FOODSHIFT 2030

FOOD SYSTEM ANALYSIS FAL OSTEND

Submission date 19/12/2023
Start date of project 01/01/2020
Duration 48 Months

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 862716.

Project Title	FoodSHIFT2030 - Food System Hubs Innovating towards Fast Transition by 2030
Contract Number	862716
Work Package	WP3 Assessing the benefits
Deliverable	FOOD SYSTEM ANALYSIS FAL OSTEND
Task(s)	T3.3 Evaluate the current state of food systems within front-runner city regions [Lead: WUELS, M05-M31]
Document Name	Food system innovation assessment report
Due Date	N/A
Submission Date	N/A
Dissemination Level	[X] P - Public [ ] CO – Confidential
Deliverable Lead	The Wrocław University of Environmental and Life Sciences (WUELS), SUSMETRO
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Keywords	the food system, city-region, foodshed, food impact, MFP, CRFA
Statement of originality	This deliverable contains original unpublished work except where indicated otherwise. Acknowledgment of previously published material and of the work of others has been made through appropriate citation, quotation, or both.
Abstract (for public dissemination only)	The following document presents methods and obtained results from the evaluation of the current state of the food system within the front-runner city region of Ostend, Belgium.

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1. Introduction

Part of the FoodSHIFT project's Work Package 3, task 3.3 (T3.3) focuses on assessing the current state of the food system through evidence-based foodshed approaches. The foodshed assessments provide the FALs with important information about the functioning of the food system in the nine participating city regions, including the demand for food, the area required to satisfy the demand for food, and the food production capacity of the city regions. The task is coordinated by WUELS and consists of three sub-tasks, led by SUSMETRO, WUELS, and ZALF and applies three complementary approaches:

- Metropolitan Foodscape Planner (MFP)
- City-Region Foodshed Assessment (CRFA)
- Carbon Footprint of local product.

2. Evaluating the current state of food systems within front-runner city regions: a methodological approach

The food system, according to FAO[1], can be defined as "*systems that encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption, and disposal of food products that originate from agriculture, forestry, or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded*".

"The food system is composed of sub-systems (e.g. farming system, waste management system, input supply system, etc.) and interacts with other key systems (e.g. energy system, trade system, health system, etc.). Therefore, a structural change in the food system might originate from a change in another system; for example, a policy promoting more biofuel in the energy system will have a significant impact on the food system"[2].

The current food system should be resilient to different vulnerabilities, such as climate change or pandemic emergencies. The weakness and uncertainty of current food systems were exposed by the covid-19 pandemic. The sustainability and resilience of the food system to different crises could potentially be verified by the foodshed approach.

[1] FAO (2018) Sustainable food systems. Concept and framework. [available online, 01.08.2022:] https://www.fao.org/3/ca2079en/CA2079EN.pdf
[2] Ibid.

Foodshed (which is also known as production capacity, local food production capacity, or local foodshed carrying capacity) is defined as a geographical area of the food supply that represents the food zone for urbanized areas and linkages established between peri-urban agriculture and urban consumption. It is a local area that produces sufficient food products to feed its population[3].

Three main types of foodshed analysis are distinguished: a) local food self-sufficiency (or capacity) studies, b) food resource flow and c) hybrid analyses[4]. Most assessments focus on determining the potential of agricultural production capacity to meet the needs of the specific region's population[5,6] or to evaluate more specific issues as part of sustainability impact and ecosystem services. Food flow assessments examine distribution networks[7], present food origins (the place where the food comes from), which can be used as a basis for assessing the local potential and the system's resilience to crisis[8]. The hybrid foodshed analyses combine agricultural capacity and current food flow analyses[9].

2.1. Metropolitan Foodscape Planner (MFP 2.0)

The 'Metropolitan Foodscape Planner' (MFP) is a spatial-functional assessment that was developed as part of the EU project FoodMetres (2012-2015). MFP enables the quantification and mapping of the ecological footprint of agriculturally productive land required to sustain the annual amount of food demand of an urban population according to the diet recognized for that country or region. Unlike the classic ecological footprint assessment model (proposed by the Global Footprint Network), the land footprint is given in 'local hectares' rather than 'global hectares'.

MFP 2.0 offers as the main outcome a spatial model of food landscape allocation, which distinguishes between (1) an urban core, (2) a recreational and natural buffer zone around this core, (3) a plant-based food production zone, including vegetables, fruits, grains, etc. for human consumption, and (4)

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[3] Świąder, M., Szewrański, S., & Kazak, J. K. (2018). *Foodshed is an example of preliminary research for conducting environmental carrying capacity analysis*. Sustainability, 10(3), 882.
[4] Schreiber, K., Hickey, G. M., Metson, G. S., Robinson, B. E., & MacDonald, G. K. (2021). *Quantifying the foodshed: a systematic review of urban food flow and local food self-sufficiency research*. Environmental Research Letters, 16(2), 023003. https://doi.org/10.1088/1748-9326/abad59.
[5] Zasada, I., Schmutz, U., Wascher, D., Kneafsey, M., Corsi, S., Mazzocchi, C., Monaco, F., Boyce, P., Doernberg, A., Sali, G., & Piorr, A. (2019). *Food beyond the city – Analysing foodsheds and self-sufficiency for different food system scenarios in European metropolitan regions*. City, Culture and Society, 16, 25–35. https://doi.org/10.1016/j.ccs.2017.06.002
[6] Kurtz, J. E., Woodbury, P. B., Ahmed, Z. U., & Peters, C. J. (2020). *Mapping U.S. Food System Localization Potential: The Impact of Diet on Foodsheds*. Environmental Science & Technology, 54(19), 12434–12446. https://doi.org/10.1021/acs.est.9b07582
[7] Karg, H., Drechsel, P., Akoto-Danso, E., Glaser, R., Nyarko, G., & Buerkert, A. (2016*). Foodsheds and City Region Food Systems in Two West African Cities*. Sustainability, 8(12), 1175. https://doi.org/10.3390/su8121175
[8] Moschitz, H., & Frick, R. (2020). *City food flow analysis. A new method to study local consumption*. Renewable Agriculture and Food Systems, 36(2), 150–162. https://doi.org/10.1017/s1742170520000150
[9] Vicente-Vicente, J. L., Sanz-Sanz, E., Napoléone, C., Moulery, M., & Piorr, A. (2021). *Foodshed, Agricultural Diversification and Self-Sufficiency Assessment: Beyond the Isotropic Circle Foodshed—A Case Study from Avignon (France).* Agriculture, 11(2), 143.

a meat-based production zone, mainly including feed and animal husbandry areas[10]. The MFP 2.0 models these zones following the concentric rings model for the locational theory of von Thünen (1823).

Within the FoodSHIFT2030 project, MFP 2.0 uses a Geographical Information System (GIS) to handle spatial data layers, and non-spatial assumptions - such as current food habits of a particular community (Table 1) to determine the footprints of a selection of city regions.

Table 1. Datasets utilized in MFP 2.0.

Name of dataset	Description	Source
CORINE Land Cover 2018	European land cover map	https://land.copernicus.eu/pan-european/corine-land-cover
Natura2000 2020	European ecological network of protected areas	https://natura2000.eea.europa.eu/
Homogenous soil mapping units FSU 2019	A European map of predicted crop areas on farm structure units. 3rd-generation Homogenous Soil Mapping Units (HSMU) as modelled by CAPRI (Kempen et al. 2005) and Eurostat crop area data disaggregated to FSU's by CAPRI for 33 crops.	https://ec.europa.eu/jrc/en/research-topic/crop-yield-forecasting
LANMAP2	European landscape map	https://www.wur.nl/en/show/The-European-landscape-map.htm
The multi-ring buffer around the city start point	Concentric rings around the city center based on the Von Thünen model (1823) represent the urban ecological footprint of a food system	GIS data processing
Food Consumption literature	Figures on food and agriculture data (crops and livestock products) both at the European and local level	Available food (FAO, 2018) (kg/capita/year) plus local data on food consumption provided by FAL lab assistant

Source: *FoodSHIFT2030 article published in the 'Frontiers in Sustainable Food Systems' Journal by Arciniegas G. et. al*. (2022).

