A Different Perspective on Garden Grabbing: Mapping the Adaptive Capacity of Home Food Production

Valerie Dewaelheyns, Frederik Lerouge, Elke Rogge, Liesbet Vranken

(PhD Valerie Dewaelheyns, Institute for Agricultural and Fisheries research, Social Sciences Unit, Burgemeester van Gansberghelaan 115, Box 2, 9820 Merelbeke, Belgium; Division of Forest, Nature and Landscape, Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, 3001 Heverlee, valerie.dewaelheyns@ees.kuleuven.be)
(Msc Frederik Lerouge, Division of Bio-economics, Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, 3001 Heverlee, frederik.lerouge@ees.kuleuven.be)
(PhD Elke Rogge, Institute for Agricultural and Fisheries research, Social Sciences Unit, Burgemeester van Gansberghelaan 115, Box 2, 9820 Merelbeke, Belgium, elke.rogge@ilvo.vlaanderen.be)
(PhD Liesbet Vranken, Division of Bio-economics, Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, 3001 Heverlee, liesbet.vranken@ees.kuleuven.be)titel

1 ABSTRACT

Current trends in urban development strive for the densification of existing urban areas. This densification can be operationalized by the decrease and intake of domestic garden area. Yet, such densification projects may result in potential losses with regards to the support of ecosystem services and the safeguarding of urban adaptive capacity. The manifold of multifunctional garden spaces present worldwide offers for example interesting perspectives for food provisioning. By developing a theoretical model to capture, quantify and interrelate the most relevant variables and constraints of potential food production in domestic gardens, insight is gained in the food production potential of domestic gardens. Also the influence of utility on the household's decision on how much space and time to devote to food production was incorporated. The model development was fostered by quantitative and qualitative data collection for the case study Flanders. These data allowed to gain insights in the current food production and potential for food production in Flemish domestic gardens. Such insights allow the exploration of spatial and temporal constraints of individual domestic gardens for food production. This contributes to a better understanding of the adaptive capacity of garden space interwoven within the urban fabric. As such, the qualities and potentials enclosed within the existing garden area can be put next to the benefits of building these areas. Moreover, insights are gained in points of attention when private garden areas would be addressed for food provisioning.

2 INTRODUCTION

There is an increasing attention for food production outside the traditional agricultural area (Algert, Baameur, & Renvall, 2014), but t his attention largely bypasses domestic gardens (Taylor & Lovell, 2014). Also other services delivered by garden space fail to receive proper attention (Davies, Edmondson, Heinemeyer, Leake, & Gaston, 2011).

Domestic gardens constitute a significant amount of the space that is not built-on (Dewaelheyns, Rogge, & Gulinck, 2014). Their coverage in urban areas ranges between 22 % for cities in the UK (Loram, Tratalos, Warren, & Gaston, 2007) and 46 % for residential areas in New Zealand (Mathieu, Freeman, & Aryal, 2007). But they are also a non-negligible land use in the countryside (Antrop & Van Eetvelde, 2008). With continuing urbanization ahead, the total area of domestic gardens worldwide is expected to increase by planned and unplanned urbanization processes (Dewaelheyns, et al., 2014).

Domestic gardens can be interpreted as multifunctional micro-spaces, with trade-offs and synergies between functions (Stoorvogel, Antle, Crissman, & Bowen, 2004). Throughout history, food production has been a most important part of gardening practices worldwide, in developing (WinklerPrins, 2002) and developed countries (Taylor & Lovell, 2014). Domestic gardens can be seen as an adaptable and accessible land resource for food production worldwide, holding potential to reduce vulnerability and improve personal food security (Barthel & Isendahl, 2013; Buchmann, 2009).

During the past decades home food production regained attention from policy (Ghosh, 2012) and from research (Taylor & Lovell, 2014). Some recent studies, mainly from the US, use scenario's to assess the contribution of private land and residential gardens to the total food production area and food needs (Grewal & Grewal, 2012; McClintock, Cooper, & Khandeshi, 2013). Others deal with food self-provisioning by exploring the motivations of individuals and limitations imposed by policies (Alber & Kohler, 2008; Jehlicka, Kostelecký, & Smith, 2013).

The contribution of domestic gardens to food production has proven difficult to measure (Kortright & Wakefield, 2011). Their private character (Kortright & Wakefield, 2011; Phillips, Page, Saratsi, Tansey, & Moore, 2008), limited accessibility (Pérez Campaña & Valenzuela Montes, 2012) and large variation in appearance, management and use (Dewaelheyns, Elsen, Vandendriessche, & Gulinck, 2013) impedes surveying and research efforts. Consequently, insights in the food production potential of gardens remains limited.

Domestic gardens are also complex social-ecological systems (Barthel, Folke, & Colding, 2010). The choices and actions of gardeners are influenced by a variety of drivers and constraints, which can be individual and social in nature (like culture, personal ideals, preferences and beliefs (Cook, Hall, & Larson, 2012), or imposed by the biophysical context (like climate, soil characteristics, hydrology, ecology (Kaye, Groffman, Grimm, Baker, & Pouyat, 2006) and the social context (like income, informal institutions in the neighborhood (Nassauer, Wang, & Dayrell, 2009).

Cleveland and Soleri (1987) stressed the necessity of analyzing internal dynamics of both gardens and households, the relationship between the two, and the relationships of both with external social, economic, political and environmental issues which determine the households' control over resources for and production from gardens.

Therefore, this paper aims to gain insight in the food production potential of domestic gardens and in the households' decision to allocate space and time to food production. The specific objective is to develop a methodological framework to capture, quantify and interrelate the most relevant determinants and constraints of potential food production in domestic gardens.

We investigate the degrees of freedom in the decision space of a household, giving food for thought on the adaptive capacity of domestic gardens for food production at the household level. This model should facilitate the discussion on the inclusion of domestic vegetable gardens within food strategies.

3 CONCEPTUAL MODEL AND HYPOTHESES

3.1 Defining the domestic garden

We define a domestic garden as the residential parcel, owned or rented, with exclusion of the associated house. The term 'domestic garden' is preferred rather than the term 'private garden', since the latter can be any privately owned garden that is not necessarily spatially linked to a dwelling. The term 'kitchen garden' refers to the vegetable and fruit productive part of the garden. Domestic gardens associated with the dwellings of farmers are included, as well as small greenhouses not used for the commercial production of food or ornamental plants. Excluded from the definition is the area used for professional agriculture, storage space for building materials or refuse, greenhouses used for commercial production and extensive woodlots. Also, gardens that are spatially not directly linked to housing, like dispersed single-plot gardens in agricultural land and allotment gardens are not considered as domestic gardens (Dewaelheyns et al., 2014).

