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Urban Gardening in Germany: Cultivating a Sustainable Lifestyle for the Societal Transition to a Bioeconomy

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Abstract: Urban gardening has the potential to turn the growing number of consumers into conscious producers by raising awareness of natural resource cycles, contributing to environmental conservation and climate change mitigation. This study investigated the motivations for urban gardening in Germany, based on an extensive review of 657 urban gardening project websites. The subsequent online survey of 380 project participants provides a characterization of the gardeners, giving insight into both cultivation methods and technologies used and the participants' consumer behavior. It was shown that urban gardening has an influence on consumer behavior and can induce a change towards a more sustainable lifestyle. The gardens provide a space for the exchange of social values, knowledge and ideas on different ways of life among the diverse participants. Hence, urban gardening creates far more than just food; it influences society on multiple levels. Urban gardening can support the bottom-up societal transition towards a bioeconomy as both have common attributes. Finally, the paper proposes an innovative, resource-efficient cultivation system that may attract further societal groups to the urban gardening lifestyle, with the aim of fostering the development of the bioeconomy.

Keywords: urban gardening; survey; motivations; characterization; cultivation methods; terrabioponics; transformative group; societal transition; bioeconomy

1. Introduction

Urban food production is currently experiencing a renaissance, with urban gardening becoming a global trend. On every continent, more and more people are starting to garden in cities [1–3]. The motivations for this development are manifold and differ from urban garden to urban garden and from region to region. In countries of the South, urban gardening is often driven by the basic human need of food consumption, as poorer people in particular garden in order to become food secure [3,4]. In the Global North, the reasons are quite different: urban gardening has become a lifestyle trend, with the gardens becoming meeting points that unite various interest groups. Some urban inhabitants want to participate in city development and the shaping of their own district or block [4,5]. In this way, urban gardening establishes new forms of public–private partnerships for the utilization, design and financing of particular (public and private) spaces in cities [6]. New green areas are created. Others want to reconnect with nature [7]. Through urban gardening, city dwellers can experience nature on their doorstep. During the process of preparing the soil, through to planting and finally harvesting a crop, they create, observe, alter and eventually come to understand the growth and decomposition cycle of natural resources. This influences their own nutrition habits and raises a

consciousness for food production as well as natural resource use and labor input [4]. Another group of gardeners is more interested in greening the city. From an environmentalist perspective, these areas serve as habitats for various plants and animals that provide a range of ecosystem services to the city [5,8]. Transpiration of plants can have a cooling effect on city climates during the hotter seasons [9]. Plant surfaces can filter air pollutants (NO₂, SO₂, O₃ and particles with a size less than 10 µm), thus helping to clean city air [10]. Additionally, green areas like public parks, private home gardens and urban community gardens, where city dwellers garden together on public and private spaces, increase the retention of water through high soil infiltration rates at times of intense rainfall events [8]. The flowering of plants throughout the gardening season attracts a wide range of pollinators [11]. In addition to providing habitats for plants and animals, green areas in cities are also meeting points for the people themselves, across generations, cultural backgrounds, occupations and income levels [5].

Cities can benefit from urban gardening in many ways. In Germany, it is seen as an important component of city development plans, for example in the guidance and research recommendations of the 'National Platform for Future Cities' [12].

In future, the number of people living in cities and metropolitan areas will increase. On a global scale, the proportion of urban inhabitants is projected to grow from 48% in 2014 to up to 70% in the year 2050 [13,14]. In some regions, these figures have already been reached, such as 72% in Europe in 2014 [14] and 75.5% in Germany in 2016 [15].

Urban gardening can turn the growing number of consumers into producers. This has the addition effect of raising awareness of natural resource cycles and their currently unsustainable exploitation. The resulting change in consumer behavior can contribute to the conservation of the environment and mitigation of climate change.

These goals are also inherent in the development of a bioeconomy. The bioeconomy strives for a sustainable economy that is based on natural matter cycles to conciliate economic growth with environmental conservation and climate change mitigation [16,17]. To achieve this, more sustainable modes of production and consumption need to be created [18]. Thus far, the bioeconomy development is mainly driven by a top-down approach of technical innovations and novel processes to substitute fossil resources with biomass as well as the creation of green business models [18,19]. However, the transition towards a bioeconomy can only be achieved when it is understood and endorsed by the society and promoted by the people themselves [16]. *"The development of the bioeconomy is part of a societal transition that unites multiple trends and initiatives from 'green economy' and 'sharing economy' to 'citizen science' and 'urban farming'"* [17]. Recently, [20] described urban gardening as local (block or quarter level) participatory approaches of transformative economic activities with the urban gardens being the nuclei of crystallization of this movement.

This study investigated the ways in which urban gardening can influence consumer behavior and act as a potential starting point for a more sustainable lifestyle. For this purpose, it explored the motivations for the establishment of urban gardening projects in Germany, based on an exhaustive review of their project websites. In addition, an online questionnaire was used to survey urban gardeners from these projects. The results were analyzed to give an overview of the demographic factors of urban gardeners, together with production methods and technologies used. The survey also explored the impacts of urban gardening on the consumer behavior of people who had begun the practice in recent years. Based on the results, an innovative, resource-efficient urban garden concept is introduced that can serve as a useful tool to further encourage the urban gardening trend. Finally, the implications of these findings for the societal transition towards a bioeconomy are discussed.

2. Materials and Methods

This study applied a two-pronged approach to explore, analyze and characterize urban gardening in Germany. The first step was the exploration of urban gardening projects based on an exhaustive web search that was carried out in August and September 2017 according the steps for conducting a literature review [21] (p. 29f): (i) The following urban gardening network websites (databases)

were screened to identify urban gardening projects: *foundation anstiftung* (map of projects all over Germany) [22], *gruenanteil* (map of projects all over Germany) [23]; *Urbane Oasen* (map listing urban gardening projects in North Rhine-Westphalia) [24]; *bonnimwandel* (map of urban gardening projects in the city of Bonn) [25]. The project name, location and website link were collected in a MSO Excel 2016 file; (ii) based on a preliminary reading of the project websites, the following key words were derived and subsequently employed in the search engine google (Google LLC, Menlo Park, CA, USA) to identify further projects not part of the networks: *urban gardening/farming*, *city gardening/farming*, *urbane(r) Garten/farm*, *Gemeinschaftsgarten*, *Nachbarschaftsgarten*, *Interkultureller Garten*, *Integration + Garten*, *Stadt + Garten/gärtnern* and *guerrilla gardening*; (iii) in this study, projects were defined as ‘urban gardening projects’ when several people (at least two) actively engage in the cultivation of vegetables, fruit (trees), herbs or ornamental plants on private (but accessible for group members and/or public) or public areas in urban or peri-urban areas. In most cases, these groups used the term ‘urban gardening’ or ‘urban farming’ on their website or called themselves a ‘community garden’, ‘neighborhood garden’, ‘intercultural garden’ or similar. Private (home) gardens, (organized) allotments and urban gardens managed by municipalities were excluded from the investigation; (iv) a list of 657 projects was compiled and the motivational aspects of the foundation of the urban gardening projects were collected by collating information on the aim(s), mission and/or vision from the websites and copying them into the excel file. Next, the aim, mission and/or vision statements of the projects were grouped into categories and labeled with a term (code), developed from the emerging information [21] (p. 186f); (v) the aim, mission and/or vision statements were broken down into buzzwords to derive a final set of distinct categories and sub-categories [21] (p. 189) (Table 1); (vi) finally, the frequency with which a sub-category was mentioned on a website was recorded, with multiple aim, missions and/or vision statements being counted separately.

Following the website review, the second step comprised an online survey using the software package *SoSci Survey* [26]. The link to the online questionnaire was sent via e-mail to all contact persons of the urban gardening projects identified in the first research step. The contact persons were asked to forward the e-mail with the survey link to all members of their urban gardening project (snowball sampling) [21]. The online questionnaire provided a resource-efficient way of contacting a large number of people in a short period of time during the non-gardening season. A total of 380 urban gardeners answered the questionnaire between 15th December 2017 and 15th January 2018.