MFP 2.0 allows quantifying the current state of the city region's food system, as well as the development of dynamic scenarios based on alternative food habits (e.g. EAT Lancet diet or a more plant-based diet). The results of MFP are to be presented and discussed with stakeholders during participatory workshops in which an interactive touch screen - the MapTable - can be used as the main

[10] Wascher, D., Zasada, I., & Sali, G. (2015). *Tools for metropolitan food planning - A new view on the food security of cities*. In book: *The Governance of City Food Systems* (pp.68-97). Publisher: Fondazione Giangiacomo FeltrinelliEditors: Mark Deakin, Davide Diamantini, Nunzia Borrelli.

interface between stakeholders and the food spatial data as well as the main means to allow the interactive modification of food-related land use (Figure 1).

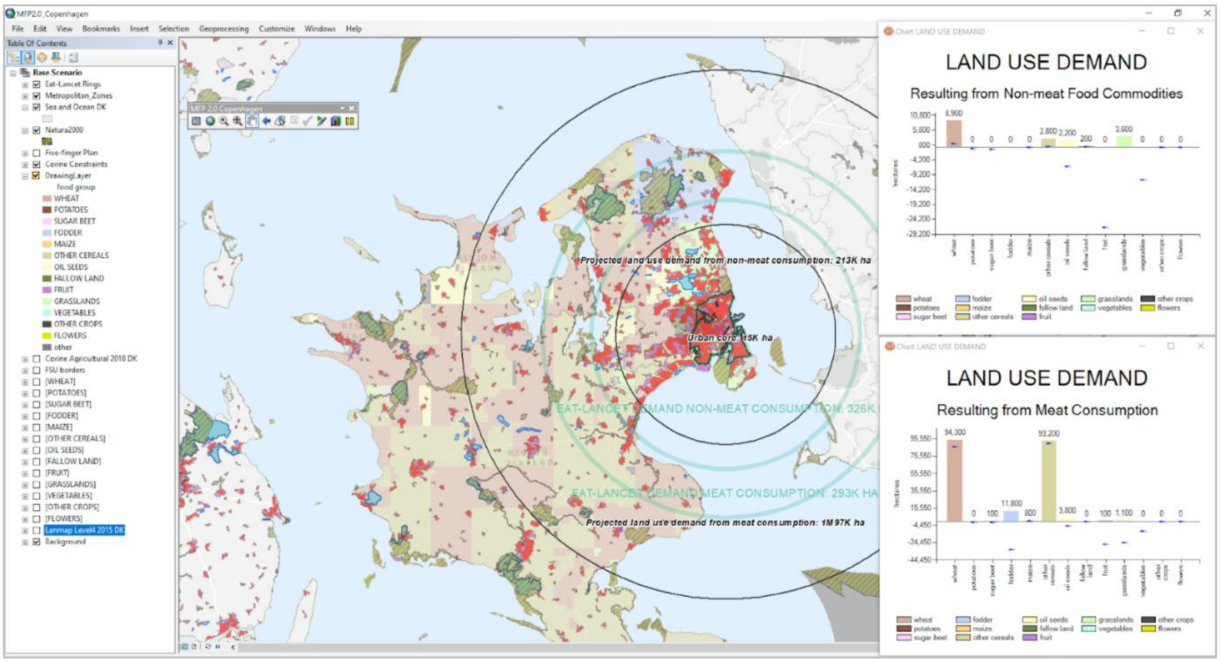

Figure 1: The main interface of the MFP 2.0 Tool is featured by a dynamic GIS. Source: *FoodSHIFT2030 article published in to the 'Frontiers in Sustainable Food Systems' Journal by Arciniegas G. et. al*. (2022).

2.2. City-Region Foodshed Assessment (CRFA)

The City-Region Foodshed Assessment (CRFA) is based on the approach proposed by Hedden in 1929[11]. Hedden's approach allows for verifying the functioning of the entire food system and its impact on the environment and social communities. In this approach, the basis for foodshed delimitation is 'food-flows' occurring between places of food production (food origin) and their consumer market. The foodshed boundary can be delineated by following the linkages between food origin and the food market. The delimitation of linkages, as well as the foodshed, is conducted using GIS tools. The initial step for foodshed delimitation – the food-flows analysis (Figure 2), allows the validation of local food system potential, which could boost the development of a more sustainable and resilient food system as part of long-term urban growth strategies or food policies[12].

[11] Świąder, M., Szewrański, S., & Kazak, J. K. (2018). Foodshed is an example of preliminary research for conducting environmental carrying capacity analysis. Sustainability, 10(3), 882.
[12] Ibid.

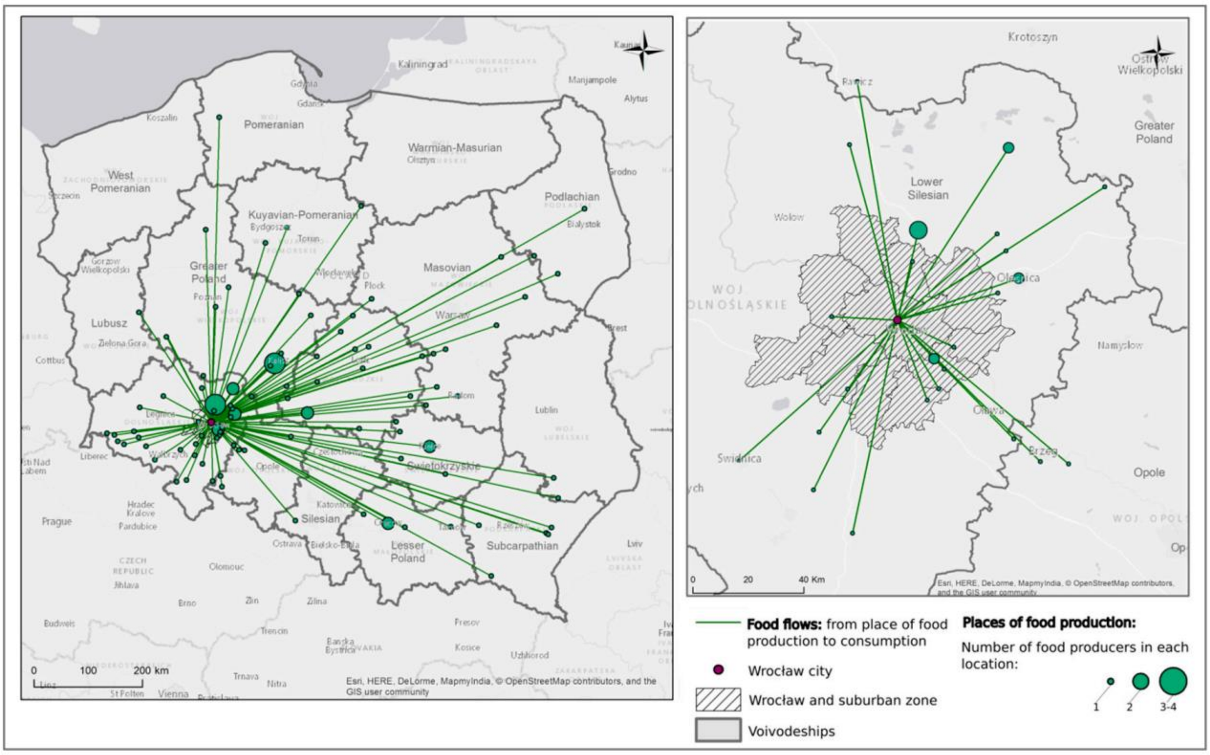

Figure 2: Food flow analysis. On the left side of the figure – Complete map of food flows based on the prepared database. On the right side of the figure – extracted nearest food flows based on natural classes. Source: *Świąder, M., Szewrański, S., & Kazak, J. K. (2018). Foodshed is an example of preliminary research for conducting environmental carrying capacity analysis. Sustainability, 10(3), 882.*

The first step of food flow analysis is the acquisition and preparation of relevant data. The data collection sheet (Table 2) includes information on the name of the producer; the address of the production site, street, number, postal code, the name of the town (food origin); the offered food groups, and (if obtainable) food product types. The most important aspect in the context of determining foodshed by the food flow approach is the food origin; however, more detailed information (food groups, types of food products) could be useful for analysing local food system potentials.

Table 2: Example of data collection sheet for food origin mapping.

No.	Name of the producer	Food origin (address: street, number, postal code, town)	Food groups	Food products	X	Y
1	Producer A	Grunwaldzka 55, 50-357 Wrocław, Poland	vegetables, fruits, eggs	tomato, cucumber, zucchini, cherries, eggs		
2	Producer B	Grunwaldzka 35, 50-357 Wrocław, Poland	eggs	eggs		
…	…	…	…	…		

The input data and/or existing databases, and services are provided by the FoodSHIFT accelerator labs (= FAL). Then, the addresses are used for obtaining coordinates (X, Y) and finally for geocoding of food origin points using ESRI ArcGIS software. Next, the food flows are drawn using a "Construct Sight Line"

GIS tool. Sequentially, the calculated distances are the basis for extracting producers nearest to the city. Therefore, values of distances are divided into natural classes according to natural distribution using the graphical method. As the last step, the minimum foodshed boundary (based on extracted nearest food flows) using the "Minimum Bounding Geometry" tool is delimited.

