The Governance of City Food Systems
Edited by Mark Deakin, Davide Diamantini and Nunzia Borrelli

Utopie / 35
Globalizzazione
The Governance of City Food Systems

Edited by
Mark Deakin, Davide Diamantini and Nunzia Borrelli
1. Introduction

Given the simultaneous presence of several factors affecting the agricultural potential of metropolitan regions, and considering the recent societal debate on food autonomy in the context of food security and sustainability, the ‘reconnection’ between food demand and supply emerges at policy agendas at both the national and international level. Tackling this phenomenon, FOODMETRES has put forward the concept of Metropolitan Agro-Food Systems as the space where urbanisation processes related to urban (food) consumption, recreational behaviour and preferences, infrastructure and urbanisation meet within a distinct eco-functional and socio-political context. Metropolitan regions must therefore, be considered as extremely dynamic in terms of extension, land use changes and landscape character. In order to frame, communicate and manage the impacts of urban food consumption on metropolitan regions, we develop a string of successive, yet complementary footprint assessment tools:

(1) the Metropolitan Economic Balance Assessment (MEBA), a measure for framing aspects of food security and supply at the statistical meta level of urban metropoles;
(2) the regional Metropolitan Area Profiles and Scenario (MAPS) demand tool, for producing scenarios at the level of administrative units;
(3) the European Metropolitan Foodscape Planner (MFP) supply tool, an interactive, spatially dynamic approach at the land use level based on GIS-technology.

Used apart or in combination, this new generation of tools operates at both the Europeans as well as the national-regional level, offering analytical, comparative and communicative support to food planning. This paper explores the tools’ capacity to contribute to informed food policy making at the examples of three metropolitan regions, namely Berlin, London, Milan and Rotterdam.
1.1. Assessment of Metropolitan Agri-food system

Within the debate of urban resilience and metabolism, reduction of ecological footprint and self-sufficiency (Wackernagel et al. 2006; Grewal and Grewal 2012; Barthel and Isendahl 2013), local food production, regionalized food systems and the shortening of supply chains, have gained increasing importance (Goodman and Goodman 2009; Sonnino 2009). Here manifold benefits, such as the reduction of urban food insecurity (Opitz et al. 2015) and disruption to global food supply (Godfray et al. 2010), are coupled with greater resource efficiency (Mundler and Rumpus, 2012) and competitiveness (Sage 2003; Nousiainen et al. 2009; Kneafsey et al. 2013). Benefits that have in turn encouraged many metropolitan jurisdictions, e.g. London (Reynolds, 2009), Toronto (Blay-Palmer 2009) and Belo Horizonte (Rocha and Lessa 2009), to develop food policies, which aim to foster local systems and reconnect cities with their food sheds (Pothukuchi and Kaufman 1999; Jarosz 2008). Such as with other fields of policymaking, food policies also require a sufficient informational and knowledge base to carry out effective actions (De Smedt 2010). Consequently, questions regarding the local and regional food production and consumption, economic viability and the food chain organisation arise (Ilbery et al. 2005; Mok et al. 2014). Essentially an accounting tool and not a forecasting tool, Ecological Footprint assessments rely on ex-post input variables when measuring the spatial impacts of current food consumption (CEC 2008). They do not contain feedback loops that would link today’s decisions with resource consumption in the future, or today’s resource consumption to impacts occurring in the future. At the same time, in reconnecting territorially food production and consumption, the need for analysis tools has grown. 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; Mok et al. 2014). A rich literature concerns this kind of assessment in several contexts according to different, though interrelated, models of analysis (Murdoch et al. 2000; Hinrichs 2003; Illbery et al. 2005; Qazi and Selfa 2005; Barham et al. 2005; Porter et al. 2014). 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:

(1) Demand-based models: models that evaluate, based on population needs, the theoretic supply in terms of quantities needed or land required (footprint);

(2) Supply-based models: models that, starting from the production capacity of the territory, estimate how many people can be fed (potentialities);
Demand-supply models: in this case, based on the real consumption and the real production of a region, rates of self-sufficiency are obtained.

Demand-based models analyses data and information about food consumption and dietary patterns, in terms of either quantities or nutritional value, and quantify the supply needed to potentially meet food demand (see for examples Gerbens-Leenes and Nonhebel 2002; Billen et al. 2009; Desjardin et al. 2010; Zhen et al. 2010; Darrot et al. 2014). 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. (2013) considered the necessity for a city to depend on productions from remote landscapes. 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 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 by developing self-sufficiency indexes themselves, as in the case of Ostry and Morrison (2013). Other studies conduct comparisons between offered daily (or annual) servings of food in relation to the total recommended dietary requirements per head of population (Giombolini et al. 2011). As well as those between food requirements and actual production of food grains (Mohanty et al. 2010) or combined food availability data at household level, with country-specific land use data for food items, by determining the required cropland associated with dietary patterns (de Ruiter et al. 2014).

