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Land use and regional supply capacities of urban food patterns: Berlin as an example

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Abstract

The future of world food security is often discussed in terms of population growth and climate change. The countries of the "Global South" are considered particularly vulnerable. However, increasing population in cities mean that food security is also of considerable relevance for the "Global North". The focus here is not on food shortages, but on the "delocalization" of the production and consumption of food, which is making cities highly dependent on external factors. Against this backdrop, a land footprint accounting was conducted in accordance with ISO 14040/44 in order to gain an overview of the land used by the city of Berlin to cater to current dietary habits; these were compared to regional supply capacities of the surrounding Federal State Brandenburg and potential actions for reducing the land requirements were examined. Of the required area to supply Berlin, 28% is located abroad resulting in a net import of virtual land. The imports are currently not offset by Berlin-Brandenburg through corresponding exports. In addition, the area of land required for nutritional purposes per person by far exceeds the acceptable social-ecological level. This gives rise to questions about the resilience of the urban nutrition system and about regional supply possibilities. It becomes clear that, in addition to a change in consumption patterns – which are also associated with a high proportion of avoidable food losses – a rethinking of domestic (regional) production would also be necessary in order to increase Berlin's capacity for self-sufficiency.

Keywords: urbanization, nutrition security, delocalization, land requirements, land footprint account, life cycle assessment, regional supply capacities, sustainable nutrition systems

Introduction and state of research

Current urban dietary and consumption patterns can be seen as a consequence of a structural change in agricultural production during the 20th century. Product prices have fallen as a result of large increases in the productivity of soils (biological-technological progress) and working methods (mechanical-technological progress), while improved logistics and transportation as well as the liberalization of agricultural markets have led to ever increasing globalization of the sector [1, 2]. Cities in particular have thus become further and further decoupled, both geographically and temporally, from the sites where their food is produced [3]. In such a "delocalized" nutrition system, "the sites of producers and processors are no longer defined by regional interrelations, but by logistical criteria geared towards global purchasing and national distribution" [original German citation translated by the authors] [4]. Similarly, the cultural and religious significance of dishes and their seasonal availability throughout the year have been set aside, "lending dietary habits in the industrialized world a more uniform character" [original German citation translated by the authors] [5]. It can be noted that, as prosperity grows, an increasing amount of products is consumed which are more resource-intensive in their production [6, 7], requiring a larger amount of agricultural land. Besides animal products [8], this also applies to vegetable oils and fats, (alcoholic) beverages and stimulants such as coffee and cocoa. Supplies of these products are relying ever since or to a large extent on imports. Indeed between 2000 and 2010 the proportion of land used abroad to feed the German population rose from 20 to 27%, while the total area of domestic land cultivated for nutrition purposes is steadily shrinking (by 4.8% over the same period). Overall, the area used to feed the German

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population is constantly increasing, and at 20.1 million ha in the year 2010 it already exceeds the total agricultural area used domestically (16.8 million ha) [9]. Changes in the global trade in agricultural products are of high importance for global food security. While consumers in industrialized nations are primarily benefitting from a wider and cheaper range, many countries (in parts of Africa and the Near East) depend on imports to ensure their food security. Under current system conditions, Fader et al. (2013) [10] calculate that in the year 2050 some 51% of all people will no longer be able to be fed by the local resources of their own countries (2000: 16%) [10]. At the same time, however, the intensification and further liberalization of the agri-food sector is also associated with an expansion of agricultural land, to the detriment of the environment and the climate [11, 12]. A high dependency of nutrition systems on imports usually results in a long-term erosion of capacities for self-sufficiency, such that importing nations are becoming increasingly dependent on a production system whose foundations lie beyond their own political and legal powers of decision-making. This is particularly true of cities whose already limited capacities of self-sufficiency are declining constantly as a result of population increases and changing food patterns. In an analysis of supply capacities from 1965–2005, this development was analyzed based on the examples of Copenhagen, Canberra and Tokyo [13]. The study illustrated the linkage of self-sufficiency with both population development and with the agricultural specialization of the surrounding regions. As such, capacities of self-sufficiency vary considerably depending on the city and products considered. The degrees of self-sufficiency (Tokyo: 27 %, Copenhagen 45 %, Canberra 90 %) demonstrate the dependency on imports.