2.3. Carbon Footprint of local products

The results obtained from foodshed analysis can be implemented for determining the carbon footprint of local products (CF_{LP}) assessment. The input information for the assessment is food flows showing the distance between the market (i.e. city, residential areas) and food origin (i.e. farm, an agro-park). The calculations of CF_{LP}[13] consider the following variables (Figure 3):

- the average amount for a local product purchased by a customer [kg]
- average number of kilometers driven to acquire the product [km]
- CO_{2eq} emissions per kilometer (depending on fuel type) [CO_{2eq}/km].

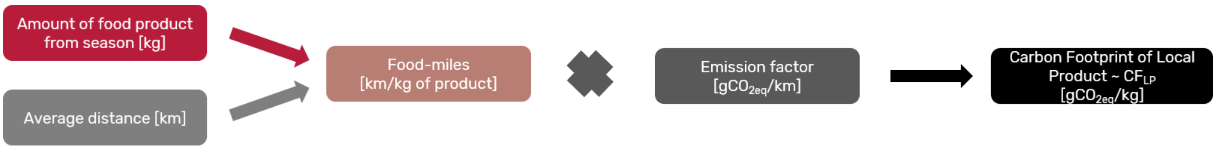

Figure 3: Scheme for the carbon footprint of local products assessment. Source: own elaboration based on *Mancini et al., (2019) Producers' and consumers' perception of the sustainability of short food supply chains: The case of Parmigiano Reggiano PDO. Sustainability 11(3)*.

The results obtained for the local carbon footprint of food are then compared with the average global carbon footprint (stage of the supply chain - transportation) of food[14]. The obtained results for innovative local supply chains could be remarkably interesting, especially in the context of the global food chain and the share of transport in total carbon emissions (assumed as 10%)[15].

3. Results

This section provides an overview of the results obtained from the current state of the food system within front-runner city regions.

3.1. MFP

The **MFP for the Ostend City Region** was conducted as a two-workshop process. Two interconnected workshops were held on September 12th and October 13th, 2023, respectively. The first workshop was

[13] Mancini et al., (2019) *Producers' and consumers' perception of the sustainability of short food supply chains: The case of Parmigiano Reggiano PDO*. Sustainability (Switzerland), 11(3). https://doi.org/10.3390/su11030721.
[14] Moore & Nemecek, (2018) Reducing food's environmental impacts through producers and consumers. Science, 360(6392), 987–992. https://doi.org/10.1126/science.aaq0216.
[15] Ibidem.

held in person and the second workshop online through Zoom. Participants of the workshops included food officers from the City of Ostend, representatives from farmer groups or institutes and food researchers from the FoodSHIFT2030 consortium. The first workshop had as main goals: presentation of the tool, discussion and validation of 1) input data required to calculate the current land footprint of the city (i.e. data on food consumption in the city, coming from FAOSTAT and the West-Vlaanderen Province), and 2) the geographical layers used to map this footprint (i.e. food crops, agricultural land available, soil type and soil suitability for agriculture, non-agricultural land, such as protected natural areas, built-up areas, water bodies), and a discussion on potential foodscape scenarios to feed the city inhabitants. The result of the first workshop was a validated table of current food demand per capita for several food commodities (or groups), such as potatoes, fruits and nuts, cereals, seeds, legumes, grasslands, vegetables, maize, sugar beet, and animal fodder, which are split up into two types: plant-based and animal-based (Table 3).

Table 3 shows food demand values in hectares for each food group. These figures are first based on food demand per capita. Food demand values are calculated using available country-specific FAO food data (kg/capita/year). If local datasets for a particular city region are available, FAO food figures can be disaggregated, and then converted into required hectares per capita.

Table 3. Food demand per capita for the city of Ostend.

Food group	**Demand (ha) plant-based**	**Demand (ha) animal-based**	**Ha per capita**
Potatoes	**1176**		0.01630
Fruits and nuts	938		0.01300
Cereals, seeds, legumes	278		0.00385
Grassland		3609	0.05000
Vegetables	108		0.00150
Maize			
Sugar beet	1176		0.0163
Fodder		9238	0.12800
Footprint	3677	12847	
TOTAL FOOTPRINT	**16524**		

The main goals of the second workshop were to 1) present and discuss the footprints calculated for the status quo and 2) present and discuss the footprints for the two scenarios proposed for the city in the first workshop. Two food consumptions scenarios were proposed at the first workshop:

- Half/half strategy: aiming at reducing the average meat consumption by 50%
- 100% plant-based diet: aiming at removing animal-based food products

To get an indication of the impacts on the food systems of these two scenarios, MFP was used to calculate the footprints of the scenarios, and to compare these results with the status quo. The total footprint of a diet scenario is the sum of the plant-based and the animal-based footprints. Table 4 shows these results. From this table, third row, we can see that the 100% plant-based scenario has the smallest total footprint when compared to the status quo, almost 50% of the statis quo total footprint. The half-half strategy scenario reduces the status quo total footprint by about 3000 hectares. A food-group-specific distribution of the food demand for the two proposed scenarios can be found in Annex B, tables B1 and B2.

Table 4. Results obtained using MFP tool for FAL Ostend.

	Status quo	Half/Half strategy	100% plant-based
Land required to satisfy plant-based needs [ha]	3677	6980	7612
Land required to satisfy meat-based needs [ha]	12847	6424	0
Total land footprint [ha]	16524	13403	7612
Land footprint per capita [ha]	0.229	0.186	0.105

The land footprints of the two scenarios were mapped using MFP. Figure 4 shows these footprints overlaid with the status quo footprint. The footprint is portrayed as two concentric rings around the urban core, namely the plant-based ring and animal-based ring. The plant-based ring is first drawn around the centre of the urban core (i.e., the main railway station). The animal-based ring is drawn from the edge of the plant-based ring and outwards. The width of each ring depends on the available productive agricultural land in hectares and is estimated via an iterative spatial analysis process in which one ring buffer is first drawn around the city and then overlaid on with the available agriculture zones. The footprint of the status quo is represented by two concentric rings with brown outlines. The footprint of the 100% plant-based scenario is portrayed as one green circle with a dashed outline. The footprint of the 50/50 scenario is represented by two concentric rings with orange outlines with the plant-based closer to the urban core and the animal-based starting where the plant-based ends. The map in the figures provides an indication of the spatial impact of the current food consumption in Ostend and the two scenarios proposed in the workshop.

