for special nutritional use**	*(82)*	*Food for sports people (labelled as such)*
		(83)	*Dietary supplements*
		(84)	*Food for weight reduction*
		(85)	*Products for special nutritional use (unspecified)*
		(86)	*Medical food (are specially formulated and intended for the dietary management of a disease that has distinctive nutritional needs that cannot be met by normal diet alone; intended to be used under medical supervision)*
(XVI)	**Snacks, desserts, and other foods**	*(87)*	*Ices and desserts*
		(88)	*Other foods (foods which cannot be included in any other group)*
		(89)	*Snack food*
(XVII)	**Starchy roots and tubers**	*(90)*	*Other starchy roots and tubers*
		(91)	*Potatoes and potatoes products*
(XVIII)	**Sugar and confectionary**	*(92)*	*Confectionery (non-chocolate)*
		(93)	*Chocolate (cocoa) products*
		(94)	*Honey*
		(95)	*Molasses and other syrups*
		(96)	*Sugar substitutes*
		(97)	*Sugars*
(XIX)	**Vegetables and vegetable products (incl. fungi)**	*(98)*	*Brassica vegetables*
		(99)	*Bulb vegetables*
		(100)	*Cocoa beans and cocoa products*
		(101)	*Coffee beans and coffee products (solid)*
		(102)	*Coffee imitates (solid)*
		(103)	*Fruiting vegetables*
		(104)	*Fungi, cultivated*
		(105)	*Fungi, wild, edible*
		(106)	*Leaf vegetables*
		(107)	*Legume vegetables*
		(108)	*Root vegetables*
		(109)	*Sea weeds*
		(110)	*Stem vegetables (fresh)*
		(111)	*Tea and herbs for infusions (solid)*
		(112)	*Vegetable products*

Table 11: list of excluded food and drinks items and products

(4)	*Spirits*
(7)	*Margarine and similar products*
(8)	*Vegetable fat*
(11)	*Composite food (incl. frozen products) (unspecified)*
(14)	*Ready-to-eat meal for infants and young children*
(18)	*Bottled water*
(19)	*Tap water*
(21)	*Amphibians, reptiles, snails, insects*
(22)	*Crustaceans*
(23)	*Fish meat*
(24)	*Fish offal*
(25)	*Fish products*
(26)	*Water molluscs*
(27)	*Cereal-based food for infants and young children*
(28)	*Follow-on formulae, powder*
(29)	*Follow-on formulae, liquid*
(30)	*Food for infants and small children (unspecified)*
(31)	*Infant formulae, powder*
(32)	*Fruit juice and herbal tea for infants and young children*
(33)	*Yoghurt, cheese and milk-based dessert for infants and young children*
(53)	*Baking ingredients*
(54)	*Condiment*
(55)	*Dressing*
(56)	*Herb and spice mixture*
(57)	*Herbs*
(58)	*Seasoning or extracts*
(59)	*Spices*
(64)	*Edible offal, farmed animals*
(65)	*Game birds*
(66)	*Game mammals*
(68)	*Meat imitates*
(75)	*Milk and milk product imitates*
(78)	*Coffee (Beverage)*
(79)	*Coffee imitates beverage*
(80)	*Soft drinks*
(81)	*Tea (Infusion)*
(82)	*Food for sports people (labelled as such)*
(83)	*Dietary supplements*
(84)	*Food for weight reduction*
(85)	*Products for special nutritional use (unspecified)*
(86)	*Medical food (are specially formulated and intended for the dietary management of a disease that has distinctive nutritional needs that cannot be met by normal diet alone; intended to be used under medical supervision)*
(87)	*Ices and desserts*
(88)	*Other foods (foods which cannot be included in any other group)*
(89)	*Snack food*
(90)	*Other starchy roots and tubers*
(92)	*Confectionery (non-chocolate)*
(93)	*Chocolate (Cocoa) products*
(94)	*Honey*
(96)	*Sugar substitutes*
(100)	*Cocoa beans and cocoa products*
(101)	*Coffee beans and coffee products (Solid)*
(102)	*Coffee imitates (Solid)*
(104)	*Fungi, cultivated*
(105)	*Fungi, wild, edible*
(109)	*Sea weeds*
(111)	*Tea and herbs for infusions (Solid)*

Table 12: per capita food and drinks consumption patterns. Breakdown of consumed amounts for selected sub-categories and categories, based on EFSA database (EFSA, 2011), Slovenian national survey (SORS, 2010) and FAO.

		BERLIN	LONDON	MILAN	ROTTERDAM	LJUBLJANA	NAIROBI
	FOOD CATEGORIES						
(II)	*Animal and vegetable fats and oils*	1.08	0.62	3.25	0.33	4.27	n/a
(III)	*Composite food*	5.52	0.29	0.90	6.39	n/a	n/a
(IV)	*Eggs and egg products*	0.57	1.50	1.73	0.37	1.51	n/a
(VIII)	*Fruits and fruit products*	30.85	12.65	17.85	16.44	19.40	n/a
(IX)	*Grains and grain-based products*	18.46	20.34	20.44	16.79	17.44	53.11
(XI)	*Legumes, nuts and oilseeds*	0.76	2.83	1.04	0.62	0.32	n/a
(XII)	*Meat and meat products*	7.94	9.08	9.09	8.65	9.74	5.40
(XIII)	*Milk and dairy products*	14.34	22.36	15.04	23.91	20.53	41.49
(XVII)	*Starchy roots and tubers*	4.73	9.75	4.02	8.20	7.51	n/a
(XVIII)	*Sugar and confectionary*	0.45	1.01	1.36	1.05	2.57	n/a
(XIX)	*Vegetables and vegetable products*	8.80	10.78	18.39	7.11	11.71	n/a
	TOTAL LOCAL	***93.50***	***91.22***	***93.11***	***89.87***	***95.00***	***100***
	TOTAL NON-LOCAL	***6.50***	***8.78***	***6.89***	***10.13***	***5.00***	***0***
	DRINK CATEGORIES						
(I)	*Alcoholic beverages*	11.40	18.80	3.58	9.19	29.75	n/a
	TOTAL LOCAL	***11.40***	***18.80***	***3.58***	***9.19***	***29.75***	n/a
	TOTAL NON-LOCAL	***88.60***	***81.20***	***96.42***	***90.81***	***70.25***	n/a

Table 13: details of the aggregation of food products, from sub-categories to staple food groups.

FOOD SUB-CATEGORY (s) (EFSA database)	PROCESSING YIELD (ty)	STAPLE FOOD (p)	STAPLE FOOD GROUP
Bread and rolls Fine bakery wares Grain milling products	Yield to bread and flour	Soft wheat	CEREALS
Pasta Grain milling products	Yield to pasta and flour	Durum wheat	
Beer and beer-like beverages	Beer-making	Barley	
Breakfast cereals	-	Oats	
		Maize	
Grains for human consumption Breakfast cereals Rice-based meals	Yield to paddy rice	Rice	
Cereal-based dishes	Minimum content of primary product	Other cereals	
Vegetable oils [unspecified] Oilseed	Oil making	Rape	OIL PLANTS
		Sunflower	
		Olive	

Berries and small fruits Citrus fruits Dried fruits Fruit juice Fruit nectar Jam, marmalade and other fruit spreads Miscellaneous fruits Mixed fruit and vegetable juice Mixed fruit juice Other fruit products (excl. beverages) Pome fruits Stone fruits Tree nuts Cider	Minimum content of primary product	Fruits	FRUITS, VEGETABLES, POTATOES
Brassica vegetables Bulb vegetables Fruiting vegetables Leaf vegetables Legume vegetables Legumes, beans, green, without pods Prepared salads Ready-to-eat soups Root vegetables Stem vegetables (Fresh) Vegetable products Vegetable juice Vegetable-based meals	Minimum content of primary product	Vegetables	
Legumes, beans, dried	-	Pulses	
Potatoes and potatoes products	-	Potatoes	
Molasses and other syrups Sugars	Yield to sugar from sugar beets	Sugar beets	SUGAR BEETS
Fortified and liqueur wines Wine	Wine making	WINEGRAPES	
Animal fat Cheese Concentrated milk Cream and cream products Fermented milk products Liquid milk	Yield to butter and cheese; minimum content of primary product	MILK	
Eggs	-	Eggs	ANIMAL PRODUCTIONS
Livestock meat Meat-based meals	Slaughtering yield	Beef meat	
Poultry Meat-based meals		Poultry meat	
Preserved meat Sausages Meat-based meals		Pig meat	

A3. Calories and producer prices

Table 14: energy content of considered staple foods (source: INRAN, accessed Sept. 2014)

Staple food group	Staple food	Energy content (kcal 100g/e.p.)	Energy from carbohydrates (%)	Energy from proteins (%)	Energy from fats (%)
CEREALS	Barley	319	*83*	*13*	*4*
	Maize	361	*91*	*7*	*2*
	Oats	373	*70*	*9*	*21*
	Rice	320	*91*	*8*	*1*
	Wheat	353	*75*	*17*	*8*
	Other cereals	345	*82*	*7*	*11*
FRUITS		78	*88*	*8*	*4*
VEGETABLES	Pulses	293	*65*	*30*	*5*
	Vegetables	29	*45*	*43*	*12*
POTATOES		148	*89*	*1*	*10*
OILPLANTS	Olives	145			*100*
	Rape	540			
	Pumpkin	446			
	Sunflower	18			
SUGAR BEETS		58	*100*		
WINE		73	*100*		
EGGS		128		*39*	*61*
MEAT	Beef meat	131		*80*	*20*
	Pig meat	288		*65*	*35*
	Poultry meat	141		*70*	*30*
MILK		48	*28*	*21*	*51*

Table 15: producer prices of staple foods in different regions (2010-2014 average). Italics were an average price considered.