3.2 Theoretical model and hypotheses

3.2.1 Theoretical model

A theoretical model (Chen & Wang, 2013; Vranken & Swinnen, 2006) is developed that describes trade-offs and synergies in area and time between food production and other functions in domestic gardens. With "food" we refer here to vegetables and fruit.

In this model we use utility theory to analyze the choice problem of households when they are confronted with the questions if and how much area and time they would allocate to domestic food production in the garden. In econometric terms, the choice problem for a consumer-producer is presented as a problem of maximizing a utility function subject to one or more constraints.

The model includes five main variables: time (T), area (L), consumed produce (C), utility (U) and input (z). Each variable is broken down into several components. We describe their interrelations at a household level.

The total available time of a household is represented by the variable time $\bar{T}$, and is divided in three components. The total time available for the household includes time used for producing home grown food in the garden t_h, the time used for working (i.e. earning a wage) t_w, and all the remaining time available for all other non-wage earning activities t_o (e.g. leisure, housekeeping, socializing, resting, non-food gardening...).

$$\bar{T} = t_w + t_h + t_o$$

A household's capital contains an endowment M (real estate, savings,...) and a wage income determined by the wage w and t_w.

The total domestic garden area available to a household $\bar{L}$ can be used either for food production or non-food related activities. The area assigned to food production is denoted L_h, while L_o is the area assigned to all other activities.

$$\bar{L} = L_o + L_h$$

The total food consumption used by the household C includes food bought on the market (in general terms) c_1 as well as home garden produce c_2. Home garden produce c_2 can be inserted in the model as the difference between the total food consumption C and bought food c_1. If the household is completely self-sustainable through home produce, c_1 equals 0 and no additional food needs to be bought from the market.

$$C = c_1 + c_2$$

Utility is defined as the whole of material and non-material benefits from a garden and from food consumption. The utility U of a household owning a garden is considered as function of the food consumed by the household C, and of the remaining area and time available for providing other leisure uses and services, Lo and to respectively. In other words, the household utility depends on food consumption, and the area and time allocated to other services consumed by the household.

$$U(c_1, c_2, t_o, t_h, L_o, L_h)$$

Households maximize their utility subject to some constraints. Household members divide their available time $\bar{T}$ between time for working t_w, time for other, non-wage earning, activities t_o, and time spent producing home grown food t_h. Time spent earning a wage t_w can be expressed in function of the total available time minus the time spent for home food production and for other activities. Due to a limited amount of wage employment opportunities ($\bar{T}_w^{max}$), there is a maximum amount of time that can that can be allocated to earning an income t_w.

$$t_w = \bar{T} - t_h - t_o$$

$$\bar{T}_w^{max} \geq t_w$$

Also the garden area $\bar{L}$ is constrained. The total amount of area that each household can allocate to either food production or provision of other services, is limited. In the model, the available garden space is either allocated to food production L_h or to other uses L_o and we assume both to be mutually exclusive.

Growing fruit and vegetables in the garden requires an amount of material input (z). This input is defined as the aggregated cost for variable inputs such as seeds, fertilizers and pesticides used for home food production. As such, domestic produce c_2 is considered a positive function of area L_h and time t_h allocated to production, and of input z.

$$c_2(L_h, t_h, z)$$

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A final constraint is defined by the assumption that the overall household budget allocated to buying food from the market at a price p should not exceed the sum of endowment M and wage income as a product of wage w and t_w.

$$M + w[\bar{T} - t_h - t_o] \geq pc_1$$

$$M + w[\bar{T} - t_h - t_o] \geq pC - pc_2(L_h, t_h, z)$$

To understand how constraints influence the households decisions on home food production, we need to solve this constrained extremum problem. Therefore we apply the Lagrange multiplier method (Chiang, 1984). This approach by-passes the need to explicitly solve the constraints. The problem is reformulated into a free extremum problem, which can be solved using relatively simple derivatives. The Lagrange multiplier itself has an economic interpretation as the marginal utilities associated with the constraints. A marginal utility is the gain from an increase in the consumption of that good or service.

The Lagrange form Z of the utility function contains the function and the constraints on capital, area and time, which are multiplied by the Lagrange multipliers λ, μ and γ. These respectively represent capital constraints (λ), area constraints (μ) and time constraints (γ).

$$Z = U\big(C, t_o, t_h, L_o, L_h\big) + \lambda[M + w[\bar{T} - t_h - t_o] - pC + pc_2(L_h, t_h, z)] + \mu[\bar{L} - L_h - L_o] + \gamma[\bar{T}_w^{max} - T + t_h + t_o]$$

To solve the constrained extremum problem, this Lagrange form of the utility function Z is derived to the Lagrange multipliers, as well as to the principal factors of the model L_h and t_h. As such, the first-order condition for the free extremum problem consists of the following five equations:

(1) $Z_\lambda = M + w[\bar{T} - t_h - t_o] - pC + pc_2(L_h, t_h, z) = 0$

(2) $Z_\mu = \bar{L} - L_h - L_o$

(3) $Z_\gamma = \bar{T}_w^{max} - T + t_h + t_o$

(4) $Z_{L_h} = \frac{\partial U}{\partial L_h} + \frac{\partial U}{\partial c_2} \cdot \frac{\partial c_2}{\partial L_h} + \frac{\partial U}{\partial L_o} \cdot \frac{\partial L_o}{\partial L_h} + \lambda p \frac{\partial c_2}{\partial L_h} - \mu = 0$

(5) $Z_{t_h} = \frac{\partial U}{\partial t_h} + \frac{\partial U}{\partial c_2} \cdot \frac{\partial c_2}{\partial t_h} \mp \frac{\partial U}{\partial t_o} \cdot \frac{\partial t_o}{\partial t_h} + \frac{\partial U}{\partial t_h} + \lambda\left[-w + p\frac{\partial c_2}{\partial t_h}\right] + \gamma = 0$

3.2.2 Hypotheses

The first condition explores the relation between income and consumption. Lower financial means are associated with a general lower consumption. The second and third conditions reflect the spatial and temporal constraints, respectively.