The online questionnaire consisted of 16 questions. Eleven were standardized single- or multiple-choice questions. The other five asked the participants to enter their year of birth, postcode, number of members in the garden project, founding year of the garden project, and number of years they had been gardening. In addition to demographic factors (age, gender, origin, education level, occupation, family status, private garden area), the participants were asked about their experience with methods and technologies used for urban gardening and whether or not they liked them. Those gardeners with no experience of a particular method or technology were asked to rate their degree of interest based on a Likert scale of 1 to 5. Further questions solicited information on their consumer behavior before and after their participation in an urban gardening project began. These questions enabled the analysis of whether their gardening activities had altered their consumer behavior.

Answers to the questionnaire were analyzed performing descriptive statistics in MSO Excel 2013. Averages, ranges and trends were calculated [21]. Finally, to further investigate the urban gardening phenomenon, a cluster analysis was employed to identify mutually exclusive segments of urban gardeners with a comparable attitude towards modern production technologies using IBM SPSS Statistics 25 (Armonk, NY, USA). All variables included in the cluster analysis are shown in Section 3.4. A two-step procedure was used as clustering method: sub-clusters were initially defined and subsequently merged until an optimal number of clusters was reached. This method was chosen, since in the second step, a standard agglomerative clustering algorithm estimates myriad solutions and

reduces them to an optimal number of clusters. To do this, we applied Schwarz's Bayesian Inference Criterion that features less subjectivity than other clustering methods [27].

Table 1. Motivation categories for urban gardening based on information given on German urban gardening project websites.

Category	Sub-Category
Social community	Social gathering and learning Social meeting, networking/exchange/community Neighbourhood vitalisation, solidarity Local identity ('Heimat')
Gardening, experience nature	Learn gardening, joy of gardening, fun Experience nature, work in/with nature
Intercultural communities	Cultural/social diversity Intercultural meeting, exchange and community Integration
Environment and ecology	Sustainability, sustainable lifestyle Future development Biodiversity Organic production, old varieties and diversity Soil fertility, permaculture Beekeeping
Public involvement	Public engagement/involvement/design Use of public spaces for communities Encourage (political) discussions Grassroots democracy, self-determination
Education	Education, environmental education Awareness of organic, regional and healthy nutrition Experimental garden, educational garden
Recreation	Relaxation, leisure time Cultural activities
(Self-)Sufficiency	Urban self-sufficiency, local food
Urban image	City greening/beautification, nature in the city Living space, local recreation areas
Health and nutrition	Healthy food, health, nutrition Organic food
Therapeutic approach	Trauma therapy, coping strategies
Commercial project	Urban gardening as a business model Production for sale (seeds, plants, foods, drinks)

3. Results

Urban gardening projects and the participants are characterized in the following, emphasizing on the motivations for urban food production, the cultivation methods and technologies used as well as attitudes of the project participants towards modern production technologies. Finally, a modern and resource-efficient urban gardening technology is introduced.

3.1. Urban Gardening Projects in Germany

A total of 657 urban gardening projects were identified in Germany (November 2017), the vast majority of which had been founded since 2010 (Figure 1a). Most projects have 11–20 participants (Figure 1b).

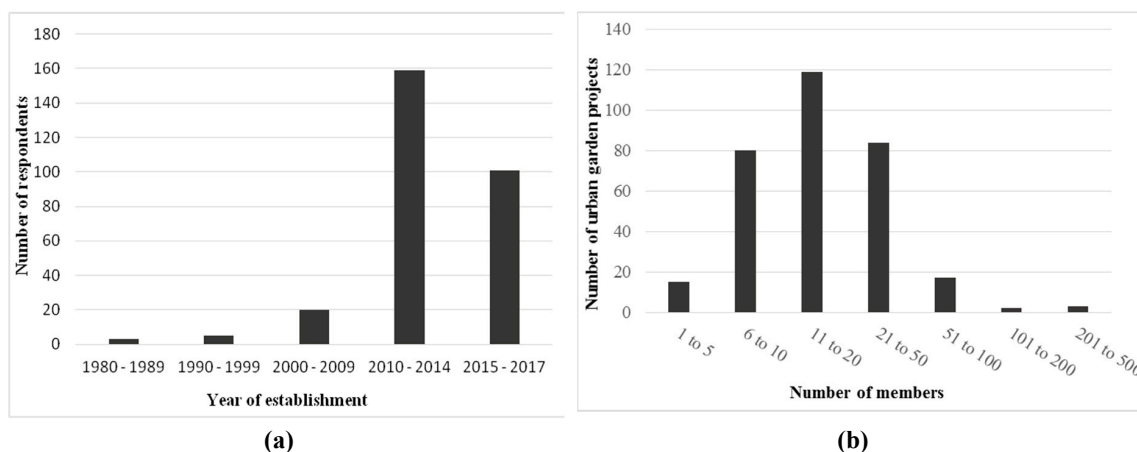


Figure 1. (a) Year of establishment of urban gardening projects in Germany 2017 ($n = 657$); (b) Number of members per urban gardening project ($n = 365$).

The reasons for the establishment of urban gardening projects in Germany are manifold (Figure 2). The most important motivations are: social interaction, intercultural exchange, working and learning with nature, and gardening ecologically to live sustainably.

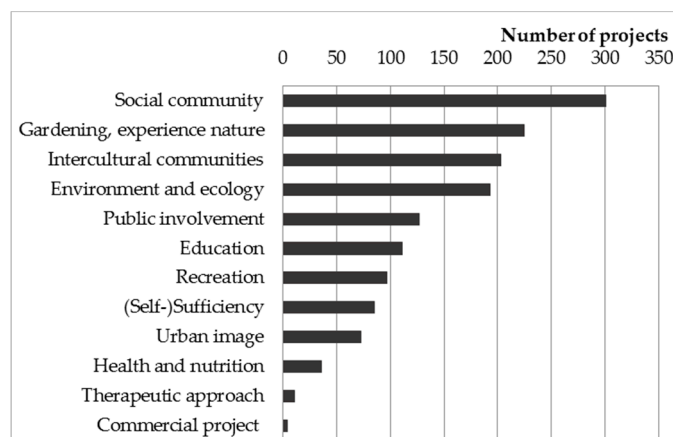


Figure 2. Motivations for the establishment of urban gardening projects ($n = 657$) in Germany up to November 2017.

Values such as community spirit, neighborhood and solidarity are central to 301 of the projects (*social community*). *Gardening as experience of nature* (225 projects), where people learn about and to work with nature, is the second most important reason for urban gardening. This is followed by the category intercultural exchange and integration (*intercultural communities*, 203 projects) and sustainable lifestyles and ecologically sound gardening practices (organic production, soil fertility, biodiversity) (*environment and ecology*, 193 projects), which have almost equal importance. The initiation of and participation in social discourse are encouraged by 127 projects (*public involvement*), calling for grassroots democracy for decisions on the utilization of public spaces. *Education* about the environment is the focus of another 111 projects. The aspects (*Self-*)*sufficiency* (85) as well as *health and nutrition* (36) were found to be of less importance. A similarly low ranking was obtained for improvement of the

urban image (73) in terms of beautification of a city through greening. Only four projects are driven by commercial interests, and eleven pursue a therapeutic approach (Figure 5).

Thus social and ecological (sustainability) aspects were found to be the main drivers of the establishment of urban gardening projects in Germany. These social and ecological values are in common with the principles and values associated with the societal transition towards a bioeconomy (Section 1).

3.2. Characterisation of Urban Gardeners in Germany

The geographical distribution, according to postcode zones, of urban gardeners who responded to the survey reveals that urban gardening is currently performed in cities throughout Germany (all federal states, Figure 3a). The participants in urban gardening projects are a very heterogeneous group. Two thirds (66%) of the survey respondents were female, suggesting that more females than males garden in cities. Further, urban gardening is performed by city inhabitants of all age groups, with most gardeners being born between 1980 and 1989 (Figure 3b). Whether the gardeners originate from rural (<5000 inhabitants—31% of respondents) or urban (>100,000 inhabitants—30% of respondents) areas does not influence their urban gardening activities.