STAPLE FOOD GROUP	STAPLE FOOD	BERLIN	LJUBLJANA	LONDON	MILAN	ROTTERDAM
PLANT ORIGIN [€/t]						
CEREALS	Barley	*203*	*203*	*203*	208	197
	Maize	169	175	104	199	200
	Oats	*165*	*165*	*165*	205	124
	Rice	*363*	*363*	*363*	363	*363*
	Wheat	192	178	207	238	199
	Other cereals	227	175	217	242	194
FRUITS [unspecified]		1,152	496	2,680	1,030	400
VEGETABLES	Pulses	157	*337*	249	140	800
	Vegetables	1,090	949	1,319	670	1,420
POTATOES		160	263	194	380	171
OIL PLANTS [unspecified]		*455*	455	455	455	455
SUGAR BEETS		47	*40*	38	40	54
WINE		*444*	450	*444*	438	*444*
ANIMAL ORIGIN [€/kg, €/pc or €/l]						
EGGS		0.10	0.10	0.06	130	83
MILK		0.37	0.35	0.33	0.40	0.37
MEAT	Beef meat	2.23	2.24	2.11	2.2	2.37
	Pig meat	1.44	1.26	1.79	1.47	1.44
	Poultry meat	0.91	1.10	0.94	1.22	0.87

Sources: BMELV; SORS; DEFRA; AGRISTAT, ENR, ISMEA, ISTAT; CBS, LEI, LEI and CBS, 2012.

A4a. Results - Berlin OECD Region

Figure 24: demanded and consumed amounts of primary agricultural products

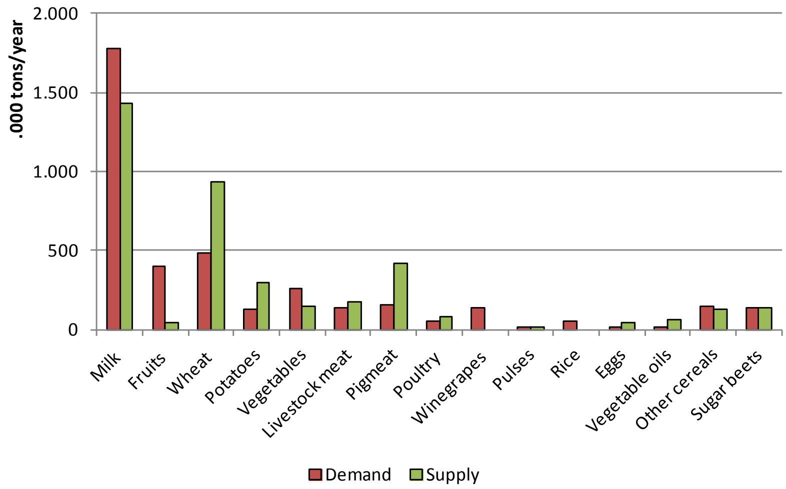


Figure 25: quantity index of each staple food group

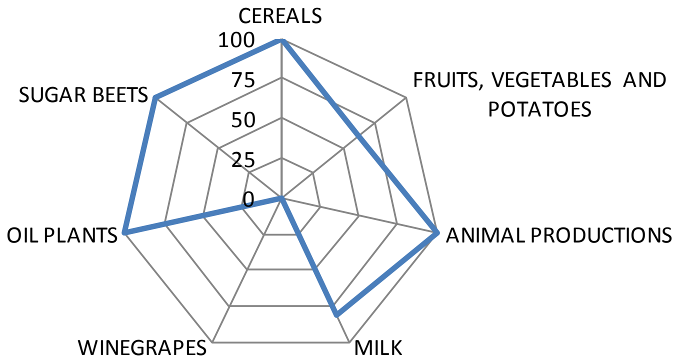


Figure 26: demanded and supplied calories per energy source

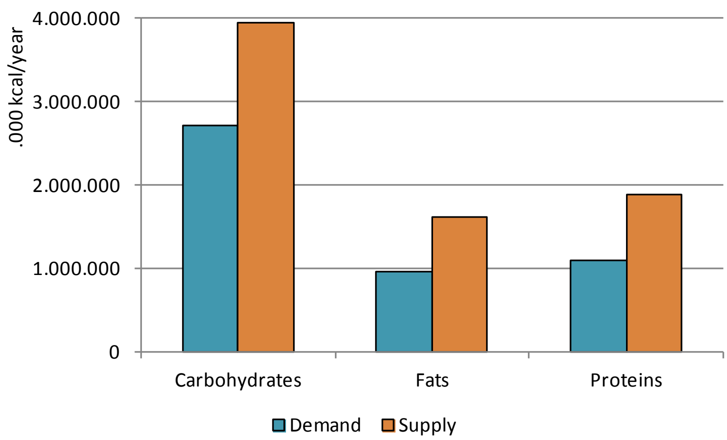


Figure 27: elements of the economi balance in the region. Dark green is th share of value from no-foo productions.

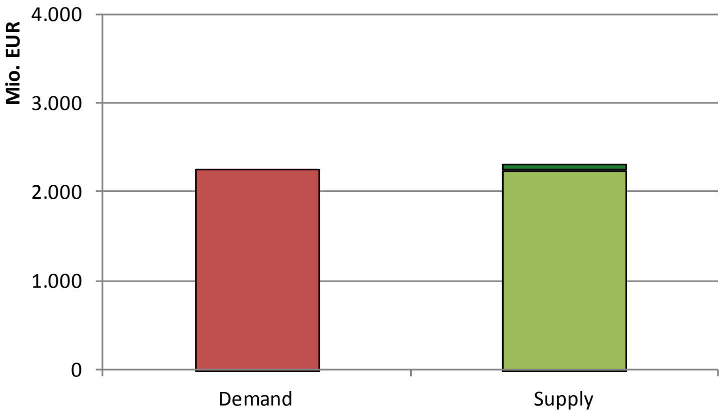
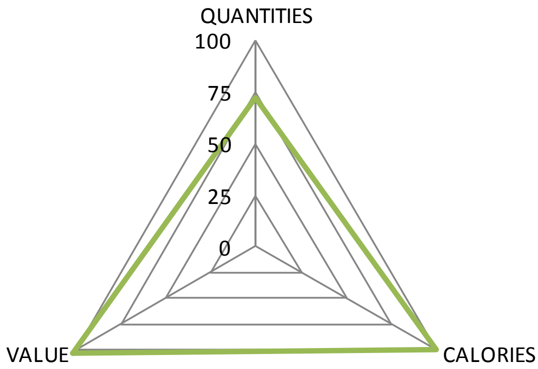


Figure 28: multidimensional profile of the MAS



A4b. Results – Berlin Redimensioned Region

Figure 29: demanded and consumed amounts of primary agricultural products

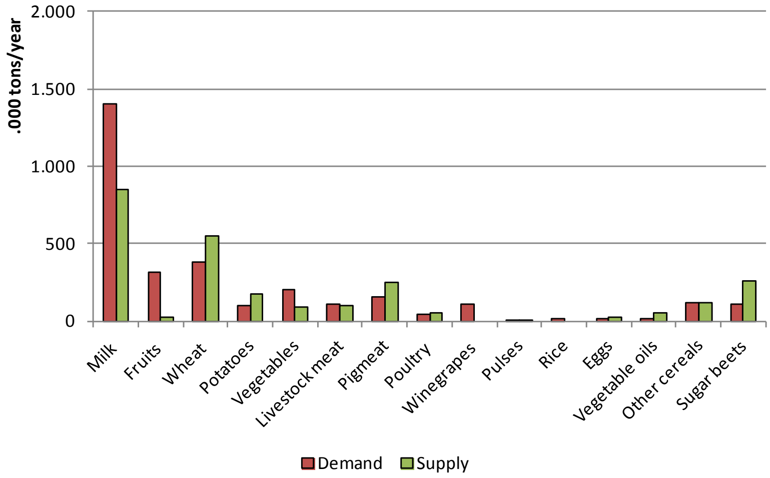


Figure 30: quantity index of each staple food group

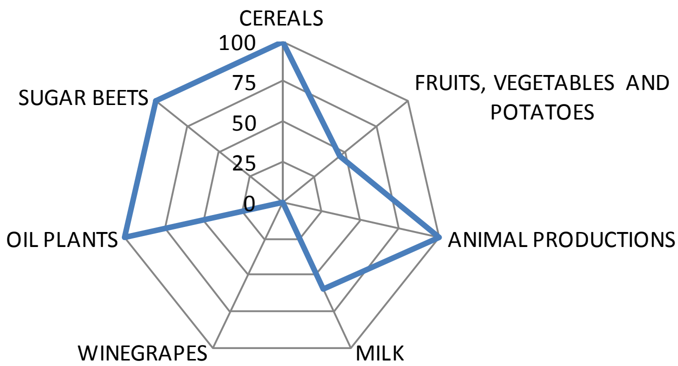


Figure 31: demanded and supplied calories per energy source

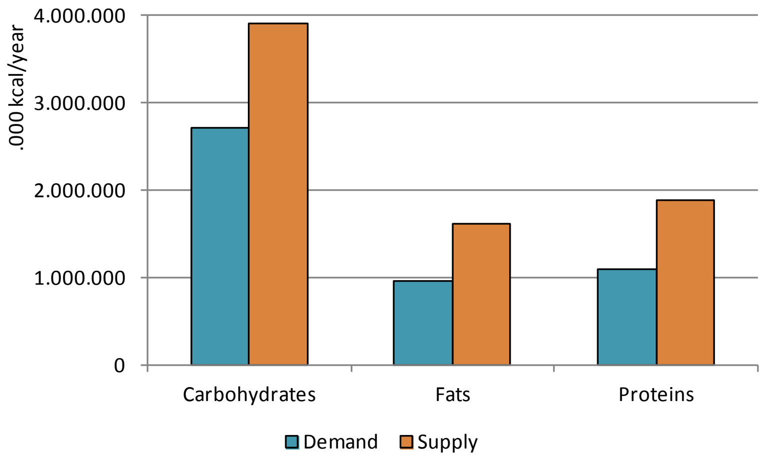


Figure 32: elements of the economic balance in the region. Dark green is the share of value from no-food productions.