The fourth condition explores the relation between garden space and domestic food consumption, and can be expressed as follows:

$$\frac{\partial c_2}{\partial L_h}[U_{c_2} + \lambda p] + U_{L_h} \geq \mu + U_{L_o}$$

with U_{c_2} the marginal utility of the consumption of home garden produce and U_{L_h} and U_{L_o} the marginal utility of allocating domestic garden area to respectively food production or other activities. The above equation learns that a household allocates more space to food production in its domestic garden as long as the left hand side of the equation is larger than the right hand side. This implies that a more binding capital constraint (λ) leads to more area being allocated to home grown production. In addition, increasing food prices (p) and a higher marginal utility of consuming home grown produce (i.e. the more one enjoys consuming home grown produce for example because it is considered more tasty or healthy) lead to more area being allocated to home grown production. Also, a higher partial productivity of home production and the higher the marginal utility of space being allocated to home grown production (i.e. the more one enjoys the visual appearance of a kitchen garden), the more it repays to allocate more garden space to food production. In addition, a higher marginal utility of L_o (i.e. the more one enjoys the visual appearance of, for example, an ornamental garden) and a more binding area constraint (μ) lead to less garden area allocated to home production.

The fifth condition explores the relation between time allocation and domestic food consumption, and can be expressed as follows:

$$\frac{\partial c_2}{\partial t_h}[U_{c_2} + \lambda p] + U_{t_h} \geq U_{t_o} + \lambda w - \gamma$$

with U_{t_h} and U_{t_o} the marginal utility of allocating time to respectively home grown food production or other non-wage earning activities. The above equation learns that a household allocates more time to food production in its domestic garden as long as the left hand side of the equation is larger than the right hand side. Less income opportunities (higher λ) and lower wages increase the time invested in home food production t_h, and the other way around. In addition, a higher partial productivity of home food production, higher food prices and a higher marginal utility of devoting time to home food production (i.e. the more one enjoys working in the kitchen garden) will also increase the time invested in home food production t_h. Finally, a higher marginal utility of to will decrease the amount of time spent on home grown production, while a higher marginal utility of consuming home grown produce will increase the time invested in home food production.

A more binding capital constraint (λ) will also affect the decision on how much time to spend on home grown food production. The impact is however not clear ex ante and depends on the magnitude of the wage the garden owner can earn as well as the labor productivity of home grown food production. A very productive gardener who can only earn a relatively low wage will increase its time allocated to home grown food production when faced with an more binding capital constraint. On the other hand, an unproductive gardener with high wage earning opportunity will spend more time on wage earning activities than on home food production when confronted with a more binding capital constraint. Now, t_h and L_h are tightly related to each other. Increasing L_h by expanding the kitchen garden is often associated with an increase in t_h, as one needs to invest more time to maintain this larger garden. Even so, the emphasis can be on increasing L_h if time restrictions (γ) are more binding, increasing t_h if spatial constraints (μ) are more binding, or both.

3.3 Scaling up to the garden complex

The private and small scaled character of domestic gardens leads to the routinely consideration of gardens as individual 'objects'. The concept of the 'garden complex' considers the totality of domestic gardens in a certain area as a region-wide landscape structure (Dewaelheyns et al., 2013; Dewaelheyns et al., 2014, masked for blind review).

More specifically, the garden complex sums of all single domestic gardens within a certain area. From a spatial viewpoint, this is the whole of individual garden areas $\sum_1^n \bar{L}$, comprising all area used for food production $\sum_1^n L_h$, and all area for other uses $\sum_1^n L_o$. The consumption of produce of all gardens can be summed $\sum_1^n c_2$. Similarly, all time spent on home food production can be summed as $\sum_1^n t_h$. As such, this concept allows for a straightforward up-scaling. While the garden complex as a whole ($\sum_1^n \bar{L}$) can be an extensive interconnected area, the decision space of the individual households is often strictly confined to the physical space of the households' property $\bar{L}$.

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4 DATA

To test the hypotheses coming out of the model, we collected both quantitative and qualitative data on the spatial composition, food productivity and gardening practices within domestic gardens.

4.1 Case study Flanders

All data are collected in Flanders, the northern region of the federal state of Belgium. Criteria used by OECD and EUROSTAT label Flanders as mainly (peri-) urban. Being present throughout the urban-rural continuum, domestic gardens are part of this peri-urban landscape. They cover in total 110.000 ha or 8 % of the Flemish territory (Dewaelheyns, et al., 2014). This is substantially more than the 200 ha covered by allotment gardens (Allaert, Leinfelder, & Verhoestrate, 2007).

We see Flanders as a case study that can inspire other peri-urban regions. Food production has been one of the historical drivers behind the Belgium urbanization model of single family dwellings with a garden in the nineteenth and twentieth century (De Decker, 2011; Meeus, De Decker, & Claessens, 2013). The government considered and promoted this model as an important safety net to counteract periods of industrial unemployment, since people maintaining a small private garden at home could produce fruit and vegetables. Before the blessings of post-war prosperity, having or renting a garden was vital for the food provisioning g of Flemish households (De Decker, 2011; Meert, 2000).

4.2 Quantitative data

Quantitative data is used to evaluate and discuss variables of the model. Data on food production and garden management were collected by an anonymous online survey among garden owners in Flanders. From the 285 variables collected within the full survey, 47 were specifically related to food production. The drop-out rate of the internet survey was 38 %. A total of 1,138 respondents were withheld for further analysis.

More detailed quantitative data on garden design and food production was collected by face-to-face survey during garden visits within the case municipality of Herent (Flanders) in 2007. Herent is characterized by a strong morphological but rather weak functional urbanization (Mérenne-Schoumaker, Van der Haegen, & Van Hecke, 1998). A stratified random sampling (Lauridsen, 2004) based on geographical data was used to define which neighborhoods would be visited. In total, 25 garden visits were conducted and analyzed. A socio-demographic profile of the respondents for both surveys is provided in Appendix A.

4.3 Qualitative data

Qualitative data is used to illustrate to what extent the constraints are binding and effecting the decisions on the amount of land and time allocated to home garden production. The qualitative data also allow to investigate the marginal utility of L_h and t_h.

A total of 37 respondents were consulted, including 21 experts and 16 garden owners. The experts are all professionally active in the broad field of action related to domestic gardens (public servants at the municipal, provincial and Flemish level working on public green, spatial planning and urbanism; staff members of interest groups on rural development, agriculture and ecological gardening; etc.). They were questioned through open in-depth interviews of about one hour, conducted between June 2013 and January 2014. Private garden owners were involved by two focus groups, each consulting 8 participants. The focus groups were moderated by an experienced moderator and took place January 27th, 2014. They lasted each about two hours.

