

## A SPATIAL TYPOLOGY FOR DESIGNING A LOCAL FOOD SYSTEM

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*Keywords: keyword urban design, urban agriculture, spatial typology, local food, design process*

*Abstract: The local food system comprises productive elements ranging from balcony gardens, kitchen gardens, community gardens and fish ponds to multifunctional urban farms, food forests or dairy farms in the green infrastructure. For planning, designing and evaluating a sustainable, local food system a spatial typology of urban agriculture is required. This leads to the following research questions. What are the spatial types required to design a local food system for an existing urban area? And how can a designer evaluate the design as to productive capacity for local food?*

*Key publications and student research provide a broad spectrum of types of urban agriculture, based on goals, organisation, production systems, products and functions. From this we can deduce a set of spatial categories.*

*The spatial typology can be used to programme and design local food production elements in urban areas. The types are related to areas with individual houses and apartment blocks, (semi-) public urban open space, and green infrastructure.*

*To be able to compare the consumption of food with the potential production a local urban food calculator (LUFC) is developed. This can be used in two ways. Firstly to chart to what extent the potential production in an urban area meets the needs of its inhabitants. Secondly it can be used as an evaluation tool to measure to what extent the design of a local food system can provide in the needs of the consumers. Two existing residential areas in the city of Arnhem in the Netherlands are used as first test case.*

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### 1. Introduction

The local food system comprises productive elements ranging from balcony gardens, kitchen gardens, community gardens, and fish farms to multifunctional urban farms, food forests, intensive greenhouses or dairy farms in the green infrastructure. For planning, designing and evaluating a sustainable, local food system for urban areas a spatial typology of urban agriculture is required. This supports integrated development of urban agricultural systems and it provides the opportunity to increase the amount of food produced. This leads to two main research questions: What are the spatial types required to design a local food system for an existing urban area? And how can a designer evaluate the design as to productive capacity for local food? In order to answer this series of research questions are defined in Scheme 1.

### 2. Spatial typology of urban agriculture

Key publications on urban agriculture edited by Philips (2013), Viljoen & Bohn (2014) and Roggema & Keeffe (2014) provide a broad spectrum of types of urban agriculture, which are based on goals, organisation, production systems, products and functions. De Graaf (2011) organised urban

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agriculture on the basis of artificial or more self-regulating systems and whether it is related to built-up structures or open field cultivation. The sources illustrate these typologies with reference projects. In a series of student projects the typology of urban agriculture has been researched. Landscape architecture students of VHL (Hommel, Streng and Verheij, 2014; Kors and Floor, 2014) analysed urban agriculture and developed spatial categories, such as the kitchen garden, the advanced kitchen garden, the landscape management farm, the urban estate and the green infrastructure farm.

**Scheme 1. Set of research questions for the evaluation of local food design**

Production	Consumption
Which types of urban agriculture elements can be planned?	What is the average diet of Dutch consumers?
What kind of crops and animal produce can these provide?	Which type of food can be produced locally in the city?
What is the average yield of the crops and produce?	How many inhabitants are there in the planning area?
What surface of each types of urban agriculture can be programmed in the area?	
What is the total potential production of local food per year in the area?	What is the total amount of food that is yearly required for the area?
To what extent does the production meets the required consumption and can this be adapted by changing the programme for urban agriculture?	

