THE ROLE OF URBAN AGRICULTURE FOR SUSTAINABLE AND RESILIENT CITIES

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Declaration

I hereby declare that this doctoral dissertation is the result of an independent investigation and it has been generated by me as the result of my own research.

Where it is indebted to the work of others, acknowledgements have duly been made.

Thomas Alexander Masyk

Augsburg, 24.03.2021

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ABSTRACT

The topic of the study is to determine the role of urban agriculture for the sustainability and resilience of cities. The investigation of its forms, technologies and implementation options shows to what extent urban agriculture is suitable for improving urban sustainability and resilience. This question is explored against the background of global climate change, the rapidly growing world population, progressive urbanization with the associated increasing degradation of the ecosystem, and threats to food security. The aim of the research is to lay the foundation for climate-adapted city and land planning concepts with new findings on the mitigation and adaptation potential of urban agricultural systems.

Based on a comprehensive definition of sustainability, resilience, and vulnerability, and using the Seed Scale and Emergence approach, the basic conditions for a successful development of urban farming initiatives and concepts are examined. A review of modern soilless cultivation methods and a SWOT analysis of the vertical farming concept provide insights into possible uses, sustainable advantages and properties that can strengthen urban resilience.

In the empirical part of the study, semi-structured interviews with city authorities, scientists and urban activists show the current embedding of urban agriculture into the green infrastructure of cities based on the goals of the German sustainability strategy, of Agenda 21 and Agenda 2030 programs. The results of an online survey with 120 participants show a broad acceptance of the different forms of urban agriculture and their high importance as a tool to mitigate and adapt to climate change. The perceived multiple benefits (ecological, economic, and social) of urban agriculture and its potential to improve urban sustainability and resilience are good reasons for strengthening its integration into current and future urban development plans.

Case studies on the function of urban agriculture according to Singapore's Climate Action Plan and of the Emirati Food Security Strategy demonstrate how urban agriculture can contribute to securing food supplies under difficult and completely different conditions as in Germany. An overview of the current state of research shows the support of the results of this study by leading scientists and various research projects which advocate a paradigm shift towards a green infrastructure. Highly productive, environmentally friendly technologies such as hydroponics, aquaponics, and roof-top and vertical farming cannot only significantly improve urban food security, but also have numerous advantages for the ecological, economic and social sustainability and resilience of a city.

Still, there is a great need for research in relation to quality and certification processes for the practical integration of urban agriculture into buildings and for analyses of the full economic life-cycle of vertical farming projects. These are an essential requirement for further establishing and up-scaling this extraordinary agricultural production method, which has the potential to revolutionize the urban food system of the future.

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LIST OF ABBREVIATIONS

ADFEC	Abu Dhabi Future Energy Company
APTERR	ASEAN Plus Three Emergency Rice Reserve
ASEAN	Association of South-East Asian Nations
AVA	Agri-Food and Veterinary Authority
AWO	Workers' Welfare Association (Arbeiterwohlfahrt)
BCA	Building and Construction Authority
BDG	Federal Association of German Garden Friends (Bundesverband Deutscher Gartenfreunde)
BfN	Nature Conservancy Association (Bund für Naturschutz)
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
BMU	Federal Ministry for the Environment (Bundesministerium für Umwelt)
BSI	Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik)
CIB	Community in Bloom
DEUS	Decentral Urban Water Infrastructure Systems
DRI	Disaster Risk Index
DRM	Disaster Risk Management
EEA	European Environment Agency
ENCA	European Network of Heads of Nature Conservation Agencies
ESPON	European Spatial Planning Observation Network
EU	European Union
EU DEAR	European Union Development, Education and Awareness Raising
FAO	Food and Agriculture Organization
FRA	Floating Responsive Agriculture
FSI	Food Security Index
GALK	German Municipal Gardens and Parks Heads Conference (Deutsche Gartenamtsleiterkonferenz)
GDP	Gross Domestic Product

GFIA	Global Forum for Innovations in Agriculture
GHG	Greenhouse Gas
GLC	Government Linked Companies
HDB	Housing and Development Board
ICBA	International Centre for Biosaline Agriculture
ICLEI	International Council for Local Environmental Initiatives
IEEP	Institute for European Environmental Policy
IFAD	International Fund for Agricultural Development
IMF	International Monetary Fund
INAPRO	Innovative Aquaponics for Professional Application
INIS	Intelligent and Multifunctional Infrastructural Systems
INSEAD	Institute European d' Administration des Affaires
IRCEL-CELINE	Belgian Interregional Environmental Agency
IRENA	International Agency for Renewable Energies
IRPUD	Institut für Raumplanung Universität Dortmund
IUCN	International Union for conservation of Nature and Natural Resources
KOYA	Knowledge, Optimization, Yield, Activation
KRITIS	Strategy for Critical Infrastructure Protection
KTPH	Khoo Tech Puat Hospital
LED	Light Emitting Diode
MIT	Massachusetts Institute of Technology
NBS	Nature Based Solutions
NEA	National Environment Agency
OECD	Organization for Economic Co-operation and Development
PM 10	Particulate Matter 10
PRT	Personal Rapid Transit
RAMSES	Reconciling Adaptation, Mitigation and Sustainable Development for Cities
RESIN	Climate Resilient Cities and Infrastructures
ROI	Return on Investment
RTG	Rooftop Greenhouse

RUAF	Resource Centers on Urban Agriculture and Food Security
SDGs	Sustainable Development Goals
SEED	Self-Evaluation for Effective Decision-Making
SGIS	Skyrise Greenery Incentive Scheme
SOC	Soil Organic Carbon
SURF	Sustainable Urban Farms
SWOT	Strength, Weaknesses, Opportunities, Threats
TNFBs	Three National Food Baskets
UA	Urban Agriculture
UAE	United Arab Emirates
UBA	Federal Environment Agency (Umweltbundesamt)
UHI	Urban Heat Island
UN	United Nations
UN DESA	UN Department of Economic and Social Affairs
UNDP	UN Development Program
UNFCCC	UN Framework Convention on Climate Change
UNICEF	UN Children’s' Emergency Fund
UNISDR/UNDRR	UN Disaster Risk Reduction
URBES	Urban Biodiversity and Ecosystem Services
WBGU	German Advisory Council on Global Change (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderung)
WCED	World Commission on Development and Environment
WEF	World Economic Forum
WFP	World Food Program
WHO	World Health Organization

1.0 INTRODUCTION

Global developments and urban problems of mitigation and adaptation to the continuing climate change constitute the framework conditions for the design and operation of urban agriculture. The focus here is primarily on rapid global urbanization, the progressive deterioration of ecosystems and the threats to food security in many countries around the world. At the same time, the increasingly numerous large and mega-cities are confronted with serious environmental problems and have to face the challenge of developing a more sustainable and resilient food system.

1.1 Urbanization

Urban areas directly or indirectly cause the largest share of environmental impacts because they emit over 75% of greenhouse gas emissions worldwide.[1] The continuing process of global urbanization process will lead to the emergence of more mega-cities (cities with over five million residents), and it is estimated that there will be about 60 such mega-cities by 2025.[2] As the population, assets, and economic activities are concentrated in cities, more risks for these areas are derived from the potential negative effects of climate change: a higher population density increases the number of possible victims of health impacts by extreme weather; a higher degree of soil sealing may increase the probability of flooding and reduced vegetation; and heat-conserving urban materials, urban geometry, and abundant heat sources contribute to the "urban heat island" effect.[3] [4]

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[1] UN Habitat (2011): Cities and Climate Change: Global Report on Human Settlements 2011. https://unhabitat.org/wp-content/uploads/2012/06/GRHS2011-9.pdf. Retrieved on 13.6.2017

[2] Megacities - Mega Challenge - Informal Dynamics of Global Change. www.megacities-megachallenge.org. Retrieved on 17.5.2017

[3] European Environment Agency (EEA) (2012): Climate change, impacts and vulnerability in Europe 2012. https://www.eea.europa.eu/publications/climate-impacts-and-vulnerability-2012. Retrieved on 13.6.2017

[4] Intergovernmental panel on climate change (2014): Synthesis Report 2014. http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SY R_AR5_FINAL_full_ wcover.pdf. Retrieved on 13.6.2017

In addition, external threats can be unrelated to humans due to floods, droughts, lack of water, earthquakes, and similar events. Since the discrepancy between rich and poor steadily increases in megacities, the poorer strata of the population will be most severely affected by any crisis. Currently, more than 70% of the European population lives in cities, and, by the middle of the century, another 36 million urban dwellers are expected.[5] Worldwide, approximately 6.3 billion people will live in urban areas by 2050, which is an increase of 3.5 billion compared to 2010. The total populated land expanse, however, is expected to triple between 2010 and 2030 because urban areas grow faster than urban populations.[6] This urban expansion will further exploit natural resources and become a heavy burden on the environment.[7]

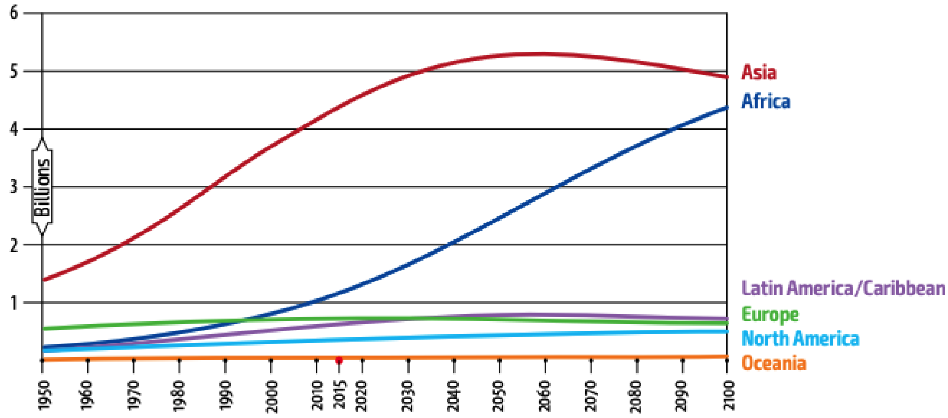

Figure 1 – Population growth by 2100 by region, UN (2015)

[5] European Commission: Nature-Based Solutions. https://ec.europa.eu/research/environment/index.cfm?pg=nbs. Retrieved on 24.9.2018

[6] ibid.