The qualitative data were analyzed according to the grounded theory approach, using inductive open and axial coding (Strauss & Corbin, 1998). During the coding process data were broken down into discrete objects or ‘concepts’ like ideas, phenomena, feelings,... and named. These concepts were further analyzed and aggregated into distinct categories. Finally, the concepts and categories were re-assembled by identifying links and cross-cuts. The authors used several techniques to ensure neutrality throughout the data collection and analysis and to prevent bias that could result from the work of one single researcher. These techniques included triangulation, a multi-staged process, partly collective data analysis and validation.

5 EMPIRICAL RESULTS AND DISCUSSION

5.1 Current home food production and its share in the household consumption

Some degree of measurement error is assumed on the survey results, e.g. due to difficulties to accurately estimate production quantities. The production figures and their financial values reported are estimates. Nevertheless, they provide a good starting point to test the validity of assumptions underlying the model and the hypotheses coming out of the model.

5.1.1 Current food production in domestic gardens

First, we discuss food production in Flemish domestic gardens(c_2), based on results for Flanders from the internet survey (Table 1). Vegetable gardens are present in 37 % and fruit production in 51 % of the surveyed gardens. Nuts are the third most represented produce group with 31 %. Only 28 % of the surveyed gardens has a food productivity (c_2) of zero, meaning that a vast majority of gardens delivers some kind of nutritional produce. In terms of productivity, 1,310 kg of vegetables were produced in 2007 per ha of vegetable garden as well as 216 kg of fruits per ha of garden (Table 2).

In 73 % of the surveyed gardens producing food, the produce is mainly for home consumption. Home consumption with occasional distributing or selling to other households occurs in 20 % of the producing gardens. Therefore, for the application of the model to the case of Flanders we assume home produce to equal home consumption c_2. This contrasts for example to Brazil, where a majority of the households (71 %) indicated that products from gardens are given away to a network of family, neighbors and friends (WinklerPrins, 2002).

Second, we discuss the results from the garden visits in Herent (Table 3). A total of 664 kg of vegetables was produced within the 25 surveyed gardens of Herent, corresponding to a productivity of 178 kg per ha of surveyed garden and 2.3 tons per ha of vegetable garden. These garden productivity figures (surveyed for vegetables, potatoes and fruit separately) are solely based on the quantities given by those respondents able to identify and quantify their yields in 2007.

Produce	Gardens with presence	Total quantity removed from the gardens
Vegetables	37 %	13 tonnes
Fruit	51 %	21 tonnes
Potatoes	20 %	1.7 tonnes
Nuts	31 %	3.4 tonnes
Eggs	25 %	69,100.00 pieces
Meat	5 %	808.00 kg
Fire wood	29 %	4,100 m³
No production	28 %	

Table 1 Domestic garden output, based on the internet survey results (N=1,138)

Produce	Productivity of kitchen gardens [unit/ha] (2007)	Extrapolation for Flanders (based on area of garden and kitchen garden)
Vegetables	1,310 kg/ha vegetable garden	11,251 tons
Fruit	216 kg/ha garden	25,896tons
Potatoes	2,566 kg/ha vegetable garden	22,042tons
Nuts	83 kg/ha garden	9 tons

Table 2 Productivity of kitchen gardens, based on the internet survey results (N=1,138)

Produce from the vegetable garden	Total	Per garden	Per ha garden[a]	Per ha vegetable garden[b]	*Per family member (N=64)*
Vegetables [kg]	664.5	26.58	177.7	2,292.5	*10.4*
Fruit [kg]	295	11.8	78.9		*4.6*
Potatoes [kg]	*680*	*27.2*	*181.8*	*2,346*	*10.6*

[a] total garden area of 3.74 ha, [b] total vegetable garden area of 0.26 ha

Table 3 Productivity of kitchen gardens, based on the results from the garden visits in Herent (N=25)

5.1.2 Share of the home produce within the household consumption of fruit and vegetables

The Herent garden visits provide figures on the output per type of produce, allowing to calculate the share of garden output within household consumption in terms of weight (Table 4).

Compared to the produce bought for home consumption by Flemish households in 2007, the garden produce in Herent amounts to 28 % of the household vegetables consumption and 29 % of the household potatoes consumption (Table 4). Home garden produce (c_2) of vegetables and potatoes thus covers about one third of the amount bought at the market (c_1). For fruit this is much less, as many popular fruits (e.g. bananas, oranges and mandarins) are difficult to grow in temperate climates.

5.1.3 Monetary values of food production in domestic gardens

For a select number of products, the Herent visits allow to calculate the monetary value of the output and its share within household consumption and expenses based on output per type of produce. These data give insights in the monetary significance of c_2.

The monetary market value of the yearly output lies between 17.64 euro for carrots and 700.40 euro for potatoes for 2007 (Table 5). For five of the eight products, the equivalent financial value of the home produce exceeds 20% of the total household expenses, with apples (27.5 %), tomatoes (26.9 %) and potatoes (25.2 %) as front runners (Table 6).

Compared to the results from Reyes-García et al. (2012) for home vegetable gardens in the Iberian Peninsula, the gross monetary value (pc_2) realized within the analyzed gardens in Herent were overall lower.

We believe that the financial profile of the gardeners can be one of the reasons for the differences. The gross financial value of home gardens per manager in the Iberian peninsula represents almost three months of the official minimum salary in Spain (Reyes-García, et al., 2012), whereas the respondents from Herent have relatively high wages so that the value of the garden produce relative to their income is much smaller.

A second explanation could be the rather low number of different vegetable types cultivated per garden in Herent compared the Iberian gardens. Reyes-García et al. (2012) found that garden managers do not seem to organize their gardens and cultivation plans in order to maximize monetary benefits (pc_2). Knowing that the vegetable garden L_h covers a mere 10 % of the garden area $\bar{L}$, indicates that also the respondents from Herent do not strive for maximizing the monetary benefits from their garden.

Produce [kg]		**Produce per family member**	**Produce bought for home consumption per person by Flemish households in 2007**	**Percentage of the home grown produce in total vegetable consumption**
General	Vegetables	10.4	36.6	22.1
	Fruit	4.6	54.8	7.7
	Potatoes	10.6	36.1	22.7
Specific vegetables and fruits	Onion	0.4	4.3	8.5
	Beans	1	0.6	62.5
	Paprika	1	1.3	43.5
	Tomato	3.4	3.2	51.5
	Carrot	0.3	5.9	4.8
	Apple[b]	2.9	6.5	30.9
	Pear[c]	1.2	2.5	32.4

[a] Flemish Centre for Agriculture and Fisheries marketing (VLAM), bron: GfK PanelServices Benelux for VLAM, [b] reference is Jonagold, [c] reference is Conference.