**Table 1. Spatial typology of urban agriculture with average surface and type of produce**

Type of urban agriculture	Organisation	Approximate production area per unit	Main crops and animal produce
Productive house (indoor) private	Private	2 to 20 m <sup>2</sup> per house	mostly vegetables, herbs, and fruits
Productive roof (flat) private	Private	20 to 50 m <sup>2</sup> per house	mostly vegetables, herbs, and fruits
Productive roof (flat), aquaponics	Private	20 to 50 m <sup>2</sup> per house	vegetables and fish
Kitchen gardens	Private	50 to 300 m <sup>2</sup> per house	potatoes, vegetables, herbs, and fruits
Allotment gardens	Private	complex 5,000 to 20,000 m <sup>2</sup>	potatoes, vegetables, herbs, and fruits
Community gardens, open field	Collective	400 to 10,000 m <sup>2</sup>	potatoes, vegetables, herbs, and fruits
Community gardens, glass house	Collective	200 to 5,000 m <sup>2</sup>	vegetables, herbs, and fruits
Edible green amenities	Public	400 to 10,000 m <sup>2</sup>	fruits and nuts
Roof gardens aquaponics	Professional	500 to 1,500 m <sup>2</sup>	vegetables and fish
Professional horticulture, open field	Professional	5,000 to 40,000 m <sup>2</sup>	potatoes, vegetables, herbs, and fruits
Professional horticulture, glass house	Professional	5,000 to 10,000 m <sup>2</sup>	vegetables, herbs, and fruits
Professional hydroponics	Professional	1,500 to 10,000 m <sup>2</sup>	vegetables, herbs, fruits, and fish
Urban farm	Professional	300,000 to 800,000 m <sup>2</sup>	combination of meat, potatoes, vegetables
Green infrastructure farm	Professional	300,000 to 1,200,000 m <sup>2</sup>	combination of meat, wheat, vegetables

An inventory of the described types of urban agriculture was made and categorised on the bases of their spatial characteristics. A spatial typology has been developed, which can be used to programme and design local food production elements in urban areas. Making use of the properties of reference projects for each spatial type an indication of the surface area, production systems, crops and products was defined (Table 1). The private ones are to be located in private houses and gardens. The collective gardens can be located in (semi) public space or unbuilt private plots. The professionally managed types need larger surfaces in order to be profitable. Roof gardens can be located on larger buildings, the farms on private agricultural land or integrated into existing green infrastructure or the urban fringe areas.

The main crops for each type are based on what is found in the reference projects in the Netherlands. For the representation in designs proposals and maps for each type an icons is made.






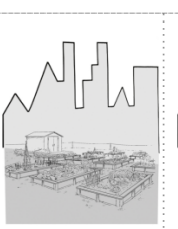
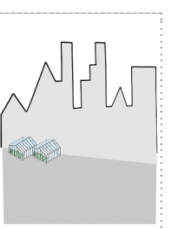

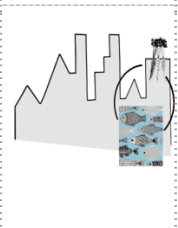
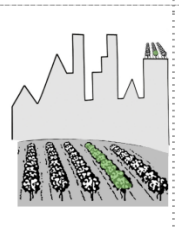
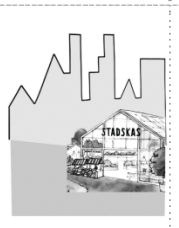
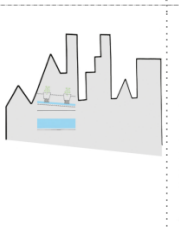
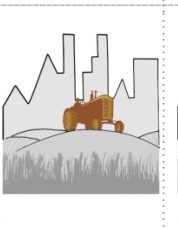
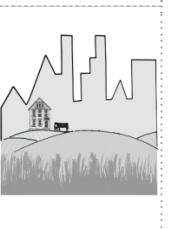
						
Private productive house	Private productive roof garden	Private productive roof aquaponics	Private kitchen garden	Allotment gardens	Community gardens, open field cultivation	Community gardens, glass house
						
Public edible green amenities	Professional roof gardens aquaponics	Professional horticulture, open field	Professional horticulture, glass house	Professional hydroponics	Urban farm	Green infrastructure farm

Figure 1. Representation of the spatial types by icons

### 3. Calculation of consumption of food

The amount of food that is required for the inhabitants of an area is based on the average diet in the Netherlands in 2010 (PBL, 2014).

For the calculation of the required amount of food the average diet is converted into kilos per year. The following elements are excluded from the calculation because these are difficult to produce locally in the Netherlands: alcoholic beverages, non-alcoholic beverages (including coffee and tea), sugar and fats. Meat is subdivided into beef (20%), pork (60%), and chicken (20%).