1.2. Contribution by FOODMETRES Approach

Funded by the European Union and running over a period of three years, the FOODMETRES (Food Planning and Innovation for Sustainable Metropolitan Regions) has involved 18 academic and business partners who engaged in a variety of research, tool and capacity-building exercises. The project incorporated an international dimension as well as focussing on concrete cases at the regional level in and around the cities of Rotterdam, Berlin, London, Milano, Ljubljana, Rotterdam and Nairobi. FOODMETRES has developed a series of technical references and decision support tools allowing stakeholders from agro-food business, governance and civil society organisations to enter a knowledge-driven debate on how to optimize the regional supply function of metropolitan areas around cities, by means of sustainable
and innovative food chain planning and governance initiatives. The project’s novel approach lies in the combination of two distinct yet closely interrelated strands of metropolitan agro-food systems; namely the *spatially explicit dimension* of regionally grown food in terms of ‘local footprint hectares’ necessary to feed the respective urban populations on the one hand, and the concrete innovation potentials for short food supply chains linking consumers with regional producers on the other (Wascher et al. 2015). The modelling approach addressed in the FOODMETRES project particularly focusses on the spatiality of metropolitan agri-food systems (AFS). It elaborates the question of area-wise relevance of food demand and food supply (Which relation is there between demand and supply?). The Metropolitan Economic Balance Assessment (MEBA) tool represents the starting point of a comprehensive cascade of complementary models. The MEBA applies an economic approach to assess the food demand-supply balance within a metropolitan region. Based on the calculation of quantitative elements expressing the relation between food production and consumption at staple food level, such an approach reveals the chances of getting them closer and serves as a tool for the assessment of performances of regional agro-food systems. The Metropolitan Area Profile and Scenario (MAPS) tool adopts a straightforward data-driven approach of connecting regional food demand (local hectares) with the regional area productivity. The tool’s objective is to assess the spatial extent of the agricultural area required for food production (“How much area is needed?”). Its main strengths are (1) the spatial representation (mapping approach), (2) model differentiation of commodity types, (3) the ability to apply different food production regimes (e.g. organic farming, food loss) and consumption patterns (e.g. vegetarian, healthy diets) or population scenarios, and (4) the analysis of theoretical self-sufficiency levels at different administrative levels. The Metropolitan Foodscape Planner (MFP), in addition, addresses the question of the spatial distribution of the various land use types, which are required for the production of specific crops (“Where to produce?”). This tool offers:

(1) hands-on assessment allowing stakeholders to re-allocate commodities on a digital maptable;
(2) quantification and geo-referencing of up to 10 commodity types at the scale of 1 hectare-grids;
(3) the analysis of self-sufficiency based on a regional concept consisting of four metropolitan food zones;
(4) landscape-ecological allocation rules to base land use decisions on sustainable principles;
(5) European data such as EFSA, LANMAP, HSMU and CORINE Land Cover to allow future top-down tool applications for all metropolitan regions throughout the EU.
The described modelling approaches differ not only in terms of methodologies, but also regarding the input data (national/European), modelling rational (demand-/supply-oriented) and the degree of stakeholder interaction (maptable interaction only in case of MFP). However, the models apply a common spatial understanding of how to minimize the distance between food production and consumption location (urban core), resulting in an idealized circular representation of food zones, comparable to the renowned model by Heinrich von Thünen (1826) about the spatial distribution of agricultural commodities as a function of transportation cost to the central market. In this paper, we will introduce three modelling approaches (MEBA, MAPS, MFP), which have been developed in the FOODMETRES project and show their applicability in the four case study regions. Our central research question is to what extent food security of urban metropoles can rely on the surrounding metropolitan agricultural food systems (AFS). In other words, we want to find out the degree to which, the metropolitan Agro-Food System is able to feed the population of its urban core and adjacent agglomeration. In the second part of the paper, we aim at approach the question of regional self-sufficiency in food supply from a more practical side by exploring the opportunities and requirements for a strengthened metropolitan AFS by the implementation of innovative food chains. We shed light on the required setting of political and economic framework conditions to encourage short food supply.

2. Methodology and Modelling Approach

2.1. Footprint basics: demand and supply

Food demand and supply are the two key dimensions of tools for metropolitan food planning. Food demand results from the average feeding habits of the urban population expressed in the dietary energy, protein and fat consumption per person. Typically, such data is only available as the national average and not per city. Given the size and biogeographic range of most European countries – France covering North-Atlantic influences, Alpine and the Mediterranean zone being probably the only exception – average figures can be considered as acceptable. Food habit surveys provide information resulting from the combination between qualitative (What is consumed?) and quantitative (How much is consumed?) aspects of food consumption. It particularly varies according to geographical area and country, economic, social and cultural aspects, population diets, available food items. FAO statistics (FAO, 2015) give a first response to this issue, summarizing and making easily comparable daily consumption for countries all over the world. Food supply can be referred to land use and available agricultural area in a specific territory or in relation to the amount of obtained raw products (quantities or productivity). This does not mean, however, that
these productions still remain confined to only local regions, since large proportions of our food products derive from the global market. This condition restricts the possibility to limit food supply to the local sphere, as it is more precisely affected by all the components of commercial balance, from productions and stocks, to imports and exports.

2.2. Case Study Regions

For the purpose of illustrating the methodologies of the different metropolitan footprint assessment tools, what follows shall focus on a subset of the project’s original six case study regions; namely Berlin, London, Milano and Rotterdam. The metropolitan areas of Nairobi have been left out here to reduce complexity when developing the key messages and because both cities deviate in terms of biogeographic location (Africa) and size (Ljubljana) from the others.

Table 1 illustrates the differences between the four selected CSA in terms of population size for the urban core, as well as the wider metropolitan region, the area size in square kilometres, the proportion of agricultural land in both square kilometres and percentage. London is by far the largest city, followed by Berlin. Rotterdam City Region and Milano are almost of equal population size, but differ substantially in term of the metropolitan region’s territory and agricultural land.