[7] Klepper, G., Schmalzbauer, B. (eds.) (2011): Global Change Research - Challenges and Strategies for a Sustainable Future. Global Change Research - Challenges and Strategies for a Sustainable Future. http://www.dkn-future-earth.org/en/publications/reports/archive-nkgcf/global-change-research-in-germany-2011.html. Retrieved on 3.6.2019

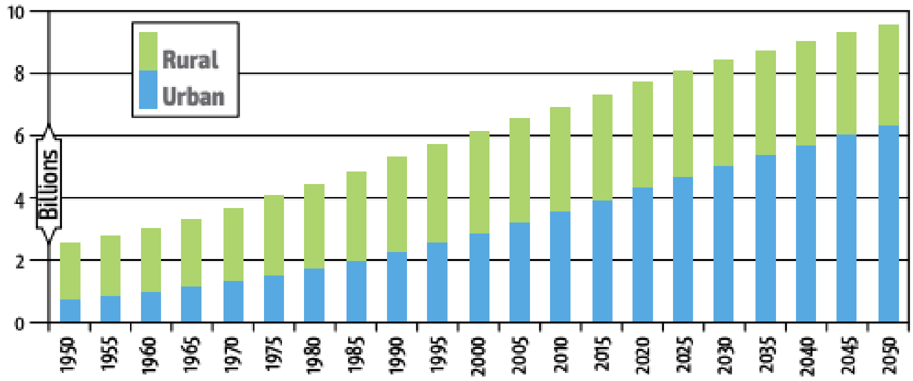

Figure 2 – Growth in global and rural populations until 2050, UN (2015)

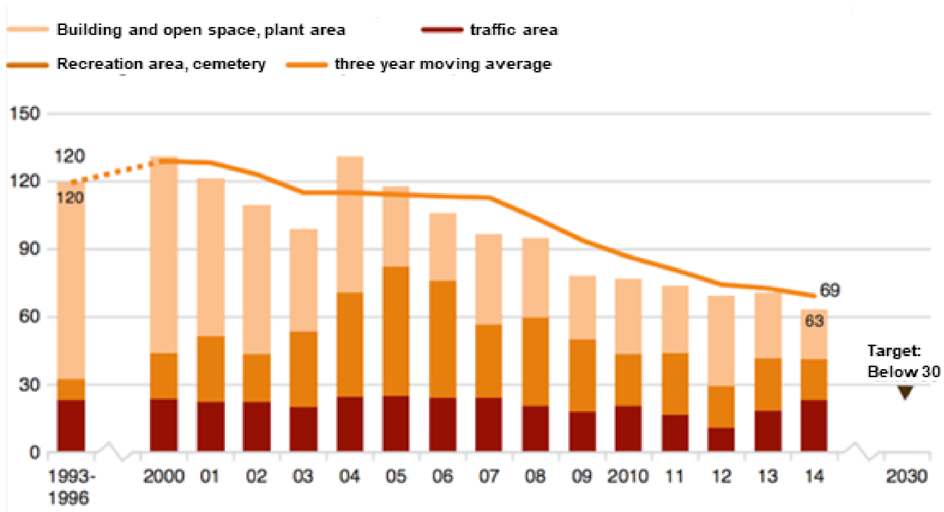

Figure 3 – Increase in settlement and traffic area, Federal Statistical Office (Statistisches Bundesamt) (2018)

1.2 Deterioration of the Ecosystem

Ongoing climate change and progressive urbanization call for new approaches to conserve natural ecosystems and the coexistence between city and nature because the interactions between climate, soil, aquatic life and flora, and a non-sustainable human land use endanger safe living conditions for future generations.[8] Each living being on earth, and especially mankind, depends upon functioning ecosystem services, such as clean air, food, water filtration, flood prevention, recreation, and climate regulation. Today, 60% of ecosystem services are already damaged or irreversibly damaged, including the most important ones, such as drinking water reserves, ocean fish stocks, and the balancing of local climate impacts. [9] The damage caused by humans cannot be remedied in the short term because of a dramatically growing demand for food, water, wood, and fossil resources. Adaptation to climate change is in principle possible for natural systems and also for human beings, but “it is clear that, there are limits in the extent to which adaptation is possible. When environmental stress exceeds a system’s thresholds for adaptation, it is increasingly likely that irreversible negative impacts will be sustained.”[10]

Although agriculture has always been resource-intensive in general, it has nevertheless protected necessary habitats for many plant and animal species in the past.[11] Today, industrialized agriculture is one of the principal menaces to biodiversity in Germany and many other countries because it pollutes soils, groundwater, and air and destroys natural habitats.[12] According to the UN Global Assessment Report on Biodiversity and Ecosystem Services,[13] one million species are at risk of extinction: “The health of the ecosystems on which we and other species depend is deteriorating more rapidly than ever. We are eroding the

[8] UN, Department of Economic and Social Affairs (2013): Sustainable Development Challenges. World Economic and Social Survey 2013. https://www.un.org/en/development/desa/publications/world-economic-and-social-survey-2013-sustainable-development-challenges.html. Retrieved on 23.5.2018

[9] Watts, J. (2019): Human society under urgent threat from loss of Earth's natural life. https://www.theguardian.com/environment/2019/may/06/human-society-under-urgent-threat-loss-earth-natural-life-un-report. Retrieved on 7.7.2019

[10] Zommers, Z., Wrathall, D., van der Geest, K. (2014): Loss and Damage to Ecosystem Services. UNU-EHS Working Paper Series, No. 2. Bonn: United Nations University Institute of Environment and Human Security (UNU-EHS), p. 4

[11] Bommert, W., Engler, S., Stengel, O. (eds.) (2016): Regional, innovativ, gesund. Nachhaltige Ernährung als Teil der Großen Transformation. Göttingen 2016

[12] Umweltbundesamt (2012): Umweltgutachten 2012. https://www.umweltbundesamt.de/themen/boden-landwirtschaft/umweltbelastungen-der-landwirtschaft/stickstoff#textpart-1. Retrieved on 14.2.2018

[13] Diaz, S. et al. (2019): Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://www.ipbes.net/global-assessment-report-biodiversity-ecosystem-services. Retrieved on 7.7.2019

very foundations of economies, livelihoods, food security, health and quality of life worldwide."[14]

This drastic reduction in biodiversity accompanies a rapid decline in global soil quality. According to the Food and Agriculture Organization's (FAO) implementation plan for Pillar One of the Global Soil Partnership,[15] soil erosion, soil organic carbon (SOC) loss, "soil compaction, soil sealing, salinization, and loss of soil biodiversity"[16] are the most serious threats to precious soil resources. If this negative development continues unchecked, the loss of fertile land would seriously jeopardize the global food system and food security, and it may be the cause of famine due to substantial price increases, particularly in undeveloped countries.

The primary global causes of soil change are the growing world population, accompanied by increasing urbanization and economic growth. The increasing spread of urban settlements on fertile land inevitably leads to an increase in soil sealing with impermeable materials such as asphalt and concrete.[17] This sealing prevents soil's important buffer and storage functions in the event of heavy rainfalls or persistent dry periods. In fact, soil sealing eliminates all vital soil functions and services, with the exemption of providing space for buildings or infrastructure. The built-up area is lost for food production, water retention and purification, carbon sequestration, and as habitat for soil organisms, nutrient cycling, and biodiversity.

Another major cause of soil damage is climate change. Higher soil temperatures, stronger rainfall, and reduced evaporation and groundwater recharge will lead to

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[14] Watson R., Chair of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IBPES), ibid.
[15] FAO (2015): Promote sustainable management of soil resources for soil protection, conservation and sustainable productivity. http://www.fao.org/3/CA2217EN/ca2217en.pdf. Retrieved on 13.4.2018
[16] ibid.
[17] ibid.

a faster SOC (soil organic carbon) decomposition rate and to more erosions and desertification, which in turn influence climate change. SOC can mitigate the influence of extreme climatic events by maintaining the water and nutrient supply of plants and alleviating runoff damage. FAO meta-analyses on the relationship between soil erosion and productivity have shown that a loss of 0.3% of the annual harvest due to erosion currently occurs worldwide, which would lead to an annual loss of 10% in 2050.[18] Since the soil erosion rate is much higher than the soil formation rate, and for intensive agricultural areas it is up to 100 to 1,000 times higher than the normal natural erosion rate, significant amounts of non-renewable, vital soil are lost forever.