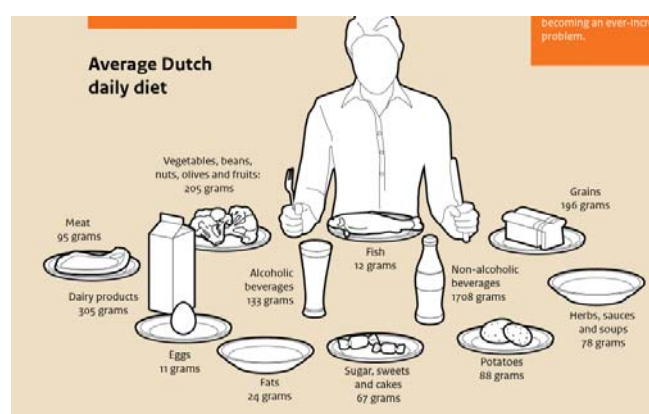


Figure 2. Average Dutch daily diet (source National Environmental Office – PBL 2014)

Table 2. Average consumption in kilos per year per person

Type of food	grams per person per day	kilos per person per year	Comments
Potatoes	88	32	
Grains (pasta and bread)	156	57	rice is not produced locally
Vegetables (excluding legumes)	145	53	
Pulse	20	7	
Fruits	40	15	mainly apples and pears
Herbs	10	4	
Beef	57	5	
Pork	19	21	
Poultry	19	7	mainly chicken
Fish	12	7	most of the fish in Dutch diets is caught at sea
Cheese	20	7	
Dairy (excluding cheese)	285	104	
Eggs	11	4	

The required amount of food is calculated by multiplying the average diet by the number of inhabitants in each area.

#### 4. Calculation of production of local food

To calculate the potential food production the following steps are taken. Firstly the types of crops and produce are defined for each spatial type. Because the calculator works with gross surfaces, part of the surface is allocated for access and facilities. The results can be seen in Table 3.

Secondly the yields of crops and production are defined on the basis of organic farming. Data are retrieved from national statistics of production ([www.cbs.nl](http://www.cbs.nl)) with addition of a series of specific research reports of the Louis Bolk Institute ([www.louisbolk.nl](http://www.louisbolk.nl)). For the fish farms and hydroponics studies of the innovation network of agriculture and agribusiness ([www.innovatienetwerk.org](http://www.innovatienetwerk.org)) are

used. For each type of urban agriculture the yields of suitable crops are selected, e.g. tomatoes, cucumber, courgette for professional horticulture in glass houses. Milk production is related to the average production per cow and the index of cattle per hectares. The amount of kilos per m<sup>2</sup> also includes the produce of fodder for cows (silage) and chickens (corn). For the production of pigs it is assumed that these are mainly fed on leftovers from other crops.

**Table 3. Percentage of surface allocated to crops and products per type of urban agriculture**

Types of urban agriculture	Crops ->												
	Potatoes	Vegetables (excl. legumes)	Legumes	Fruits	Herbs	Grains	Beef	Pork	Poultry	Fish	Cheese	Dairy (milk, yoghurt)	Eggs
Productive house (indoor) private		70%	10%		20%								0%
Productive roof (flat) private		50%	10%	10%	10%								30%
Productive roof (flat), aquaponics		25%	5%							30%			40%
Kitchen gardens	20%	35%	10%	20%	5%								10%
Allotment gardens	20%	35%	10%	20%	5%								10%
Community gardens, conventional	20%	40%	5%	15%	5%							5%	10%
Community gardens, glass house		55%	5%	30%									10%
Edible green amenities				30%									70%
Roofgardens aquaponics, professional		27%	3%							30%			40%
Professional horticulture, conventional	20%	40%	5%	20%	5%								10%
Professional horticulture, glass house		50%	5%	30%	5%								10%
Professional hydroponics		50%	5%		5%					30%			20%
Urban farm	15%			5%		20%	10%	5%	5%		5%	20%	10%
Green infrastructure farm						10%	20%	15%	10%		5%	30%	5%

In order to define the production space that is available in an urban area, the following data are collected: the number of houses, and the total surfaces of private gardens, flat roofs, and public green space. The surface of unbuilt land that is or can be used for horticulture, an urban farm,

etcetera is measured too. Consequently the available surface is allocated to one of the spatial types. Where the spatial types can be placed depends on the urban structure in the area, limitations like traffic, the size of plots and needs for other functions like recreation, water retention, alignment of roads, etcetera.