Hence, the question of how to define food security in the context of cities results on the one hand from the fact that more and more population growth is occurring in urban areas. In the so-called industrialized countries, the proportion is 80 % on average [14]. On the other hand, Western dietary patterns, which are particularly accentuated by urban consumption habits, are not compatible with a sustainable use of elemental production factors (e.g. soil, water, energy). Not only do industrialized countries require a disproportionately high area of land per capita for nutritional purposes, but natural resources are also threatened by a loss of fertility and biodiversity as a result of exhaustive land use and the consequences of climate change [15]. Moreover, there are now only limited possibilities of extending global acreage without causing lasting damage to ecosystems [16]. If the limits of the "safe operating space" [17, 18] are not to be exceeded, then from 2020 every person would have just 0.2 ha (2,000 m²) available for nutritional purposes. For Germany, various studies estimate current per capita land use to be between 0.23 and 0.24 ha per year, as measured based on current dietary patterns [19, 20]. This also includes (avoidable) food waste.

Against this backdrop the following article used the capital Berlin as an example to investigate different options industrialized nations (in particular urban areas) may have in order to contribute to a globally fairer and ecologically more sustainable supply system. To this end, a land footprint accounting was conducted to examine how Berlin currently feeds itself. This information was compared with the areas available locally in Berlin and Brandenburg.

Method, system boundaries and data sources

The methodology applied is based on the ISO standard 14040/44 for life cycle assessments (LCA) [21]. However, subject of this investigation are not various environmental impacts, which are examined usually in a LCA. Instead it focused on all agricultural areas necessary to produce different commodities for human consumption – including the areas for feed (for the production of animal products), food and drinks (here referred to as "virtual land") [22]. Land used for food processing, for the manufacture of packaging materials and for activities in the gastronomy sector and in households were not considered in the evaluation, because these are of minor relevance in total land footprint of a product [23].

Scope

The evaluation concentrated on areas actually used for nutrition (differentiating between cropland, grassland and permanent crops). Land use was also examined with regard to the levels of supply, consumption, intake and avoidable consumption losses in households, in order to gain an orientation of how much area could be saved by reducing food losses at different stages in the value chain (distribution, consumers).

The functional unit is defined as the land requirements in m² per kg of food (m²/kg). The starting point of the analysis is average consumption by the population of Berlin in the year 2006, which was identified as part of the National Nutrition Survey II (NVS II) [24]. The recorded average quantities consumed per person per year are allocated to 24 product categories (such as dairy products, pork, cereal products, sugar and confectionery); these were broken down using data from the Statistical Yearbook of the then Federal Ministry of Food, Consumer Protection and Agriculture (BMELV) [25] and from FAOSTAT [26] in terms of their composition into primary products (such as wheat, tomatoes, apples) and origin (domestic = Germany, abroad = EU and non-EU countries). This enabled identifying the domestic, European and non-European share of each product (as measured by Germany's degree of self-sufficiency and the corresponding trade volumes) and translate the corresponding yields into a food-specific land use factor (m^2/kg). Unlike the data from NVS II, which refers to the year 2006, the land use factors refer to the period from 2009–2011, with the three-years average being used for both production and trade data.

The land use factors x for the respective product groups are calculated as weighted averages depending on the product group's composition of all raw materials i, with p describing the proportion of i in the product group. In addition, every i is weighted according to import share t from the country/region of origin j (or the degree of self-sufficiency s for domestic production D) and the corresponding land use factor f of the same. Consequently, the following formula applies when calculating the land use factors

$$x = \sum_{i=1}^{n} [p_i \cdot \left(\sum_{j=1}^{m} f_{i,j} \cdot t_{i,j} + f_{i,D} \cdot s_i \right)]$$

where the following factors are defined as:

$$s + \sum_{j=1}^{m} t_j = 1 \quad \text{and:} \quad \sum_{i=1}^{n} p_i = 1$$

The evaluation also included the type of land (cropland, grassland, permanent crops). In order to take account of area changes in processing from the raw product to ready-to-eat food, on the one hand technical conversion factors [25, 27] and on the other production-related recipes (confectionery, cereal products, dairy products, soft drinks etc.) were incorporated in the analysis. Estimates from previous studies were used in order to convert the intake data into the corresponding quantities for supply, consumption and avoidable consumption losses [28–31]. However, these studies reflect the national average, meaning they do not precisely represent the Berlin-specific context. The Federal State of Brandenburg was selected as the regional reference because of simpler access to data. The data on agricultural land use in Brandenburg were taken from statistics provided online by the Office of Statistics of Berlin-Brandenburg [32, 33]. The demographic information about the current population of Berlin and Brandenburg was derived from DESTATIS [34].