Since the crisis in 2008, the realizations that soil is an important, non-renewable, global resource, and that the present agricultural production area of about 1.6 billion hectares can only be expanded to a limited extent, have alarmed politicians and scientists. A growing population faces a limited area of available and fertile farmland, and the only way to solve this dilemma is the persistent progress of agricultural intensification, especially in developing countries, and sustainable agriculture with effective containment of urban sprawl in industrialized countries.[19] [20] [21]

In Europe, the main causes of soil degradation are overuse, over-fertilization, urbanization, mining and industrial activities, and conversion. This is accompanied by sealing, salinization, contamination, and the loss of soil organic substances. The FAO recommendations of mitigation measures are to drastically reduce the conversion of green areas, make built-up areas denser, re-develop brownfields, use permeable materials instead of concrete and asphalt, and

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[18] FAO (2016): Status of the World's Soil Resources. Technical Summary. http://www.fao.org/3/a-i5126e.pdf. Retrieved on 28.5.2017

[19] Montanarella, L. (2015): Agricultural policy: Govern our soils. Nature, 528(7580), pp. 32–33

[20] Montanarella, L., Alva, I.L. (2015): Putting soils on the agenda: The three Rio Conventions and the post-2015 development agenda. In: Environmental Sustainability, 15, pp. 41-48

[21] Troell, M. et al. (2014): Does aquaculture add resilience to the global food system? Proceedings of the National Academy of Sciences of the United States of America, 111(37), pp. 13257–13263

support green infrastructure programs. To this end, spatial planning in all relevant governance levels needs to adopt an integrated approach that accounts for the value of soils.

1.3 Food Security

Among experts and politicians, there is consensus that, by 2050, the demand for food in the world will increase dramatically. The determining factors for this food needs are the growth of the world's population and economic growth. By 2050, the global population is estimated to grow by 27% to nine billion, and to 10 billion by 2100. The bulk of this population growth will occur in cities.[22] Traditional farming methods will not be able to produce sufficient food for the future world population, and 795 million people are already starving. This condition will worsen significantly if mankind does not succeed in increasing food production by at least 60% within the next few decades.[23] “For the 2030 Agenda, all countries are ‘developing countries’. Along with this profound conceptual change, there is a striking sense of urgency and ambition in the new sustainable development agenda, in terms of both the ends and the means.”[24]

Worldwide, the competition between food and agricultural non-food production has resulted in adverse consequences for agriculture and local food security. At the same time, the global food system has become more concentrated in the hands of a few large agro-companies, while more and more small farmers have left the food production system. However, the sustainable cultivation practices of smaller farms could be of great importance for climate change adaptation efforts because high-input, resource-intensive farming systems are the opposite of

[22] European Parliament (2013): Technology options for feeding 10 billion people. Synthesis report options for sustainable food and agriculture in the EU. November 2013. http://www.europarl.europa.eu/RegData/etudes/ etudes/join/2013/513539/IPOL-JOIN_ET (2013) 513539EN.pdf. Retrieved on 22.5.2017
[23] FAO (2017): The future of food and agriculture trends and challenges. http://www.fao.org/3/a-i6583e.pdf. Retrieved on 11.1.2019
[24] ibid.

sustainable agriculture, which should be urgently pursued.[25] An increase in production using conventional agricultural methods "is likely to lead to more intense competition for natural resources, increased greenhouse gas emissions, and further deforestation and land degradation."[26]

An agro-ecological transformation process that mitigates the effects of climate change and improves ecosystem services by embracing all relevant areas of the food system such as food production, processing, packaging, storage, and trade is necessary for the preservation of sufficiently good living conditions for future generations.[27] "One of the greatest challenges of our time is how to produce healthy food for a growing world population without increasing the pressure on the planet's ecosystems or eroding other functions. This is much about how we adjust our resource use to existing planetary boundaries and reverse ongoing trends of homogenization and instead strive for multifunctionality."[28]

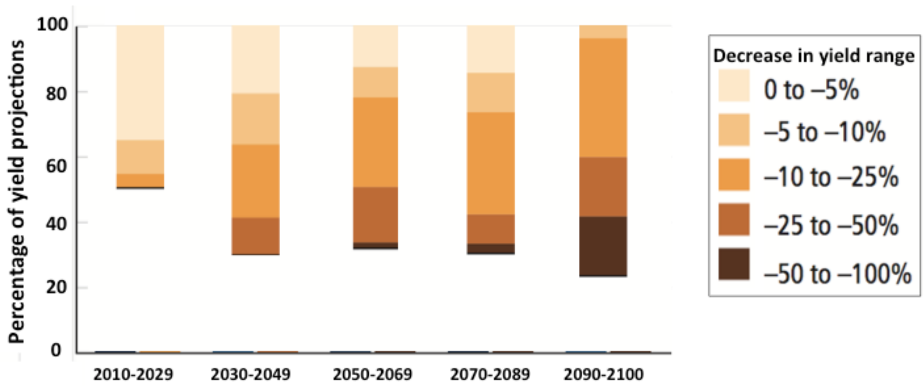

Figure 4 – Summary of projected changes in crop yields due to climate change over the 21st century, IPCC AR5 (2014)

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[25] Porter, J. et al. (2014): Food security and food production systems. In: IPCC. 2014. Climate Change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 485–533. Cambridge, UK 2014

[26] FAO (2017)

[27] FAO, IFAD, WFP (2013): The State of Food Insecurity in the World 2013. The multiple dimensions of food security. http://www.fao.org/3/a-i3434e.pdf. Retrieved on 24.3.2018

[28] Stockholm Resilience Centre: Research. http://www.stockholmresilience.org/research.html. Retrieved on 9.5.2017

In 1993, only 15% of the food consumed in cities was grown there, but by 2005, that number had increased to 30%; currently, urban farms produce one-fifth of the whole world's food consumption.[29] As more and more people migrate to cities, the need for food produced within or near urban areas has dramatically increased. Although there are practically no limits on imports due to perfected logistics systems, the associated burden on the regional and global ecosystems is immense but nevertheless neglected in the true cost.[30]

Global motorization and logistics, with their exploitation of non-renewable fossil energy resources, produce dangerous contaminants and climate damage, which could lead to a collapse of the biosphere and regional ecosystems in the future. In response to this development and as an expression of sustainability and closeness to nature, urban gardening has developed in the last few decades and become a rapidly expanding movement that constantly gains new followers in Germany and all over Europe.[31]

1.4 International Agreements

Article 2 of the Paris Agreement in 2015 explicitly recognized the importance of food security and of protecting food production systems against the negative effects of climate change.[32] Here, the signatory states agreed to "foster climate resilience and lower greenhouse gas emissions development, in a manner that does not threaten food production."[33] Recognizing that all major issues of climate change are closely linked to food security, the states were called upon to

[29] GreenBiz. https://www.greenbiz.com/article/urban-farms-now-produce-15-worlds-food. Retrieved on 7.8.2017
[30] Kreibich, R. (2009): Zukunftsforschung zur Nachhaltigkeit - Forschungsfelder, Forschungsförderung, Forschungspolitik Arbeitsbericht Nr. 34/2009. https://www.izt.de/fileadmin/publikationen/IZT_AB34.pdf. Retrieved on 11.11.2017
[31] Troell, M. et al. (2014): Does aquaculture add resilience to the global food system? Proceedings of the National Academy of Sciences of the United States of America, 111(37), pp. 13257–13263
[32] UNFCCC: The Paris Agreement. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. Retrieved on 12.1.2019
[33] ibid.

strengthen food security through national and regional programs. They must include local initiatives because they cause fewer food miles and are particularly suited to mitigating shortages in food supplies. “To achieve food and nutrition security, a food systems approach is required to stretch over the whole food chain (production through consumption), all food security dimensions (availability, access, utilization and stability) and should be placed within a larger economy and broader ecosystem function (land, water, and energy).”[34]

An important step in integrating the role of urban food production into political objectives and programs was made at the Milan Expo 2015 with the signing of the Milan Urban Food Policy Pact,[35] in which the mayors and representatives of 138 local governments committed themselves to supporting sustainable urban and peri-urban food systems with concrete measures:

> 1. We will work to develop sustainable food systems that are inclusive, resilient, safe and diverse, that provide healthy and affordable food to all people in a human rights-based framework that minimize waste and conserve biodiversity while adapting to and mitigating impacts of climate change.
>
> 2. We will encourage interdepartmental and cross-sector coordination at municipal and community levels, working to integrate urban food policy considerations into social, economic and environment policies, programs and initiatives, such as, inter alia, food supply and distribution, social protection, nutrition, equity, food production, education, food safety and waste reduction.[36]

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[34] ibid.
[35] Milan Urban Food Policy Pact: Pact 2016. http://www.milanurbanfoodpolicypact.org/wp-content/uploads/2016/06/Milan-Urban-Food-Policy-Pact-EN.pdf. Retrieved on 30.5.2017
[36] ibid.

In the same year that the Milan Urban Food Policy Pact was signed, the EU Commission decided to establish the project Food Smart Cities for Development[37] to coordinate food policy and the international cooperation of 12 urban regions. As part of the EU Development, Education, and Awareness Raising (DEAR) program,[38] this initiative aims to support the role of cities in the transformation of urban food production and consumption paradigms and to create a change in consciousness: “Reduce food waste, promote healthy eating and encourage the purchase of food produced respecting the rights of people and of the environment, are local actions that can trigger a global change.”[39]

The cooperation among the 12 participating cities, in which best practices projects are performed, is intended to build a network for the exchange of experiences and the participation of citizens and civil society organizations. The establishment of local food autonomy pre-supposes that spatial planning provides adequate urban and peri-urban areas for food production so that “local authorities can exercise their food sovereignty towards more sustainable, local, fair and right-to-food-oriented local food system.”[40]

Recognizing that, in the future, current food systems will not be sufficient to ensure an adequate diet for the poorer urban population in particular, a reorientation of the urban food supply with the aim of increased food security is necessary. Small farmers and private households in the city or in the immediate vicinity can play a key role in building a resilient, sustainable food system, linking consumers to rural as well as urban producers.