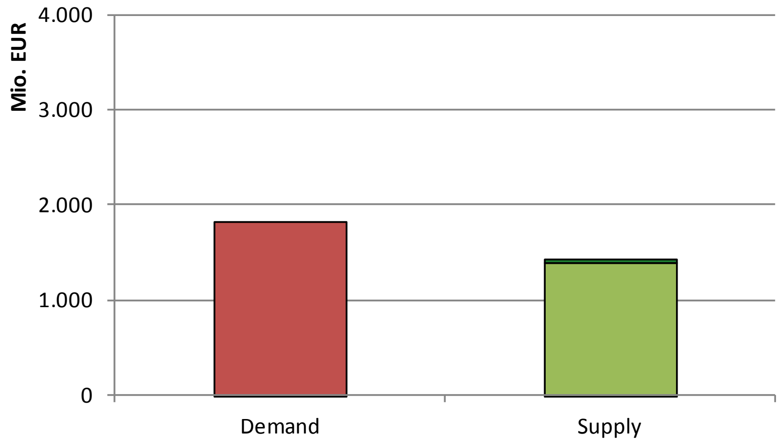
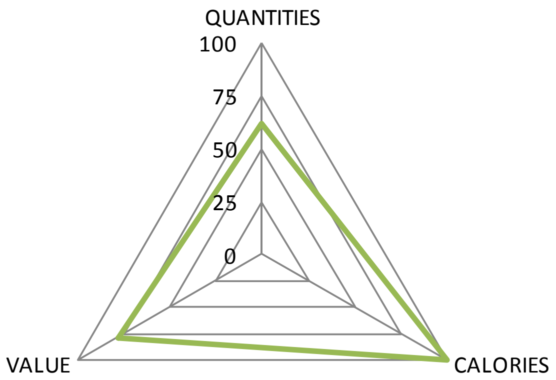


Figure 33: multidimensional profile of the MAS



A4c. Results – Ljubljana OECD Region

Figure 34: demanded and consumed amounts of primary agricultural products

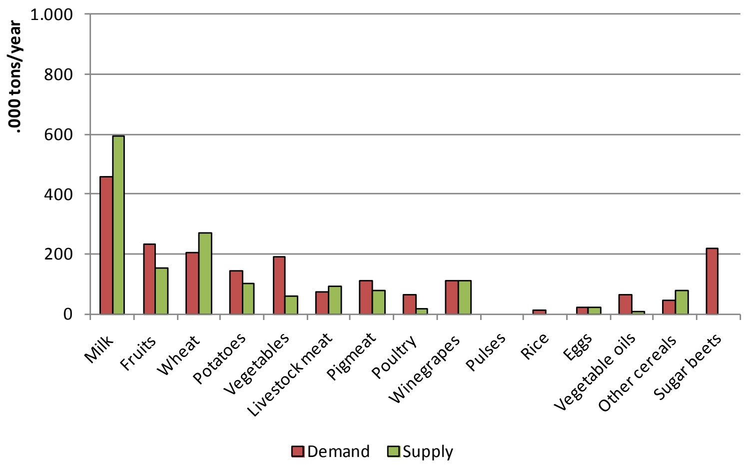


Figure 35: quantity index of each staple food group

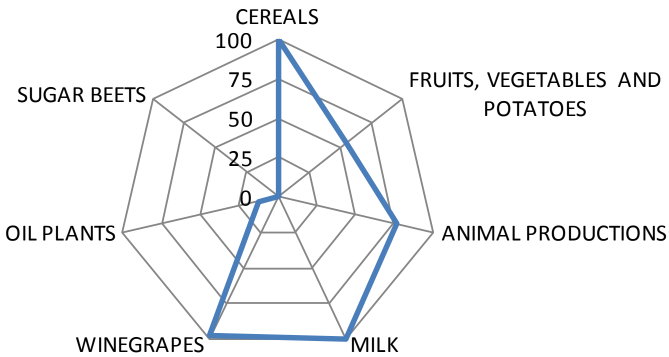


Figure 36: demanded and supplied calories per energy source

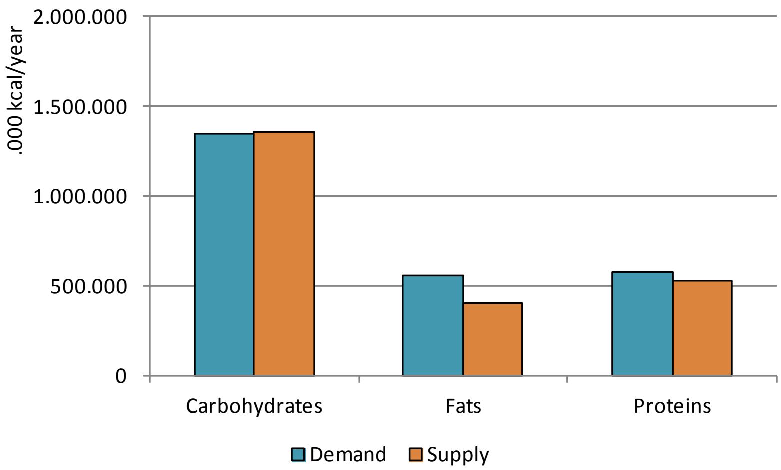


Figure 37: elements of the economic balance of the region. Dark green is the share from no-food productions.

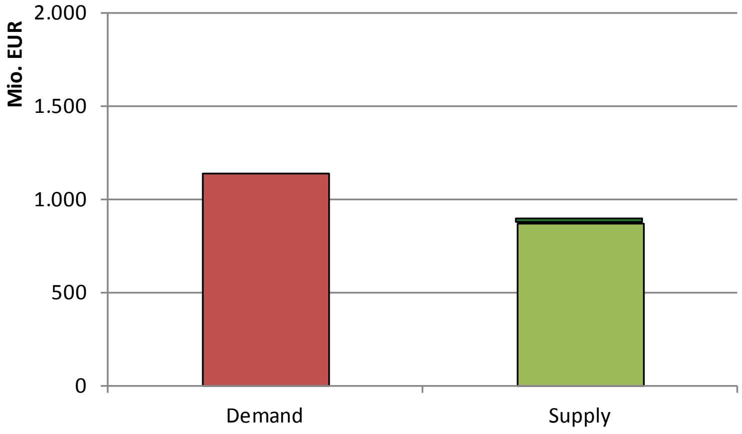
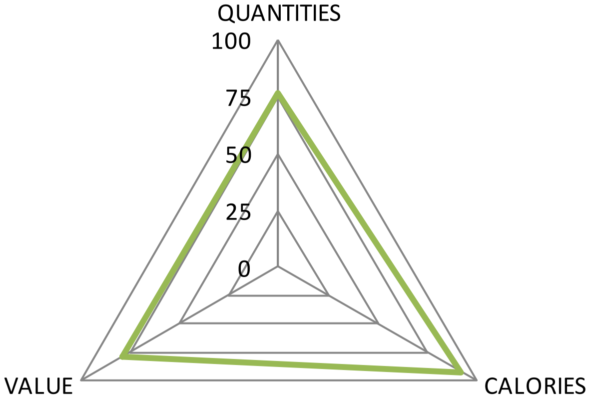


Figure 38: multidimensional profile of the MAS



A4d. Results – London OECD Region

Figure 39: demanded and consumed amounts of primary agricultural products

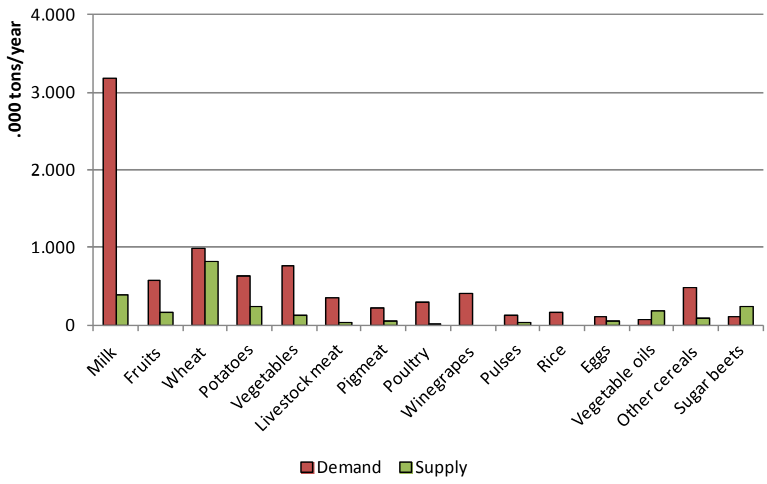


Figure 40: quantity index of each staple food group

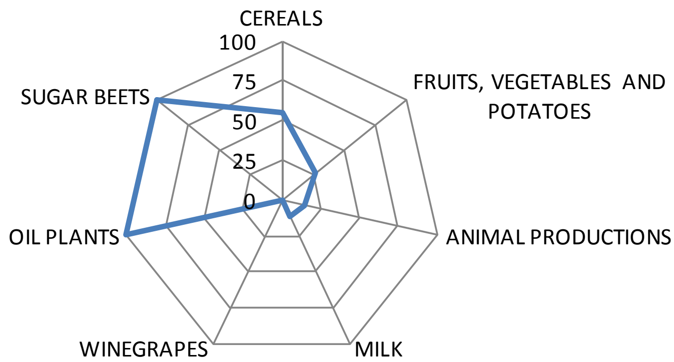


Figure 41: demanded and supplied calories per energy source

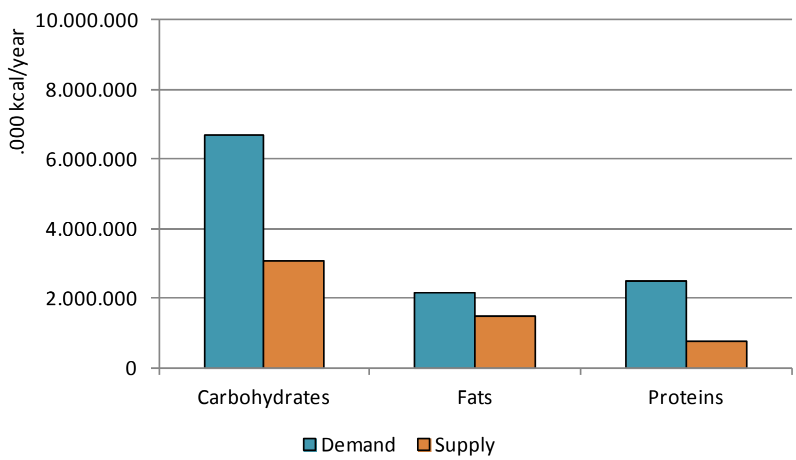


Figure 42: elements of the economic balance of the region. Dark green is the share from no-food productions.