Results

For the observation period, ◆ Table 1 shows both the amounts of each product consumed per capita (intake) and the amounts available per person (supply), the resulting avoidable losses and overall consumption. Furthermore, the respective amounts (kg) have been compared with the required area (m^2).

Supply requires an area of 2,374 m^2 per person per year. Some 202 m^2 are attributable to consumption losses arising as a direct result of consumers' improper handling of foods or consumption preferences (n = 91 kg). If these results are multiplied by the current population of Berlin (3.46 million), then the supply of the city requires a total area of around 821,433 ha. Without food losses in the distribution and on household-level the required area would be lower accounting for 614,292 ha and 518,435 ha, respectively. Whereas 62% of the total area is required for animal products, 22% is used for plant-based foods and 16% for stimulants and beverages such as confectionery, coffee, and alcoholic drinks.

Two reference factors need to be considered in order to understand the absolute areas: on the one hand, the land use factor of the respective product, which specifies how much (domestic, European and non-European) area is required to produce 1 kg of the ready-to-consume product, and on the other the amounts in kg consumed annually. Multiplying these two values calculates the absolute area use (◆ Figure 1b). Accordingly, high values result for products which are highly resource-intensive (meaning they display a high land use factor, ◆ Figure 1a), and/or consumed in particularly large quantities. For illustrative purposes, ◆ Figure 1 shows the individual products' absolute area use compared to their land use factors, both domestically and abroad. Here it becomes clear that the production of pork is responsible for the highest absolute area use, even though it does not have a land use factor as high as for other animal products. This is due to the fact that the consumed amount of pork is quite high, showing three times the amount of beef.

Domestic and foreign land use

◆ Figure 1 also shows the proportions of the land use factors accounted for by domestic, EU and non-EU land. It is particularly striking here that the EU proportions of the land use factors are significantly lower than those from non-EU countries. This is interesting because one might expect EU proportions to be higher given not just the geographical proximity, but also the strong integration of European markets and the common trade policy. This is indicative of a food sector, which is highly globalized, leaving questions about international social and ecological standards unanswered. Information is provided in ◆ Figure 2 about the exact areas used domestically, in the EU and in non-EU countries to feed Berlin. 59% of these areas are cropland, the majority of which is situated in Germany. Grassland (meadows, pastures) is located almost exclusively within Germany, although in recent years an increasing number of these areas have been sub-

	kg/Person				m²/Person			
	supply[a]	consumption [b]	intake[c]	avoidable losses[d]	supply	consumption	intake	avoidable losses
butter	6.6	5.4	4.7	0.7	103.4	85.4	73.4	10.8
cheese, quark	25.1	21.8	18.8	2.8	199.9	174.3	149.9	22.1
creamy dairy products	43.3	38.2	32.9	4.9	183.8	162.4	139.7	20.6
milk, dairy drinks	71.9	58.5	50.3	7.4	142.3	115.8	99.6	14.7
beef, veal	11.1	8.1	6.8	0.6	290.6	211.0	177.3	16.3
pork	48.8	23.2	19.5	1.8	368.3	175.4	147.3	13.5
poultry	16.7	11.1	9.3	0.9	82.0	54.7	45.9	4.2
other meat (sheep/goat/game)	2.4	1.1	1.0	0.1	66.3	31.6	26.5	2.4
egg products	12.8	8.3	6.9	1.2	39.5	25.4	21.3	3.7
fish products	17.6	12.5	10.8	1.0	3.0	2.1	1.8	0.7
cereal products	136.0	139.5	107.4	28.2	250.7	257.2	198.1	52.0
vegetables (including legumes, soy)	115.8	118.9	88.0	15.6	49.7	51.0	37.8	6.7
fruits	93.9	119.9	91.1	15.9	58.0	74.0	56.3	9.9
nuts and seeds	4.1	1.6	1.3*	0.2	27.6	10.4	8.8	1.1
potato products	74.5	36.2	26.8	6.3	22.3	10.9	8.0	1.9
vegetable oils, fats	16.0	7.4	6.3	0.7	115.1	52.8	44.9	5.3
sugar, confectionery	31.6	20.8	17.7	2.7	194.2	128.0	108.8	16.8
water	389.9	389.9	389.9	0.0	0.0	0.0	0.0	0.0
soft drinks, juices	135.5	135.5	135.5	0.0	16.7	16.7	16.7	0.0
herbal tea, fruit tea	91.4	91.4	91.4	0.0	2.3	2.3	2.3	0.0
coffee, tea (black, green)**	217.7	217.7	217.7	0.0	80.0	80.0	80.0	0.0
beer	118.5	54.5	54.5	0.0	44.9	20.6	20.6	0.0
wine, sparkling wine	17.5	17.5	17.5	0.0	28.7	28.7	28.7	0.0
spirits	1.4	1.4	1.4	0.0	4.3	4.3	4.3	0,0
total	**1,699.9**	**1,540.4**	**1,407.4**	**90.9**	**2,373.6**	**1,775.0**	**1,498.1**	**202.1**