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[37] Milan Urban Food Policy Pact: The project. http://www.milanurbanfoodpolicypact.org/project/. Retrieved on 30.5.2017

[38] European Commission: Development education and awareness raising. https://ec.europa.eu/europeaid/sectors/human-rights-and-governance/development-education-and-awareness-raising_en. Retrieved on 30.5.2017

[39] ibid.

[40] Milan Urban food Policy Pact: Food Smart Cities for Development Recommendations and Good Practices. http://www.milanurbanfoodpolicypact.org/wp-content/uploads/2017/02/FSC4D-Recommendation-and-good-practices.pdf. Retrieved on 30.5.2017

The necessary support of urban and peri-urban food producers should also include the provision of favorable bank loans and leases for community gardeners and smallholders to use urban land for local agricultural production. In addition to such financial assistance, technical training in the areas of distribution, marketing, waste recycling, and green energy generation should also be provided.[41]

The goal must be to offer the urban population access to fresh, seasonal food that reaches local markets without the burden of storage, long transport routes, and air pollution. “We call for the development and implementation of holistic ecosystems-based approaches for city-region food systems that ensure food security, contribute to urban poverty eradication, protect and enhance local level biodiversity and that are integrated in development plans that strengthen urban resilience and adaptation.”[42]

[41] Urban and Peri-Urban Agriculture. http://www.fao.org/unfao/bodies/coag/Coag15/X0076e.htm#11. Retrieved on 4.3.2018

[42] ibid.

2.0 URBAN CHALLENGES

2.1 Climate Change

The ongoing climate change, which continues steadily worldwide and with some extreme manifestations in Europe as well, is one of mankind's most challenging problems. It increases the probability of extreme weather events, which can seriously endanger the global ecosystem, human health, the economy, biodiversity, and quality of life.[43] [44] However, forecasts for the climate of the 21st century are still burdened with high uncertainty because climate change is partly due to natural, uncontrollable causes and, on the other hand, is enhanced or accelerated by anthropogenic influences.[45] [46]

Paleological studies and reconstructions of sea-level deviations have shown that sea level fluctuations of up to one meter in warm periods can be considered "normal": Recent paleoclimate research indicates that the global climate over the past one hundred thousand years has experienced multiple fluctuations.[47] -Often, climate change, which has both natural and anthropogenic causes, is falsely equated with the term "global warming," but the natural influences on climate change also include changes in sun activity, the inclination of the earth's axis, continental drift, and volcanism. Anthropogenic causes for climate change include the burning of fossil fuels, cutting down rainforests, agriculture, and livestock. Large amounts of methane, CO2 and nitrous oxide – so-called greenhouse gases – are emitted into the atmosphere, where they absorb the

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[43] European Parliament (2018): Infographic: how climate change is affecting Europe. http://www.europarl.europa.eu/news/en/headlines/society/20180905STO11945/infographic-how-climate-change-is-affecting-europe. Retrieved on 3.10.2018

[44] European Commission: How will we be affected? https://ec.europa.eu/clima/policies/adaptation/how_en. Retrieved on 6.3.2019

[45] Pasqui, M., di Guiseppe, E. (2019): Climate change, future warming, and adaptation in Europe. https://academic.oup.com/af/article/9/1/6/5272568. Retrieved on 10.2 2019

[46] Klepper, G., Schmalzbauer, B. (eds) (2011): Global Change Research in Germany. Challenges and Strategies for a Sustainable Future. Kiel 2011

[47] ibid.

long-wave heat radiation of the sun. The continuous increase of global greenhouse gas emissions is the main cause of anthropogenic warming, which leads to a rise of the mean annual temperatures and an increase of heavy rainfalls and winter precipitation.[48]

In its 2010 State of the World Report, the British World Watch Institute stated that the current overall ecological footprint shows that "humanity now uses the resources and services of 1.3 earths. In other words, people are using about a third more of Earth's capacity that is available, undermining the resilience of the very ecosystems on which humanity depends."[49] One ecosystem service in particular, climate regulation, is heavily impaired in its function due to a growing human population that consumes more meat and natural resources than any previous generation. This development of modern consumption patterns has a frightening potential to create disastrous consequences for the environment if it is not curbed.[50] [51]

A 2009 study from the Massachusetts Institute of Technology (MIT) using the Integrated Global Systems Model indicated a "median probability of surface warming of 5.2 degrees Celsius by 2100, with a 90% probability range of 3.5 to 7.4 degrees"[52] if business and consumption continues as usual. Even if all countries implement their ambitious CO2 reduction measures, the temperatures would still increase by 3.5° Celsius, meaning that "policy alone will not be enough. A dramatic shift in the very design of human societies will be essential."[53] With a

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[48] Umweltbundesamt (2019): Indicator: Greenhouse gas emissions. https://www.umweltbundesamt.de/en/indicator-greenhouse-gas-emissions. Retrieved on 7.8.2019

[49] World Watch Institute (2010): 2010 State of the World. Transforming Cultures. From Consumerism to Sustainability. New York, London 2010, p. 4

[50] Gardner, G, Assadourian, E., Sarin, R. (2004): The State of Consumption Today. In: The Worldwatch Institute (ed.) (2004): The Consumer Society. State of the World. http://erikassadourian.com/wp-content/uploads/2013/07/SOW-04-Chap-1.pdf. Retrieved on 2.5.2018

[51] Randers, J. (2012): 2052. Der neue Bericht an den Club of Rome. Eine globale Prognose für die nächsten 40 Jahre. München 2012

[52] Chandler, D. (2009)

[53] Worldwatch Institute (2010): State of the World 2010 Transforming Cultures from Consumerism to Sustainability. London 2010, p. 5

global warming of 2° Celsius, significantly higher average temperatures are expected over the Arctic, with corresponding consequences for the region.[54] If the 2° Celsius limit is exceeded, tipping points would be reached, which could result in further, non-linear, irreversible developments whose consequences are scarcely estimable.[55] Global warming of just 1.5° Celsius could be enough to trigger severe thawing of Siberian permafrost up to the 60° latitude.[56] Since the permafrost of the northern hemisphere stores a carbon amount twice that of the pre-industrial level of the atmosphere, there is a high risk for a strong discharge of methane and carbon dioxide from this source, thus leading to further warming.

International efforts to curb global warming by reducing CO2 emissions led to the signing of the so-called Kyoto Protocol[57] in 1997, which only went into effect in 2005 and was extended until 2020. It determined how much each country should reduce its carbon dioxide emissions; however, the goal of reducing exhaust emissions worldwide by 5% compared to 1990 failed because, by 2010, global greenhouse gas emissions had already increased by 29%.[58]

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[54] Smith, J. et al. (2009): Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC), http://www.pnas.org./content/106/11/4133. Retrieved on 2.4.2017

[55] Jaeger, C., Jaeger, J. (2011): Three views of two degrees. In: Regional Environmental Change, March 2011, 11, pp. 15-26

[56] Helmholtz-Zentrum Geesthacht: Impact 2 C Project, Final Report. http://impact2c.hzg.de/imperia/md/content/csc/projekte/ impact2c_final.pdf. Retrieved on 8.3.2017

[57] Landeszentrale für Politische Bildung, Baden-Württemberg: https://www.lpb-bw.de/kyoto_protokoll.html. Retrieved on 3.2.2017

[58] Bundesamt für Umwelt: Internationale Klimapolitik: Kyoto-Protokoll. https://www.bafu.admin.ch/bafu/de/home/themen/klima/fachinformationen/klima--internationales/internationale-klimapolitik--kyoto-protokoll.html. Retrieved on 14.3.2019

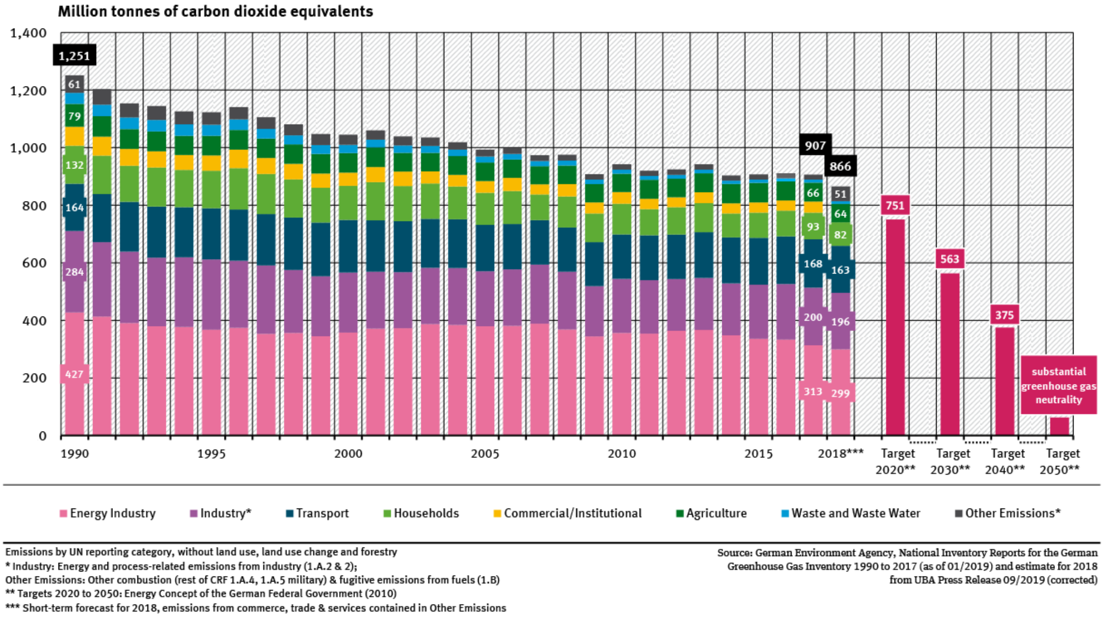

Figure 5 – Emissions of greenhouse gases covered by the UN Framework Convention on Climate, German Environment Agency (2019)

2.2 Environmental Problems

The main challenges in the future will be violent storms with associated damages and costs, higher food prices with ever-decreasing arable land, higher costs for carbon reduction, and an increased migration from underdeveloped regions.[59] [60] [61] Further far-reaching consequences of climate change will be a continuous loss of soil through water erosion, reduction of biodiversity, fluctuations in groundwater levels, and reduced water quality.[62] Many effects of climate change and their far-reaching impact on ecosystems, the economy, and human health are already felt throughout Europe.