On average, the respondents have been active in an urban gardening project for 3.3 years and already have 12.8 years' gardening experience. The majority of respondents are employees, self-employed or students (71%), followed by pensioners (Figure 4a). Consequently, urban gardening is, to a large extent, a leisure activity.

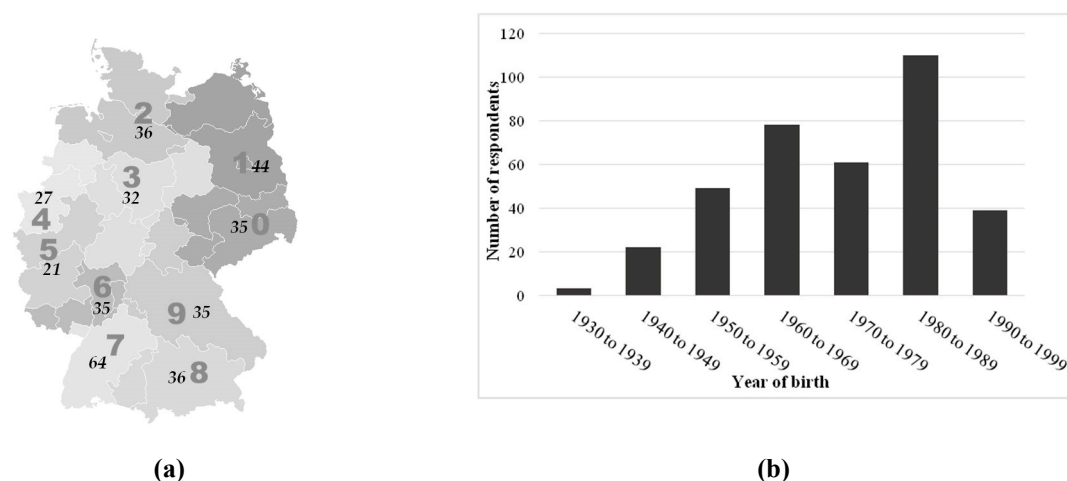


Figure 3. (a) Geographical distribution of urban gardeners in Germany ($n = 365$) according to postcode zones (Map adapted from [28]); (b) year of birth of the surveyed urban gardeners in Germany ($n = 362$).

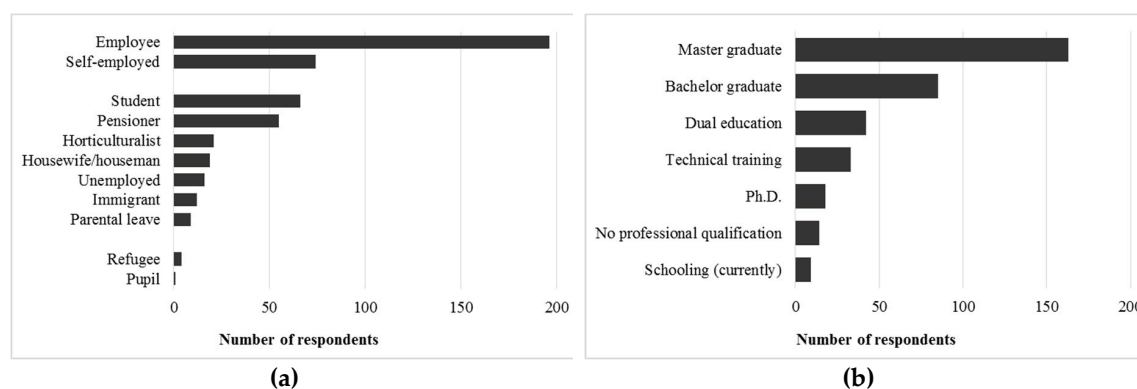


Figure 4. (a) Occupation/legal status of urban gardeners in Germany ($n = 473$, multiple responses allowed); (b) Highest educational qualification of urban gardeners in Germany ($n = 364$).

The highest proportion of urban gardeners (54%) is in a partnership, 40% of respondents are single without children, and 33% of the respondents have children.

Furthermore, urban gardening tends to be performed by people with a higher education (73%, Bachelor's degree from a university, incl. university of applied sciences, or higher) (Figure 4b).

Urban gardening projects offer the only possibility of gardening, apart from on windowsills, for 27% of the respondents (Figure 5). One third of the respondents have at least a balcony or terrace that could be used for urban gardening, while 29% have a home garden or garden property.

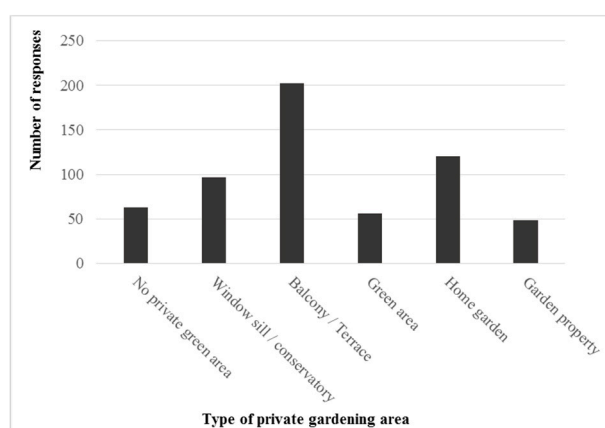


Figure 5. Private area available for cultivation to urban gardeners in Germany ($n = 365$; multiple responses allowed).

The major reason for joining an urban gardening project is that the project represents ‘something bigger’ that the participants want to support or join, such as the integration of refugees, societal transformation and environmental protection. Many of the respondents are either the founder or a member of the founding group of the project. Many people were attracted by gardening projects in their neighborhood or were personally invited by project members. Another group of respondents had actively searched for a project in their city (Figure 6).

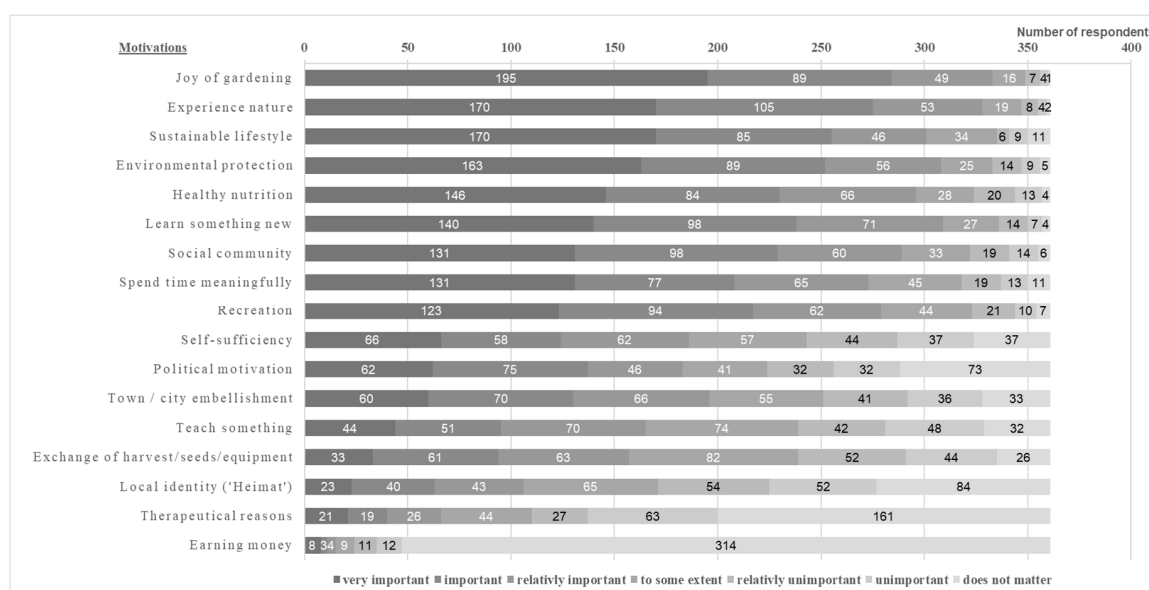


Figure 6. Reasons for joining an urban gardening project ($n = 359$).