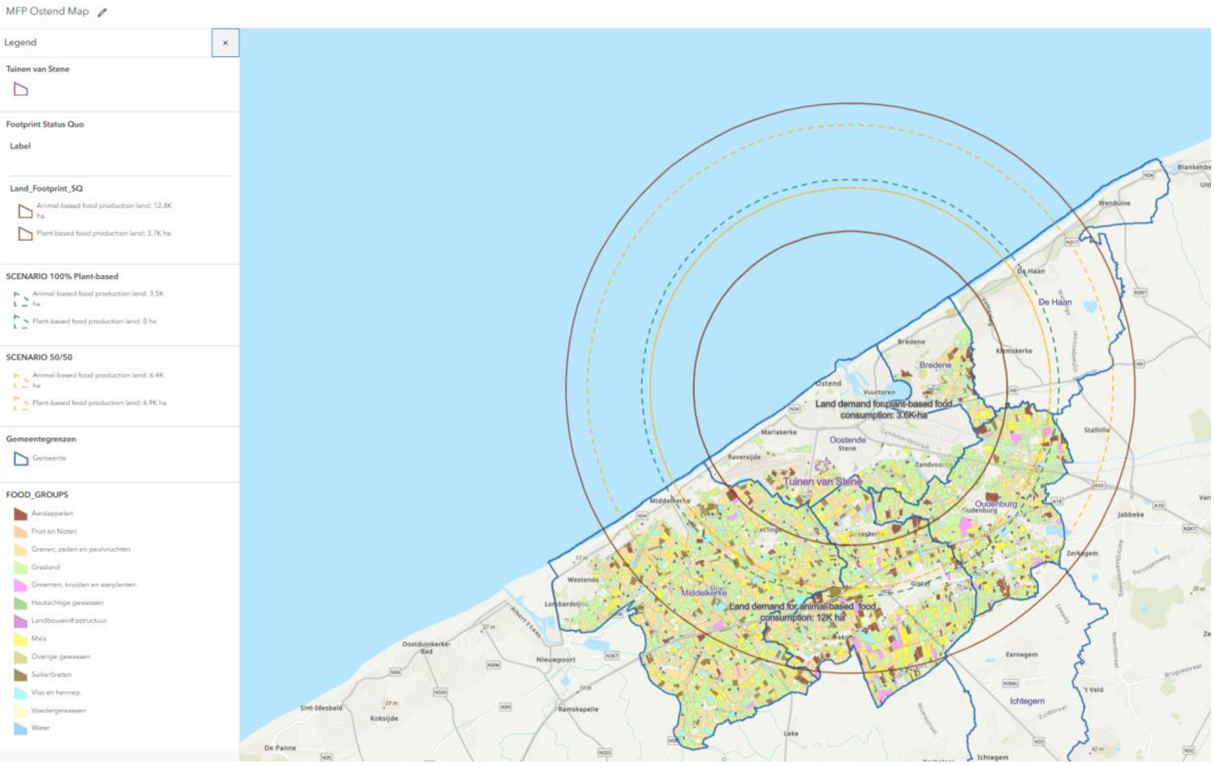

Figure 4: Land footprint of two proposed food consumption scenarios vs status quo, for the FAL Ostend.

MFP is an online web application built within ESRI GeoPlanner®, which runs on any internet browser. Figure 5 shows a screenshot of the GeoPlanner interface. MFP is typically used in combination with a touchscreen. MFP can be viewed as an interactive GIS with both co-design and impact assessment capabilities. MFP users can browse through the map layers, toggle layer on and off, change transparencies, navigate across the study area, and make map layer combinations to support the discussion. Additionally, MFP allows users to select a scenario and change the agricultural use on desired spots in the area. Users first select an area, discuss changes, and then implement these changes by selecting a new land use (i.e., a food group or innovative crop) from a palette and 'paint' it on the desired parcel to replace it. MFP immediately recalculates indicators, such as hectares per food group or food production. The interactive full list of available map layers for Ostend can be found in this link:

https://geoplaza.maps.arcgis.com/apps/mapviewer/index.html?webmap=3b92b5583a4f40b7b09b919023115786

The information on food consumption footprints was also used by the workshop participants to discuss and explore potential changes in agricultural land use in the city of Ostend. The soil quality was also used substantially for these tasks. More sustainable crops, or perhaps more suitable for the soils in Ostend, such as sorghum and quinoa were considered as alternative crops for land use allocation. Similarly, food innovations, such as agro-parks, food forests, and community gardens were considered for agricultural land use reallocation.

Sorghum needs much less nitrogen fertilization than wheat and corn. Wheat needs 240 kg/ha of nitrogen fertilization, maize 190 kg/ha and sorghum 70 kg/ha. For example, in the Dutch wheat area is 150,000 ha and that of maize 230,000 ha. If the livestock farming fresh menu is divided, half, or 115,000 hectares, of the corn can be replaced by sorghum. The nitrogen gain is then 120 kg/ha or a total of approximately fourteen million kilograms. Quinoa can be a meat substitute. Quinoa can grow in the cold, dry highlands of South America and produces high yields without requiring intensive cultivation of the land. Quinoa is resistant to night frost and can grow in very poor soil. Food forests are production forests that consist of seven to nine productive layers. Together these form their own ecosystem that produces a lot of food. Workshop participants used MFP to quantify the impacts of two scenarios:

- All maize fields around Ostend become SORGHUM fields
- The ‘stadsrandbos’ forest located near the ‘Gardens of Stene’ agro-park to become a FOOD FOREST

Figure 5 shows a screenshot of the MFP tool with map of the study area around the city of Ostend, in which all maize fields have been replaced by sorghum fields. A dashboard above the map shows the total number of hectares of sorghum and the projected sorghum production for this scenario. This projection was calculated using FAOSTAT using 2021 as the reference year, and available here:

https://ourworldindata.org/grapher/sorghum-yield

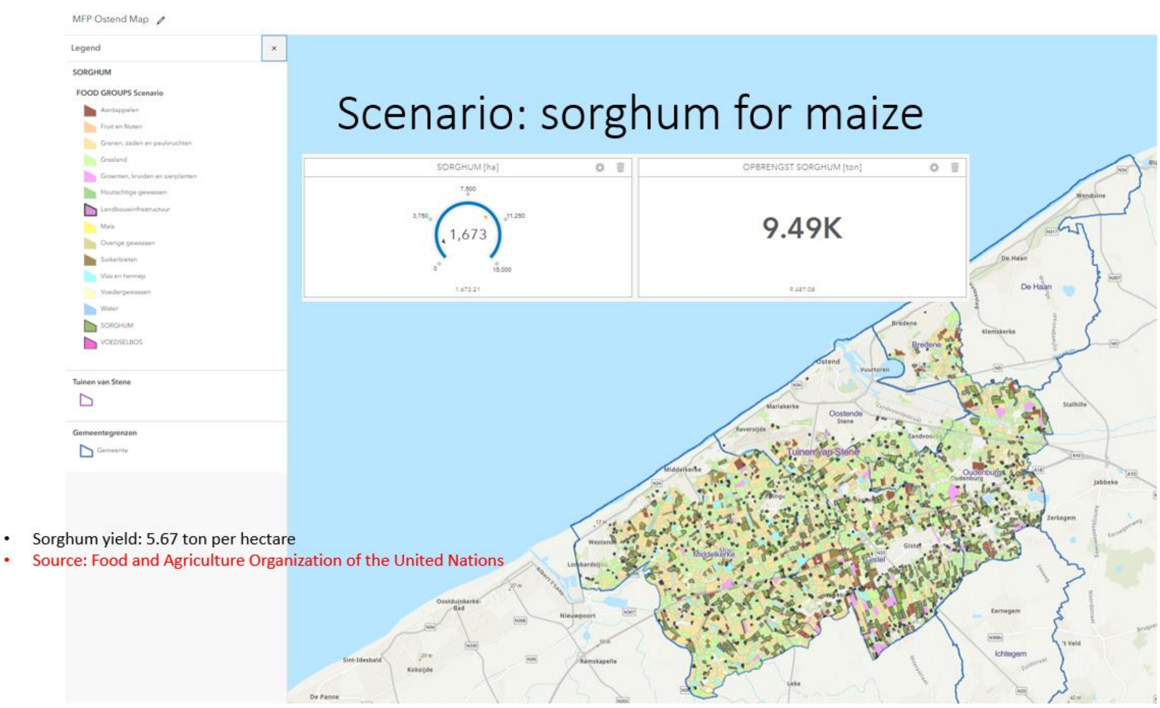

Figure 5: Agricultural land use scenario. Screenshot of MFP showing the mapping of the scenario and their effects in the dashboard.

Figure 6 show a screenshot of MFP with a map of the city forest and its location with respect to the agro-park 'Gardens of Stene'. The figure shows the scenario that replaces the forest with a food forest food innovation. The projected production of this new food forest is also show in the dashboard: 114 hectares of food forest would result in around 1020 tons of vegetables, fruits, and other food products. While this scenario is a radical and rather unlikely scenario to be realised because the city forest is designated as a nature development area, it allowed participants to get a feel of the consequences of changes in agricultural land use for the city.