Table 4 Share of vegetable garden produce of the produce of the gardens of Herent in respect to the Flemish consumption in 2007, based on the surveyed gardens in Herent (N=25 gardens surveyed; in total covering 64 family members)

Produce N=25 gardens	**Total output in kg in 2007**	**Average product prices per kg in 2007[a] [euro]**	**Total output in euro in 2007**	**Number of gardens where the produce is grown**	**Output in euro per garden where the produce is grown in 2007**
Potato	680	1.030	700.40	6	117
Onion	25	0.937	23.43	4	6

Beans	65.5	4.48	293.44	8	37
Paprika	64	3.486	223.10	4	56
Tomato	220	2.172	477.84	4	119
Carrot	23	0.767	17.64	8	2
Apple	185	1.947 [b]	360.20	5	72
Pear	80	1.549 [c]	123.92	1	124

[a] Based on the average product prices in 2007, source: NIS Household budget survey 2007, reference value for fresh vegetables, [b] reference price for Jonagold, [c] reference price for Conference

Table 5 Economic value of domestic garden produce, based on the surveyed gardens in Herent (N=25)

Produce (N=25)	**Financial value of the total output [euro]**	**Total expenses for N=25 households in Herent[a]**	**Percentage of the financial value of home grown produce versus average expenses**
Potato	700.40	2,075	25.2
Onion	23.43	600	3.8
Beans	293.44	1,100	21.1
Tomato	477.84	1,300	26.9
Carrot	17.64	525	3.3
Apple[b]	360.20	950	27.5
Pear[c]	123.92	725	14.6

[a] Based on the average expenses per Flemish household in 2007, source: NIS Household budget survey 2007, reference value for fresh vegetables

Table 6 Comparison of the average expenses of Flemish households for purchased produce with the monetary value of home grown produce, based on the surveyed gardens in Herent (N=25)

5.2 Non-productive use value of gardening

Gardens do not only provide utility because of home production, but also because of leisure activities. The qualitative data provides insights in the non-production use value (aesthetic and recreational value) of a garden for a household. This use value is defined by consumer preferences. We discuss the value of having an own garden the consideration of gardening as a burden or a hobby and motivations for home food gardening.

5.2.1 The own garden: a valuable space

For the majority of the Flemish households, it is important to have a garden. Being or becoming a owner of a house with a garden is an integral part of the way of life for a Belgian household (De Decker, 2011). The significance of a garden contains multiple aspects of experience, like relaxation, contact with nature, relation with food and prestige (Table 7). This experience is not solely considered from the individual perspective. The garden is also seen as a nourishing meeting place for family, friends and neighbors.

Categories	**Concepts**	
Gardening is personal	Individual experience, philosophy, identity, taste	
	Collective experience	
	Considerations on the multifunctional lay-out	
		Different life phases require different needs
	Unlocking hidden capacities	
Contact with nature	Contact with green and nature	
	Being outside	
	Independence	
Relation with food and food quality		
Prestige		
Freedom		
The garden is a place to relax		
The garden is a place to work		

Table 7 Categories and concepts related to the significance of domestic gardens for garden owners, based on the qualitative data

The most prominent association garden owners made with the domestic garden was ‘freedom’. This freedom is reflected in the autonomy Flemish gardeners have in deciding which services and functions are present in the garden, and how the garden is managed. Such gardening autonomy has been illustrated (Goddard, Dougill, & Benton, 2010).

Respondents indicated that no tradition exists in top-down (governmental) interfering with garden design and management in Flanders. This implies that the consideration of which trade-offs are made between food

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production and other services provided by the domestic garden is a personal one, influencing the magnitude of U_{L_h} and U_{L_o}. Such considerations are determined by the utility of gardening perceived by the household, what is reflected in consumer preferences.

"So, where for one [person] the visual aspects are important, the other [person] values the significance of the garden. The way someone lives and experiences everything is expressed within the garden." *(Employee of a NGO concerned with rural development)*

Consumer preferences are a major factor in determining the use of the garden space. This is in line with Kortright and Wakefield (2011) who found out that it is not the available garden area $\bar{L}$ that is the determining factor in enabling food growing in the garden, but the priorities the household expresses over the garden area. Depending on the stage in their life, households express different requirements for their garden space, L_o or L_h.

Also context is a determining factor in decision making. Context-dependent effects were observed by Kortright and Wakefield (2011) who found that access to a nearby communal playground for children allowed relatively more garden space to be allocated to food production L_h or to aesthetic functions, which forms part of L_o. In addition, informal institutions and neighborhood norms are powerful determinants for the individual choices on garden lay-out and management (Thompson, 2004).

5.2.2 Food gardening: a hobby or a burden?

We hypothesized that people who perceive kitchen gardening as a pleasant occupation will increase their utility by producing extra food in their garden. This is reflected in U_{t_h} and U_{t_o} in the fifth condition. People gaining utility from spending time or land to vegetable gardening are expected to make different choices in the allocation of t_h and L_h compared to people experiencing home food gardening as a burden, or than people gaining more utility from ornamental gardening. Several studies consider food production in domestic gardens in developed countries to be a sheer recreational rather than an economic activity (Jehlicka, et al., 2013; Reyes-García, et al., 2012).

5.2.3 Motivations for home food production

The qualitative data indicated specific motivations for having an own kitchen garden (Table 8). These include self-sufficiency and tradition. The relevance of tradition should not be surprising since having a vegetable garden was deliberately stimulated by housing policies and government incentives (De Decker, 2011; Meert, 2000; Meeus, et al., 2013).

"I inherited the practice of vegetable gardening." *(Man, 60 years, municipal worker)*

The respondents did not mention the quality of garden produce as a motivation. Yet, according to literature home food produce is stimulated by the perception that own food is better than commercial fruit and vegetables in terms of taste and nutrition (Jehlicka, et al., 2013). Food sovereignty and economic independence are also important reasons (Calvet-Mir, Gómez-Baggethun, & Reyes-García, 2012).