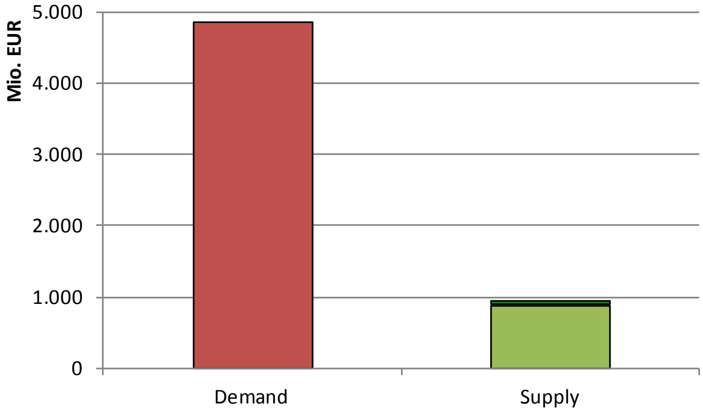
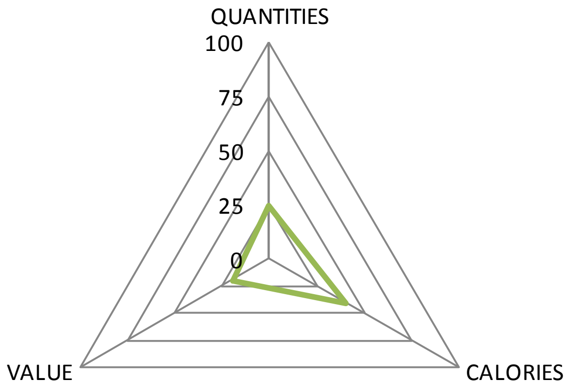


Figure 43: multidimensional profile of the MAS



A4e. Results – Milan OECD Region

Figure 44: demanded and consumed amounts of primary agricultural products

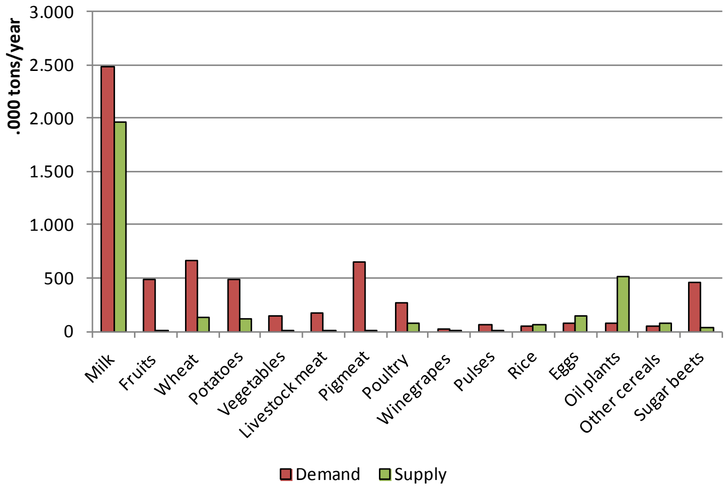


Figure 45: quantity index of each staple food group

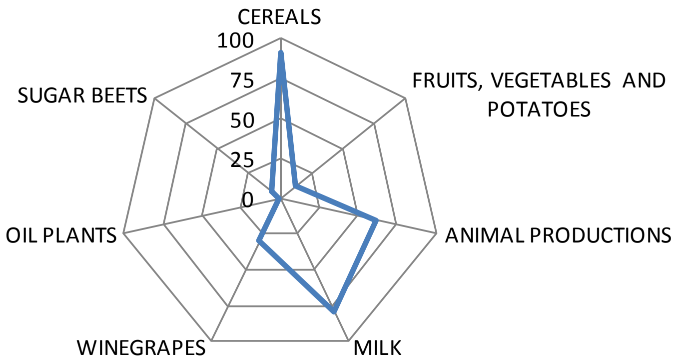


Figure 46: demanded and supplied calories per energy source

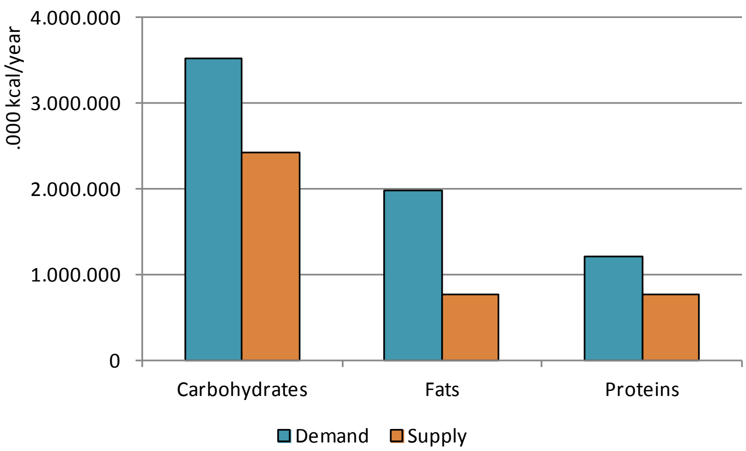


Figure 47: economic value requested and generated in the territory. Dark green from no-food productions

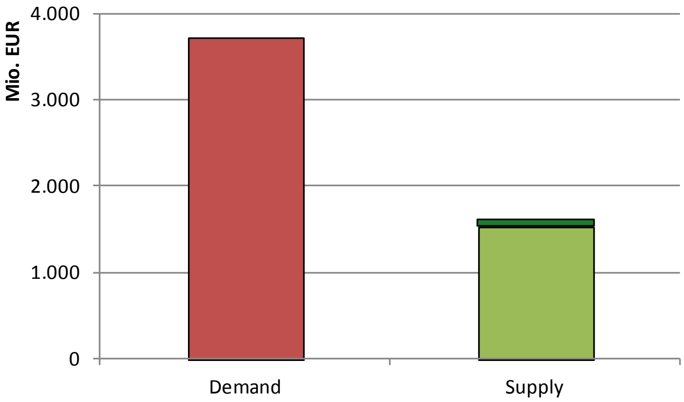
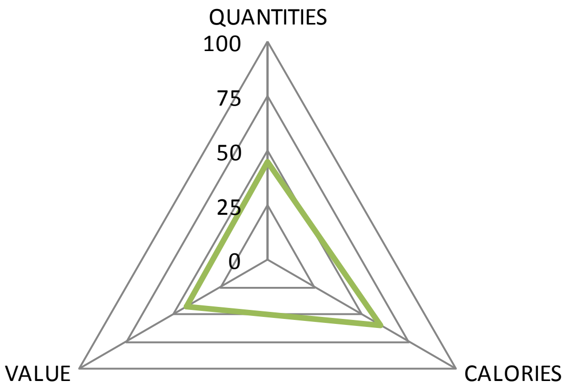


Figure 48: multidimensional profile of the MAS



A4f. Results – Rotterdam OECD Region

Figure 49: demanded and consumed amounts of primary agricultural products

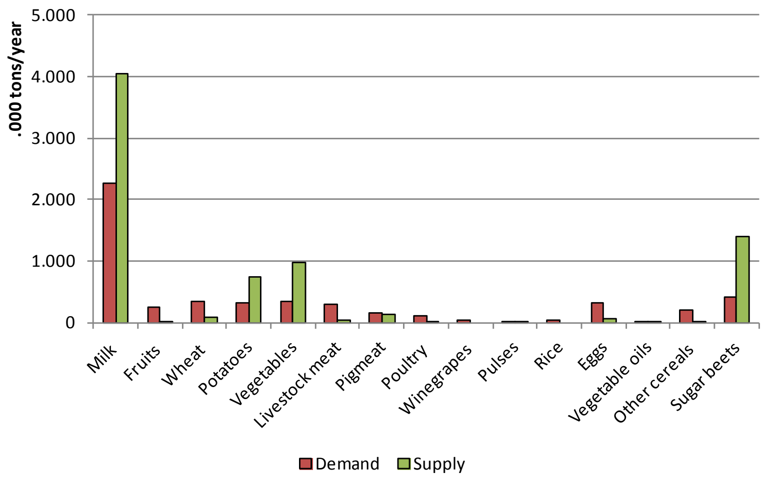


Figure 50: quantity index of each staple food group

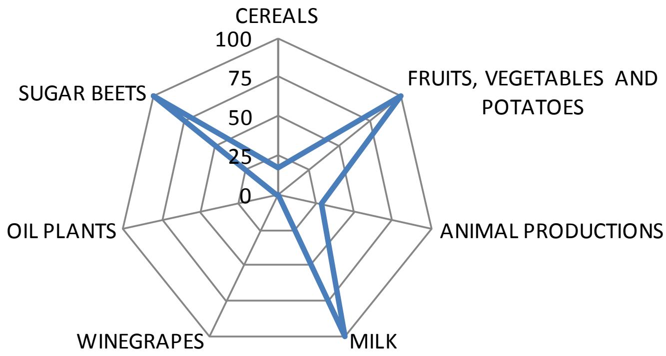


Figure 51: demanded and supplied calories per energy source

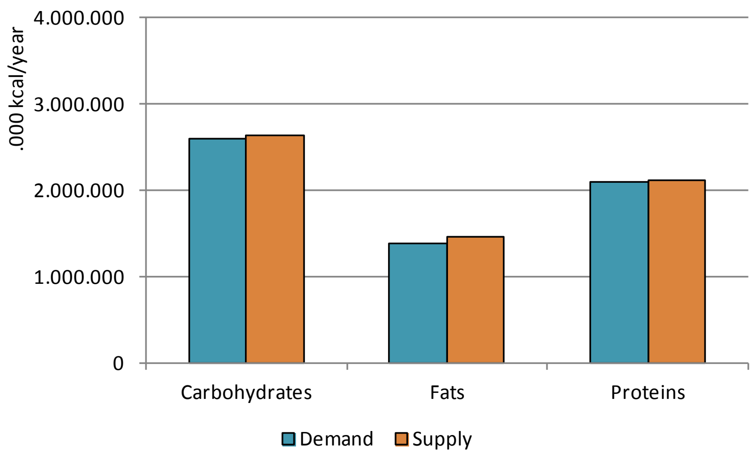


Figure 52: economic value requested and generated in the territory. Dark green from no-food productions