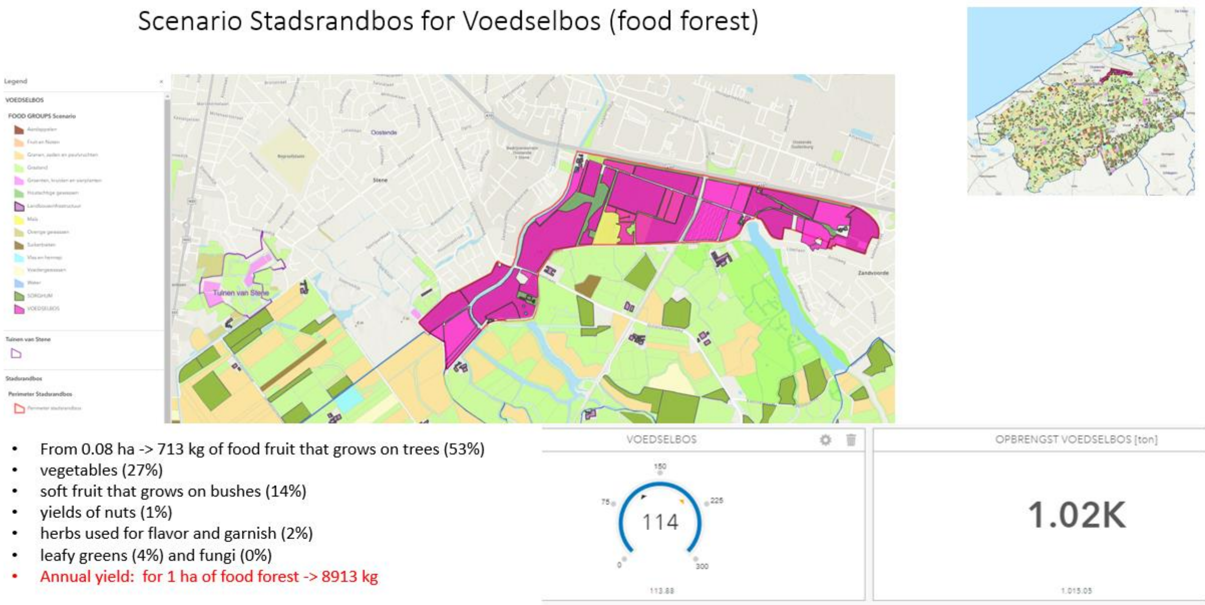

Figure 6: Agricultural land use scenario for the city forest in Ostend. *Source: Josefine Lærke Skrøder Nytofte, Christian Bugge Henriksen (2019). Sustainable food production in a temperate climate – a case study analysis of the nutritional yield in a peri-urban food forest. Urban Forestry & Urban Greening, Volume 45.*

3.2. CRFA

The main source of data for **Ostend FAL** was the online short chain map 'Korte Keten Kaart' platform[16]. The collaboration with Ostend FAL resulted in obtaining 164 food origin of food products available in the region around Ostend. The research didn't consider the quantity of the food, nor the type of the food, whilst the focus was on the location - food origin.

Then, an attempt was made to classify the data into class intervals to select the first class of divided data which should represent the closest ('most local') food origins required for foodshed delimitation.

[16] https://www.korteketenkaart.be/kaart

For this purpose, the natural interval method (Natural Breaks/natural ranges) was used. Natural ranges are based on the principle of minimizing differences between data collected within a class and maximizing differences between classes. However, due to the convergence of collected food origin data, it was not possible to separate significantly different classes from each other - the data set was not characterized by variability (variance). Therefore, all obtained food origins and delimited food flows represented one class and were used for foodshed delimitation.

Foodshed was delimited using the "Minimum Bounding Geometry" tool creating feature classes containing polygons that represented a specified minimum bounding geometry enclosing each input feature (food origins). There were delimited two types of geometry: (1) convex hull - the smallest convex polygon enclosing an input feature, and (2) circle - the smallest circle enclosing an input feature.

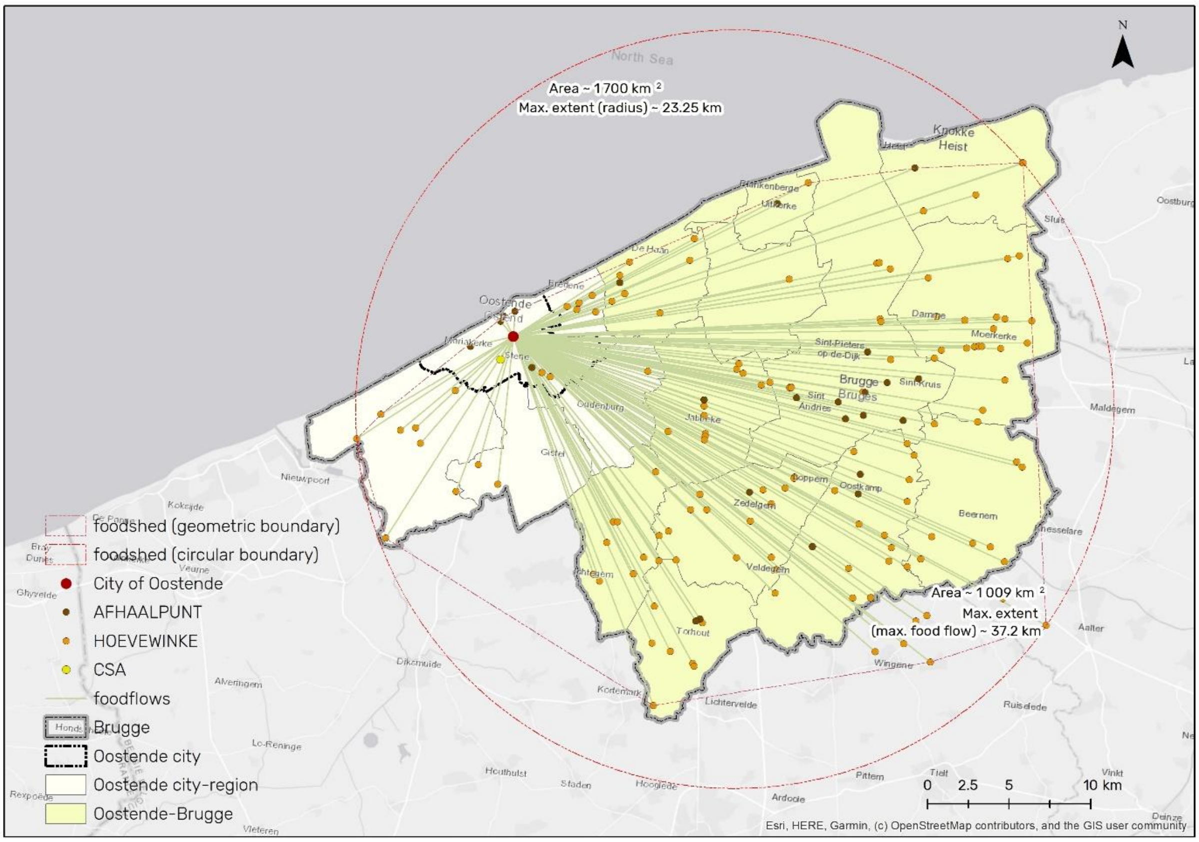

Figure 7: Results of foodshed delimitation using food-flow analysis for OST FAL. *The white area (Ostend city-region) represents the so called functional urban area – FUA. The yellow area (Ostend-Brugge) represents the supra-local context – out of the FUA.*

The area of the foodshed delimited as polygon (using convex hull) has almost 1009 km^2, wherein circular is almost 1700 km^2 and maximum extent (radius) of 23.25 km (Figure 7). The results presented the local food availability extent (radius) as 23 km and maximum food flow – 37 km are in line with the results obtained by Karg et al. (2016) noted that 50% of the metropolitan resident's food demands are met by an average radius of ca. 100 km[17].

Having geocoded food origins, the additional analysis for Ostend FAL was conducted (Figure 8). Therefore, areas of high and low occurrence of food origin were delimited using the "Hot Spot" statistical analysis and heat-map visualization.