Categories	**Concepts**	
Own vegetable garden	Motivators	Tradition and past obligations (e.g. 'kleine landeigendom'
		Yields
		Being self-sufficient
		Search for authenticity
	Characteristics	Short supply chain
		Food safety
	In need for an economic valuation of home-grown produce	
Relation with food	Barbeque with family and friends	
	Food processing, for example for the freezer	
Place within food strategies for cities and food planning		

Table 8 Categories and concepts related to motivations for home food production, based on the qualitative data

5.3 Use of garden space

The results from the Flemish internet survey indicate that for a third of the surveyed gardens, the area of vegetable garden L_h covers up to one fourth of the garden area $\bar{L}$ (Table 9). Almost half of the gardens holds a vegetable garden. Also, half of the respondents has fruit trees in the garden.

The results from the garden visits of Herent (Table 10) fit these results for Flanders in terms of magnitude. The spatial dominance of lawn relative to other garden components, including vegetable garden and sealed space, is apparent in the visualization based on the Herent survey data (Figure 1). Presence of and coverage by vegetable gardens roughly match the results from Belém (Brasil), where 22 % of the garden space was devoted to vegetables (Madaleno, 2000).

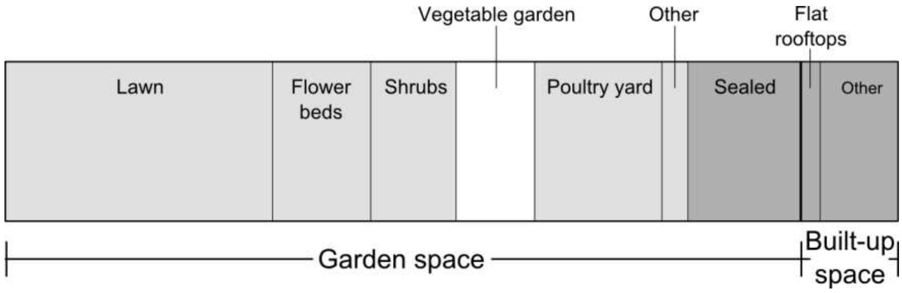

Figure 1 Summarizing use profile of the domestic gardens in Herent, based on the average area per garden component (N=25)

An extrapolation of the area of actual productive vegetable gardens L_h can be made for Flanders. Based on the internet survey (n=1,138), the total garden area $\bar{L}$ containing a vegetable garden is calculated. First, the estimated average size for a vegetable garden is calculated using the lower and upper limit of the area classes. Then, this average size is multiplied by the garden area percentages containing vegetable gardens. This results in an estimated $\sum_1^n \bar{L}_h$ area of 86 km² of vegetable garden for Flanders.

6 THE IMPACT OF CONSTRAINTS ON THE ALLOCATION OF LAND AND TIME FOR FOOD PRODUCTION IN HOME GARDENS

The interrelation between the allocation of area and time invites to further explore how capital, area and time constraints are affecting decision on the area (L_h) and time (t_h) for food production in domestic gardens (all in ceteris paribus terms).

Given the emphasis of this paper on the spatial perspective, we discuss three strategies to by-pass the spatial constraints represented by μ (Figure 2). We solely consider area-bound solutions. We associate time constraints (represented by γ to each of the three strategies.

6.1 Stock of food productive space within the single garden

While in principle the total garden space can be used for home garden production, this is seldom the case in reality. Part of the non-productive garden space is transformable to home garden production while other parts are less (or not) transformable. The smaller the non-transformable part of the garden, the less likely the area constraint will become effectively binding.

In Flanders, the main components of non-productive garden space (L_o) are lawn and sealed surface (Table 9). A lawn is an example of transformable garden space because its transformation requires virtually no cost and effort. Combined with its omnipresence, large spatial coverage, uniform and unsealed character, but also its rather negative environmental reputation (Giner, Polsky, Pontius Jr, & Runfola, 2013) (in terms nutrient and other inputs and of quantities of mowing), it represents the most prominent transformable space in a typical garden. Transitions from lawn towards more food productive vegetable gardens are realistic (Haeg, 2008). An extrapolation similar to the one for vegetable gardens results in a total lawn area of 435 km² in Flanders showing potential for food production.

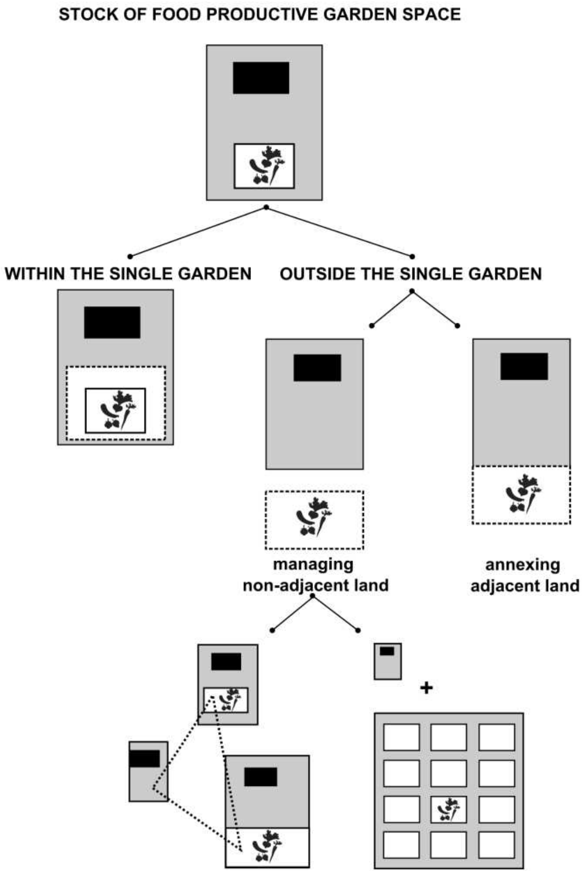

Figure 2 Summarizing the spatial potential for home food production. The discussed strategies are visualized within a response tree.

In terms of coverage, sealed surfaces are the second most important garden component (Table 9). We assume that these sealed surfaces are a non-transformable part of the garden L_o, i.e. that garden owners will not easily break out their terraces, driveways and garden paths. Therefore, the area of sealed surfaces puts a distinct physical constraint on the decision space of a household. An increase of the sealed surface would substantially limit spatial adaptation possibilities. Verbeeck et al. (2011) found an average increase of impervious area by 1.3 m² per year for residential parcels due to gradual autonomous development for Flanders. This sealing evolution restricts the potential for increasing L_h within the own garden. If the area of non-transformable garden space is low, it becomes less likely that area constraint will be binding and the larger the decision space of the household on how much time to allocate to home gardening and on how much food to buy or produce themselves.