Table 1: Population and agricultural area of the four case study regions

<table>
<thead>
<tr>
<th>Case Study Regions</th>
<th>Berlin &amp; Brandenburg</th>
<th>London, South-East &amp; East England</th>
<th>Lombardy</th>
<th>South Holland City Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core city</td>
<td>Berlin</td>
<td>London</td>
<td>Milan</td>
<td>Rotterdam</td>
</tr>
<tr>
<td>Administrative region</td>
<td>Berlin &amp; Brandenburg</td>
<td>London, South-East &amp; East England</td>
<td>Lombardy</td>
<td>South Holland City Region</td>
</tr>
<tr>
<td>Population core city 2015, in 1000 inhabitants</td>
<td>3,502</td>
<td>8,174.</td>
<td>1,242</td>
<td>1,209</td>
</tr>
<tr>
<td>Population region 2015, in 1000. inh.</td>
<td>6,037</td>
<td>22,656</td>
<td>7,885</td>
<td>3,695</td>
</tr>
<tr>
<td>Total area, in km²</td>
<td>30,530</td>
<td>38,260</td>
<td>13,111</td>
<td>2,819</td>
</tr>
<tr>
<td>Utilisable Agricultural Area (UAA), in km²</td>
<td>14,576</td>
<td>26,566</td>
<td>4,892</td>
<td>1,685</td>
</tr>
<tr>
<td>Share UAA, in %</td>
<td>47.7</td>
<td>69.4</td>
<td>37.3</td>
<td>59.8</td>
</tr>
</tbody>
</table>
2.3. The Metropolitan Economic Balance Assessment (MEBA)

The MEBA model aims 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 at obtaining information that provides the quality of the agro-food system of any region, in relation to: (i) the degree of compliance with food habits and food diet; (ii) the level of food security, defined here as the capability of the system to ensure nutritional and caloric requirements expressed by the population dietary pattern, and (iii) 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.

The first dimension concerns the quantitative dimension of food demand (i.e. the consumption) and supply (i.e. the primary production). The amount of per capita consumption depends on specific dietary pattern and finally affects total consumption in combination with the population size of the area. It is therefore clear the latter element is the main driving factor in determining food needs within a territory. On the other hand, the capability of the system to provide food and meet demand varies according to the available agricultural land use area, to the suitability of the territory itself and to 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 regions are identifiable at staple food-level, giving preliminary indications on the potentialities of the system in responding to the compliance with diet.

Dietary habits are also reflected in total caloric intake provided by the diet itself, while supplied quantities affect the availability of one or more specific energy source. 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-region 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.

Concerning the economic aspect, the production value generated by the agricultural system, compared with the corresponding value of staple foods consumed by the population, aims at deepening the potentialities of the system in reconnecting demand
and supply, apart from the actual trade balance, import/export flows and value added generated through the food chain. In this case, whenever an incomplete self-reliance and consequently a negative economic balance occurs, an eventual new value generated (by process or product innovations) in the territory could potentially be retained there, balancing the equivalent amount of the economic dimension required through the diet.

2.4. Metropolitan Area Profiles and Scenario (MAPS)

Focussing at the spatial extent of the footprint of food production, the Metropolitan Area Profile and Scenario (MAPS) tool represents a spatial model which takes both parameters of regional yields and diets into consideration, broken down to a set of commodity groups. This allows the model’s sensitivity regarding alternative agricultural systems (conventional and organic), reduction of food loss and waste, different diets (given and health recommendations) and temperate domestic and necessary global production. It is the main objective of the MAPS tool to develop an easy-to-adopt approach to spatially assess the necessary agricultural area to supply a pre-defined city, metropolitan area or region. It further should allow for comparative assessments of area demand for food production (based on regionalized agricultural production, diets and population data), scenario analysis of effects of organic, healthy or vegetarian diet change, prevention of food waste and loss and the regional self-sufficiency.

Scenario Application

As one of the main objectives of the MAPS tool, various food demand-supply scenarios can be applied to the reference situation. These scenario settings can include variations of the agricultural production system and intensity, such as extensive production, organic farming, intensive greenhouse production or forms of sustainable intensification. As an example of different agricultural production intensities, we have differentiated conventional production (reference system) and organic production. Therefore, the meta-analysis of Posinio et al. (2014), who have reviewed and interpreted a high number of empirical studies on yield differences between conventional and organic production. The authors found a range from in average lower yields of 19.2% to 8.5% (with multi-cropping and crop rotation) to conventional production. In addition, potentials through the reduction of food losses and waste are taken into consideration. According to the Food and Agriculture Organisation (FAO) food losses and wastes sum up to about one third of the edible parts of food produced for human consumption, which is roughly 1.3 billion ton per year at the global scale.
Consumers in Europe and North-America alone waste between 95-115 kg/year per capita, while it is way lower in sub-Saharan Africa and South and Southeast Asia (6-11 kg/year) (FAO 2011). However, food is also lost within the whole food supply chain, including (1) Agricultural production; (2) Post-harvest handling; (3) Processing and packaging; (4) Retail and distribution; (5) Households and catering (FAO 2011). At each of the single steps a certain share of the food gets lost, avoidable and unavoidable, increasing the demand in total. By implication, food losses and waste represent the potential to reduce the food demand and therewith the agricultural area demand. There are a number of studies, which aim at quantifying these shares at national, European or global scale (FAO, 2011; European Commission 2010). In our modelling exercise, we referred to the figure of the FAO (2011) as well as Buzby and Nyman (2012). These are translated into area factors. At the demand side, scenario elements can encompass changing (future) population numbers or changing diets, e.g. to estimate impacts of changing population composition (i.e. new dietary cultures through in-migration) or changing eating behaviours and trends (i.e. seasonality, healthy, vegetarian or vegan diets).