The personal motivation for urban gardening is strongly related to the experience of nature, for example through the joy of gardening activities, pursuit of a sustainable lifestyle, and protection of

the environment (Figure 7). The personal aspect of healthy nutrition and the social aspect of being part of a community are also very important. The gardeners want to spend their (free) time meaningfully for example by learning something new, but also enjoy spending time in the gardens for recreation purposes. Some urban gardeners seek to achieve food self-sufficiency, aim to embellish their town/city through the gardens or are politically motivated. Other motivations include teaching others and exchanging harvest/seeds/equipment. Earning money through urban gardening is not a motivation for the vast majority of gardeners.

Furthermore, the answers given by the respondents to the question ‘How important are the following criteria when buying gardening equipment?’ underline the importance of sustainability in their consumer behavior (Figure 8). Functionality, durability and regionally sourced products made from sustainable resources are important buying criteria for garden tools and materials. Cheap prices are only important to some extent or relatively unimportant, while the design does not matter for the majority.

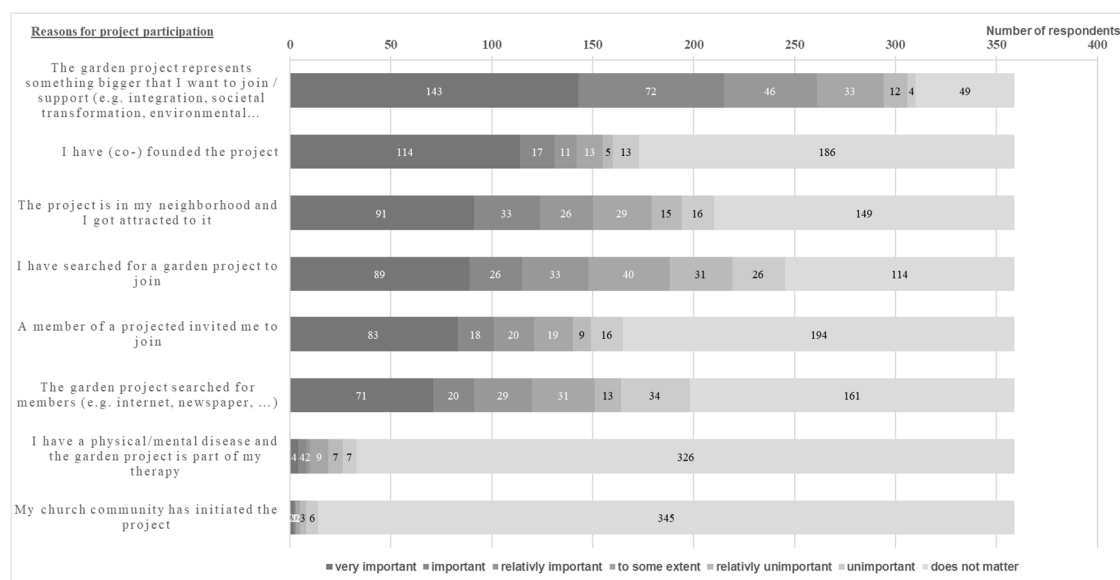


Figure 7. Motivations for urban gardening ($n = 361$).

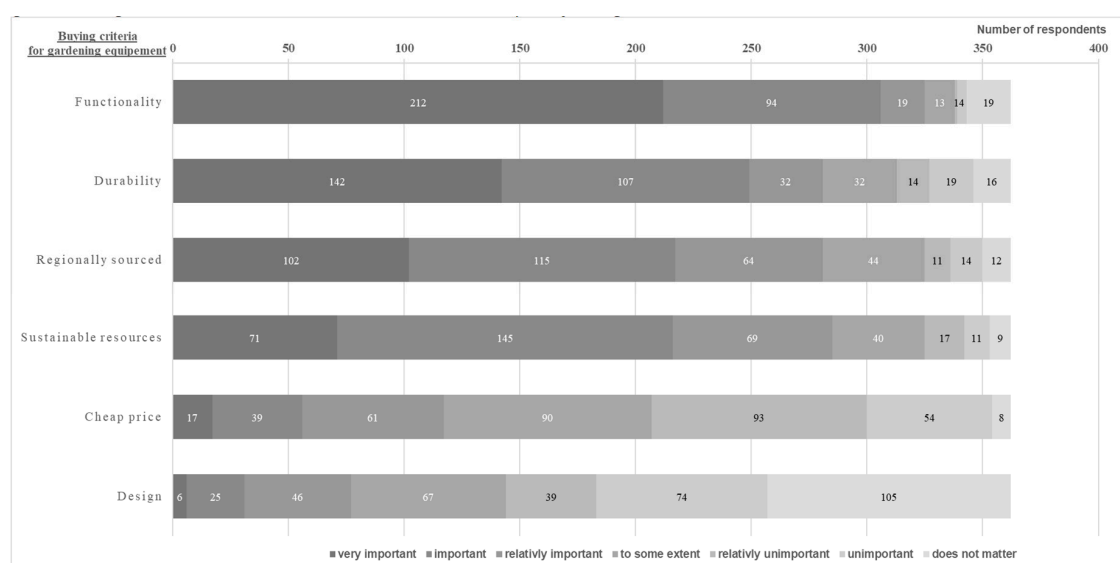


Figure 8. Relevant criteria for urban gardeners when buying gardening equipment ($n = 362$).

3.3. Urban Gardening in Germany: Production, Cultivation Methods and Related Technologies

Almost all urban gardeners in Germany cultivate food crops. Ornamental plants constitute the second most frequent produce (Figure 9). Livestock, predatory insects, animals (non-food use) and energy currently only play a minor role. However, livestock production, the keeping of pets and the promotion of predators are likely to increase in the coming years at the urban gardening projects. Over a third (36%) of respondents is also considering energy production (electricity, gas, heat) in their garden.

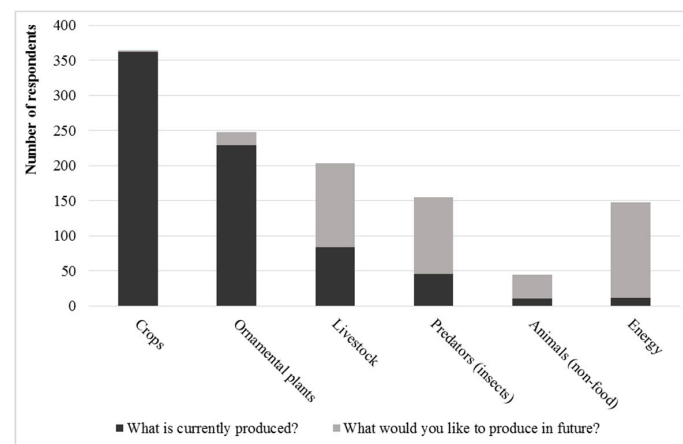


Figure 9. What is currently produced in urban gardening projects in Germany and what gardeners would like to produce in future ($n = 380$).

Common plant cultivation methods include traditional garden beds and raised beds (Figure 10a). Cultivation in pots and tubs is also popular, but 12% did not like this method. Mound cultures (similar to raised beds, but without a surrounding support structure) are also built and used. The interest in these cultivation methods expressed by gardeners who have no experience of them shows the same pattern (Figure 10b). Vertical garden structures (e.g., attached to walls) are not very common. However, those who have tried (and possibly needed) these structures rated this gardening form positively (Figure 10a). The interest in vertical gardening is also quite high (Figure 10b). To date, the modern hydroponic and aquaponic systems are not very well known. The few gardeners who have tried these systems seem disappointed and consequently rated these cultivation methods negatively (Figure 10a). However, a few gardeners who have no experience of aquaponic (22%) or hydroponic (14%) systems are interested in trying them (Figure 10b).