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[59] National Climate Assessment. https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather. Retrieved on 7.1.2019

[60] Carbon Brief: https://www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world. Retrieved on 15.3.2019

[61] NASA. https://climate.nasa.gov/effects/. Retrieved on 15.3.2019

[62] Gruehn, D. (2013): Klimaschutz und Klimaanpassung: Notwendigkeit- Herausforderungen- Standort- und Wettbewerbsvorteile. Dortmund, 13.2.2013. http://www.llp.tu-dortmund.de/index.php?id=64. Retrieved on 13.10.2016

In Europe, a rise in number and intensity of heat waves and an increase of the urban heat island phenomenon (UHI) are likely towards the end of the century, with an increase by a factor of nearly 10.[63] This development will be linked to a higher heat-related excess mortality rate and to significantly higher particulate matter (PM10) concentrations.[64] At the same time, there will be also an increased vulnerability in Europe due to climate change elsewhere in six major areas: "the trade of agricultural commodities, the trade of non-agricultural commodities, infrastructure and transport, geopolitics and security risks, and human mobility related to migration and finance."[65]

According to the RAMSES research project[66] which assessed over 500 cities, there are four major threats to European cities that are likely to become more serious in the future: flooding (sea, tidal, fluvial, and pluvial), storms, heat waves (including air pollution), and droughts. Heat waves are exacerbated by soil sealing and urban sprawl, and the risk of experiencing more and more severe heat waves is relatively high for mid-latitude European cities and Southern European cities.[67] Regarding the incidence and intensity of droughts, the worst changes in drought conditions are projected for cities in Southern Europe, where – in a worst-case scenario – they face a 70% probability of being in an unprecedented drought, which could be 2.5 times worse than in the past.[68]

While considerable progress has been made to protect lives, economic losses due to disasters continue to rise and have never been so high. Europe's 10-year average of disaster losses of US $13.4 billion makes it the third most affected

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[63] RAMSES. http://www.ramses-cities.eu/. Retrieved on 11.6.2017

[64] IRCEL-CELINE: What is the influence of climate on particulate matter? http://www.irceline.be/en/documentation/faq/what-is-the-influence-of-climate-on-particulate-matter. Retrieved on 11.6.2017

[65] European Environment Agency. http://www.eea.europa.eu/publications/climate-change-impacts-and-vulnerability-2016/key-findings. Retrieved on 3.3.2017

[66] RAMSES. http://www.ramses-cities.eu/. Retrieved on 11.6.2017

[67] Coumou, D., Robinson, A. (2013): Historic and future increase in the global land area affected by monthly heat extremes. Environ. Res. Lett., 8, pp. 1-6

[68] Intergovernmental panel on climate change: Climate Change 2014 Synthesis Report - Summary for Policymakers. https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf. Retrieved on 15.5.2017

region in the world after the Americas and Asia. Recent floods in the Bosnia and Herzegovina, Bulgaria, Croatia, Serbia, the United Kingdom, and Germany have shown the need for Europe to prioritize risk reduction by effective adaptation and mitigation strategies. Because the frequency of such severe flooding across Europe is set to double by 2050, there could be a nearly fivefold increase in the annual economic losses resulting from floods.[69]

A special problem for cities is the UHI effect, which can be defined as the “phenomenon whereby urban regions experience warmer temperatures than their rural surroundings.”[70] It can easily be distinguished by measuring the surface temperature of an urban surface and comparing it with the rural surroundings. The darker the surface, the lower the albedo, which defines the proportion of reflected surface radiation. Dark roofs and paved roads in particular have a low albedo value because they absorb much of the sun's rays and thus heat their immediate surroundings. In addition, the thermal bulk properties of construction materials easily absorb solar radiation and emit this energy into the surrounding environment as heat. Due to the lack of green vegetation, there is no evaporation or transpiration, which blocks the natural water cycle. The lack of shading and carbon sequestration significantly increase inner-city temperatures compared to rural areas.

Further reinforcing factors for the development of urban heat islands are the so-called urban canyon effects, which result from narrow, compact buildings and permit little wind movement. By replacing once permeable surfaces with buildings, roads, and other infrastructure, most of the urban environment is impermeable, dry, and inhibits effective wind movement. Thus, the lack of

[69] World Conference on Disaster Reduction: Implementing the Hyogo Framework for Action in Europe: Advances and challenges 2005-2015. http://www.unisdr.org/files/48254_hfareport2016.pdf. Retrieved on 26.10.2017

[70] Environmental Protection Agency’s Office of Atmospheric Programs (2014): Reducing Urban Heat Islands: Compendium of Strategies. https://www.epa.gov/sites/production/files/201406/documents/basicscompendium.pdf. Retrieved on 3.3.2019

convection causes increased near-ground ozone levels and further warming of the environment.[71]

Urban heat stress increases mortality risk, especially in the elderly and those with respiratory diseases.[72] [73] In 2003, the heat wave called for around 70,000 additional deaths in Europe.[74] The harmful effects of UHI cause not only respiratory problems but also diseases of the digestive system and the entire nervous system that result in insomnia, depression, and loss of memory. [75] [76]

2.3 Urban Food Security

2.3.1 Definition

A generally accepted definition of "food security" was provided at the World Food Summit in 1996: "Food security exists when all people, at all times, have physical, social[77] and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life."[78] [79] [80]

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[71] Taha, H. (1997): Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat. https://doi.org/10.1016/S0378-7788(96)00999-1. Retrieved on 7.7.2019

[72] Schlünzen, H. et al. (2018): Stadtklima in Hamburg. doi: 10.1007/978-3-662-55379-4_3. Retrieved on 7.7.2019

[73] Scherber, K., Langner, M., Endlicher, W. (2013): Spatial analysis of hospital admissions for respiratory diseases during summer months in Berlin taking bio-climatic and socio-economic aspects into account. Erde, 144, pp. 217–237

[74] von Storch, H. et al. (eds.) (2011): Hamburger Klimabericht – Wissen über Klima, Klimawandel und Auswirkungen in Hamburg und Norddeutschland.

[75] Rajagopalan, P., Lim, K., Jamei, E. (2014): Urban heat island and wind flow characteristics of a tropical city. Solar Energy, 107, pp. 159-170

[76] Yang, L. et al. (2016): Research on Urban Heat-island Effect. http://creativecommons.org/licenses/by-nc-nd/4.0/. Retrieved on 11.7.2019

[77] The term "social" was added to the 1996 definition in 2002.

[78] International Committee of the Red Cross: Food security in armed conflicts. https://www.icrc.org/eng/resources/documents/article/other/57jncy.htm. Retrieved on 2.5.2017

[79] World Food Insecurity and Malnutrition: Scope, Trends, Causes and Consequences. http://www.fao.org/3/ai799e/ai799e02.pdf. Retrieved on 4.11.2018

[80] FAO: 2018. The State of Food Security and Nutrition in the World. http://www.fao.org/state-of-food-security-nutrition/en/. Retrieved on 4.11.2018

Historically, agriculture and cities have always been inextricably linked, and a strict separation between urban and rural areas is counter-productive when improving the use of the limited source land, adapting to climate change, and improving food security. Growing urbanization has an increasingly negative influence on the climate, and, simultaneously, climate change increases cities' vulnerability. The quest for a sustainable, ecological food supply is the expression of the desire for more resilience, independence, and security in times of crisis because the urban population's supply of food from supermarkets is not certain and can be securely maintained for only a few days.[81]

In Europe's highly industrialized countries, where the motives for urban gardening are not predominantly associated with subsistence and food security, urban agriculture is anti-cyclical to economic trends. In times of economic and civilian crises or conflicts with low food security, urban agriculture expands, thus providing the foundation of an informal crisis economy. This emergency food can be used as an exchange commodity or local currency, and, at the same time, it creates new jobs for the local population.[82]

2.3.2 Resilient Urban Food System

A sustainable and resilient urban food system should aim at the following goals:[83]

- the improvement of the population's health and wellbeing
- reducing the negative impact of food production on the environment
- the support of local food producers as part of a green economy
- the fight against limited access to adequate, healthy nutrition in terms of social justice

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[81] Farmer, B. (2018): Four meals from anarchy: How Britain would collapse in just days if power supply is cut. https://www.telegraph.co.uk/news/2018/03/17/britain-four-meals-away-anarchy-cyber-attack-takes-power-grid/. Retrieved on 4.11.2018

[82] Smit, J. (1996): Urban Agriculture. Food, Jobs and Sustainable Cities. http://www.jacsmit.com/book/Chap07.pdf. Retrieved on 12.8.2017

[83] IUCN (International Union for conservation of Nature and Natural Resources): Food security Policies: making the ecosystem connections. http://www.fao.org/forestry/37145-07a8322d5c9e07487af4c8a94caba0291.pdf. Gland, Switzerland 2013. Retrieved on 2.3.2019

- imparting important know-how in food production and ecological technologies
- the reinforcement of urban-rural linkages.