**Table 4. Average yields or produce per year of organically grown products**

Crop or product	kg/m <sup>2</sup> *)	comments
Potatoes	2.9	the same for all spatial types
Grain	0.7	the same for all spatial types
Legumes	1.5	the same for all spatial types
Vegetables	5	open field, the same for all spatial types
	30	glass house, the same for all spatial types
Herbs	1,5	the same for all spatial types
Fruits	4	mostly apples and pears: farms, orchards, edible green
	2	berries in roof gardens, kitchen gardens
	8	berries in glass houses, tunnels (professional horticulture)
Beef	0.07	pasture in urban farm or green infra farm
Pork	0.57	urban farm or green infra farm, outdoor
Poultry	0.11	urban farm combination indoor/outdoor incl corn fodder
Fish	6.67	organic aquaponics, with fodder production and facilities
Cheese	0.15	1/10 of milk production per hectare
Dairy	1.50	2 cows per hectare, 7500 litres per cow per year
Eggs	0,4	urban farm combination indoor/outdoor including fodder (corn)
*) the sources of the key figures can be found in the Excel file of the local urban food calculator, see Appendix 1 The produce per square meter is without taking into account the space for facilities, infrastructure, transport, and energy		

A first test was made for two neighbourhoods in the city of Arnhem: Presikhaaf III, an example of modernism that mainly consists of high rise buildings and Elderhof, a residential area from the 1980's with terraces houses (Figure 3).

Presikhaaf III offers a huge amount of flat roofs and a good spatial structure to embed community gardens and some glass houses. Elderhof consists of a fine maze structure of private gardens and in the north a park area with allotment gardens. In the south there is space for glass houses and a fish farm.





Figure 3. Google map and map with public green space of Presikhaaf III and Elderhof

## 5. Discussion

The local urban food calculator (LUFC) uses a defined series of typologies of urban agriculture. The actual production may take place in units that are a mixture of these types. It is also possible that producers in a certain type grow more or less of a type of crop than defined in Table 3. For a specific area or a design the LUFC can be adapted to this.

In other countries the diet may be different and in the Netherlands scenarios exist for vegetarian or flexitarian diets. In a designated area the consumption may differ because of income and culture. For the calculation an average diet is used, but diets may vary depending on what can be locally produced and is offered.

In the calculation certain types of food were excluded, because these could not be produced locally in the Netherlands. It is possible to look for alternative types of food and drink, e.g. elderflower syrup replacing soft drinks, rhubarb wine as an alcoholic beverage. For products like coffee and tea there might also be alternatives, but it is doubtful to which extent consumers would be willing to adapt.

In the two test cases the planner decided how the available space was to be used for different types of urban agriculture, based on the interpretation of aerial views and the maps with the green structure. The percentage of the available space that is to be designed for the types of local food production (e.g. the percentage of the surface of private gardens for kitchen gardens, or the amount of houses that can be converted into productive houses) is to be based on reference projects. However, the actual production largely depends on the willingness of people to change ornamental gardens into productive gardens. Besides this there is always an amount of space needed for other

functions like terraces, recreation, parking, tool sheds, etcetera. Therefore it is recommended to use the local urban food calculator in a bottom-up planning process is recommended.

## 6. Conclusions and further research

The first tests in Arnhem for two neighbourhoods show that the local food system within the urban area can only provide a small amount of the total nutritional needs of the local population. The local production in these two areas may provide for half the amount of vegetables and fruits and to a lesser extent for the amount of potatoes and fish. Within these areas there is no space for dairy production and grains. Production can be raised by introducing more glass houses, polycultures and hydroponics in the area, but these types of urban agriculture are less attractive. The open field cultivation types also have a social and recreational function.

The next step in this research is to extend the analysis of available space for the different typologies to the whole city of Arnhem and to develop a set of scenarios for more and less intensive food production in relation to social and recreational use.

## 7. Postscript and acknowledgments

An Excel file with the urban local food with a short explanation on its functioning can be obtained from the author, by sending an e-mail to [jeroen.devries@wur.nl](mailto:jeroen.devries@wur.nl).

The first author gratefully acknowledges the support of Ir. G. J. van der Burgt, Professor Dr. Ir. E.T. Lammerts van Bueren, and Professor Dr. Ir. P.C. Struik for leading him to the relevant key figures on yields and produce of organic farming.