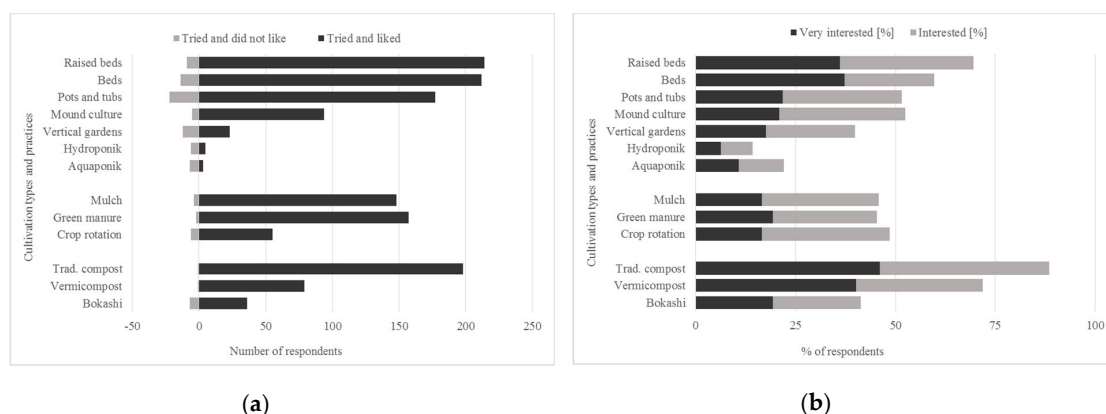


Figure 10. (a) Cultivation areas and gardening practices tried and assessed (liked/not liked) by urban gardeners ($n = 10$ – 226); (b) interest in cultivation areas and gardening practices of those urban gardeners who have no experience of the respective area or practice ($n = 134$ – 353).

Half of the gardeners apply mulch (42%) to their cultivation patch and/or plant green manure (44%). Both methods are rated positively. Only 17% of the gardeners plan and keep to crop rotations on their cultivation patches, and of these 11% are not satisfied with them (Figure 11a). Almost half of the gardeners are interested in using these three cultivation methods (Figure 10b).

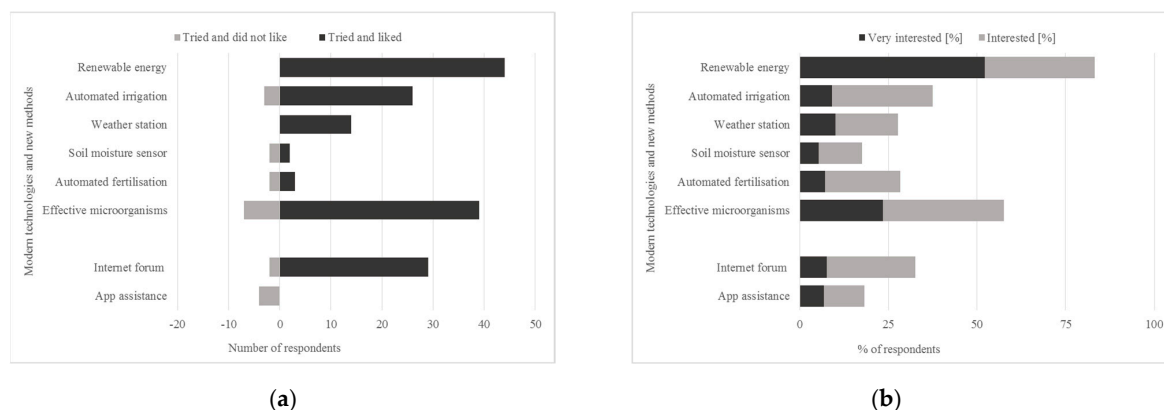


Figure 11. (a) Modern technologies and new methods tried and assessed (liked/not liked) by urban gardeners ($n = 4\text{--}46$); (b) interest in modern technologies and new methods of those urban gardeners who have no experience of the respective technology or practice ($n = 316\text{--}358$).

About half (55%) of the urban gardeners produce their own fertilizer from traditional composting and are satisfied with it. One in five gardeners (22%) uses and likes the special form of vermicomposting, while 12% use the Bokashi method (Figure 10a). Of those who do not compost, 88% are interested in starting it. Vermicomposting has very much caught the attention of urban gardeners, with 72% of the respondents expressing their interest in it (Figure 10b). Organic production methods including composting, green manure and mulching are quite common among the urban gardeners.

Finally, the gardeners were asked about both their interest in as well as their experience of modern technologies and practices that can aid gardening, for example by decreasing effort, increasing yields, making it easier to obtain detailed information, and producing renewable energy (Figure 10a,b).

The latter received the most attention. Those gardeners (12%) who already use a renewable energy technology in the garden project are satisfied with it (Figure 11a). Another 83% would like to produce renewable energy in their garden (Figure 11b). Effective microorganisms are used by 12% of the respondents to improve composting, soil fertility and plant health. About 15% are not satisfied with this method, while 57% of the urban gardeners show great interest in it (Figure 11a,b). Approximately one third of urban gardeners either use or are interested in Internet forums for information exchange (33%) and automated irrigation (37%). Other modern technologies and methods included in the survey are not in use to date. A few urban gardeners expressed their interest in weather stations and automated fertilization (both 28%), while only 18% would welcome a gardening information app and only 17% are interested in using soil moisture sensors.

3.4. Urban Gardeners' Attitudes towards Modern Production Technologies

A two-step cluster analysis was performed to analyze urban gardeners' interest in the modern production technologies *vertical production*, *aquaponics* and *hydroponics* in greater detail. Two different segments of urban gardeners (clusters) were identified (Table 2). The box plots of the cluster analysis reveal intra-group differences (Figure 12).

Respondents belonging to cluster 1 are highly interested in the production technologies mentioned above. About 40% of respondents belong to this group, mainly younger male gardeners. The other approximately 60% of the gardeners belong to cluster 2; these respondents tend to be older and female. Whether the urban gardeners grew up in rural areas or cities does not influence their interest in modern technologies.

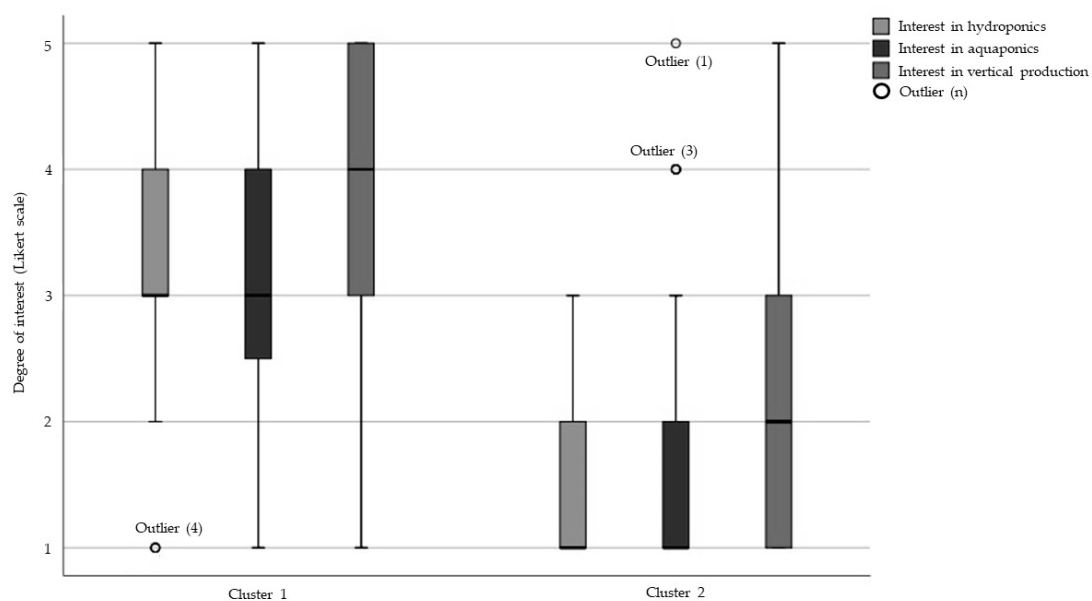


Figure 12. Box plots of the two-step cluster analysis. Degree of interest based on Likert scale: 1 = no interest, 5 very high interest (circles indicate outliers in the clusters).

Table 2. Interest of urban gardeners in modern production technologies based on a two-step cluster analysis ($n = 303$).