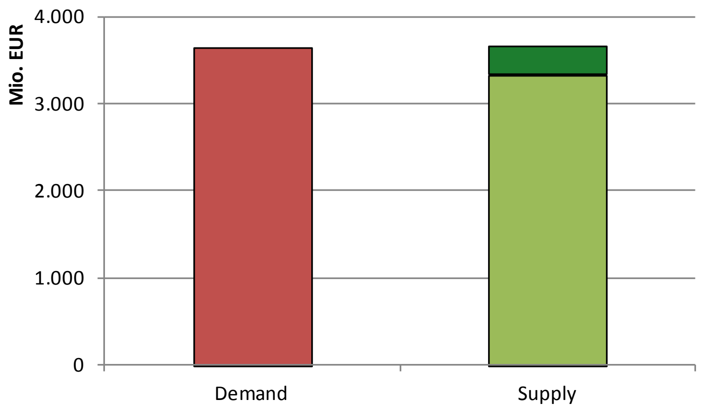
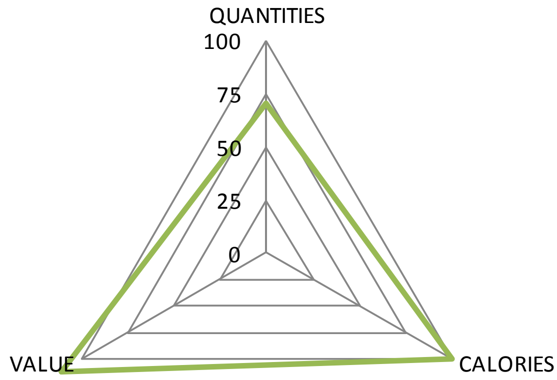


Figure 53: multidimensional profile of the MAS



A5. Results – Performance of case studies

Figure 54: relationship between quantity and value indexes in case study areas

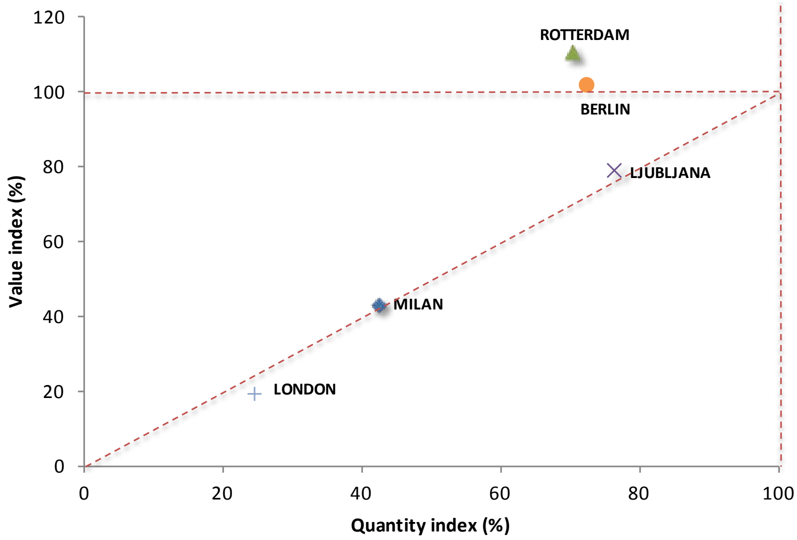


Figure 55: relationship between calorie and value indexes in case study areas

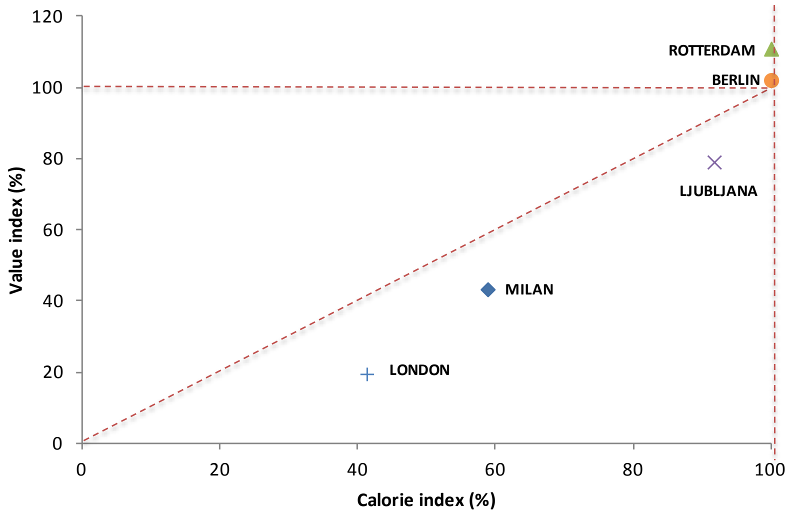
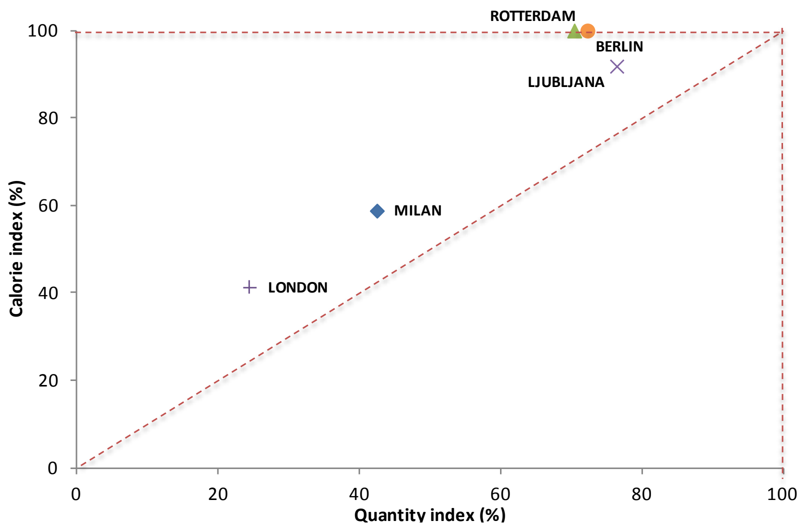


Figure 56: relationship between quantity and calorie indexes in case study areas

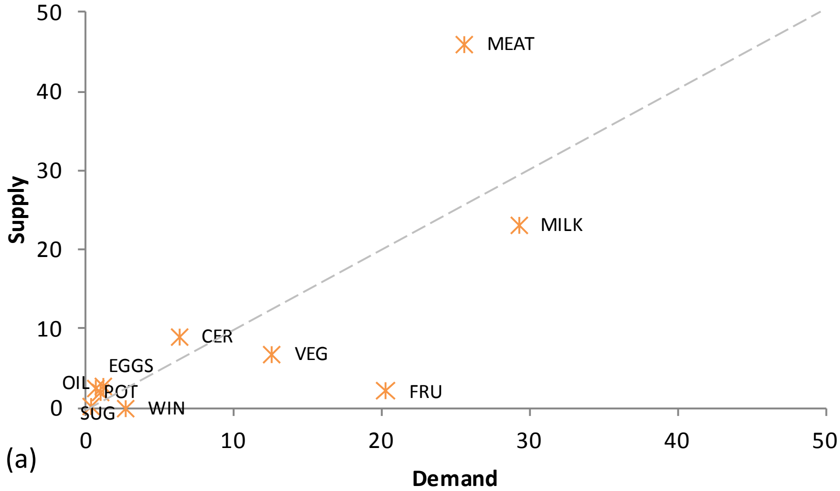


A6. Results – Relative importance of products in case study areas

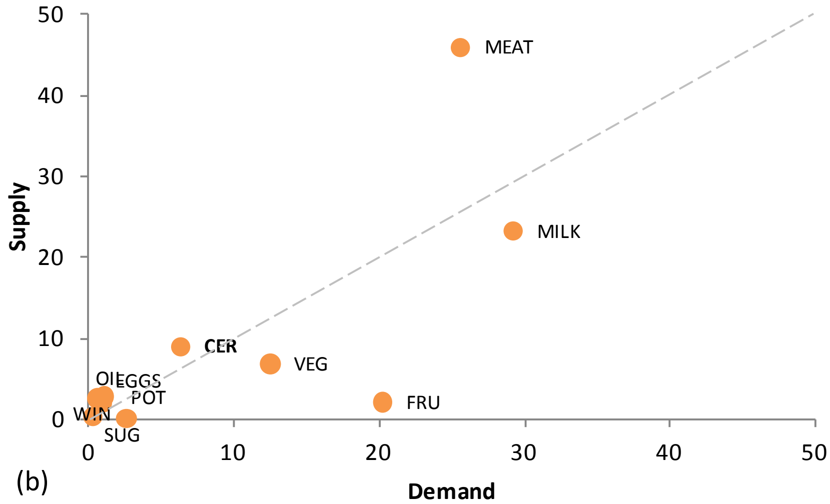
Figure 57: relative importance of products, compared to demand and supply in the different case study areas:

(a) BERLIN REDIMENSIONED
(b) BERLIN OECD
(c) LJUBLJANA
(d) LONDON
(e) MILAN
(f) ROTTERDAM

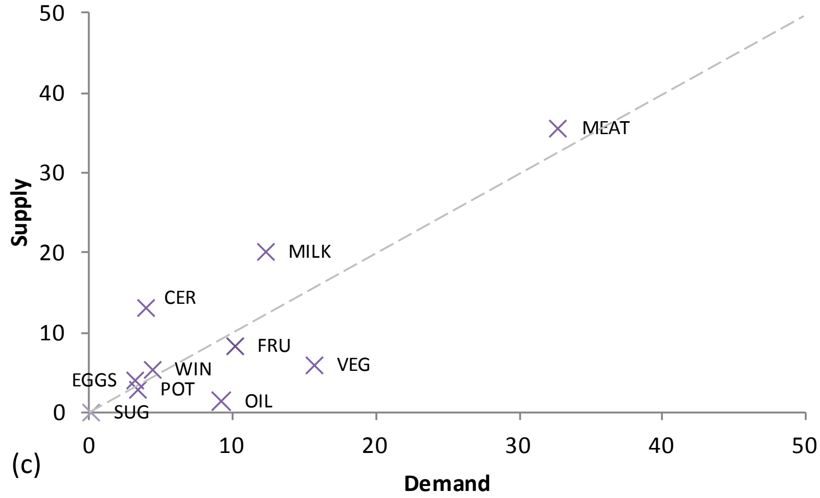
MEAT = meat
MILK = milk
FRU = fruits
VEG = vegetables
CER =cereals
EGGS = eggs
POT =potatoes
OIL = oil plants
WIN = wine grapes
SUG = sugar beets