A city's food security is founded on the smooth functioning of central areas that are closely linked and include water management and logistics. Basic inputs to a secure food production within a multi-crop system composed of urban, peri-urban, and rural agriculture require the allocation of additional land use for food production within the city borders, the storage of rainwater or the alternative use of treated wastewater for irrigation, and adequate amounts of disease-resistant seeds. In a resilient urban food system, poorer families can use home-grown vegetables, both for their own consumption as well as for the generation of additional revenue. In such a system, the food production inside city borders is complemented by peri-urban agriculture that reduces the dependence on food imports by permitting a high degree of food self-sufficiency, establishing short supply chains, and keeping the profits of food production in the region.

Food security also always needs to be combined with effective waste management in order to regain fertilizer from composted organic waste and avoid the spread of diseases caused by rotting or contaminated garbage accumulation.[84] None of these can effectively function without a sufficient energy supply and alternative, diverse supply sources, such as centralized power plants and decentralized local energy systems based preferably on renewable power sources. Technical stressors can have a profound negative effect on a city's functions and services, on the economy in general, and on food security specifically. If they are combined with human stressors such as terrorism, war, crime, and riots, their impact can significantly endanger the well-being and survival of a city and its people by reducing the food and water supply.[85]

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[84] ibid.
[85] Harrigan, J., Martin, P. (2002). Terrorism and the resilience of cities. Economic Policy Review – Federal Reserve Bank of New York, 8(2), p. 97

Barthel and Isendahl[86] have conclusively argued that urban resilience is highly dependent on a broad diversity of options available to a city in terms of food production and distribution. The ability to transport and distribute food is an important aspect of the food security system, whose resilience can be strengthened by the local proximity of food and water production to consumers. Therefore, according to Barthel and Isendahl, agricultural production is not the "anti-thesis of the city" but should be an integrated urban activity to be an indispensable prerequisite for resilience. "In complement to the well-known resilience function of long-distance trade when harvests fail owing to environmental anomalies and changes, the longue durée perspective applied here shows that urban food security can be built to manage événement chocks by keeping options open for producing and storing food and water in close spatial proximity to the consumers."[87]

Additionally, urban green spaces need to be protected, and knowledge on how to grow food needs to be supported to link urban people with their life-supporting regional and local ecosystem.[88] Garcia-Sastre and Kallis share this view,[89] and their research shows that urban agriculture has significant potential to build resilience in cities because of its multi-functional downscaling to the local production level and the use of the empirical knowledge of food production.

2.3.3 Urban Food Security Strategy

According to the FAO, a credible, sustainable intensification of food production for the growing world population is necessary while protecting, and wherever

[86] Barthel, S., Isendahl, C. (2013): Urban gardens, agriculture, and water management: Sources of resilience for long-term food security in cities. Ecological Economics, 86, pp. 824-834

[87] ibid. p. 231

[88] ibid.

[89] Garcia-Sastre, A., Kallis, G. (2011): Building resilience in cities with urban agriculture. A case study for hurricane response in Havana city' in European Society for Ecological Economics, 9th International Conference of the European Society for Ecological Economics: Advancing Ecological Economics Theory and Practice. Istanbul, Turkey, June 14-17, 2011

possible, restoring vital environmental ecosystem services.[90] A new paradigm needs to be followed to re-arrange the existing food system by building diverse supplies geographically close to the consumers in a way that allows an improved management and distribution of food from both global and local origins.[91] The old paradigm, that the food system is largely a rural issue, has lost its validity. Urban and rural food systems should no longer be strictly separated; rather, they should complement each other to form a meaningful unity.[92]

According to estimates by the Food and Agriculture Organization of the United Nations, food production must increase by approximately 60% over the next decades, including a 40% increase in feed production.[93] In addition to rapid population growth, climate change poses a major challenge for growing food production. Although individual extreme events cannot be predicted, nor can their impact on global agriculture, harvest losses of up to 30% are considered possible for cereals. At the same time, an expanding agricultural sector promotes the emission of greenhouse gases and deforestation of land and thus climate change with its negative consequences. The desire to increase food security while simultaneously reducing agricultural emissions and preserving the natural ecosystem appears infeasible, but a pragmatic strategy based on a catalog of mutually compatible measures, integrating particularly innovative agro-technological approaches of urban and urban-friendly agriculture has already been proved in many projects.[94] [95]

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[90] Teng, P., Morales, M. (2015): A new paradigm for food security: robustness as an end goal. doi: 10.13140/RG.2.1.3613.5126. Retrieved on 13.10.2018

[91] Corbould, C. (2013): Feeding the Cities: Is Urban Agriculture the Future of Food Security? http://www.futuredirections.org.au/publication/feeding-the-cities-is-urban-agriculture-the-future-of-food-security/. Retrieved on 16.3.2018

[92] FAO (2017): The future of food and agriculture. Trends and Challenges. http://www.fao.org/3/a-i6583e.pdf. Retrieved on 11.2.2019

[93] Alexandratos, N., Bruinsma, J. (2012): World's Agriculture towards 2030/2050. The 2012 Revision. http://www.fao.org/fileadmin/templates/esa/Global_persepctives/world_ag_2030_50_2012_rev.pdf. Retrieved on 22.5.2017

[94] Agroeco: https://agroeco.org/projects/. Retrieved on 5.6.2019

[95] Ministère de L'Agriculture, der L'Agroalimentaire et de la Forêt: Agroecology in France. Changing Production Models to Combine Economic and Environmental performance. ProjetGB_cle8a75db (1). *agriculture.gouv.fr/telecharger/58144? Retrieved on 20.7.2019*

The ongoing urbanization process, in which the urban population already outnumbers the rural population, will intensify urban poverty and food insecurity.[96] With the large majority of the world's population living in cities, it is critical that cities start to develop their own successful food systems in order to avoid severe food insecurity and land degradation, and to complement the national food system.[97] "As cities grow by 5-10% per year, meeting the food needs inside the city will create a market for the people who will produce food in the area. This is not to say that we are not going to depend on rural areas: we will have to integrate the urban-rural linkages. Agriculture is a part of the urban mix."[98]

In this context, governments are asked to "shift subsidies and research funding from agro-industrial monoculture to small farmers using agroecological methods"[99] and to foster the development of ecological forms of urban agriculture. The reason for re-thinking the policy towards industrial agriculture is that, currently, 80% of the subsidies and 90% of the research funding in the EU supports conventional industrial culture, although "empirical and scientific evidence shows that small farmers feed the world"[100] and that 70% of the globally consumed food comes from small farmers whose access to productive sources must be strengthened.

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[96] European Parliament (2013): Technology options for feeding 10 billion people. Synthesis report options for sustainable food and agriculture in the EU. November 2013. http://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/513539/IPOLJOIN_ET(2013)513539_EN.pdf. Retrieved on 22.5.2017

[97] UN (2014): World's population increasingly urban with more than half living in urban areas. http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html. Retrieved on 13.5.2017

[98] Cadman, D.: Local Governments for Sustainability, ICLEI. www.fao.org./3/a-au725e.pdf. p. 36. Retrieved on 7.5.2017

[99] Elver, H. cited in: Nafeez, A. (2014): UN: only small Farmers and Agroecology can feed the World. https://www.tni.org/my/node/13492. Retrieved on 2.5.2017

[100] Elver, H. cited in: Nafeez, A. (2014): Food Shortages, Global Warming/Climate Change, Plant Systems, Society, Soil Erosion & Contamination, Village Development, Water Contaminaton & Loss. https://permaculturenews.org/2014/09/26/un-small-farmers-agroecology-can-feed-world/. Retrieved on 2.5.2017

At present, agriculture in Europe uses about 174 million hectares, making the EU the largest food importer and exporter of the world.[101] In view of the increasing conversion of arable land for urban purposes and infrastructure development, this situation is likely to change. European agriculture has already destroyed or severely damaged the habitat of numerous animal and plant species: “The EU has lost half of its common farmland bird populations and half of its grassland butterfly populations, and over three quarters of the semi-natural habitats have an unfavorable conservation status.”[102]

A way out of this dilemma could be a people-centered approach to food security performed by multi-level governance in which local governments closely cooperate with grassroots movements, food security networks, social campaigns, and urban farmers’ associations. However, the importance of adequate, sufficient nutrition for the world’s future population has not yet arrived in the consciousness of the responsible actors, who pursue their supply strategy irrespective of a possible collapse of the ecosystem. “The current food systems are efficient only from the point of view of maximizing agribusiness profits” therefore, “at the local, national and international levels, the policy environment must urgently accommodate alternative, democratically-mandated visions.”[103]

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[101] European Commission: Landwirtschaftlich genutzte Fläche in der EU von 2003 bis 2013 konstant, doch Zahl der landwirtschaftlichen Betriebe sank um mehr als ein Viertel. https://ec.europa.eu/eurostat/documents/2995521/7089771/5-26112015-AP-DE.pdf. Retrieved on 22.5.2017

[102] ibid., p.17

[103] Olivier de Schutter in his final report to the UN Human Rights Council. In: SrFood.org: Democracy and diversity can mend broken food systems. http://www.srfood.org/en/democracy-and-diversity-can-mend-broken-food-systems-final-diagnosis-from-un-right-to-food-expert. Retrieved on 13.5.2017