	Cluster 1	Cluster 2	Total
Number of respondents	119	184	303
Interest in 'new' production methods [1 = not interested; 5 = very high interest]			
<i>vertical production</i>	3.93	2.38	2.99
<i>aquaponics</i>	3.31	1.51	2.21
<i>hydroponics</i>	3.27	1.38	2.12
Gender [1 = male; 0 = female]	0.41	0.28	0.33
Gardening experience [in years]	11.07	13.53	12.56
Age [in years]	43.13	46.70	45.30
Residence during childhood [1 = town < 5,000 inhabitants; 4 = City > 100,000 inhabitants]			
	2.50	2.43	2.46
Motivation for urban gardening [1 = not applicable; 7 = fully applicable]			
<i>Earn money</i>	1.22	1.23	1.23
<i>Therapeutic aspects</i>	2.66	2.56	2.60
<i>Self-sufficiency</i>	4.61	4.20	4.36
<i>Political motivations</i>	4.24	4.20	4.21
<i>City/town beautification</i>	4.60	4.43	4.50
<i>Local identity</i>	3.58	3.26	3.39
<i>Learn something new</i>	6.03	5.67	5.82
<i>Healthy nutrition</i>	5.97	5.45	5.66
<i>Environmental protection</i>	5.93	5.78	5.84
<i>Sustainability</i>	5.95	5.73	5.82
<i>Exchange of harvest/seeds/tools</i>	4.51	3.95	4.17
<i>Solidarity within the gardening group</i>	5.76	5.55	5.63
<i>Recreation</i>	5.63	5.66	5.65
<i>Meaningful utilization of leisure time</i>	5.72	5.45	5.56
<i>Experience nature</i>	6.11	6.14	6.13
<i>Gardening pleasure</i>	6.29	6.18	6.22
<i>Dissemination of knowledge</i>	4.29	4.03	4.13

The general motivation for urban gardening differs only slightly between the two groups. Gardeners interested in modern production technologies perform urban gardening because a self-sufficient, healthy nutrition is important to them. This group is interested in exchanging harvest, seeds and tools, learning something new and using free time for meaningful activities. Environmental protection and sustainability aspects associated with urban gardening (Section 1) tend to be more important to them than to cluster 2. The cluster 2 respondents tend to consider urban gardening as a form of recreation in which they can experience nature. They favor conventional garden beds or raised beds for gardening.

3.5. Urban Gardening Impacts Consumer Behavior

Urban gardening reconnects urban inhabitants with nature [7]. The gardeners learn about natural resource use as well as the time and labor inputs required to produce food. To analyze the effect of this on consumer behavior, the survey asked urban gardeners whether they actively changed their food-buying habits since they started gardening. Indeed, the results show distinct changes in consumer behavior (Table 3).

Urban inhabitants increased their food self-sufficiency in summer by 471% and in winter by 79% compared with the year before they started gardening. As their produce is self-consumed, with a proportion being preserved for the winter, the percentage of fresh cooking ingredients also increased (+18%). With the freedom of choice of what to plant in their gardens, the consumption of traditional fruit and vegetable varieties also rose by 25%. As the vast majority of urban gardeners produce vegetables (Figure 9) and only a few raise livestock, participation in a gardening project also leads to a decrease in consumption of meat and sausage (−10%) and other animal products, such as dairy products (−4%).

Table 3. Changes in consumer behavior of urban gardeners since their active participation in an urban gardening project ($n = 310$).

Investigated Aspects of Consumer Behavior	Change [%]
Food self-sufficiency during summer	+471
Food self-sufficiency during winter	+79
Consumption of meat and sausage	−10
Consumption of other animal products	−4
Cooking with fresh ingredients	+18
Consumption of traditional fruit and vegetable varieties	+25
Organically produced food	+26
Regionally produced food	+35
Seasonally produced food	+42
Engagement in other projects supporting a sustainable future	+5

In addition, the method of production and origin of the food purchased became increasingly important to the urban gardeners. The respondents purchase 26% more organic food, 35% more regionally produced food and 42% more seasonally produced food. These figures show that urban gardening alters the consumer behavior of the gardeners beyond the borders of the gardening project. The consumer behavior becomes more organic, regional and seasonal, coupled with a healthier diet (less animal products, more fresh ingredients). Consequently, urban gardening alters urban food systems, rendering them more sustainable.

4. Discussion

4.1. Urban Gardeners—Characteristics of a Transformative Group

Urban gardening projects have grown up in cities in all German federal states, mainly within the past decade.

4.1.1. Characterization of Urban Gardeners in Germany

Urban gardeners in Germany are a heterogeneous group in terms of demographic factors—age, gender, occupation, educational background and origin. The majority of gardeners are between 29 and 59 years old, have a relatively high education level and are in employment. This is in line with the findings of [5], who sampled 38 urban gardens in Germany in 2013 with 60% of the interviewees being female and 47% having an academic background. Similar educational background, income level and gender (more females than males) characteristics were also identified for participants in self-harvest gardens in Germany [29].

Due to the diversity of the participants, urban gardens can be characterized as spaces with a high potential for the exchange of social values, knowledge, (gardening) practices and ways of life. In addition to creating diverse forms of gardening, the project activities can lead to lasting relationships between people in groups with significant power and social status differentials. This in turn provides the basis for a strong collective capacity, which can benefit society through the active shaping of city development [30].

In collective action theory, however very heterogeneous groups are deemed as negative for social interaction and consensus building [31]. Rogge et al. [2] recently analyzed the heterogeneity of urban gardening groups in Germany with respect to social sustainability and the social capital created. Their results indicate that a too high heterogeneity within gardening groups has a negative impact on the social sustainability of the projects. However, [2] state that the heterogeneity measured is neither too high nor too low, leading to the assumption that the participant diversity is positive for the creation of social capital. The interaction of diverse cultural identities, viewpoints, backgrounds and lifestyles can promote mutual learning. Urban gardeners are and need to be creative with respect to both gardening practices (e.g., space-efficient vertical gardens, pots and container gardens, renewable energy production), their organizational structure and their collaboration with municipalities [32], as the urban environment are primarily not predestined for gardening. The heterogeneity is also reflected in the multiple motivations for urban gardening.

4.1.2. Motivations for Urban Gardening

The motivations for urban gardening are manifold. This is expressed by the project founders as well as by the gardeners themselves. The founders see the creation of a social community as their main motivation. This is grounded in the collective desire of the majority of participants to live an ecologically sound lifestyle that connects them with nature and, at the same time, helps protect the environment. This phenomenon of reconnection with nature [33] is described by [34] as ‘re-grounding’. Various studies in Germany [2,7,20], Switzerland [35], Austria [36], Italy [37], the US [30,33,38], and Canada [38] confirm the importance of community building and social exchange through gardening. The members participate in the projects because they enjoy gardening activities, being close to nature, working with living plants and animals, and ‘getting their hands dirty’ to create tangible (e.g., garden beds, food, flowers) and non-tangible outputs (e.g., meeting points, local recreation areas, knowledge sharing, participation in city development).

However, the respective importance of the various motivational aspects for urban gardening vary from case to case. Studies in the US and in Switzerland confirm the ‘joy of gardening’ as the top-motivation for urban gardening activities [33,35]. A case study in Milan (Italy) ranked the aspect of healthy food most important, followed by gardening as exercise and for relaxation [37]. Food self-sufficiency is a benefit for the gardeners to some extent, but is not a major motivation for gardening activities. The same result was also reached by case studies from Ljubljana, Milan and London that analyzed the economic performance of urban gardens in these cities [39]. The amount of food produced and/or revenues created are often too low to be of significance in economic terms [20]. However, [40] point out that urban food production can yield sufficient vegetables to meet the recommended personal dietary intake, using less than 10% of urban areas. Hence, urban

gardening can decrease the pressure on rural farmland in particular through the production of crops consumed fresh, such as vegetables, fruit and herbs.

The socio-ecological motivations to live a sustainable lifestyle based on a sustainable and healthy nutrition form the backbone of urban gardening, also in the US where the movement began [38]. The urban gardening movement has since spread around the globe, with these motivations being the main driver of urban gardening in the Countries of the North [4]. International institutions, including the Food and Agricultural Organization of the United Nations (FAO), the World Health Organization (WHO), Resource Centers on Urban Agriculture and Food Security (RUAF Foundation) conceptualize urban gardening based on these main motivations [41].