Garden components	**Flanders** Percentage of the surveyed garden area					
	Absent [%]	<25%	25-49%	50%	50-75%	>75%
Lawn	0.5	17	29.8	21.1	24.6	6.9
Flowerbeds	3.9	67.4	24.3	2.3	1.6	0.4
Vegetable garden	58.3	33.1	6.7	1.1	0.4	0.3
Poultry yard	67.8	28.4	2.5	0.5	0.4	0.3
Sealed surfaces	3.3	83.7	11.2	1.1	0.4	0.2

Table 9 Relative spatial coverage by garden components for Flanders, based on the internet survey (N=1,138)

	Herent	
Garden component	**Presence** (% gardens)	**Mean area** (m^2)
Lawn	100	515.4
Flower beds	96	99.5
Shrubs	80	105.9
Vegetable garden	56	187.4
Poultry yard	36	549.7
Sealed surfaces	100	144.2

Table 10 Presence and mean area of garden components for Herent, based on the garden visits (N=25)

6.2 Stock of food productive space outside the single garden

In practice, the finite single garden space $\bar{L}$ is not always an absolute limitation. The individual land constraints (represented in the model by μ) may be bypassed by available L_h outside the own garden.

6.2.1 Managing non-adjacent land

We present two different strategies to increase L_h with non-adjacent land outside the own garden.

The first strategy is managing the vegetable garden of family, friends and neighbors. This strategy can be considered as a response within the garden complex, as it involves existing domestic gardens.

Capability for garden management can decrease due to time constraints γ, for example when the available time for gardening (t_o and t_h) decreases. Possible reasons are an increase of t_w, for example in the two-income family model, or a decrease of t_h as soon as it becomes difficult to maintain the garden yourself, for example in an ageing household. Likewise, a decreasing t_w causes the available time t_o and t_h to increase, for example at retirement or when becoming unemployed. This time can then be spent in the own garden, or in the garden of others. Several studies indicate that home gardening is mainly conducted by retired people (Domene & Saurí, 2007; Reyes-García, et al., 2012) as this group has not only time but also knowledge (Madaleno, 2000).

There is an interaction with the available t_w, t_o and t_h over different households. The garden owner can rent out part of the garden to others. Garden produce might be shared amongst the garden owner and garden manager which can be considered as an in-kind rental payment. In-kind rental payment is a payment in a form other than cash, in this case garden produce. Such renting is illustrated by Meert (2000) with the example of a grandson maintaining his grandmother's vegetable garden in exchange for a part of the produce.

"In [...] there are many elderly that have a garden but who can't manage it. They can give loan that garden to people that would want to manage it." *(Head of a city green management department of a medium scaled city)*

The second strategy is joining a co-gardening project or allotment garden. Within such projects, the social interactions and the distribution of the gardening (and the time it allocates t_h) amongst several households are seen as important surplus values (Table 11). This second strategy thus includes land outside the garden complex.

"The new allotment gardens in the city increasingly have a communal character […] you have the 'garden clusters', where one cluster is jointly managed by 4 to 5 families. The obvious advantage for young families is that you only have to go there once or twice a week" *(Staff member of the city spatial planning department)*

Categories	**Concepts**	
Interaction	Sharing and exchanging	Gardening material
		Yields
		Seeds
		Knowledge and experiences
		Garden: garden sharing
	Social contact	
	Temporary gardening support	
Search for collectivity		

Table 11 Categories and concepts related to the social surplus for garden owners when joining co-gardening projects, based on the qualitative data

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6.2.2 Annexing adjacent land

The individual extension of the total garden area $\bar{L}$ is also possible by annexing adjacent land through renting or buying. The annexed land may or may not be part of the garden complex, e.g. when buying garden space from neighbors.

We discuss further the annexing of non-garden space, and focus on agricultural land. Gardens in the Flemish countryside or peri-urban areas are currently being expanded by annexing (a part of) an adjacent agricultural parcel to the garden (Dewaelheyns, et al., 2014).

7 GENERAL DISCUSSION AND CONCLUSION

Increasing demand for food, raising energy prices, growing land scarcity, climate change and other factors put pressure on food systems (Fraser, Simelton, Termansen, Gosling, & South, 2013). As food security is an essential point of interest with respect to the adaptive capacity of our society, the strategic importance of local food systems cannot be ignored.

In this paper, we want to reinforce insights in the potential contribution of domestic gardens to the adaptive capacity of (local, urban, …) food systems. Attention for the food productive role of domestic gardens is rather limited, especially in the developed world. The intrinsic complexity of functions and services provided by domestic gardens may be one of the reasons. Their fragmented and private character impedes a comprehensive understanding of their relevance. A few studies, however, have gained insights in the productivity and gross financial benefits of vegetable gardening (Algert, et al., 2014; Reyes-García, et al., 2012). Understanding the potential of the garden complex in building adaptive capacity requires insights in food production decisions within the garden complex.

This is captured in the model by exploring direct linkages between the household utility and constraints in land and time with respect to home food production. Utility theory helps to understand consumer preferences and provides insights on how to unlock or at least safeguard the existing food productive potential, in financial and spatial terms, of domestic gardens. The most noted result was for vegetables and potatoes, where the amount of home garden produce is equivalent to about one third of the amount of these products bought at the market.

Land potentially available for food production could increase within and outside the individual garden. In order to provide the vegetable needs for a household of four persons, it is estimated that about 350 m² of vegetable garden is needed (Seymour, 1976). For the 6 million inhabitants of Flanders, this translates to 525°km² of vegetable garden. Currently 86 km² of the Flemish garden space is used for vegetable production. Using an additional 439 km² (or 39 %) of the Flemish garden space for garden food production theoretically allows Flemish households to become self-sufficient in vegetables consumption.

Technically spoken, lawn could be easily transformed into vegetable gardens. The estimations of lawn area for Flanders (435 km²) can be added up to the current estimated area of vegetable gardens. This results in a potentially food productive area of 521°km², almost equivalent to the required area of 525°km². The spatial potential exists to nearly provide in the vegetable needs of all Flemish inhabitants depending solely on domestic gardens.

This reflection obviously applies to the larger spatial level of the garden complex and ignores some aspects of demand. At the household level, the available garden area is unequally distributed. It is also impossible to grow the entire diversity of preferred vegetables and fruits in the garden, e.g. because of climatological limitations. There are also additional constraints on the available garden space, like historical pollution with heavy metals.