Tab. 1: **Supply, consumption, intake and avoidable losses of products per person (Berlin) in kg and m² in 2010** [own calculations based on NVS II, BMELV, FAOSTAT and others]

[a] Supply' means the entire amount available (= food supply) after imports and exports, reductions for industry and energy as well as post-harvest and processing losses during the initial further processing stages.

[b] 'Consumption' describes the amount that actually reaches the consumer. Market and distribution losses are no longer included here. At this level (large consumers and households), the amounts are either consumed or lost as avoidable and unavoidable waste.

[c] 'Intake' refers to the amounts actually eaten according to the data in the National Nutrition Survey II (NVS II) for Berlin.

[d] 'Avoidable losses' are those consumption losses which arise as a direct result of consumers' improper handling of foods (storage, understanding the 'best before' date), a lack of awareness or as a result of purchasing behavior or consumption preferences. Berlin generates approximately 91 kg of avoidable food waste per person per year.

* The value for nuts and seeds was not identified at federal state level. For this reason, the value corresponds to the German average.

** Data are based on 1 L of ready-to-consume drink. According to the Statistical Yearbook [24], this corresponds to a dry mass of 9 g of tea and 35 g of coffee per liter.

grey values = there was no source for the conversion factors in the categories supply, consumption and avoidable losses. The intake value was therefore applied for supply and consumption.

stituted by arable crops domestically and abroad (primarily protein-rich concentrate feeds such as soy and rapeseed) [9]. The domestic proportion is particularly low for products originating from permanent cultivation. These include for example fruits, nuts, coffee, tea, cocoa, tropical fruits, wine and palm oil. More than two thirds of permanent crop acreage is located in non-EU countries, which often involves the use of plantations. These are frequently subject of criticism due to ecological and social grievances [35, 36]. According to the calculations, Berlin's level of self-sufficiency as a result of domestic areas is 72%; just 7% of the virtual area comes from other EU countries, and 21% is imported from non-EU states.

Regional area capacities

How dependent is Berlin on the structures of the agri-food system depicted and how can this dependency be reduced? In order to answer these questions, Brandenburg's agricultural land was first compared to the actual area requirements (Berlin´s plus Brandenburg's land requirements). Around 13% of the area of Brandenburg is attributable to the production of energy crops or lies fallow (about 175,177 ha) [37]. Consequently, the degree of self-sufficiency for arable land in particular is therefore overstated in ◆ Figure 3. Moreover, the fact that an area is available does not indicate what can be cultivated there due to site-specific conditions. Many products which form an integral part of everyday diets cannot be grown at all, or can only be grown to a limited extent in Germany (e.g. wine, cocoa, coffee). However, it can be seen that the city of Berlin cannot compensate for the land it imports virtually by