4.1.3. Urban Cultivation Methods and Technologies

First and foremost, food and ornamental plants are cultivated and animals are raised in cities in a variety of ways. Fresh food is self-produced locally and seasonally, using mainly organic cultivation methods [5]. Being a producer means satisfying the basic human need for food in a self-controlled, self-dependent and thus responsible way [20].

In this sense, urban gardening encompasses a strong social innovation dimension [41,42], even though the frequently applied cultivation methods—beds, raised beds, mound culture and composting—are not innovative themselves [5]. The survey and subsequent cluster analysis revealed that modern cultivation systems such as hydroponics, aquaponics and certain production technologies (e.g., automated fertilization, soil moisture sensors, weather stations and app support) are only being adopted slowly. Modern technologies, such as hydroponic and aquaponics systems as well as roof-top farms, have higher resource use efficiency and productivity [42–44], but require substantial amounts of construction material and energy input. Hence these technologies diffuse more slowly than low-tech applications like rainwater harvesting and irrigation systems, which are easier and cheaper to install and maintain [42].

The urban gardeners surveyed in this study are more interested in organic cultivation systems that reconnect with nature, such as traditional composting, vermicomposting, effective microorganisms, mulching and crop rotations. Renewable energy technologies are also being increasingly implemented to provide electricity in the gardens, for example for automated irrigation.

4.1.4. Influence of Urban Gardening on Consumer Behavior

The values associated with urban food production are based on knowledge of production and processing, control over and trust in these methods, with respect to freshness, flavor and organic production [45]. This study shows that self-production of food in urban gardens has a large influence on consumer behavior. Since taking up gardening, the participants of urban gardening projects in Germany purchase more seasonally, regionally and organically produced food. This indicates that there is interest and willingness to learn where the food comes from and how it is produced.

The interest in and demand for traditional fruit and vegetable varieties has also increased. The gardeners are attracted by the broad spectrum of fruit and vegetable varieties. One main reason for this may be the widespread public belief that the contents of mineral macronutrients, trace elements and vitamins are much higher in traditional/old varieties than in modern high-yielding varieties [46]. Although this is only partly true and very much depends on the specific varieties and their growing conditions [46], the trend contributes to healthy nutrition and agricultural diversity.

The change in consumer behavior is a strong political statement that calls for sustainable food production methods and supply chains.

4.1.5. Multifunctional Roles and Societal Impacts of Urban Gardening

Urban gardening is currently triggering societal discourse on the sustainability and future viability of agricultural production, food value chains and consumer behavior. Food and nutrition has become a democratic instrument for sensitizing society to food systems, markets and demands

nutrition habits and wasteful consumer behavior, while encouraging alternative food networks [42,45]. Cities form the starting point of this debate—in the past because of the lack of trust in production and processing methods, today additionally because the neoliberal food value chains are threatening human livelihoods (especially in countries of the South), biodiversity, natural ecosystems and climate for the sake of economic growth [20].

One aspect that is particular to urban gardening is the fact that the participants act on several levels at the same time [20]. Most of the gardening projects see themselves as open learning and sharing platforms [5,20], which can foster social values like the common sharing of goods and the empowerment of people [42]. The projects often focus on knowledge dissemination to stimulate open learning processes [42], for example by offering workshops on and trainings in topics such as organic growing, alternative cultivation methods (e.g., raised beds, container/pot and mobile gardens), food processing and conservation. In addition, new forms of collaboration with local stakeholders are initiated, for example canteen/restaurant-supported gardening, pop-up gardening on abandoned areas, communal kitchens and school gardens [5,32]. A strong network of support and exchange is vital to gardening projects from the very beginning. The initiation of a gardening project first requires the ownership of the cultivation space to be clarified, followed by implementation of supportive structures for the creation of basic infrastructure and knowledge exchange. Close collaboration between the garden projects and municipalities can often help develop the full potential of urban gardening with its associated benefits for cities (see Section 1) [5]. For example, the project ‘Himmelbeet’ in Berlin gave rise to strategies for tackling exclusion, disinvestment and depoliticization of public spaces [6].

Urban gardening provides a strong social bridge with the capability to increase civic engagement and social empowerment [42]. This is based on sharing and exchanging diverse knowledge, cultural values and practical skills. All three arise from food production and are transferred into various levels of society and governance, actively shaping city development [5,20,40].

The societal transition potential of urban gardening reaches far beyond just growing food in cities. By digging the soil and planting vegetables, urban inhabitants actively engage in the discourse on global sustainability [38] and contribute to overcoming key challenges posed by urbanization: climate change, food security, biodiversity and ecosystem services, agricultural intensification, resource efficiency, urban renewal and regeneration, land management, public health, social cohesion, and economic growth [47]. Global agricultural and environmental threats are tackled bottom-up by becoming a producer at ground level. This characteristic is important in addressing the complex requirements for social change [20]. Urban gardeners are a growing group of people who denounce the imperial lifestyle with respect to food production, distribution and consumption and their fatal consequences on the environment, climate and livelihoods of people in Countries of the South [20].

Consequently, urban food production fosters environmental and social values [45]. This results in a strong political statement being sent out from the urban gardens to the adjacent neighborhood, local political institutions (e.g., city development departments) and international institutions with the aim of supporting the sustainable development goals [4,5,20,30,40,42,47].

4.2. Urban Gardens—Cultivation Areas for the Growth of the Bioeconomy?

Urban gardening actively transforms consumer behavior, shapes city development and brings the current agricultural production system into public discourse. Since urban inhabitants have started to garden, the ecological and socially sound production of food has increased in importance. The survey also showed that urban gardeners purchase gardening equipment based on the criteria *functionality*, *durability*, *regionally-sourced*, and *sustainable materials*. *Cheap prices* and the *design* are only of secondary importance. It is likely that urban gardeners also apply these criteria in their choice of other products and services consumed, such as new products made from biobased rather than fossil resources. The urban gardening trend helps make more people understand natural matter cycles. This awareness can be transferred to other areas in life, indicating the great potential for urban gardening to alter demand and consumer behavior in society towards sustainable products.

The supply of sustainable products made from biobased resources is the core of the growing bioeconomy. Urban gardening and the bioeconomy share common attributes: both are based on natural ecosystems, matter flows and natural cycles of growth and decomposition. Currently, scientific and technical innovations are among the major driving forces of the bio-based economy [19]. A holistic and system approach in the realization of technical innovations is crucial to the bioeconomic transformation process. The technical innovations require social acceptance, economic feasibility and the creation of ecologically sound value chains [17]. The success of the societal transition towards a bioeconomy ultimately depends on people's understanding of natural matter cycles, and their support of and commitment to the sustainable use of natural resources [16]. Technical innovations made for the development of the bioeconomy need to be matched to the interests of political, economic and civil society stakeholders. Hence, the adoption of innovative technologies and new products (e.g. made from biomass rather than fossil resources) is a social development process that requires the transformation of social values and consumer behavior [48]. Knowledge and understanding of sustainable natural resources utilization in society are vital for the transition towards a bioeconomy. In this respect, (urban) food self-production is a very promising activity for the stimulation of sustainable resource use.

4.3. Terrabioponic Gardening—Sowing the Seeds of Natural Resource Appreciation

In line with the motivations for urban gardening and technology preferences of the gardeners assessed in the survey, a resource-efficient urban gardening technology is proposed here to further encourage the urban gardening trend and the societal transition towards a bioeconomy: Terrabioponic smart-garden systems (Figure 13). These garden systems recycle plant nutrients from organic household waste by vermicomposting (*bio*). The resulting organic nutrient solution ('vermitea'), containing plant nutrients and beneficial microorganisms [49] is directed to the crops via an automated irrigation system in the bottom layer of the planting containers (*ponic*). Solid vermicompost added to organic planting substrate as nutritive organic fertilizer ensures natural growing conditions by supplying humus, macro- and micronutrients, beneficial soil microorganisms (including N-fixing and P-solubilizing bacteria) and growth hormones (*terra*) [49]. The integrated water and nutrient cycle is operated automatically by a 12V solar system with battery and timer. Additionally, the terrabioponic garden system is equipped with a smart control and management board with an interactive user interface (app). This allows the system to be controlled from anywhere and offers a smart planting calendar to guide the user through the gardening season. Water level and dissolved oxygen sensors indicate when irrigation/water change is necessary in the planting pots. Temperature and light sensors provide information on plant growth and calculating the harvest date of individual crops. Sensors measuring pH and EC (electric conductivity) indicate the decomposition rate of the organic waste (indicator of compost worm activity) and the resulting fertilization effect of the nutrient solution.