**Self-sufficiency of food supply**

Another application of the MAPS tool is the analysis of the local and regional self-sufficiency level (SSL), i.e. the percentage ratio between supply and demand expressing the extent of a territorial unit to meet its own food requirements. The analysis of the spatial distribution for each individual locality provides indications about their food self-sustainability and the possibility to satisfy urban demand through proximity agriculture. It gives therefore indications of local hotspots and of possible future food stresses. Figure 1 provides an overview of the SSLs in the CSRs. Values of 100% (green colour) and more indicate theoretical self-sufficiency in the respective area, whereas jurisdictions with values lower than 100% (red colour) cannot be supplied from their own territory and require “import” from outside. Regional differences regarding the spatial distribution of SSL is illustrated by the frequency of SSL class occurrence in figure 2.

**2.5. Metropolitan Foodscape Planner (MFP)**

The *Metropolitan Foodscape Planner (MFP)* represents a tool to spatially distribute land uses for food production within different zones (green, vegetable, protein, transition zone) within the metropolitan agri-food system. With its interactive GIS-geared interface, it enables users to detect concrete spatial locations and the available amounts of suitable farmland (supply) for the most essential food groups and simulate
them. Other than MAPS, MFP is a dynamic tool in the sense that users can directly undertake – by drawing with a pen on a digital table – land use changes in order to increase the self-sufficiency potential of urban food consumption. MFP allows the spatial allocation up to 12 food groups (depending on the respective case) making use of the European data sets shown in Table 2. Making use of internationally harmonised data deriving in the ‘Chronic food consumption statistic (EFSA 2011), MFP identifies the urban food demand for 12 categories of crops/land use, namely: (1) wheat, (2) other cereals, (3) rice, (4) oil crops, (5) pulses, (6) potatoes, (7) sugar beet, (8) vegetables, (9) fruits, (10) wine grapes, (11) food crops and (12) grasslands. Building the Metropolitan Foodscape Planner tool (MFP) requires a series of data management and GIS operations to be performed in Excel and Arc-Info. MFP allows users to detect concrete spatial locations and the available amounts of suitable farmland (supply) around cities for the most essential food groups on the basis of urban population figures (demand). Each zone calculation is based on the total demand in ha for the population and the total area available for agriculture per ring. The demand per capita can differ for different zones and for vegetable products and animal products. The total area available for agriculture is the area classified in Corine Land Cover as agricultural areas, sport and leisure facilities, green urban areas, natural grasslands and sparsely vegetated areas, minus the protected areas in Natura2000. The allocation of crops within the zones is based on the land cover, landscape typology and the protected area database. Table 2 provides an overview of the databases used.

*Table 2: Data Layers applied in the MFP model.*

<table>
<thead>
<tr>
<th>Data Layer</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cities_startpoint_Berlin</td>
<td></td>
</tr>
</tbody>
</table>
version 8 april 2014, download 13 jan 2015  
in arccat export.tif als esrigrid in MFT.gdb |
shapefile Natura2000_end2013_rev1.shp |
| Lanmap2v1                        | European Landscape Typology LANMAP (Mücher et al. 2006)  
lanmap2_v1_level_4_ls-cod |
| Multi-ring-buffer around city_startpoint: first calculate radii based on: | combine distance-raster and 3 rasters with the correct legenda and  
greyed areas  
total demand per ring |
| HSMU                             | Homogenous Soil Mapping Units (HSMU) as modelled by CAPRI  
(Kempen et al. 2005) and Eurostat crop area data desaggregated to hsmu’s  
by CAPRI.  
Key to the approach is the Land cover disaggregation towards HSMU commodity groups by calculating the area for each crop category according to the crop category table, both absolute and relative to the total HSMU area (= density). We joined these data sets into the HSMU geometry and made a selection of it on the basis of crop data, extracting the HSMUs within the outer zones boundary. In a next step the result was merged with the zones (rings) defined previously and aggregate based on the zone-id and HSMU-ID. Making use of the European HSMU datasets introduces high levels of data aggregation to our method.

We were interested to run a validation of the results by comparing with national land use data at higher resolution and accuracy. The most recent Dutch land cover map is LGN (Landgebruik Nederland) version 7 (LGN7) which we re-classified for the selected area in Rotterdam within a 40km radius from the urban city central point (up to the boundary of the Metro-Food-Ring protein). This re-classification was necessary to ensure that we reach a high level of comparability with the HSMU-approach. When comparing the land cover areas of the two datasets, we found that 70% of the LGN-grassland matches the HSMU-dominant crop type grassland. And vice-versus, 73% of the HSMU-grassland is also LGN-grassland. In the case of ‘rotation’-crops, 63%, 61% and 64% of LGN-potatoes, sugar beet and wheat are matching the HSMU-crop type ‘rotation’. The validation exercise demonstrates that using European HSMU-data sets for assessing the spatial distribution of major crop types in Europe clearly compromises accuracy. We assume these observed cases of inaccuracy are mainly related to data inconsistencies in the relatively high levels of European aggregation, as compared to the more detailed and recent national inventory. The latter requires further validation efforts.