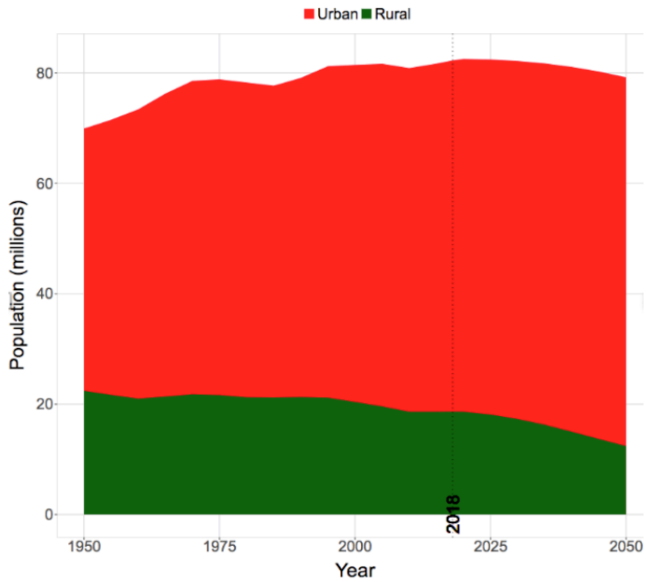

Figure 6 – Urban and rural population in Germany, UN – DESA (2018)

3.0 AIM OF THE STUDY

3.1 Creating New Awareness

In the face of these threats to the living conditions of this and future generations, the goal and motivation of this study is to make a modest contribution to solving some of these problems by examining whether and to what extent urban agriculture can strengthen the sustainability of a land management that aims to increase urban resilience. Since a relatively high level of food safety can be assumed in Germany and other EU countries, the primary task of such land management must be to improve urban resilience with regard to the protection of regional and local ecosystems (climate, air, water, soil). Of course, this also includes that the land planning takes into account various innovative UA technologies and forms of implementation for land use (vertical cultivation, hydroponic and aquaculture, gardens close to the city for the use of city residents).

The aim is to develop ideas and create the basis for a climate-adapted city and land planning concepts while focusing on the preservation, protection, and improvement of ecological functions and the quality of people’s lives. A distinction between adaptation and mitigation measures is conceptually possible, but in practice it is of little pragmatic value. In both areas, a sustainable land management plays a key role in safeguarding the development opportunities of future generations and “is a highly complex field of action, which reaches into all areas of human life and integrates aspects such as the handling of water, soil and biodiversity, regional value creation, urban-rural relations, quality of life, etc.”[104]

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[104] Quote translated by the author. Bekanntmachung des Bundesministeriums für Bildung und Forschung von Richtlinien über die Fördermaßnahme „Nachhaltiges Landmanagement“ from 24.10.2008. https://www.bmbf.de/foerderungen/bekanntmachung-389.html. Retrieved on 24.8.2017

Global challenges such as climate change, the demand for resources, land use, mobility, and demographic change determine the need for action in urban planning policy. Responsible land management that is geared towards an optimally secure future must always combine a suitable adaptation strategy with mitigation measures to form an overall concept. This can best be achieved by anchoring not only central elements of a green infrastructure but also urban agriculture in landscape planning. In practice, this means that the legal goals of environmental protection and landscape management are set out in concrete terms in the corresponding land use plans and landscape plans. Frequent economic interests that conflict with measures to maintain or expand urban green spaces are given priority in the implementation. Therefore, one purpose of this study is to lay the foundations for a new guiding principle centered on green infrastructure and urban agriculture as an independent planning unit within an urban recycling economy.[105]

A new awareness of food sovereignty and of local and regional food-producing options can be the impetus for a viable "post-oil city" strategy to maintain "modern, sophisticated structures in highly industrialized countries without sacrificing comfort and despite reduced fossil energy resources."[106] In order to be successful, such a strategy needs to preserve and integrate local, regional, and national characteristics that the population accepts.[107]

Urban agriculture has already become synonymous with environmentally friendly food production and is a prime example of emergent, grassroots initiatives to shape the immediate environment and nutritional situation. For this reason, a

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[105] Gaßner, R. (2013): Szenarien für eine integrierte Nachhaltigkeitspolitik – am Beispiel: Die nachhaltige Stadt 2030 Band 1: Überblick und Fazit. https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4413.pdf. Retrieved on 3.2.2019

[106] Quote translated by the author. Knieling, J., Kretschmann, N. (2016): Nachhaltige Stadtentwicklung im 21. Jahrhundert - klimaangepasst, smart, postfossil? https://link.springer.com/content/pdf/10.1007/978-3-662-46900-2_86-1.pdf. Retrieved on 15.7.2019

[107] Weith, Th. et al. (eds.) (2013): Nachhaltiges Landmanagement: Was ist das? Diskussionspapier Nr. 7. April 2013, p. 10. Quote translated by the author

further goal of this study is to show that the present urban agricultural movement is not a short-lived trend but a social development, which is a response to the megatrends of this century. As shown in this study, any type of urban agriculture can improve the stability of an existing food system. However, for Germany as well as for the other EU member states, UA does not primarily fulfill the function of increasing food security. Much more important is its social and, above all, ecological significance with regard to significant opportunities for improving the urban climate, the air and biodiversity which is an important goal of a sustainable land management.

Furthermore, this study not only aims to be scientifically relevant, but, at the same time, to fulfill a social function. Urban people are not directly affected by the environmentally harmful effects of conventional food supply chains. Understanding how the key functions of urban farming can enhance the urban climate, keep air and water clean, conserve biodiversity, and improve food security can serve as a basis for expanding urban agricultural activities. Rooftop gardens, community gardens, and many other potential projects can bring city dwellers closer to nature and maintain a healthy diet by closing the mental and spatial gap between the consumer and his food.[108] A greater awareness and presence of urban food production in mass media and political programming presentations could support the change towards a sustainable, resilient food system, which is largely based on urban and peri-urban production and can usefully complement the global food system.

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[108] Marsden, T., Morley, A. (eds.) (2014): Sustainable food systems: building a new paradigm. Earthscan Food and Agriculture, London 2014

3.2 Filling Research Gaps

Preliminary studies have shown that the scientific analysis and eco-political evaluation of urban agriculture with regard to sustainable land management and climate change mitigation has not yet been sufficiently investigated despite the fact that evaluation methods have been developed and applied in the past.[109] In science and the public sphere, urban agricultural culture tends to have a niche existence with few but active representatives. However, the emergence of various pilot projects in Germany and impressive commercial applications in many other countries show the relevance of the research topic.[110] [111]

Although many benefits of urban agriculture for people and nature are well known, it has received relatively little attention in discussions about global and urban food security.[112] Many studies on urban agriculture to date are based on the specific situation of a country or a city and focus on the historical role of urban agriculture, its subsistence functions in developing countries, or general greening and local-food aspirations of local initiatives. However, the opportunities to improve urban food security with highly productive, eco-friendly and resource-saving technologies have so far been neglected in science.[113] [114] [115] Several recent publications on resilience research concentrate on deviations in the emphasis and parameter definitions for measuring and describing urban

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[109] Gruehn, D. & Kenneweg, H. (2002): Erfolgskontrolle und Weiterentwicklung der örtlichen Landschaftsplanung im Kontext zur Agrarfachplanung. BfN-Skripten 61. Bonn-Bad Godesberg 2002

[110] Ahern, J. (2010): Planning and design for sustainable and resilient cities: theories, strategies and best practices for green infrastructure. https://www.researchgate.net/publication/285476760_Planning_and_design_for_sustainable_and_resilient_cities_theories_strategies_and_best_practices_for_green_infrastructure. Retrieved on 23.3.2018

[111] Clinton, N. et al. (2018): A Global Geospatial Ecosystem Services Estimate of Urban Agriculture. https://doi.org/10.1002/2017EF000536. Retrieved on 22.5.2019

[112] Foley, J. et al. (2011): Solutions for a Cultivated Planet. doi: 10.1038/nature10452. Retrieved on 10.10.2018

[113] Grimm et al. (2008): Global Change and the Ecology of Cities. doi: 10.1126/science.1150195. Retrieved on 8.11.2018

[114] Viljoen, A., Bohn, K. (2012): Scarcity and Abundance: Urban Agriculture in Cuba and the US. https://doi.org/10.1002/ad.1422. Retrieved on 1.8.2019

[115] FAO (2014): Growing Greener Cities in Latin America and the Caribbean. http://www.fao.org/3/a-i3696e.pdf. Retrieved on 1.8.2019

resilience.[116] [117] [118] In the course of these academic and introspective discussions, pragmatic solutions are often neglected, with the consequence that the knowledge of adequate framework conditions for successful, efficient urban agriculture is less widespread.[119]

Often, sustainability studies tend to investigate certain problem areas of water, energy, and the food supply in isolation, although urban agriculture, with its interconnectedness to natural and finite resources, should be studied from a multifunctional, comprehensive perspective that use both qualitative and data-driven quantitative methods.[120] Larger studies on the importance of urban agriculture and its interactions with environmental, economic, and social urban subsystems are still lacking.[121]

So far, no studies have addressed either the transformation processes in the creation of a local urban food system or the promotion and upscaling options of commercial local food production facilities, such as vertical farms. There is also a lack of studies on popular concepts as such as “Edible Cities” (Andernach, Kassel, Heidelberg, etc.), which proves the importance of using inner-city areas as gardens at the municipal level.[122]

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[116] Greiving, S., Fleischhauer, M. (2010): ExWoSt Forschungsfeld „Urbane Strategien zum Klimawandel“ – Vorstudie, Forschungsfeld, Modellvorhaben. https://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/BBSRInfo/2009_2010/DL_2_2010.pdf?__blob=publicationFile&v=3, Retrieved on 13.4.2020