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### Student projects VHL relating to functional and spatial typologies of urban agriculture

- Hommel, Ouren, Ferry Streng & Udin Verheij. 2014. Stadslandbouw verankerd, Een onderzoek naar de verankering van stadslandbouwinitiatieven in stadsranden, afstudeeronderzoek 4e jaar landschapsarchitectuur, VHL Hogeschool, Velp
- Kors, Milly & Aranea Floor. 2014. Voedsel dichterbij! Onderzoek naar typen stadslandbouw. Afstudeeronderzoek Tuin- en landschapsinrichting, VHL Hogeschool, Velp



**APPENDIX 1. Detailed table with yields per m2 of crops and products**

<b>Overview of yields and produce of organic crops and animal produce in kilo per m<sup>2</sup></b> <i>This is the net surface so without the space for facilities, infrastructure, transport, and additional energy</i>				
<b>Diet category</b>	<b>Crop or product</b>	<b>kg/m<sup>2</sup></b>	<b>Comments</b>	<b>Source</b>
Potatoes	Potatoes	2.9		<a href="http://www.cbs.nl/NR/...5C74.../2009biologischelandbouwmaatwerk2009.xls">www.cbs.nl/NR/...5C74.../2009biologischelandbouwmaatwerk2009.xls</a>
<b>Potatoes</b>		<b>2.9</b>	<b>the same for all spatial types</b>	
Grain	Wheat	0.7	winterwheat	<a href="http://www.louisbolck.org/downloads/1459.pdf">www.louisbolck.org/downloads/1459.pdf</a>
Grain	Corn	0.9	only the corns, not the leaves	<a href="http://www.cbs.nl/NR/...5C74.../2009biologischelandbouwmaatwerk2009.xls">www.cbs.nl/NR/...5C74.../2009biologischelandbouwmaatwerk2009.xls</a>
<b>Grain</b>		<b>0.7</b>	<b>the same for all spatial types</b>	
Legumes	Legumes: Green peas for packing	0.7		<a href="https://www.wageningenur.nl/upload_mm/9/d/e/fdcfad65-920f-48c3-9a5e-335a882f6705_Flyer%20rapportage%20Bodemkwaliteit%20op%20zandgrond%202012.pdf">https://www.wageningenur.nl/upload_mm/9/d/e/fdcfad65-920f-48c3-9a5e-335a882f6705_Flyer%20rapportage%20Bodemkwaliteit%20op%20zandgrond%202012.pdf</a>
Legumes	Green Peas	1		personal communication Prof. Dr. Ir E. Lammers van Buren and Prof. Dr. Ir P.C. StruiK
Legumes	Green Beans	2		personal communication Prof. Dr. Ir E. Lammers van Buren and Prof. Dr. Ir P.C. StruiK
<b>Legumes</b>		<b>1.5</b>	<b>the same for all spatial types</b>	
Vegetables	Onions	5.4		<a href="http://www.louisbolck.org/downloads/1459.pdf">www.louisbolck.org/downloads/1459.pdf</a>
Vegetables	Onions	5.2		<a href="http://www.cbs.nl/nl-NL/menu/themas/landbouw/publicaties/artikelen/archief/2009/2009-2740-wm.htm">http://www.cbs.nl/nl-NL/menu/themas/landbouw/publicaties/artikelen/archief/2009/2009-2740-wm.htm</a>
Vegetables	Endive	3.5	winter crop	<a href="http://www.louisbolck.org/downloads/2117.pdf">http://www.louisbolck.org/downloads/2117.pdf</a>
Vegetables	Lettuce - open field cultivation	5	4 crops, 12 /m2, 400 gr /p; 1st of May till end of Oct	personal communication Prof. Dr. Ir E. Lammers van Buren and Prof. Dr. Ir P.C. StruiK
<b>Vegetables open field</b>	<b>OUTDOOR</b>	<b>5</b>	<b>the same for all spatial types</b>	
Vegetables	Bell pepper	17	yearround	<a href="http://www.louisbolck.org/downloads/1899.pdf">http://www.louisbolck.org/downloads/1899.pdf</a>
Vegetables	Tomato	39	1/2 Jan to end of Oct; with one crop of lettuce	<a href="http://www.louisbolck.org/downloads/1899.pdf">http://www.louisbolck.org/downloads/1899.pdf</a>
Vegetables	Cucumber	26	yearround	<a href="http://edepot.wur.nl/323447">http://edepot.wur.nl/323447</a>
<b>Vegetable glass house</b>	<b>GLASS HOUSE</b>	<b>30</b>	<b>the same for all spatial types</b>	
Fruits	Apples	4		<a href="http://www.cbs.nl/nl-NL/menu/themas/landbouw/publicaties/artikelen/archief/2014/2014-4180-wm.html">http://www.cbs.nl/nl-NL/menu/themas/landbouw/publicaties/artikelen/archief/2014/2014-4180-wm.html</a>
Fruits	Pears	4		<a href="http://www.cbs.nl/nl-">http://www.cbs.nl/nl-</a>