3. Results

3.1. Results of the Metropolitan Economic Balance Assessment (MEBA)

Case study regions show different profiles depending on properties of both sides of the system, consumption and production (Figure 1). The Milano region, even if covers 59% of caloric need, is able to comply not more than 42% of diet assumed by inhabitants and to produce 43% of the production value of goods allocated into the region. These values are dependent on different reasons. First of all, the polycentric shape of the metropolitan region matches a high density of population, coupled with a scarcity of agricultural land, mainly due to intense competition over land use. Moreover, the productive agricultural sector results also show a strong degree of specialization, mainly devoted to the production of cereals (rice), milk and dairy
products (Figure 2). This leads to an incomplete fulfilment of several food sectors as vegetables, fruits, meat, potatoes.

The area of Rotterdam has a strong level of specialization too, similar to that of the Milano region and concentrated mainly in milk, vegetables and potatoes, but it covers a higher share of diet (58%) and it is able to provide all quantity and types of calories needed by the population. The most impressive evidence emerging from the Rotterdam case study is the strongly positive economic balance (238%), due to a vast area dedicated to protected crops in Westland. It is noteworthy that in Rotterdam, the very high level of productivity reached with this production model, means this case study provides the only example of a region able to hold a largely positive agricultural economic balance. A different situation seems to be shown by Berlin and London. In the first case, the mono-centric shape of Berlin-Brandenburg allows this region to rely on a wide agricultural area, while a heterogeneous productive structure achieves productions rather diversified. The compliance with the diet rises to 72% and there are seven food categories, which cover more than 75% of requirements. All calorie needs are fulfilled and the production value is roughly equal to the value of staple food consumed. In the case of London, despite the low coverage ratio (47%), due to a large population, the agricultural system appears quite diversified, managing to cover significant shares of several food categories (cereals, vegetables, eggs, oil crops, potatoes, sugar). The low specialisation does not allow reaching a high value index (60%), though some products are widely spread in the region with a significant surplus (sugar beet, cereals, oilseeds, potatoes).

![Figure 1: Radar chart comparing Quantity, Calorie and Value indexes (left) and scatter plot combining Quantity index and Value index of CSRs (right). Source: Sali et al. unpublished.](image)
3.2. Results of Metropolitan Area Profiles and Scenario (MAPS)

3.2.1. Metropolitan Area Profiles

In the Berlin case 6,827 km² for the city of Berlin or 11,770 km² for the entire region is required. This equals a per capita area demand of 1,950 m² in the status quo situation (population and food consumption 2015). So despite the poor soil conditions (most or the rural area is designated as less favoured area), both city and regions can theoretically supply itself within their own boundaries, as the total farmland cover an area of about 13,230 km² (2012). Especially the relative low population density (and the related low food demand) of the surrounding region mitigates particular food stress. The London case is characterised by a high demand for food from the urban core as well as other major cities in the region, resulting in an area demand of 13,989 km² (London) and 38,773 km² (London, South-East & East England). Per capita area demand is 1,711 m². Despite high agricultural area share with more than 26,500 km² farmland,
the demand clearly exceeds the regional self-sufficiency potential by nearly 50%. Particularly due to the high population density in the direct vicinity of London as well as the area constraints of the footprint area of the British Midlands and the island location, serious food stress can be considered.

The competition between the core city (Rotterdam) and surrounding region (South Holland) is even more pronounced in the Dutch case. Despite a farmland share of 60% (1,684 km²) and an area demand of 1,133 km² for Rotterdam, the regional demand of 6,713 km² overdraw the regional potential four times (per capita area demand 1,817 m²). A compensation of the resulting food stress from neighbouring regions can also not be expected (high population density in the Netherlands, Belgium and Northern France, which is already belonging to the Paris footprint area, as well as the coastal location). Also the Lombardy metropolitan region is characterised by a mountainous situation in the North and agricultural plains in the South of the region. In addition, a small-scale administrative structure is noticeable. For whereas the area demand for food production of the city of Milano (2,548 km²) can be covered by the surrounding region (4,892 km²), the demand from the regional population (16,178 km²) is more than three times higher than the regional available farmland. The area demand per capita is 2,052 m². Circular representation of municipal and regional food production area demand is depicted in Figure 3.
In the scenario situations, first of all the agricultural area demand per capita is variable. These changes occur similarly throughout all CSRs into the same direction, even though with different amplitudes. Particularly impacts of food loss and waste reduction (S3, S4) as well as of conversion of production towards organic farming (S5) are clearly depicted. However, the scenarios also show the potential of certain organic systems (S9) or the combinations with food loss and waste reduction (S7, S8, S11, S12) to have a reduced area impact.
3.2.2. Self-sufficiency of food supply

The mono-centric Berlin metropolitan region is characterised by a concentration of municipalities which show undersupply of farmland for the city of Berlin and its direct adjacency, whereas large parts of the peripheral rural areas can realise significant food production surpluses, being able to “export” to food stress areas. Whereas also in the London region, the core city faces a strong food deficit, the majority of urban places can be easily supplied by the near surrounding, which show an SSL of 100% and more.

However, the absolute area demand through the high population number results in an undersupply at regional level. In the majority of municipalities in the South Holland region (Rotterdam) are characterised by an SSL of below 100%, often even not exceeding 25%, so that a rather continuous food stress can be expected in the region.