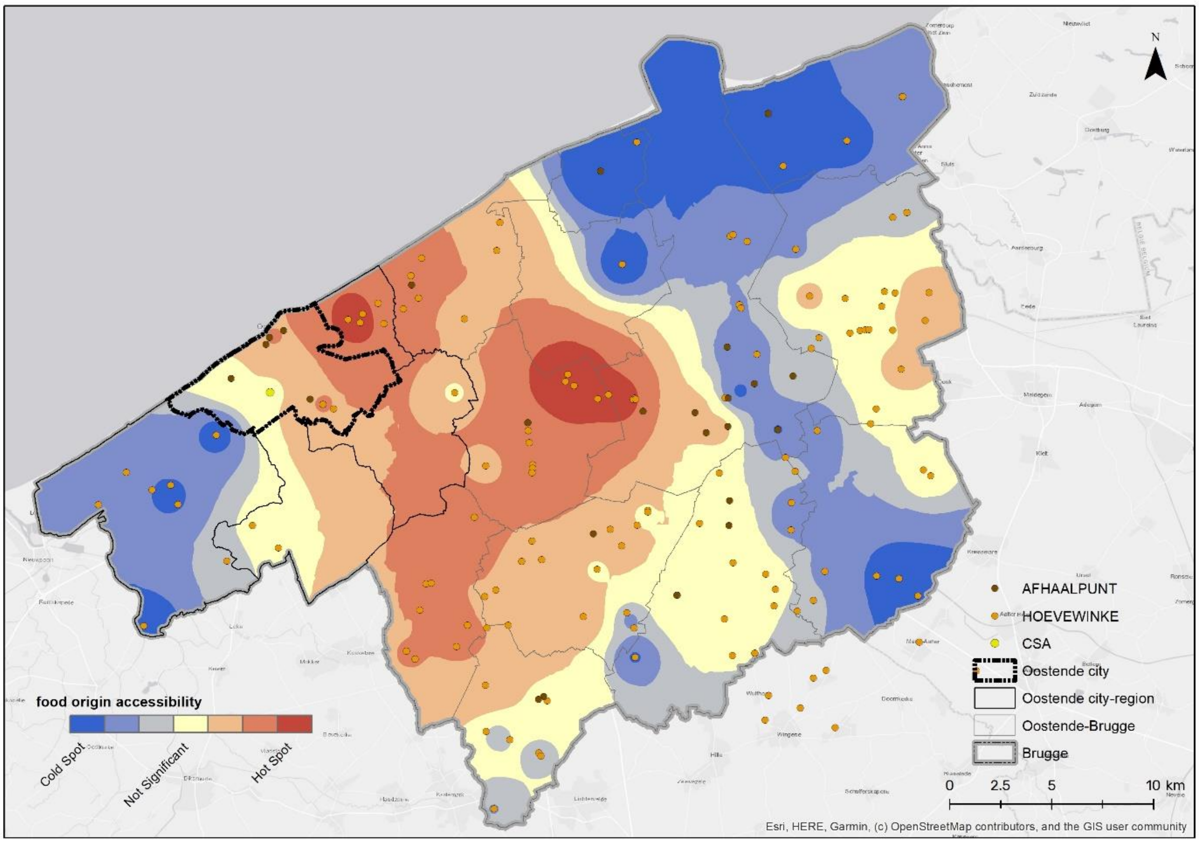

Figure 8: Hot-spot analysis of food origin for OST FAL. *The high occurrence of food origin is marked by red colour. The low occurrence is marked by blue colour. The yellow colour represents statistically insignificant locations.*

The designation of an area as a "Hot Spot" is expressed on a scale based on statistical confidence intervals, which makes the areas determined by this method statistically significant and the final visualization less subjective. The results showed that statistically significant areas of the high occurrence of food origins are located southeast and east of the Ostend city border.

3.3. Carbon footprint of the CSA in the Gardens of Stene

To assess the carbon footprint of the vegetables harvested in the community supported agriculture (csa) in the agro-park Gardens of Stene (CF_{LP}), we considered:

[17] Karg H., Drechsel, P., Akoto-Danso, E., Glaser, R., Nyarko, G., & Buerkert, A. (2016). *Foodsheds and City Region Food Systems in Two West African Cities.* Sustainability, 8(12), 1175. https://doi.org/10.3390/su8121175

- the average amount for local vegetables purchased by a customer [kg],
- the average number of kilometres driven to acquire the product [km],
- CO_{2eq} emissions per kilometre (depending on fuel type) [CO_{2eq}/km].

The average amount for a local product purchased by a customer [kg] was assessed based on input data representing delivered food (vegetables) available within CSA boxes as a basis for calculations. The average amount of each food product for whole season was assessed based on three different veg boxes possible to obtain from agro-park Tuinen van Stene: (1) 2-weekly box (14-daags packet); (2) large weekly box (groot wekelijks packet); (3) small weekly box (klein wekelijks packet). The date of the harvest of 2022 was used. These vegetable amounts in the boxes were then extrapolated to the total number of participants in the csa, where the majority picks their own vegetables. Of the 57 plants, some characterized the largest delivery (Table 5) as lettuce 3.833 kg, spring onion ~ 1.917 kg, carrot ~ 1.879 kg, or potatoes ~ 1.583 kg (for more see **Appendix A**).

Table 5. The greatest annual overall product delivery volumes among the 57 plants .

vegetable	lettuce	spring onion	carrot (bunch)	cucumber	potato	fennel	celery	kohlrabi	chicory endive	pumpkin
Total gewicht (kg)	3833.33	1916.67	1879.17	1833.33	1583.33	1500	1500	1312.5	1250	1216.67

The average number of kilometers driven to acquire the product [km] was assessed based on distances calculated between centroid of residential areas (selected from Corine Land Cover – CLC) and location of Tuinen van Stene – official address Steensedijk 121, Ostend 8400 was used to be geocoded as a point location. It gave the average distance [km] - mean: 2.74 km (Figure 9).

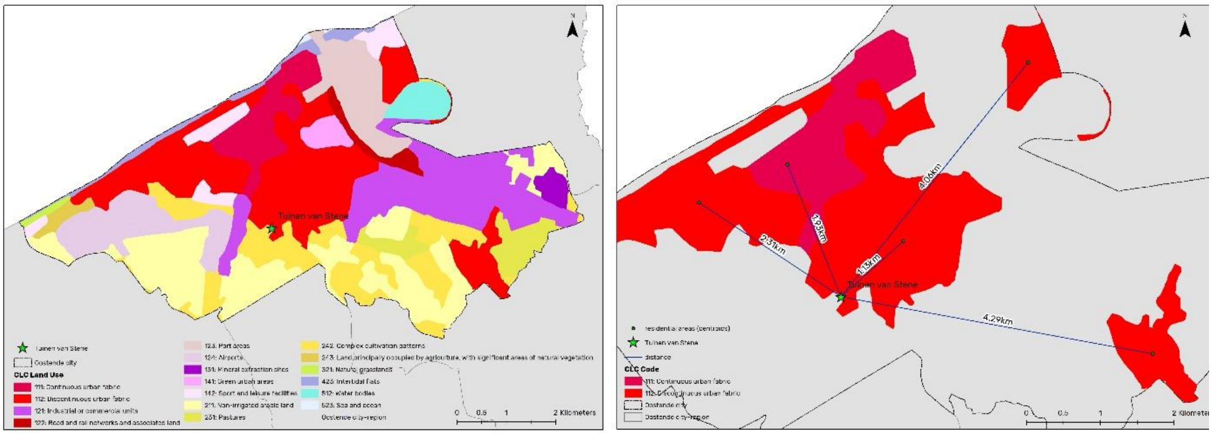

Figure 9: Calculation of distances between residential areas centroids and location of Tuinen van Stene.

The CO_{2eq} emissions per kilometre [CO_{2eq}/km] was assessed based on assumptions obtained from the city of Ostend, which estimated that 20% of the vegetables were picked up by car, and 80% by bike or foot. For assessment we used emission factors[18], as 170g CO_{2eq} for car and 16g CO_{2eq} for bike-foot. Thus, the car emission was assumed as 170g, and bike-foot as 16 g. Taking into consideration the share of pick-up by car (20%), and bike-foot (80%) to the final assessment value of **46,8 g CO_{2eq}** (0.2×170g + 0.8×16g) was used.

Having the average number of kilometres driven to acquire the product, and the average amount of each food product available per box or food share, it was possible to calculate **food-miles** (number of kilometres per kg of a given product). The quotient of food-miles and the emission factor allowed to calculate the carbon footprint of the local product per kg/l of product. Thus, products that were characterized by the smallest number of kg, and thus the largest food-miles (the more kg for the same distance travelled by food, the smaller the food-miles) were also characterized by the highest footprint values (Table 6; for more see Appendix A).

Table 6. The highest values of food-miles and CF of local food products.

Vegetable	**Food-miles** [km/kg] *using an average distance 2.74km*	**Carbon Footprint of Local Product** [gCO_{2eq}/kg] *using the emission factor 46.8 gCO_{2eq}/km*
mustard salad	0.329	15.3972
corn salad	0.329	15.3972
chiogga beet	0.164	7.6752
parsnip	0.164	7.6752
red beet	0.164	7.6752
parsley	0.132	6.1776
cherry tomato	0.082	3.8376
carrots	0.082	3.8376
carrot	0.051	2.3868
asian lettuce	0.037	1.7316

Finally, the quotient of the total amount [kg] and CF_{LP} [gCO_{2eq}/kg] of products allowed to calculate the **total CF** for the 250 boxes provided during the whole season, which gave 7188.37g CO_{2eq} (28.75 gCO_{2eq} per box). Moreover, if the same products, or the groups of products to which they belonged (see more Appendix A, Table A3), were purchased from a global supply chain rather than an agro-park, the carbon footprint would be 641 times higher from a global chain vs. agro-park. The value from the whole season from the global chain was quantified as (see more in Appendix A, Table A4):

4 609 693 gCO_{2eq}, and per box as 18 438.77 gCO_{2eq} (18.5 $kgCO_{2eq}$!).