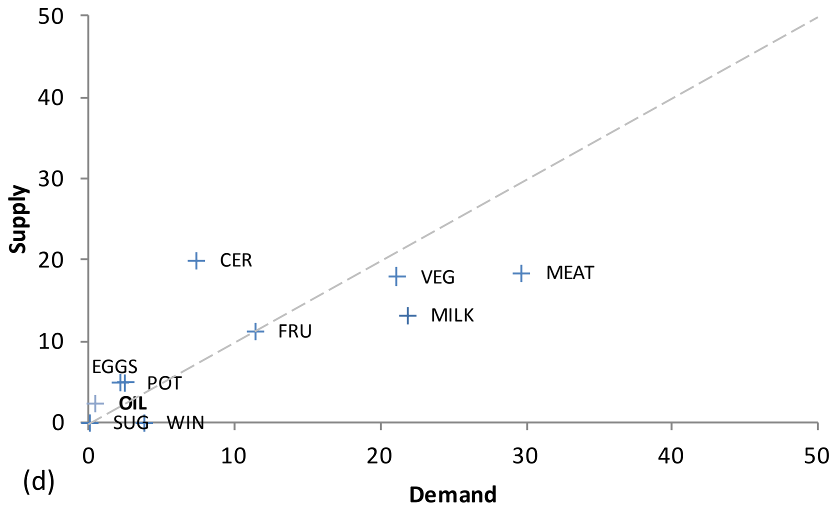
(a)



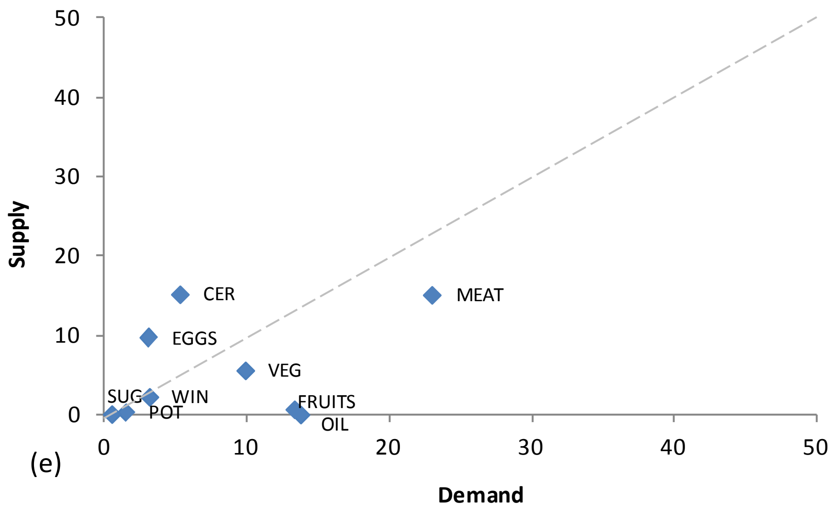
(b)

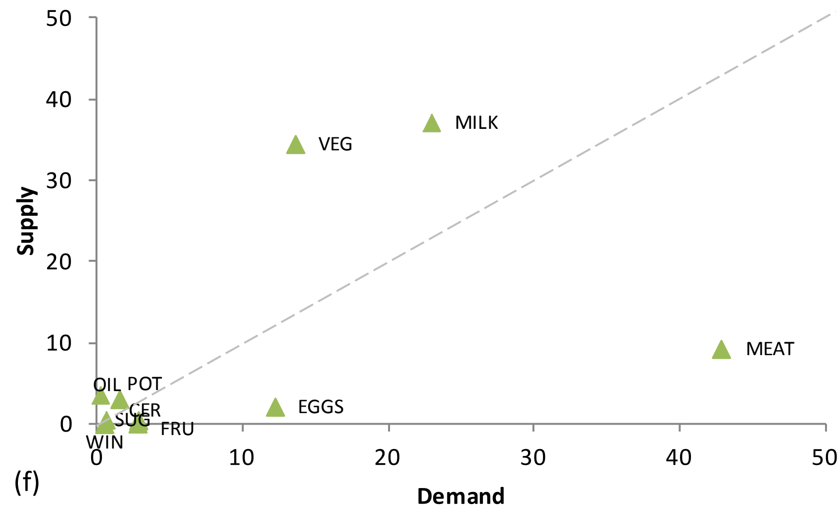

50
40
30
20
10
0
Supply
MEAT
MILK
CER
FRU
VEG
EGGS
WIN
POT
OIL
SUG
0
10
20
30
40
50
Demand

(c)


50
40
30
20
10
0
Supply
CER
VEG
MEAT
MILK
FRU
EGGS
POT
OIL
SUG
WIN
0
10
20
30
40
50
Demand

(d)


Supply
Demand
CER
MEAT
EGGS
VEG
SUG
WIN
POT
FRUITS
OIL


Supply
Demand
MILK
VEG
MEAT
OIL
POT
CER
SUG
EGGS
FRU
WIN

A7. Results – Food groups scatter plots in different case study areas

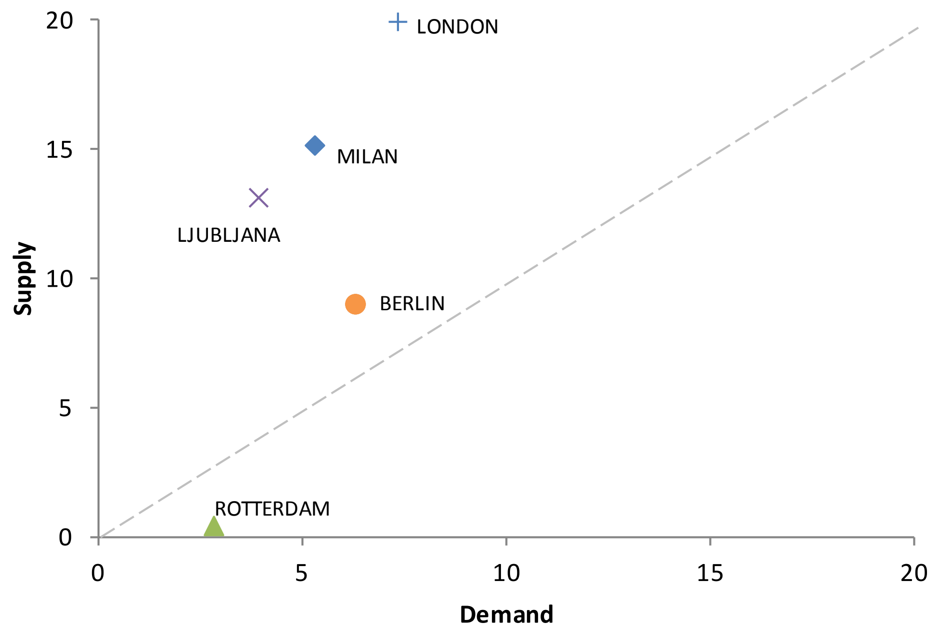


Figure 58: relative importance of CEREALS in case study areas.