Similarly, but less pronounced is the food stress situation of Milan and the Lombardy region, with a majority of municipalities without theoretical self-sufficiency. However, the specific administrative structure of Lombardy deserves attention, which is characterised by many urbanised communities with a small territory on the one side and large rural communities on the other. Figure 4 shows the self-sufficiency at municipality level in the four case study regions.
3.3 Results of Metropolitan Foodscape Planner (MFP)

Due to the large share of land designated to nature protection (30%) large parts of the surrounding area of Berlin is not available for land or food production. However, as in the case for the urban fringe and the green buffer (about 13km wide), existing grassland is considered as being available for non intensive, ecological dairy farming with low density of livestock (ca. 1 livestock unit per hectare). Berlin still has a substantial amount of arable land incl. grasslands available in its direct urban...
periphery, namely a total of 65 tsd. ha (zone 1, see Figure 5). The metropolitan food production zone for plant-based products (zone 2) covers the area between 38 km and 53 km distance from the centre, providing a total of about 110 tsd. ha for food production. The livestock production zones reaches out to 80 km distance (equal to a production area of 450 tsd. ha), whereas the transition zones covers larger regions of Poland, requiring 1.5 Mio ha of land for plant- and livestock-based food production.

As Figure 5 shows, the London metropolitan area consists of an urban core of about 25 km in diameter. According to the planning scheme this translates into a green buffer of 12.5 km width. Within the urban core (periphery) and the green buffer we calculate a potential of about 100 tsd. ha for ecological forms of dairy farming on grassland. For the 8.6 million inhabitants of London’s urban core, the metropolitan food production zone for crops used to provide plant-based food (zone 2) is contingent upon the green buffer, between 38 km and 61 km from the city centre, providing a total of about 320 tsd. ha of arable land. The metropolitan food ring required to provide feedstuff and facilities for livestock farming (zone 3) will need to span between 61 and 86 km distance from the centre, covering a total of 850 tsd. ha. Thus, almost three times the areas of the plant-based food ring. The city’s location in close proximity to the North Sea implies, that the rings required for feeding the city of London need to be larger, because a great percentage is not available for food production because it is covered by sea water.

The demand-supply analysis (Figure 6) reveals that the available crop rotation contingent (potatoes-sugar beet-wheat) is exceeding the actual demand by a factor of three. Rotation crops dominate the regions northeast, east and southeast of London (from Kent up to Leicestershire). Grasslands are well represented in the southwest and west of London (from Sussex up to Northamptonshire) with a surplus of about 100 tsd. ha based on the actual consumption needs of the London population. Other surplus crops are non-wheat cereals and oilseed plants. Food crops are notoriously under-represented, pointing at the need for substantial feedstuff imports for livestock farming. The transition zone for both plant- and animal-based food crops (zone 4) requires an area of 1.2 Mio ha for food production, reaching out to a distance of 124 km from its urban centre.
In the wider metropolitan region of Milan, the presence of the Alpine high-elevation landscapes constitute a severely limitation for food production. Overall it is striking that the area demands in the Milano example are clearly lower which is due to another footprint calculation mode based on EFSA-data only. We see high surplus provision with other cereals as well as with rice – a crop that is unique to the Po valley region South of Milan. Most of the rice and other cereals are used for export. Surprisingly for Mediterranean location we see deficits for both, fruit and vegetables production.

In the Rotterdam region the plant-based production zone (2) extents between 15 and 24 km distance from the centre. The entire consumption needs arising from the 1.2 Mio
The inhabitants of Rotterdam can theoretically be satisfied within this zone. However, the current land use is still focusing strongly on livestock farming so that land for perennial and rotation crops, cereals and oilseed plants are lacking. Due to the extensive glasshouse production in Westland and Oostland, the Rotterdam area shows a major surplus for vegetables (> 3,000 ha), when comparing to other European metropolitan regions. But today this production is dedicated to 90% for food export and is strongly dominated by a few lead crops. Given the resource intensity of animal-based food products it is not surprising that zone 3 (24-40 km distance from the city centre) requires a surface area four times as large as the one for plant-based production (> 160 tsd. ha). In this zone the largest deficit is for fodder crops (ca. 100 tsd. ha), which are normally imported from elsewhere (van Gelder and Herder 2012). On the other hand, we see a clear surplus of grassland production for dairy farming. The transition zone (4) spans over a distance between 40 to 150 km from the city centre, even covering parts of Belgium and Germany.

The results of the MFP model application is not only meant as assessment results for framing the impact of urban food production on the different metropolitan zones, but are also providing operational input to a stakeholder-oriented foodscape-planning device. For this purpose we introduce the data into the so-called ‘digital maptable’ (Wascher et al. 2015), which allows users to perform land use allocations by means of a digital pen. Addressing the surplus and demand figures resulting from the assessment, users can then propose where and how to change the existing land use (food crops) in order to better meet the demands identified by the tool.
4. Discussion

4.1. Contribution of quantitative modelling approaches to metropolitan agri-food system planning

The results of the modelling approaches presented in this paper reveal strong commonalities across regions in terms of diets, area demands, etc., allowing for derivation of generic mechanisms and impacts of changing scenario situations and political and technological efforts to change the metropolitan AFS. The tools and models (MEBA, MAPS, MFP) deliver relevant information on the (i) food and area demand-supply balance, (ii) ex-ante assessment of changing scenario situations (population sizes and composition, diets), agricultural system and intensity (intensive, greenhouse, organic), (iii) the role of geographical framework conditions, and (iv) potentials to optimise production (spatial distribution, food chain organisation). These results and functionalities are essential as basis to inform food planning and policy making in the case study regions and elsewhere. They provide important knowledge on the “room for manoeuvre” in setting policy goals towards enhanced regional self-sufficiency through shortening of food chains and regionalisation of food production.
MEBA offers a basic set of information about the shape of agro-food system, revealing the relation between the first and the last step of food chain, production and consumption, at the level of raw products. The latter aspect strongly connects the diet profile with the cropping pattern decisions taken by farmers, revealing which sectors are lacking and what policy actions can be undertaken. Though production choices are driven by global market, new social pressures as well as security and environmental concerns could lead to rethinking of the land use planning role in defining what and where to produce.