The proposed terrabioponic smart-garden system is based on the cultivation methods and technologies that were identified as most favored by the urban gardeners in the survey: raised beds, vermicomposting and automated irrigation based on renewable energy. Terrabioponic cultivation is derived from recirculating aquaponic systems [43]. The aquaculture part was replaced by a vermicompost and the fish feed with organic kitchen wastes as nutrient source. The Cuban cultivation approach *organopónico* also utilizes vermicompost in planting pots, but manual watering [50]. The terrabioponic garden system circulates vermitea through the planting containers via an underground irrigation layer. This enables automated, efficient irrigation and organic fertilization simultaneously.

The autonomous garden systems are designed for balconies, terraces, backyards and flat roofs. Food production is based entirely on available urban resources—organic waste, water and solar energy—for ecologically sound production on a seasonal and local basis. The fact that organic waste, fed into the vermicompost, can be used as a single nutrient source for vegetable production was demonstrated by [51]. Natural resource cycling provides the core of terrabioponic gardening. Natural growth and decomposition processes are directly observable and become tangible for the

users. The users are (re-)connected with these processes, by directly working with them guided by the app. Knowledge is gained about how food is produced, what resources are needed, where these resources come from and how natural cycles influence production. The understanding of these basic natural principles and resource cycles is also vital for the societal transition to a bioeconomy [16].



Figure 13. (a) Overview of the terrabioponic garden system: functionality diagram; (b) test garden system on a private balcony with 3x planting containers, 1x vermicompost, 1x water tank and solar power supply in Freiburg i.Br., Germany; (c) vermicompost with *Eisenia foetida*; (d) aerated water tank for the production of the organic nutrient solution ('vermitea'); (e) irrigating gravel layer in a planting container with plant roots (bottom right). Further information: <http://www.geco-gardens.de>.

The terrabioponic smart-garden systems combine all three dimensions of the bioeconomy [52]: *Bio-resources* are used directly in a *bio-ecological* system. The terrabioponic smart-garden system thus represents an innovative biotechnological tool that enables the population to perform bioeconomic on a daily basis.

The terrabioponic smart-garden systems are therefore deemed a promising tool for the cultivation of bioeconomic thinking in further societal groups. The involvement of the younger generation in particular is necessary for the development of a future, knowledge-based bioeconomy. However, the survey revealed that the generation younger than 29 is not very active in urban gardening. This group, often referred to as 'digital natives', may be attracted through the app interface and the smart gardening guide. The terrabioponic garden allows food self-production in a digital and 'playful' way. Given that the well-known Facebook game 'FarmVille' has been installed by over 700 million people worldwide [53], there is a large potential for technophile people to start 'playing' FarmVille in real.

In addition, the cluster analysis revealed that more males than females are interested in modern cultivation methods and technologies including vertical gardens, hydroponics and aquaponics, which apply automated irrigation, sensor control and technological setups [1]. Therefore, the perspective of using modern technologies to build and control a biological (garden) system may encourage more males to take up urban gardening.

Automation also has the advantage of making gardening less time-demanding. The terrabioponic smart gardens require maintenance about once a week to feed the compost worms with a defined amount of organic waste (depending on the size of the growing area) and refill the water tank (if not attached to a tap or a drainpipe from the roof). This lowers the entry point for gardening by reducing time-consuming activities such as regular watering and fertilization.

The space-efficient, smart gardens with an attractive design are also deemed suitable for canteens and restaurants. Fresh food ingredients can be produced directly where these are prepared and consumed. Organic kitchen wastes can additionally be recycled into vegetables and herbs. This value proposition may also be attractive to companies and institutions as it emphasizes their sustainability thinking.

Utilizing modern technology to grow food in urban areas can therefore be an effective practical tool to make urban gardening attractive to societal groups other than those identified in the survey (Figure 14). Terrabioponic smart gardens make natural matter cycles visible and tangible. Urban citizens experience natural resource cycles through a circular garden system based on growth and decomposition. Guided by the smartphone app, the gardeners obtain new knowledge that can stimulate the understanding and appreciation of natural resource cycles (Figure 14). This production method promotes environmental (natural resource cycles), social (effort/labor of crop cultivation) and economic (value of the produce) values. These values create an awareness of agricultural food production and in turn alter consumer behavior towards more sustainable (regional, seasonal, organic, fresh) food purchasing decisions. Hence, urban gardening can alter the consumer behavior of various societal groups in an environmentally sound way, facilitating the societal transition towards a bioeconomy.

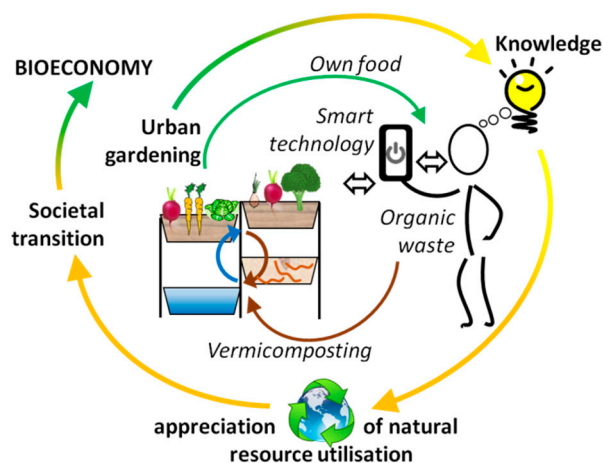


Figure 14. Resource cycles and socio-technical interactions of the terrabioponic smart-garden systems (vegetable and resource symbols from [54]).

5. Conclusions

This study explored the motivations for urban gardening in Germany, characterized the participants in terms of demographic factors, production methods and technologies used and analyzed the impacts of urban gardening on consumer behavior. First, the aims and mission/vision statements on the project websites were explored; subsequently an online survey was sent to the project participants. This approach was limited by the fact that not all urban gardeners could be reached, as the projects included in the study are only those with a website. Secondly, contact with the project participants could only be established via the project contact persons, who were asked to forward the link to the survey. Further research might benefit from face-to-face interviews at the project sites to reach all subgroups of gardeners, including those without email access and non-German speakers. In addition, the link between urban gardening and the development of the bioeconomy conceptualized

here, needs be investigated in more detail, for example by exploring the interest and/or activities of urban gardeners in other initiatives such as the renewable energy transition, clean mobility, biobased (fossil-free) products, the sharing economy etc. Nevertheless, 657 project websites were screened and 380 urban gardeners surveyed in this study, such that the results can be considered reliable.

The socio-ecological motivations to live a sustainable lifestyle based on sustainable and healthy nutrition form the backbone of urban gardening in Germany. These motivations influence the consumer behavior of the participants: since taking part in gardening projects, they purchase more seasonally, regionally and organically produced food. The projects create social communities and promote mutual learning by connecting people with diverse cultural identities, viewpoints, backgrounds and lifestyles. This renders urban gardens transformative spaces that drive the public discourse on the sustainability and future viability of agricultural production, food value chains and consumer behavior, including their fatal impacts on biodiversity, natural ecosystems and the climate. This coincides with the main motivations for the development of a bioeconomy. Through its multiple functions and a strong collective capacity, urban gardening can trigger societal change towards a knowledge-based bioeconomy, which goes far beyond providing sustainably produced biomass, especially food [55]. Consequently, urban gardening activities offer great potential for the bottom-up fostering of the societal transition towards a bioeconomy and provide the social counterpart to the techno-economically driven bioeconomy policies advocated top-down by political and scientific institutions.

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