Despite these restrictions we can state however that the potential of domestic garden area for food provision is far from marginal. This fits the statement from Kortright and Wakefield (2011) that the potential land for food production from domestic gardens is likely to be far more than from community gardens in the near future.

The insights in the spatial potential for food production in domestic gardens indicate that domestic gardens should not be neglected within discourses on adaptive capacity of urbanized areas. For example, the model shows how increasing food prices or increasing preferences with home grown produce (because for example its low carbon footprint) may lead to more garden area to be allocated for food production. This adaptive response is subject to the constraints and preferences of the household and is reduced when more garden space is sealed and not or not easy transformable to home garden production. In that way, safeguarding the unsealed space which is easily transformable to home grown food production increases the adaptive capacity and hence the resilience of the social-ecological system in question.

The ‘victory gardens’ clearly illustrate the contribution of home food systems to adaptive capacity of the society. During World War II, the victory gardens provided in 44% of the fresh produce in the US (Pothukuchi & Kaufman, 1999). They were an effective response initiated and stimulated by policy (Ginn, 2012) to a heavy shock in the society. Part of the adaptive capacity lies in the short feedback loops between production and consumption, also present in domestic gardens. Producing your own vegetables can be implemented at short notice, on the precondition that sufficient space remains available and the effort is effectively coordinated.

“If we go to a period in which attention for food production in the garden is really needed, as it was the case for the generation of our grandparents, it remains to be seen of we are doing well with those very small gardens.” *(Staff member of the city spatial planning department of a large-scaled city)*

Sufficient transformable garden space is not the only precondition of mobilizing the adaptive capacity of home food gardening. Gardening requires gardening knowledge as this influences the land and labor productivity of home grown food production. Safeguarding this knowledge and its exchange amongst family and neighbors increases the adaptive capacity. The case of Cuban urban agriculture illustrates this (Buchmann, 2009). During the communist regime, the agricultural system in Cuba was determined by a high wealth, high degree of connectedness, a low diversity and high dependence of the international economy all preconditions for a high vulnerability to shocks (Fraser, Mabee, & Figge, 2005; Rodríguez, 1987). The collapse of the Soviet Union, being Cuba’s most important trading partner, has lead to the implosion of Cuban food systems due to the loss of high-tech agricultural practices (Febles-González, Tolón-Becerra, Lastra-Bravo, & Acosta-Valdés, 2011; Maal-Bared, 2006). Subsequently, this lead to the start of the ‘Special Period’, marking a clear shift in household decision-making towards home garden food production in order to increase the individual adaptive capacity (Buchmann, 2009). This evolution was part of the Economic Reanimation (Febles-González, et al., 2011). The emergence of private markets provided an incentive to cultivate formerly barren patches of land and gardens (Alvarez & Puerta, 1994). To be able to cultivate, local gardening knowledge had to be rebuilt again through collective learning, which allowed an increase in food production a few years after the collapse in the early 1990s and resulted in a reorientation toward agroecology (Palma, Toral, Parra Vázquez, Fuentes, & Hernández).

Capturing and exchanging information between actors in a social-ecological system can be defined as safeguarding the social-ecological memory, and is a major source of community resilience (Barthel, et al., 2010). In Flanders, the housing policy in the twentieth century (par. 3.1) was accompanied by the dissemination of gardening knowledge amongst the population, especially in the post world war II period. A number of organizations were established to that end. Men had to learn modern horticultural techniques and how to make cultivation plans, while women followed cooking lessons and learned how to preserve vegetables through brining and sterilization (Segers & Hermans, 2011). These educational goals were pursued by a range of levers, including lectures and the publication of books and brochures, model gardens and the mobilization of status and identity through shows and competitions (Segers & Hermans, 2011). With the decline of such dissemination efforts, gardening knowledge is diminishing, with negative consequence for the resilience of social-ecological systems.

8 FUTURE RESEARCH

This paper illustrates the productive potential of domestic gardens and their potential contribution to the adaptive capacity of food systems. A more comprehensive database on garden produce c_2 is needed to better assess the food production potential and adaptive capacity of domestic gardens. There is a lack of monitoring of home grown food production and consumption. A continued assessment of the adaptive capacity of food provisioning within domestic gardens needs comprehensive panel data, which could be gathered during monitoring programs. Logbooks kept in a (semi-) autonomous way and calibrated portable scales (Algert, et al., 2014) could be useful. Survey efforts should be spread in time or at least supplemented with alternative approaches to assess garden production (Niñez, 1987).

To safeguard the productive and adaptive potential of domestic gardens, it is also crucial to understand households' decision to allocate space and time to home grown food production. More information about household preferences to allocate time and space to a kitchen garden or to other activities would help to refine the model developed in this paper. One could for example rely on choice experiments for this. Such experiments could quantify the households marginal utility in relation to area and time allocated to home produced food.

Input (z) is another important variable that we currently could not unravel due to lack of data. Yet, it is a crucial variable to evaluate sustainability questions. Several studies indicate negative environmental impacts from the (mis-)use of inputs (Robbins, Polderman, & Birkenholtz, 2001; Syme, Shao, Po, & Campbell, 2004). Where home food production is part of a food strategy, the environmental aspects of production are of special interest (Kortright & Wakefield, 2011; Madaleno, 2000). Especially since garden management is not monitored nor regulated for the use of fertilizers and chemicals, as is the case for agriculture (Dewaelheyns, et al., 2013). Future research should aim at raising understanding in input usage and its environmental impact.

Input use is influenced by habits, the available gardening knowledge and experiences. We believe that the exchange of knowledge in society plays an essential role. Gaining insights in the capturing, organization, prevalence and exchange of gardening knowledge is a crucial research track to better understand the input variable. Cleveland and Soleri (1987) already found that a lack of understanding of, and adaptation to local conditions results in garden design and management strategies unsuited for the local environmental and social conditions.

"My daughter also gardens, as long as it goes wells. As soon as something goes wrong, I have to solve it" *(Man, 67 years, retired)*

Throughout the acquisition of new data, the model developed in this paper can be refined and inform policy on the potential role of domestic gardens in food strategies, as well as on opportunities and pitfalls that have to be considered. When provided with the proper data, the model should be able to deliver quantitative estimates of the identified trade-offs. Although developed based on insights generated from a case in the developed world, we think that this model –when tweaked– could also be applicable in developing countries.

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