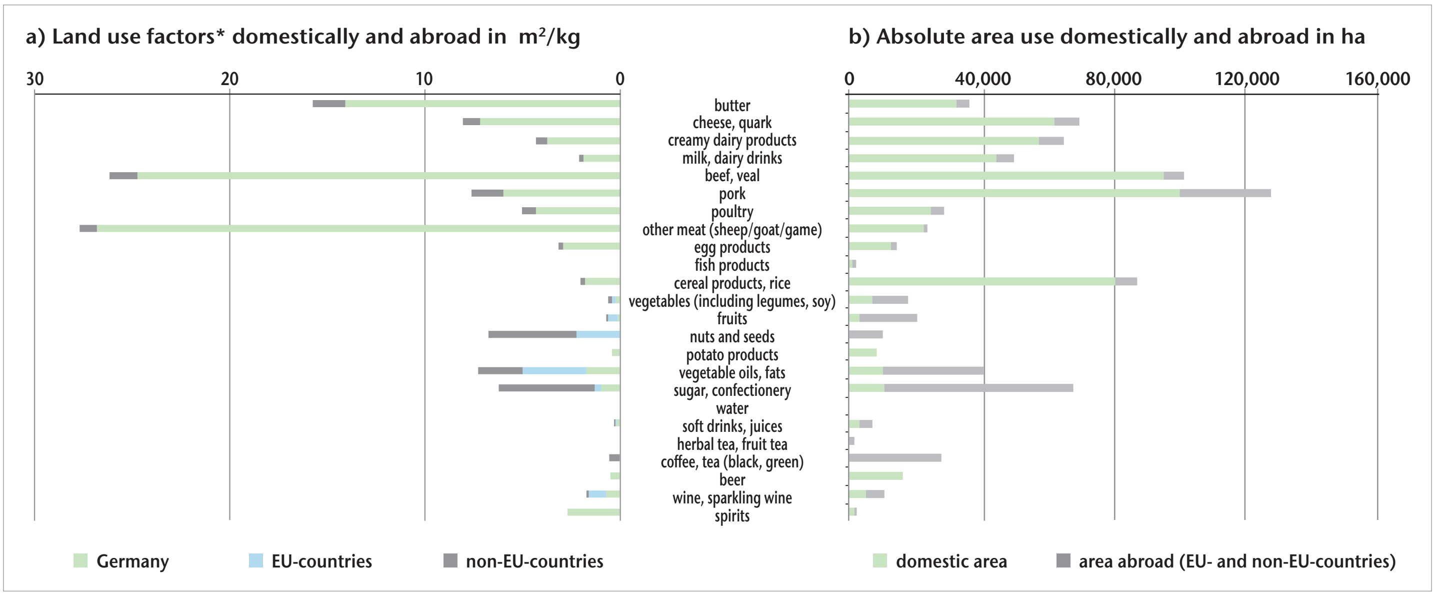

Fig. 1: **Land use factors and absolute area use of food groups for supplying Berlin, 2010**
[own presentation and calculation based on NVS II, BMELV, FAOSTAT and others]
* The land use factors indicate how much area (in m²) is required to produce 1 kg of the ready-to-consume product available in Germany.

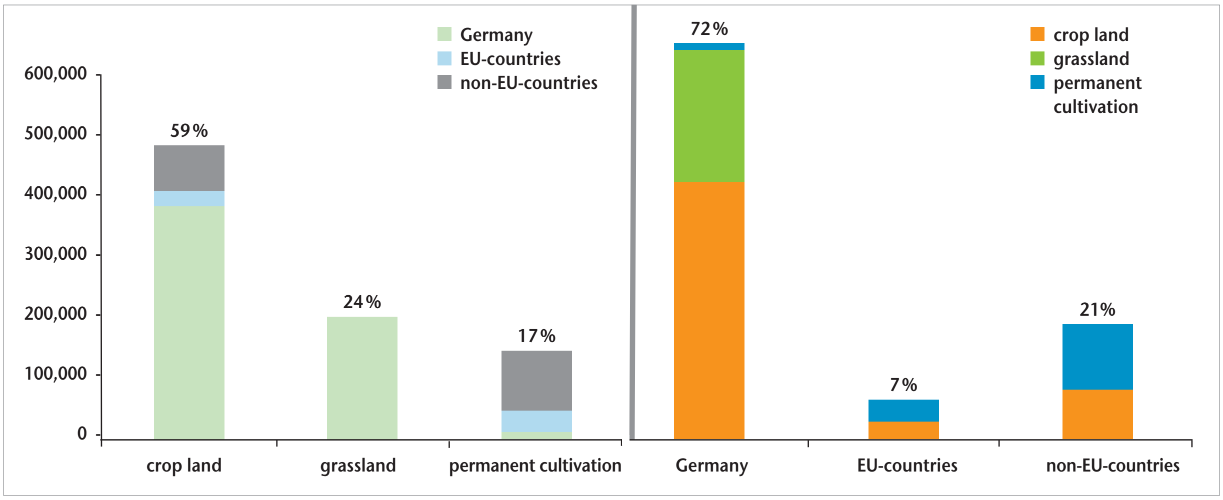

Fig. 2: **Area use in ha and per cent for supplying Berlin according to type of land (left) and region of origin (right) in 2010** [own presentation and calculation based on NVS II, BMELV, FAOSTAT and others]