**Overview of yields and produce of organic crops and animal produce in kilo per m<sup>2</sup>**  
*This is the net surface so without the space for facilities, infrastructure, transport, and additional energy*

Diet category	Crop or product	kg/m <sup>2</sup>	Comments	Source
				NL/menu/themas/landbouw/publicaties/artikelen/archief/2014/2014-4180-wm.html
Fruits	Strawberries	1.7	open field cultivation	<a href="http://www.cbs.nl/nl-NL/menu/themas/landbouw/publicaties/artikelen/archief/2009/2009-aardbeien-art.htm">http://www.cbs.nl/nl-NL/menu/themas/landbouw/publicaties/artikelen/archief/2009/2009-aardbeien-art.htm</a>
Fruits	Strawberries	8	cold frame or tunnel	<a href="http://www.cbs.nl/nl-NL/menu/themas/landbouw/publicaties/artikelen/archief/2009/2009-aardbeien-art.htm">http://www.cbs.nl/nl-NL/menu/themas/landbouw/publicaties/artikelen/archief/2009/2009-aardbeien-art.htm</a>
Fruits	Black berries	3.6	open field cultivation	
Fruits	Blue berries	5.8	open field cultivation	
<b>Fruits</b>		<b>4</b>	<b>farms, orchards, edible green</b>	
<b>Fruits</b>		<b>2</b>	<b>roof gardens, kitchen gardens</b>	
<b>Fruits</b>		<b>8</b>	<b>glass houses, tunnels (professional horticulture)</b>	
<b>Herbs</b>		<b>1.5</b>	<b>open field cultivation</b>	<a href="http://www2.vlaanderen.be/landbouw/downloads/fijne_groententeelt.pdf">www2.vlaanderen.be/landbouw/downloads/fijne_groententeelt.pdf</a> , peterselie: 1,5 kg / m2
<b>Beef</b>	Beef	<b>0.07</b>	<b>pasture in urban farm or green infra farm</b>	30% milk cows (sausages etc.), 70% meat cows, 1,5 cow/hectare, 240 kg consumption meat per cow, 180 days
<b>Pork</b>	Pork	<b>0.57</b>	<b>urban farm or green infra farm, outdoor</b>	additional fodder by leftovers of crops and food, 27 pig / ha, 70 kg consumption meat per pig, 120 days
<b>Poultry</b>	Poultry	<b>0.11</b>	<b>urban farm combination indoor/outdoor incl corn fodder</b>	4 cycles per year, 4,1 m2 per chicken, 1,3 kg per chicken, m.bestman@louisbolk.nl
<b>Fish</b>	Fish	<b>6.67</b>	<b>organic aquaponics, with lemna minor, worms, tilapia</b>	innovatienetwerk, nutri-hof 10 ton plant ecological faming
<b>Cheese</b>	Cheese	<b>0.15</b>	<b>1/10 of milk production / ha</b>	personal communication Prof. Dr. Ir E. Lammers van Buren and Prof. Dr. Ir P.C. StruiK
<b>Dairy</b>	Dairy (milk, yoghurt, etc)	<b>1.50</b>	<b>2 cows per hectare, each 7500 litres (kg) per year</b>	personal communication Prof. Dr. Ir E. Lammers van Buren and Prof. Dr. Ir P.C. StruiK
<b>Eggs</b>	Eggs	<b>0.34</b>	<b>urban farm combination indoor/outdoor incl corn fodder</b>	leenstra a.o., m.bestman@louisbolk.nl