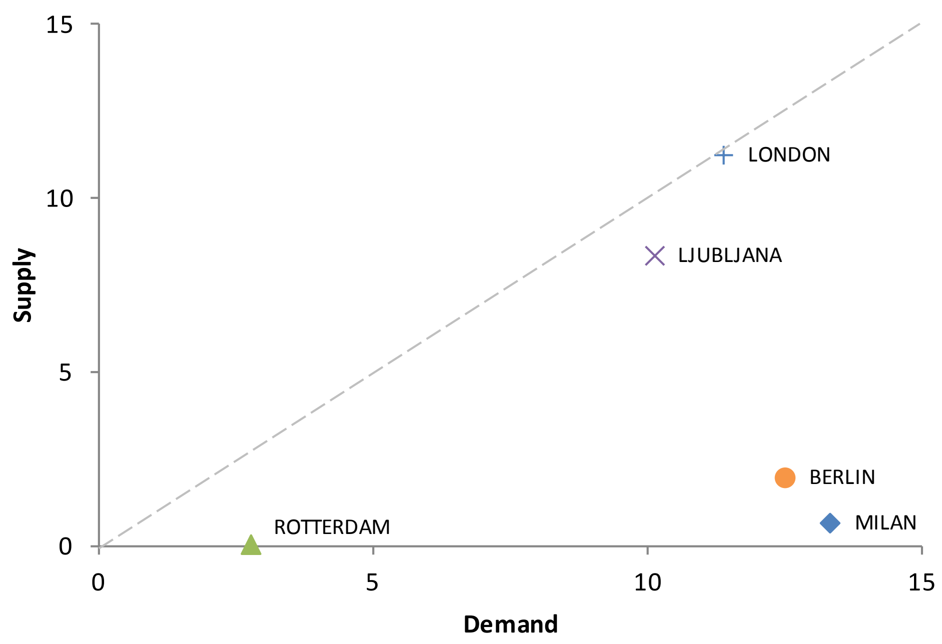


Figure 59: relative importance of FRUITS in case study areas

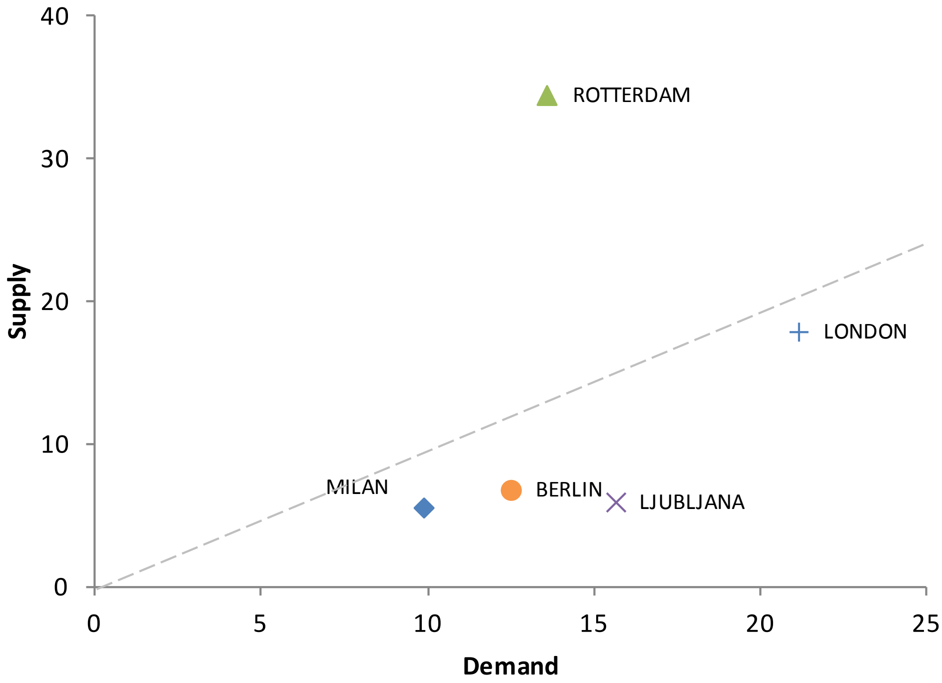


Figure 60: relative importance of VEGETABLES in case study areas

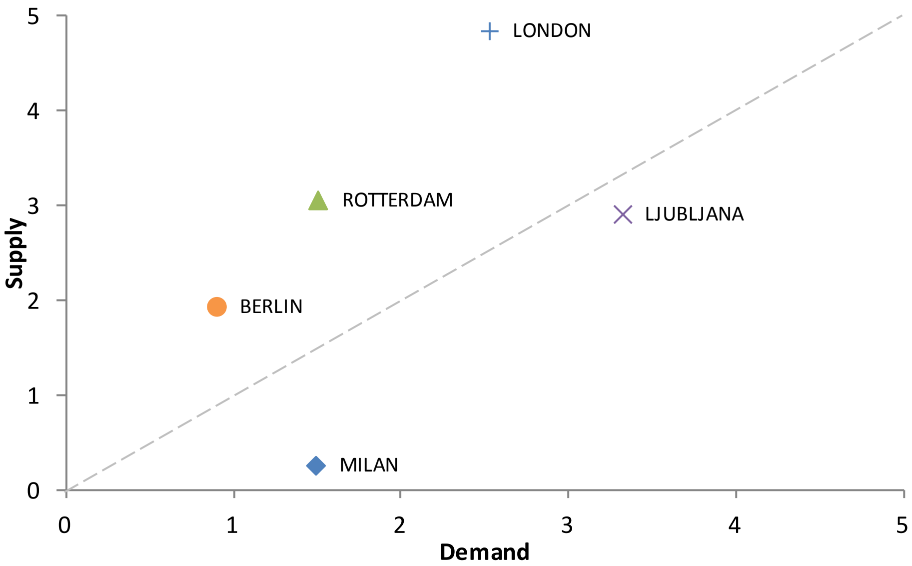


Figure 61: relative importance of POTATOES in case study areas

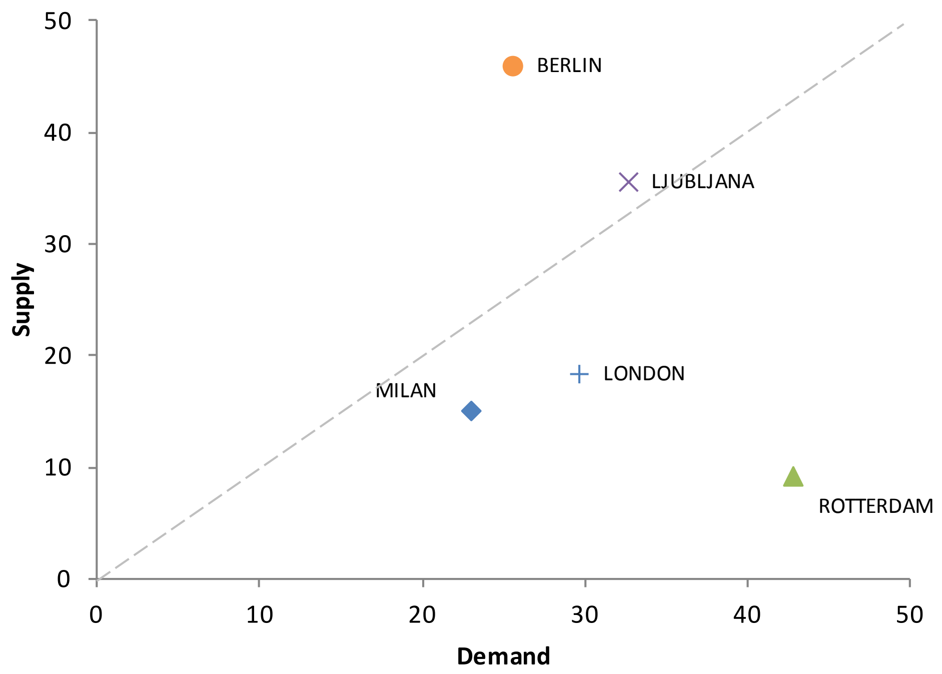


Figure 62: relative importance of MEAT in case study areas

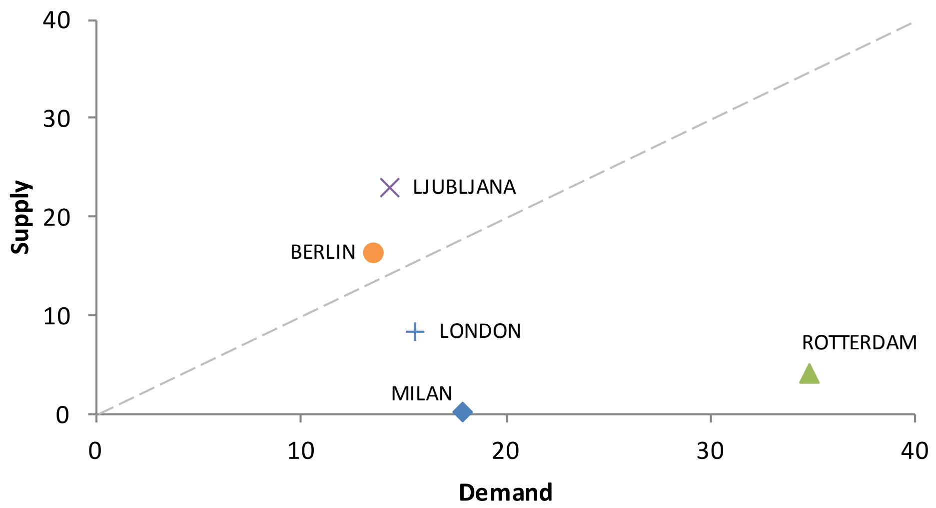


Figure 63: relative importance of BEEF MEAT in case study areas

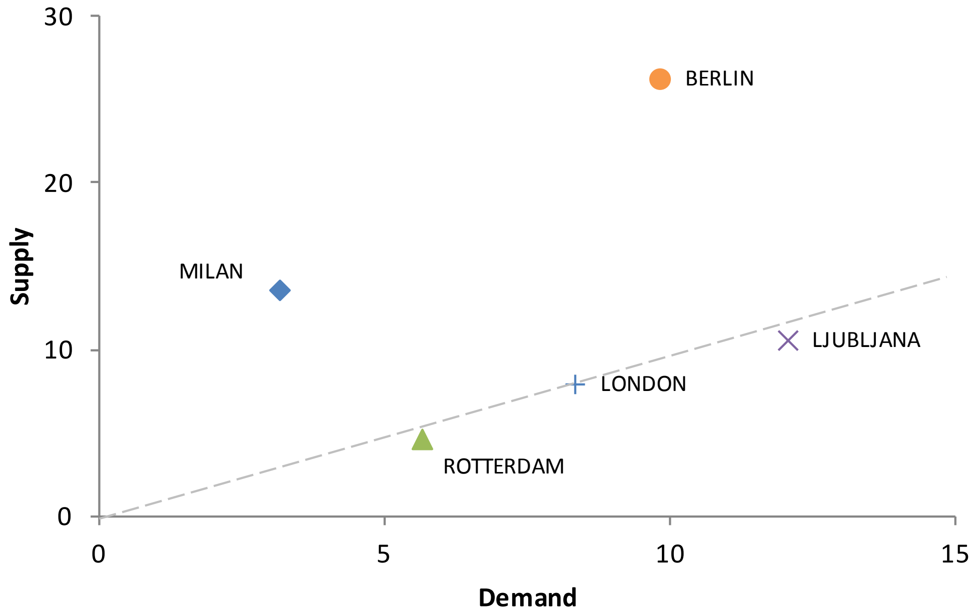


Figure 64: relative importance of PIG MEAT in case study areas