transferring its own products (◆ Figure 3). While cropland exceeds the actual requirements by a factor of 1.22, for grassland this factor is at 0.86, while permanent crops display a factor of just 0.02. This means that almost 100% of products from permanent crop cultivation need to be imported. It would already be possible to achieve an improvement of the self-sufficiency level of 76%, and in turn a reduction in the use of areas abroad, through the targeted avoidance and rerouting of food surpluses. This would mean on the one hand removing avoidable food losses on the part of the consumer, and on the other hand gearing supply more strongly towards consumption, so as to reduce distribution losses on the retail level (referred to here as "optimized demand"). If this were possible in 100% of cases, then besides cropland there would also be enough grassland areas to satisfy the demand domestically. As regards the overall land balance, this would mean that Berlin-Brandenburg would become a net exporter of agricultural land. Only in the case of permanent crops is it not possible to achieve a higher level of self-sufficiency; the high dependency on imports remains. This applies in particular to plant-based products and the category of confectionery and luxury foodstuffs.

A more detailed analysis of the agricultural statistics from Brandenburg does however show that, under current conditions, self-sufficiency for plant-based products could be achieved only for cereals, vegetable oils and fats from arable farming, and also for sugar if requirements were optimized. In the case of vegetables, the degree of self-sufficiency is currently 22% (optimized demand: 24%), and even for potatoes just 17% of the demand is currently met (optimized demand: 41%) (◆ Table 2).
For a higher degree of self-sufficiency, a combination of three factors is therefore crucial: the reduction of food losses, the orientation of regional agriculture to food requirements and the development of dietary patterns that are less resource-intensive and geared towards regional supplies.

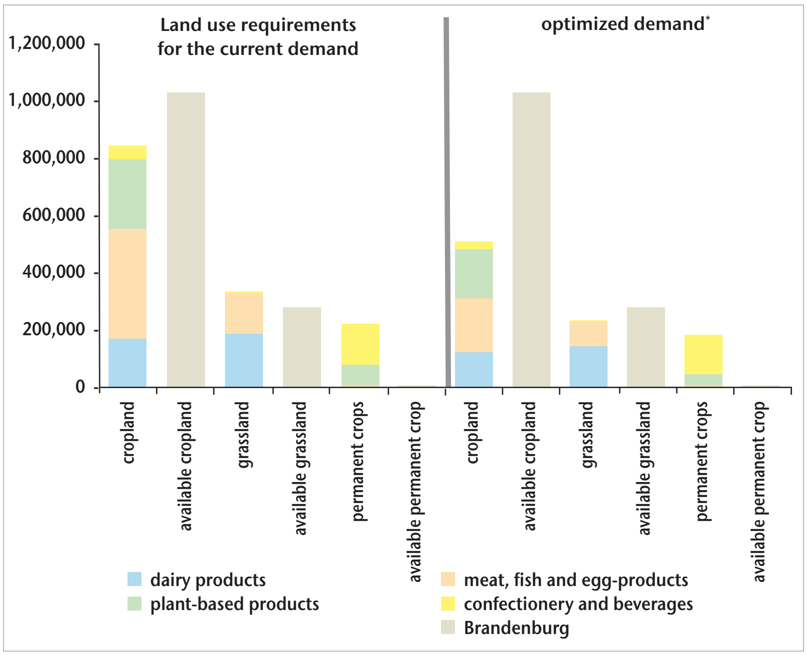

Fig. 3: **Self-supply capacities for current demand and optimized demand* by type of land use and product groups in ha** [own presentation and calculation based on the Office of Statistics Berlin-Brandenburg]
* Optimized demand here means a reduction in food losses (in households, distribution, trade and manufacturing).