Thus, the Ostend case and its innovative local short supply chain can illustrate how shortening transportation can makes a major difference in reducing the impact of this stage of the supply chain.

[18] The average CO_{2eq} emission per km by diesel car is 171 g; petrol car is 170 g; bike 16 to 50 grams CO_{2eq} per km. *Source: UK Government, Department for Energy Security and Net Zero*: https://ourworldindata.org/travel-carbon-footprint

4. Conclusions

The analyses carried out to assess the current state of the food system in Ostend can contribute to the discussion on the creation of new food strategies/policies.

The aspect of food policy is increasingly getting more attention, which relates to uncertainties due to the ongoing climate and epidemiological crisis. As the "overview" has shown, a very important aspect for all FALs is a community building around food, as evidenced by the many demonstrated food initiatives created for the community and by the community.

Results indicate that a food system assessment would need to be done by delimitation of two different types of areas providing food for cities – two different foodsheds (plant-based and meat-based).

The results obtained can show the potential of city regions in terms of available products, and food origins, within a range of 100 kilometres. The analysis can answer the question of to what extent cities are resilient to potential crises that could undermine food systems. For this purpose, could be important research, equally in terms of food origins, but also food self-sufficiency.

It should be emphasized that the food system assessment analyses were carried out following the needs of the FAL Ostend and tailored to these needs. Studies in this area are also characterized by certain limitations that cities aiming to conduct this type of analysis must bear in mind, these are primarily the availability, acuity, and detail of input data for analysis.

Appendix A: The total results for 250 food boxes delivered from agro-park.

Table A1: Results obtained for whole season: total weight of provided food; food-miles and carbon footprint of local product.

vegetable	Total [gewicht (kg)]	Food-miles [km/kg] *using average distance 2.74km*	Carbon Footprint of Local Product [gCO2eq/kg] *using the emission factor 46.8g CO2eq/km*
mustard salad	8.33	0.329	15.3972
corn salad	8.33	0.329	15.3972
chiogga beet	16.67	0.164	7.6752
parsnip	16.67	0.164	7.6752
red beet	16.67	0.164	7.6752
parsley	20.83	0.132	6.1776
cherry tomato	33.33	0.082	3.8376
carrots	33.33	0.082	3.8376
carrot	54.17	0.051	2.3868
asian lettuce	75	0.037	1.7316
basil	83.33	0.033	1.5444
palm cabbage	83.33	0.033	1.5444
romanesco	83.33	0.033	1.5444
chard	83.33	0.033	1.5444
kale	125	0.022	1.0296
Brussels sprouts	137.5	0.02	0.936
wasabini	146.67	0.019	0.8892
broccoli	166.67	0.016	0.7488
winter purslane	166.67	0.016	0.7488
bush bean	200	0.014	0.6552
Jerusalem artichoke	216.67	0.013	0.6084
parsley root	212.5	0.013	0.6084
bell bell pepper	229.17	0.012	0.5616
warmoes	250	0.011	0.5148
turnip	316.67	0.009	0.4212
yellow beets	333.33	0.008	0.3744
pointed cabbage	333.33	0.008	0.3744
eggplant	325	0.008	0.3744
pak choi	416.67	0.007	0.3276
turnip	416.67	0.007	0.3276
fennel	366.67	0.007	0.3276
chervil (bunch); french parsley	583.33	0.005	0.234
red cabbage	583.33	0.005	0.234
celeriac	500	0.005	0.234
spicy pepper	500	0.005	0.234
radicchio	500	0.005	0.234
white cabbage	500	0.005	0.234
cauliflower	750	0.004	0.1872
parsley	750	0.004	0.1872
chinese cabbage	666.67	0.004	0.1872
endive (lettuce chicory)	666.67	0.004	0.1872
beet (bunch)	895.83	0.003	0.1404

Tomato	862.5	0.003	0.1404
zucchini	833.33	0.003	0.1404
radish (bunch)	833.33	0.003	0.1404
savoy cabbage	833.33	0.003	0.1404
leek	783.33	0.003	0.1404
potato	1583.33	0.002	0.0936
fennel	1500	0.002	0.0936
celery	1500	0.002	0.0936
kohlrabi	1312.5	0.002	0.0936
chicory endive	1250	0.002	0.0936
pumpkin	1216.67	0.002	0.0936
lettuce	3833.33	0.001	0.0468
spring onion	1916.67	0.001	0.0468
carrot (bunch)	1879.17	0.001	0.0468
cucumber	1833.33	0.001	0.0468

Table A2: Total carbon footprint of local products in delivered 250 boxes from agro-park.

vegetable	Total [gewicht (kg)]	Carbon Footprint of Local Product [gCO2eq/kg] *using the emission factor 46.8g CO2eq/km*	CF Total [gCO2eq]
lettuce	3833.33	0.0468	179.40
potato	1583.33	0.0936	148.20
cauliflower	750	0.1872	140.40
parsley	750	0.1872	140.40
fennel	1500	0.0936	140.40
celery	1500	0.0936	140.40
pak choi	416.67	0.3276	136.50
turnip	416.67	0.3276	136.50
chervil (bunch); french parsley	583.33	0.234	136.50
red cabbage	583.33	0.234	136.50
turnip	316.67	0.4212	133.38
Jerusalem artichoke	216.67	0.6084	131.82
bush bean	200	0.6552	131.04
wasabini	146.67	0.8892	130.42
asian lettuce	75	1.7316	129.87
carrot	54.17	2.3868	129.29
parsley root	212.5	0.6084	129.29
bell bell pepper	229.17	0.5616	128.70
kale	125	1.0296	128.70
Brussels sprouts	137.5	0.936	128.70
warmoes	250	0.5148	128.70
basil	83.33	1.5444	128.69
palm cabbage	83.33	1.5444	128.69
romanesco	83.33	1.5444	128.69
chard	83.33	1.5444	128.69
parsley	20.83	6.1776	128.68

mustard salad	8.33	15.3972	128.26
corn salad	8.33	15.3972	128.26
chiogga beet	16.67	7.6752	127.95
parsnip	16.67	7.6752	127.95
red beet	16.67	7.6752	127.95
cherry tomato	33.33	3.8376	127.91
carrots	33.33	3.8376	127.91
beet (bunch)	895.83	0.1404	125.77
broccoli	166.67	0.7488	124.80
winter purslane	166.67	0.7488	124.80
chinese cabbage	666.67	0.1872	124.80
endive (lettuce chicory)	666.67	0.1872	124.80
yellow beets	333.33	0.3744	124.80
pointed cabbage	333.33	0.3744	124.80
kohlrabi	1312.5	0.0936	122.85
eggplant	325	0.3744	121.68
Tomato	862.5	0.1404	121.10
fennel	366.67	0.3276	120.12
celeriac	500	0.234	117.00
spicy pepper	500	0.234	117.00
radicchio	500	0.234	117.00
white cabbage	500	0.234	117.00
chicory endive	1250	0.0936	117.00
zucchini	833.33	0.1404	117.00
radish (bunch)	833.33	0.1404	117.00
savoy cabbage	833.33	0.1404	117.00
pumpkin	1216.67	0.0936	113.88
leek	783.33	0.1404	109.98
spring onion	1916.67	0.0468	89.70
carrot (bunch)	1879.17	0.0468	87.95
cucumber	1833.33	0.0468	85.80
		Total:	**7188.37**
		Total per box:	28.75

Table A3: The results of comparing the emissivity of local products and global or local products with global product groups, where local products can be included.