Despite its spatial representation, the purpose and functionality of the MAPS tool is less a spatial analysis as such, but should be rather understood a mean of communication of the spatial dimension of food consumption and production. It shall raise awareness among stakeholders and decision-makers in urban and regional food planning and policy about the agricultural area required. It also provides the opportunity to assess the effects of future changes in either food consumption, e.g. healthy or vegetarian diets or population changes, reduction of food waste and loss or changes in the agricultural production systems, such as organic and expensive production or sustainable intensification. In this sense the MAPS tool can be used to explore difference regional scenarios and future pathways.

The main strengths of the tool lie in the attempt to explicitly delineate the specific agricultural area necessary to cover the food demand, but to model the necessary area and illustrate the actual extent through a mapping approach. It helps increasing of regional resilience by provide a broad and diverse basis stock of food supply across many commodities. It also supports the identification of hot and cold spot areas of food stress and help to quantify political targeting in terms of food policy. The MAPS tool can be used to develop a “food land account”, which informs on the questions of the availability of food production area, its utilization, the necessary changes for regional supply (where the MFP tool links in).

The Metropolitan Foodscape Planner (MFP), at the contrary, offers a (1) hands-on impact assessment tool for balancing commodity surpluses and deficits, (2) visual interface that depicts food zones to make impacts spatially explicit, (3) landscape-ecological allocation rules to base land use decisions on sustainable principles, and (4) European data such as EFSA, LANMAP, HSMU and CORINE Land Cover to allow future top-down tool applications for all metropolitan regions throughout the EU.

The concept of spatially allocating specific food groups for which a certain supply deficit has been recognised – e.g. vegetables or oil seeds are typically underrepresented in the metropolitan surroundings of cities – to areas with clear food supply surplus
coverage, for example grasslands, points at the need to guide such stakeholder decisions by offering additional land use related references. We are aware that introducing clear spatial demarcations for different food groups in the forms of zones is drastically contrasting with the everyday situation in our current metropolitan regions. However, rather than intending to reflect the agricultural status quo, the MAPS-concept offers a quantitative look at agricultural resource potentials in which key issues such as the impacts and location of protein consumption, human requirements for recreation and nature, as well as availability of land to provide regional food is visualised in one scheme. Making use of the digital MapTable technology, stakeholders can engage in ‘serious gaming’ exercises and develop proposal for increasing the supply with regional food for up to 12 food groups on the basis of the urban consumption needs. In order to provide further guidance during this process, MFP offers the spatial references of the European Landscape Typology (LANMAP) to ensure that stakeholders receive ‘alert’ messages if their changes they propose are in conflict with the allocation rules laid down as part of the landscape- ecological references. Both the MFP-zoning concept and the LANMAP-based allocation rules are in principle open to stakeholder revisions prior to engaging in the Maptable exercise. This way, a high level of tool transparency and flexibility can be achieved – the basis for gaining trust and ownership throughout the process.

4.2. Towards a new food system paradigm

Despite the shortcoming, we found the underlying principles of the Urban Footprint Tool as a valid starting point when developing a European-wide approach towards footprint-based impact assessment. Though the tools described have been created to fill an important gap in quantitative assessments of urban food supply. Their main purpose is to stimulate a debate on practical questions of regional food supply. The large variety of methodological approaches on the one hand, and the more abstract notion of many global footprint assessments on the other; did not really help to improve our understanding of metropolitan food systems, but on the contrary, has resulted in the belief that existing agricultural lands around Europe’s cities will never be able to provide enough food for all citizens. Studies such as ‘How to feed Tilburg’ (Bruins et al. 2009) have demonstrated that a fair amount of the required global hectares is actually available, but is used for other purposes, among it exporting agricultural goods to remote locations.

Looking at the existing footprint assessments and reference in the light of a societal debate that seems to be polarised between two utopian world views, namely the grow-it-yourself philosophy of the urban gardening movement and the resource-efficiency
paradigm of modern industrial agriculture, there appears a clear need to bring the symbolic and at the same time conceptual nature of global footprint assessments down to the level of real regional land use conditions, food chain actors and political opportunities. The idea was to develop traditional ecological footprint assessments further by allowing comparison between entirely different cities (MEBA), by breaking down the assessments to the level of small communities for showing local hotspots of possible future food stresses in a composite map-image (MAPS), and by making the regional food supply of major food groups (up to 10) not only spatially explicit, but by also facilitating hands-on land use allocations, supported by ‘live’- impact assessments. In combination, these tools offer a substantially more complex and specific knowledge base for policy makers to set up regionally suitable food policies, for economic players to seize business opportunities and for civil society to benefit from a more resilient agro-food system. In this way, the proposed tools seem able to give back the actual comparison between food consumption and land use (MEBA), the territorial potential in providing food (MAPS) and the spatial allocation opportunities for optimizing land use and land planning (MFT). In particular, the Metropolitan Foodscape Planner tool allows users to detect the concrete locations and the available amounts of suitable farmland (supply) in relation to urban consumption needs for the most essential food groups on the basis of urban population figures (demand). If global hectares footprint assessments confront with images of enormous, yet abstract and homogenous spatial impacts, this new generation of local hectare footprint assessments – especially the MAPS and the MFP tools – depict simultaneously impacts and opportunities at the level of concrete land use in the direct vicinity of cities. Looking at the results which can come across as normative, it quickly becomes obvious that they point in the direction of rather unclear or even irritating questions, ranging from a blunt ‘so what?’ to ‘are the observed imbalances seriously implying a fundamentally alteration to a mainly market-driven agricultural system?’. The latter question must be considered relevant because of polarisation in the current debate on food that surfaced during the IUFN conference on the ‘Hungry City’ in Paris (2013), where two conflicting paradigms were addressed in the following way:

The first one is the **agro-industrial paradigm** where food is considered as a commodity and food security equals resource efficiency interpreted as the combination between soil quality (if not footloose), production costs and technology, independent from the geographic location of food consumption. This is in essence about “going on with the productivity model with a further intensification and maximization in the use of natural resources”.

- 91 -
The second is the socio-ecological paradigm where food is considered as a human right with a keener interest in product diversity and importance given to the workforce, knowledge and abilities and where food security, safety and quality increases with the spatial proximity between production and consumption with urban agriculture being considered as its most successful model. This is in principle about “revolutionizing the agro-industrial paradigm with the goal of establishing a bottom-up self-support food system”.

Confronted with these two options, the EU opts for the first paradigm: Tassos Hanoitis (Director Economic Analysis, Perspectives and Evaluations, DG Agri) clearly states that “in EU context food security is not linked to risks about the supply of food”. This is echoed by a landmark UK report Foresight. The Future of Food and Farming (The Government Office for Science, London 2011): “This Report rejects food self-sufficiency as a viable option for nations to contribute to global food security, but stresses the importance of crafting food system governance to maximise the benefits of globalisation and to ensure that they are distributed fairly”.

Rather than subscribing to one or the other of the above directions, the FOODMETRES metropolitan footprint tools have been designed to support a third paradigm that can be outlined as a agro-geographical resilience paradigm where food security builds upon bio-geographic food planning strategies that aim for high levels of regional food supply and diversity adhering to the principles of circular/bio-based economy and in accordance with governance-controlled standards able to support the multi-functionality of the metropolitan landscape. Embracing innovation and resource-efficiency principles as crucial pre-conditions for optimizing agro-food chains at the level of metropolitan regions, the agro-geographical resilience paradigm (AGR-paradigm) considers large-scale food export only as appropriate where this does not negatively affect regional supply potentials, food safety issues, social cohesion, fair competition and landscape quality. The agro-geographical resilience paradigm ultimately seeks to grant these values by increasing the basic regional food security for all regions at the global scale. The AGR-paradigm does not suggest top-down land-reforms, but the development of metropolitan agro-food strategies that are able to defy external impacts triggered by oil-price or other drivers of food supply at the global level.

5. Conclusion

In this paper a metropolitan footprint assessment approach is presented, which consists of a set of three tools of analysis and planning that meet the growing interest
around food systems at regional and metropolitan scale. This increasing level of interest requires adequate responses in terms of managing both the information complexity characterizing a food system and the multiplicity of scale levels to which the system relates. As a matter of fact, the issue of territorial reconnection between food production and consumption involves many aspects: from the cohabitation of global and local supply chains, up to the evolution in consumer preferences; from the environmental sustainability of food supply to the productive potential of territory; from the need to meet the growing global food demand, up to the point of valuing local products and supply chains. The work we carried out sought to tackle this complexity, on the one hand by identifying common lines by which to address the food policies and on the other, by bringing out the differences among food chains. To this end, the proposed methodology, starting from the population’s food habits, allows for an analysis of how local production can comply with consumption, which impact on the production system by way of changes in the relations between production and consumption and through the effects these in turn impart on agricultural land use.

The results allow for some methodological and operational considerations. These considerations are based also on the broader reflection accompanying the development of the project FOODMETRES, involving the role that innovation, in its various forms – technological, social, governmental – plays in directing the evolution of economic systems towards a horizon of security and sustainability. From a methodological point of view, the policies for agri-food metropolitan systems can rely on the availability of new decision support tools, such as the food balance at regional scale, the scenario analysis and the participatory approach to agricultural land planning. Each of the proposed tools is functional to provide specific information and support the formulation of policies on security, sustainability and resilience. In particular, the tool-set FOODMETERS offers can support a new generation of food planning policies in support of a agro-geographical resilience paradigm able to overcome the limitations of both the agri-industrial and the socio-ecological food systems.

Irrespective of the geographic, demographic, climate and farming differences of the analysed metropolitan areas, in all cases the tool has been able to highlight those sectors with a greater chance, compared with the others, of territorial rapprochement either for environmental reasons, or in order to simplify the supply chain in respect of consumer demand. This means that, if properly addressed, specific agri-food chains can be encouraged to embark on a process of adaptation to a greater proximity to the consumer. Similarly, the tested instruments have shown that supply chains already solidly operating in the global market can help meeting food demand by acting on international markets. In this case, the action of food planning aims at enhancing the
role of global player of the most competitive food chains. This dual orientation of metropolitan food systems, local and global, is going towards a new equilibrium: if managed with appropriate policies, it might be the most important innovation for cities to improve security and sustainability of food supply.

6. References