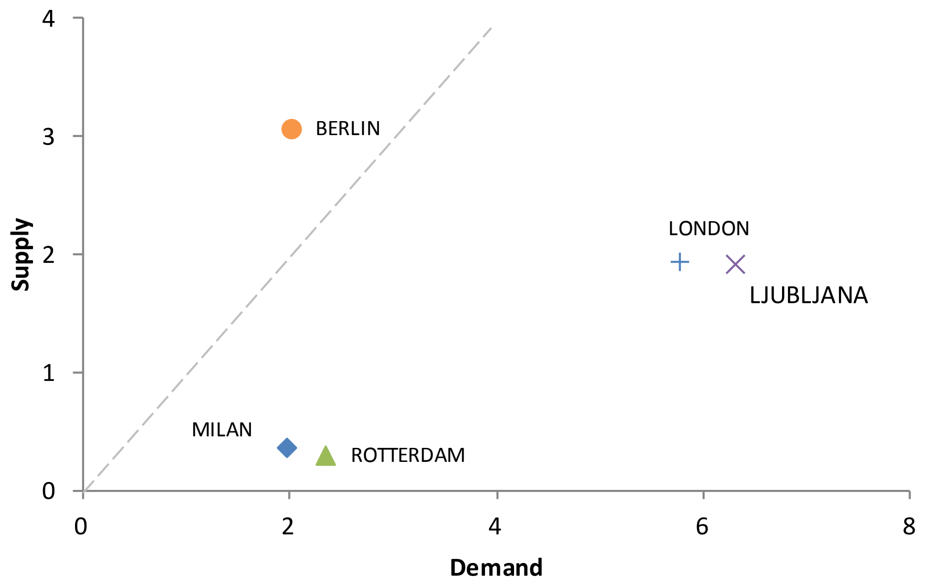


Figure 65: relative importance of POULTRY MEAT in case study areas

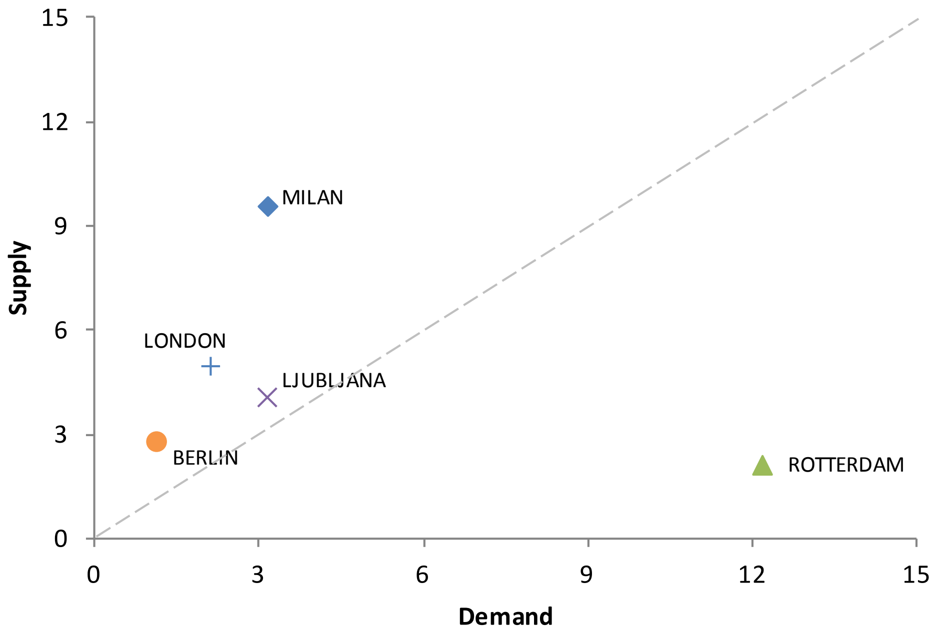


Figure 66: relative importance of EGGS in case study areas

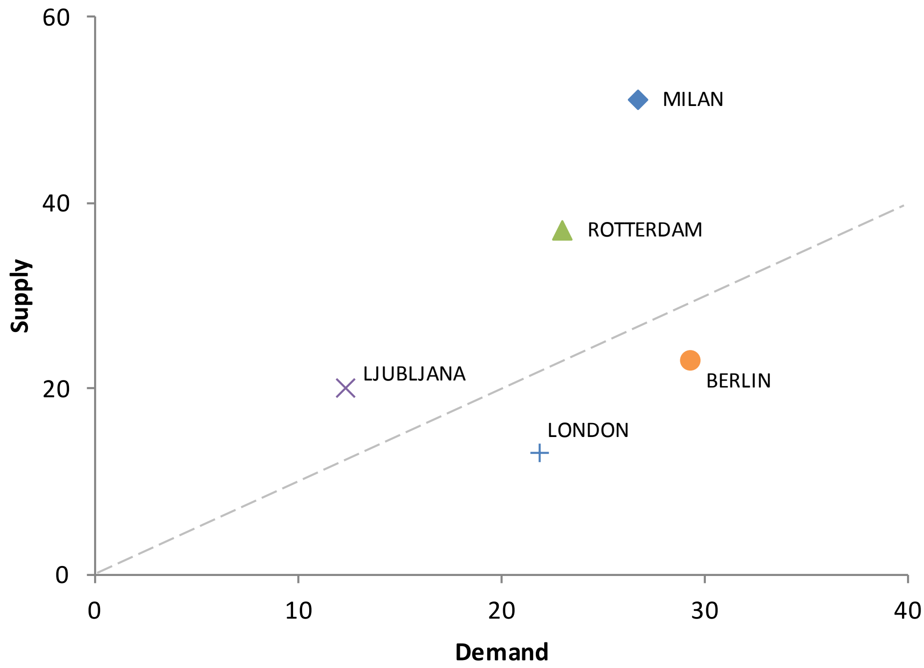


Figure 67: relative importance of MILK in case study areas

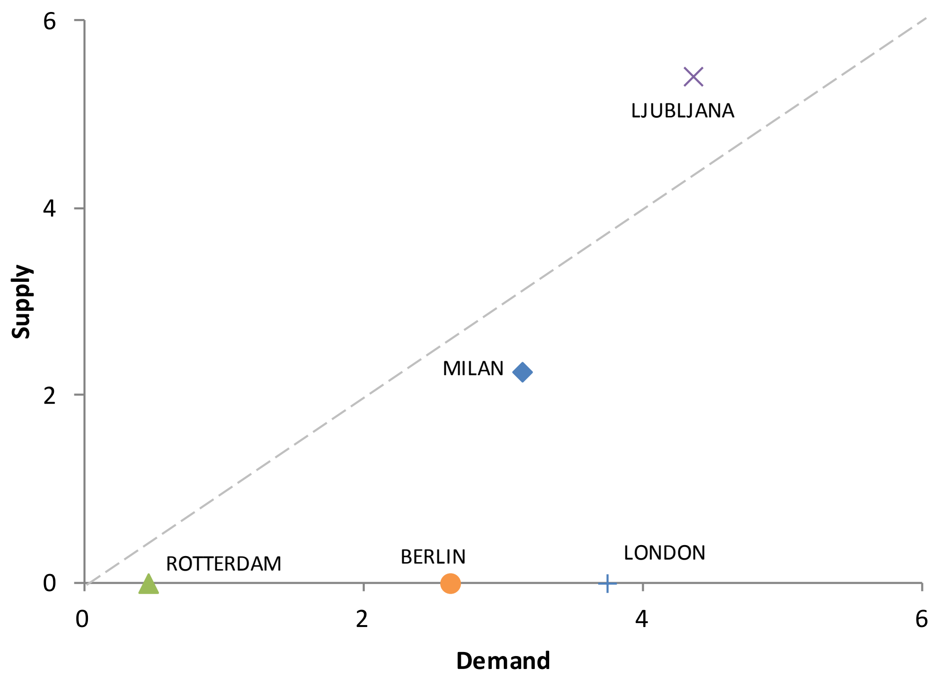


Figure 68: relative importance of WINE GRAPES in case study areas

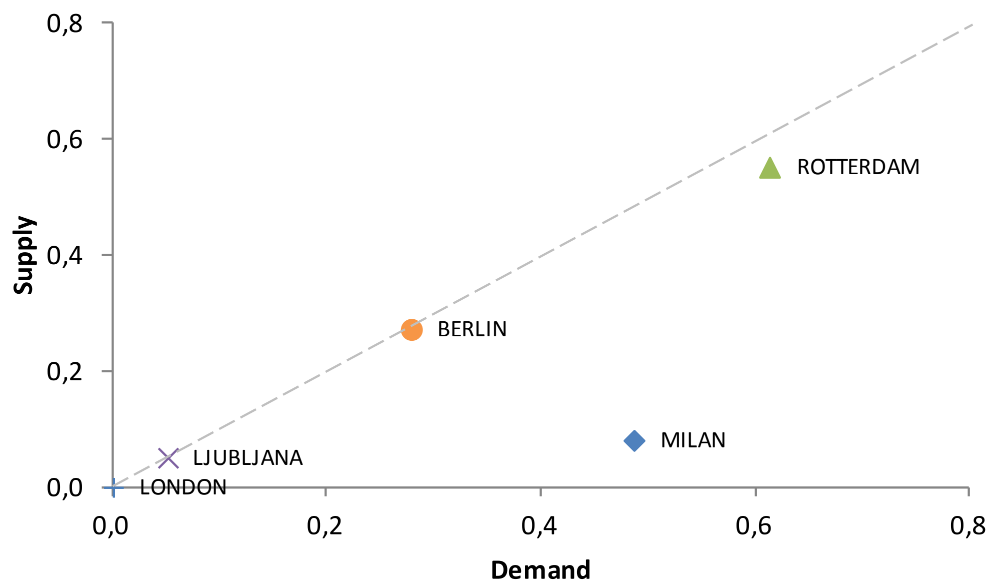


Figure 69: relative importance of SUGAR BEETS in case study areas

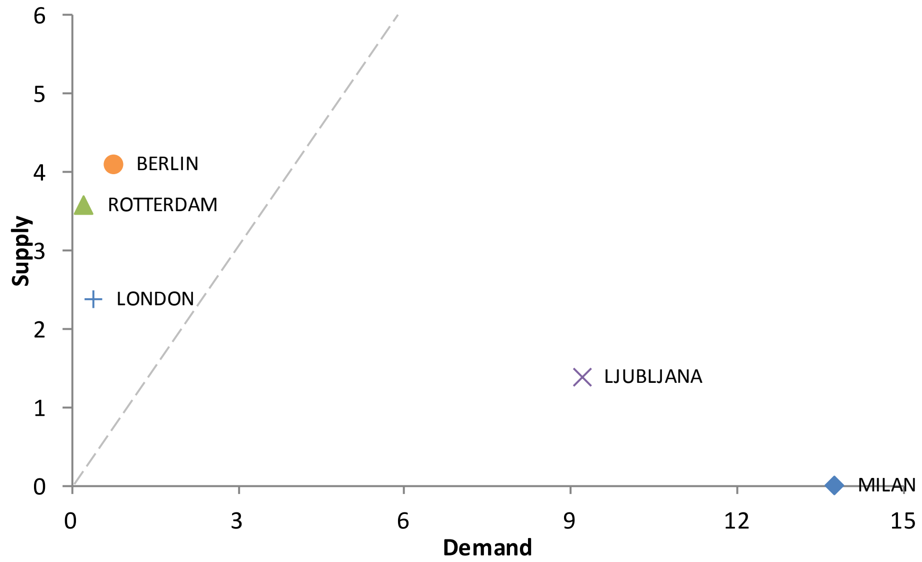


Figure 70: relative importance of OIL PLANTS in case study areas