vegetable ENG	Product or product group for comparison (Nemeck & Poore)	Carbon Footprint of Local Product [gCO2eq/kg]	Carbon Footprint of Global Product Transport [gCO2eq/kg]	Difference CFLP vs CFGP
lettuce	Other Vegetables	0.0468	165.55	3537.4
cucumber	Other Vegetables	0.0468	165.55	3537.4
carrot (bunch)	Root Vegetables	0.0468	113.77	2431
spring onion	Onions & Leeks	0.0468	94.78	2025.3
fennel	Other Vegetables	0.0936	165.55	1768.7
kohlrabi	Other Vegetables	0.0936	165.55	1768.7
chicory endive	Other Vegetables	0.0936	165.55	1768.7
pumpkin	Other Vegetables	0.0936	165.55	1768.7
Tomato	Tomatoes	0.1404	177.11	1261.5
celery	Root Vegetables	0.0936	113.77	1215.5
beet (bunch)	Other Vegetables	0.1404	165.55	1179.1
zucchini	Other Vegetables	0.1404	165.55	1179.1
potato	Potatoes	0.0936	93.87	1002.9
parsley	Other Vegetables	0.1872	165.55	884.3
endive (lettuce chicory)	Other Vegetables	0.1872	165.55	884.3
radish (bunch)	Root Vegetables	0.1404	113.77	810.3
chervil (bunch); french parsley	Other Vegetables	0.234	165.55	707.5
spicy pepper	Other Vegetables	0.234	165.55	707.5
leek	Onions & Leeks	0.1404	94.78	675.1
savoy cabbage	Brassicas	0.1404	94.64	674.1
cauliflower	Brassicas	0.1872	94.64	505.6
chinese cabbage	Brassicas	0.1872	94.64	505.6
fennel	Other Vegetables	0.3276	165.55	505.3
celeriac	Root Vegetables	0.234	113.77	486.2
eggplant	Other Vegetables	0.3744	165.55	442.2
red cabbage	Brassicas	0.234	94.64	404.4
radicchio	Brassicas	0.234	94.64	404.4
white cabbage	Brassicas	0.234	94.64	404.4
turnip	Root Vegetables	0.3276	113.77	347.3
warmoes	Other Vegetables	0.5148	165.55	321.6
yellow beets	Root Vegetables	0.3744	113.77	303.9
bell bell pepper	Other Vegetables	0.5616	165.55	294.8
pak choi	Brassicas	0.3276	94.64	288.9
parsley root	Other Vegetables	0.6084	165.55	272.1
turnip	Root Vegetables	0.4212	113.77	270.1
pointed cabbage	Brassicas	0.3744	94.64	252.8
winter purslane	Other Vegetables	0.7488	165.55	221.1
Jerusalem artichoke	Root Vegetables	0.6084	113.77	187
wasabini	Other Vegetables	0.8892	165.55	186.2
bush bean	Other Pulses	0.6552	96.18	146.8
broccoli	Brassicas	0.7488	94.64	126.4
basil	Other Vegetables	1.5444	165.55	107.2
chard	Other Vegetables	1.5444	165.55	107.2

Brussels sprouts	Brassicas	0.936	94.64	101.1
asian lettuce	Other Vegetables	1.7316	165.55	95.6
kale	Brassicas	1.0296	94.64	91.9
palm cabbage	Brassicas	1.5444	94.64	61.3
romanesco	Brassicas	1.5444	94.64	61.3
carrot	Root Vegetables	2.3868	113.77	47.7
cherry tomato	Tomatoes	3.8376	177.11	46.2
carrots	Root Vegetables	3.8376	113.77	29.6
parsley	Other Vegetables	6.1776	165.55	26.8
chiogga beet	Root Vegetables	7.6752	113.77	14.8
parsnip	Root Vegetables	7.6752	113.77	14.8
red beet	Root Vegetables	7.6752	113.77	14.8
mustard salad	Other Vegetables	15.3972	165.55	10.8
corn salad	Other Vegetables	15.3972	165.55	10.8

Table A4: Results of carbon footprint assessment using local and global emission factors.

vegetable	Total [gewicht (kg)]	Carbon Footprint of Local Product - CF_{LP} [gCO_{2eq}/kg]	Carbon Footprint of Global Product transport - CF_{GP} [gCO2eq/kg]	CF_{LP} Total [gCO_{2eq}]	CF_{GP} Total [gCO_{2eq}]
asian lettuce	75	1.73	165.55	129.87	12416.23
basil	83.33	1.54	165.55	128.69	13795.26
beet (bunch)	895.83	0.14	165.55	125.77	148304.42
bell bell pepper	229.17	0.56	165.55	128.70	37939.03
broccoli	166.67	0.75	94.64	124.80	15773.80
Brussels sprouts	137.5	0.94	94.64	128.70	13013.12
bush bean	200	0.66	96.18	131.04	19235.39
carrot	54.17	2.39	113.77	129.29	6162.90
carrot (bunch)	1879.17	0.05	113.77	87.95	213792.53
carrots	33.33	3.84	113.77	127.91	3791.94
cauliflower	750	0.19	94.64	140.40	70980.66
celeriac	500	0.23	113.77	117.00	56884.83
celery	1500	0.09	113.77	140.40	170654.49
chard	83.33	1.54	165.55	128.69	13795.26
cherry tomato	33.33	3.84	177.11	127.91	5903.10
chervil (bunch); french parsley	583.33	0.23	165.55	136.50	96570.13
chicory endive	1250	0.09	165.55	117.00	206937.17
chinese cabbage	666.67	0.19	94.64	124.80	63094.24
chiogga beet	16.67	7.68	113.77	127.95	1896.54
corn salad	8.33	15.40	165.55	128.26	1379.03
cucumber	1833.33	0.05	165.55	85.80	303507.30
eggplant	325	0.37	165.55	121.68	53803.66
endive (lettuce chicory)	666.67	0.19	165.55	124.80	110367.04
fennel	366.67	0.33	165.55	120.12	60702.12
fennel	1500	0.09	165.55	140.40	248324.61
Jerusalem artichoke	216.67	0.61	113.77	131.82	24650.47
kale	125	1.03	94.64	128.70	11830.11
kohlrabi	1312.5	0.09	165.55	122.85	217284.03
leek	783.33	0.14	94.78	109.98	74245.49
lettuce	3833.33	0.05	165.55	179.40	634606.77
mustard salad	8.33	15.40	165.55	128.26	1379.03
pak choi	416.67	0.33	94.64	136.50	39434.02
palm cabbage	83.33	1.54	94.64	128.69	7886.42
parsley	750	0.19	165.55	140.40	124162.30
parsley	20.83	6.18	165.55	128.68	3448.40
parsley root	212.5	0.61	165.55	129.29	35179.32
parsnip	16.67	7.68	113.77	127.95	1896.54
pointed cabbage	333.33	0.37	94.64	124.80	31546.65
potato	1583.33	0.09	93.87	148.20	148622.69
pumpkin	1216.67	0.09	165.55	113.88	201419.40
radicchio	500	0.23	94.64	117.00	47320.44
radish (bunch)	833.33	0.14	113.77	117.00	94807.67
red beet	16.67	7.68	113.77	127.95	1896.54
red cabbage	583.33	0.23	94.64	136.50	55206.87

romanesco	83.33	1.54	94.64	128.69	7886.42
savoy cabbage	833.33	0.14	94.64	117.00	78867.09
spicy pepper	500	0.23	165.55	117.00	82774.87
spring onion	1916.67	0.05	94.78	89.70	181665.58
Tomato	862.5	0.14	177.11	121.10	152758.04
turnip	416.67	0.33	113.77	136.50	47404.40
turnip	316.67	0.42	113.77	133.38	36027.44
warmoes	250	0.51	165.55	128.70	41387.43
wasabini	146.67	0.89	165.55	130.42	24281.18
white cabbage	500	0.23	94.64	117.00	47320.44
winter purslane	166.67	0.75	165.55	124.80	27592.17
yellow beets	333.33	0.37	113.77	124.80	37922.84
zucchini	833.33	0.14	165.55	117.00	137957.56
Total emissions for all box products from the entire season [gCO_{2eq}]				**7188.368**	**4609693.44**
Total emissions for all products for one box from the entire season [gCO_{2eq}]				**28.753**	**18438.774**

Appendix B: Food demand per capita for the city of Ostend for the scenarios

Table B1. Scenario 100% plant-based (based on assumptions, there are no dietary guidelines available for plant-based diet)

Food group	Demand (ha) plant-based	Demand (ha) animal-based
Potatoes	**1765**	
Fruits and nuts	3284	
Cereals, seeds, legumes	1116	
Grassland		
Vegetables	271	
Maize		
Sugar beet	1176	
Fodder		
Footprint	7612	
TOTAL FOOTPRINT	**7612**	

Table B2. Half/half strategy

Food group	Demand (ha) plant-based	Demand (ha) animal-based
Potatoes	**1765**	
Fruits and nuts	3284	
Cereals, seeds, legumes	493	
Grassland		1804
Vegetables	262	
Maize		
Sugar beet	1176	
Fodder		4619
Footprint	6980	6424
TOTAL FOOTPRINT	**13403**	

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 862716.