Discussion

With 2,347 m² per capita the land footprint for supplying the city of Berlin with food exceeds the natural limits based on a globally fair distribution of 2,000 m² (0.2 ha) per person. On the part of consumers, the share of animal products contributes significantly to an overuse of resources. At the same time, however, there is also a clear oversupply, thus contributing to a waste of food.
The capacity of the surrounding region (Brandenburg) to supply Berlin with the areas it requires is equal to 76% of current supplies. Due to the current composition of diets and the orientation of Brandenburg's agricultural production, this proportion could not be significantly increased by optimizing demand alone. This reveals a dependency on import products, which are not cultivated sufficiently in Brandenburg (such as fruits, vegetables, potatoes) or cannot be cultivated there (such as coffee, cocoa, tropical fruits, soy). Given the current land management, the areas in Brandenburg are therefore unable to serve current consumption habits. These habits can be regarded as the expression of a globalized food system which, as

	area	supply requirements in 1,000 ha	optimized demand	degree of self-sufficiency in %
cropland	1,029.3	844.1	518.5	**122 (199)**
grassland	285.2	330.1	228.7	86 **(125)**
permanent crops	4.8	239.6	179.8	2 (3)
cereals (including beer)	514	171.2	129.5	**300 (397)**
potatoes	2.3	13.9	5.6	17 (41)
sugar	8.3	18.2	6.4	46 **(130)**
vegetable oils	143.5	62.1	25.6	**231 (560)**
vegetables	6	27.8	24.8	22 (24)
fruits	3	43.9	47.8	6.8 (6.3)

Tab. 2: **Area for the supply of individual plant-based products from Brandenburg's official agricultural statistics** [own presentation and calculation based on Office of Statistics of Berlin-Brandenburg]
bold = degree of self-sufficiency above 100%

the economist Edgar LANGE already noted in 1911, has liberated consumers "from the inadequate output of the surrounding area" [original German citation translated by the authors] [38]. What was already demonstrated for Canberra, Tokyo and Copenhagen by PORTER et al. (2014) [13] also applies in the case of Berlin: the agricultural practice in the surrounding area is geared more towards international competitiveness than to self-sufficiency and diversity of production. Consequently, the dependency of these cities is not due to a lack of resources, but to the alignment of prevailing agricultural policies.

Among the global challenges for food security discussed at the outset, it is important to ask whether current agri-food systems can and should be further "uniformed" and intensified, or whether regional supplies should be boosted by re-diversifying agriculture. In particular, the question arises as to what form resilient nutrition systems for cities might take [39] and whether administrative framework conditions could grant supply networks in and near cities to add value over more distant production sites, or whether the supply of metropolises should be subject to the liberal market alone. Interesting initiatives in this context include community-supported agriculture (CSA), 'food assemblies', 'nutrition councils' and direct marketing opportunities for regional suppliers in cities, all of which are currently being developed in many European cities and thus addressing the issue of nutrition in the urban context [41]. The fact that this subject does not only concern private and civil society actors was demonstrated in October 2015, for example, when more than 100 cities – including Berlin – signed the Milan Urban Food Policy Pact with the aim of developing more sustainable and social food systems for the cities [42]. It is however not possible at this stage to assess the actual potential and possible limitations of such approaches. The successful strengthening of regional supply capacities is largely dependent on the willingness of consumers and politicians to change dietary habits. While several studies have already analyzed the optimal composition of an environmentally compatible diet [19, 28, 29, 40], there is still a lack of investigations with a local/regional focus. This leads to a number of unanswered questions for further research: What are the dominant supply and consumption structures for nutrition in cities? How great is the potential for (inner) cities to supply food? How are dietary patterns evolving? Are there discernible differences between urban and rural areas and between individual regions?

Finally, it should be emphasized that nutrition represents just one aspect of current lifestyles and consumption habits [43]. In order to obtain a satisfactory answer to the questions raised in this article, it would be necessary to extend the discussion to the wider area of lifestyles and consumption.

Limitations

The methodology used for the evaluation was based on the ISO standard 14040/44 [18] on life cycle assessments, which provides a suitable framework for considering nutritional systems in an environmental context. In order to generate the most representative results possible, data from official statistics as well as the NVS II were used, although the diverse supply and demand structures mean that these data are unable to cover every detail. The more detailed the origin and composition of processed products, the more complicated it is to compile the necessary data. For this reason, some information could only be estimated or derived from a range of sources. Furthermore, the information on supply, consumption and intake varies, and distinctions between these three are not always clear. This applies for example to the processing of raw materials for confectionery and exact information about soy products and nuts. The consequence of this is a certain degree of statistical inaccuracy, which must be pointed out when interpreting the results. There are still too few relevant data for a more detailed analysis of cities as areas of investigation.

Conflict of Interest
The authors declare no conflict of interest.

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