[117] Schaefer, M, Thinh, N., Greiving, S. (2020): How Can Climate Resilience Be Measured and Visualized? Assessing a Vague Concept Using GIS-Based Fuzzy Logic. Sustainability. January 2020 DOI: 10.3390/su12020635. Retrieved on 10.4.2020

[118] Birkmann, J., Greiving, S., Serdeczny, O.)2017): Das Assessment und Unsicherheiten von Vulnerabilitäten, Risiken. DOI: 10.1007/978-3-662-50397-3_26. Retrieved on 10.4.2020

[119] Coaffee, J., Lee, P. (2016): Urban Resilience: Planning for Risk, Crisis and Uncertainty. London 2016

[120] Roorda, C. et al. (2014): Transition Management in the Urban Context: Guidance Manual. Rotterdam 2014

[121] Sharifi, A. et al. (2017): Conceptualizing Dimensions and Characteristics of Urban Resilience: Insights from Co-Design Process. Sustainability 2017, 9(6). https://doi.org/10.3390/su9061032. Retrieved on 4.4.2019

[122] Bohn, K., cited in: Kemmer, N. (2018): “Wollen Sie in einer essbaren Stadt leben?” Food Revolution im Kunstgewerbemuseum. https://blog.smb.museum/wollen-sie-in-einer-essbaren-stadt- leben-food-revolution-im-kunstgewerbemuseum/. Retrieved on 5.3.2019

4.0 THEORETICAL FOUNDATION

4.1 Definitions of Terms

4.1.1 Urban agriculture

Urban agriculture can be briefly defined as plant production and animal breeding in cities and their immediate periphery.[123] The main difference between rural and urban agriculture is that the latter is fully integrated into the economic and environmental system of a city: “Such linkages include the use of urban residents as laborer, use of typical urban resources (like organic waste as compost and urban wastewater for irrigation), direct links with urban consumers, direct impacts on urban ecology (positive and negative), being part of the urban food system, competing for land with other urban functions, being influenced by urban policies and plans, etc.”[124]

Urban agriculture is not a modern phenomenon and can be dated to 3,500 BC in Mesopotamia, when cities, which consisted of small farming villages, included plots of land designated for farming and producing food for city dwellers.[125] [126] Today, urban farming has different shapes and types depending on socio-economic, geographic, and political circumstances, and thus it can be defined only very generally.

In the 2007 agricultural report of the FAO, urban agriculture is defined as “the growing of plants and the raising of animals for food and other uses within and

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[123] FAO. http://www.fao.org/urban-agriculture/en/. Retrieved on 2.3.2019
[124] RUAF, International Water Management Institute (2007): Creating a food and nutritionally secure future. Hyderabad, India, p. 3. https://www.ruaf.org/sites/default/files/Potentials%20for%20urban%20and%20peri%20urban%20agriculture%20in%20Hyderabad-India.pdf. Retrieved on 8.3.2019
[125] History on the Net. https://www.historyonthenet.com/mesopotamia. Retrieved on 19.2.2019
[126] Timemaps. https://www.timemaps.com/encyclopedia/ancient-mesopotamia-history/. Retrieved on 19.02.2019

around cities and towns, and related activities such as the production and delivery of inputs, processing, and marketing of products."[127] Depending on where urban farming is practiced (roof top, vertical or horizontal greenhouses, terraces, house gardens, community gardens, unused lots, roadside, river banks) and what is produced (flowers, vegetables, herbs, small animals), it can be divided into different categories. However, all forms and types have in common that they are positioned close to the consumer and local markets, their space is relatively limited, and urban resources such as water, organic waste, etc. are used.[128] [129] According to the Food and Agriculture Organization of the United Nations, 800 million people worldwide currently grow vegetables and fruits or raise animals in cities, thus producing 15% to 20% of the world's food.[130] This astonishing potential of urban farming is expected to double in the next 20 years.[131]

In the history of mankind and urbanization, agriculture was inevitably always urban agriculture. There was no strict separation of city and countryside because long, efficient transport possibilities for fresh vegetables and animal foods did not exist. Prior to the development of modern sewage and waste disposal, urban and peri-urban agriculture were the only way to safely dispose of urban waste. Therefore, until the 18th century, about half of the city area was reserved for urban agriculture, while the area around the city wall was also used for intensive food production for which urban waste served as fertilizer.[132] [133] With the replacement of the horse as the main means of transport and the motorization of

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[127] FAO (2007): Profitability and sustainability of urban and per-urban agriculture, United Nation food and agriculture organization. http://www.fao.org/3/a-a1471e.pdf. Retrieved on 17.2.2019

[128] van Veenhuizen, R. (ed.) (2006): Cities Farming for the Future - Urban Agriculture for Green and Productive Cities. RUAF Foundation. https://www.ruaf.org/publications/cities-farming-future-urban-agriculture-green-and-productive-cities. Retrieved on 18.2.2019

[129] FAO. http://www.fao.org/3/w1358e/w1358e07.htm. Retrieved on 15.2.2019

[130] FAO. http://www.fao.org/urban-agriculture/en/. Retrieved on 19.2.2019

[131] Crawford, A. (2018): Big Data Suggests Big Potential for Urban Farming. https://www.citylab.com/environment/2018/02/big-data-suggests-big-potential-for-urban-farming/552770/. Retrieved on 19.2.2019

[132] Universität Bielefeld: Stadt und Region im Mittelalter. wwwhomes.unibielefeld.de/esteinberg/pdf/stadt geschichte/ mittelalter/stadt_und_region_im _mittelalter_begrenzte_marktbeziehungen.pdf. Retrieved on 12.8.2017

[133] Coleman, Eliot (1999): Four-season Harvest: Organic Vegetables from Your Home Garden All Year Around. White River Junction, VT, 1999

the entire logistics chain, food production increasingly moved away from the cities into regions with more favorable climatic conditions and more expansion possibilities. For agriculture, the scientific-technical revolution brought new technologies for machines and the intensification of crop production with artificial fertilizers and pesticides. The most cost-efficient production possible and the exploitation of economies of scale in the supply chain became the top priorities.

As city dwellers no longer supplied themselves with food, the traditional, closed agricultural cycle was destroyed, and agriculture was banished from cities. Thus, the direct link between production and consumption was replaced, and an increasingly anonymous supply system established. As a consequence, city dwellers became mere consumers, and local-level trade was kept to a minimum. At the same time, industrialization created a new social class of poor worker families who suffered from adverse living conditions and insufficient nutrition. In order to improve their nutrition and offer them healthy leisure activities, Abbé Lemire in France and Dr. Schreber in Germany founded the Schrebergarten movement to enable poor workers to produce fresh food for themselves.[134]

Today, there are more than one million small gardens, mainly in cities, with a total area of over 46,000 hectares (460 km²). Five million people use such an allotment garden in about 14,000 clubs, which are organized in 330 regional associations (city, county, district, and territorial associations) and 19 state associations under the umbrella of the Federal Association of German Garden Friends (BDG).[135] Moreover, about 100,000 people are actively engaged in these associations as administrators, gardeners, plant protection experts, and other volunteers.[136] [137]

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[134] Stein, H. (1998): Inseln im Häusermeer. Eine Kulturgeschichte des deutschen Kleingartenwesens bis zum Ende des Zweiten Weltkriegs. Frankfurt/M. 1998
[135] Bundesverband Deutscher Gartenfreunde e.V. https://www.kleingartenbund.de/de/bundesverband/zahlen-und-fakten/. Retrieved on 16.2.2019
[136] ibid.
[137] Müller, C. (ed.) (2011): Urban Gardening. Über die Rückkehr der Gärten in die Stadt. München 2011

The “new” urban agriculture movement that originated in the USA with “guerilla gardeners” and “rooftop farmers” differs from the Schrebergarten movement, which mainly aims at providing healthy food and leisure activities to poorer worker families. In fact, it represents a counteroffensive to the globalization of the food system, in which the ordinary citizen has no control over farming methods, the use of fertilizers, pesticides, and the ecological footprint of the products offered at local supermarkets.[138]

In times when the city has lost its influence on the design of the food supply, which is now fully geared to global standards, a widespread fast-food culture favors the profitability of large farms. A change of lifestyle and a growing awareness towards sustainability and healthy, organically grown food has evolved because consumers want to know the origin of their food and how it is produced.[139] [140] Thus, even in the rich, industrial countries, farmers' markets have spread, and small urban farmers sell their products to restaurants and can barely meet the demand of the city dwellers.[141] [142]

Another important reason for the current boom of the urban gardening movement in Europe is the desire for neighborhood initiatives and other groups to have access to more green spaces and to revitalize brownfields and degraded urban areas.[143] Added to this is the desire to acquire one’s own horticultural knowledge, to enjoy the many benefits of outdoor physical activity, and to gain some independence from industrial food production. If, by 2050, nearly 80% of the world's population will live in cities, industrial agriculture will not be able to sustain

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[138] Reynolds, R. (2009): Guerilla Gardening. Ein botanisches Manifest. Freiburg im Breisgau 2009
[139] Ernaehrungsdenkerwerkstatt. http://ernaehrungsdenkwerkstatt.de/keller/kartei/locavore-essen-aus-der-region/. Retrieved on 20.2.2019
[140] Stanton, J. et al (2012): Who are the locavores? Journal of Consumer Marketing, 29(4), pp. 248-261. https://doi.org/10.1108/07363761211237326
[141] Corrigan, M. (2011): Growing what you eat: Developing community gardens in Baltimore, Maryland. https://doi.org/10.1016/j.apgeog.2011.01.017. Retrieved on 19.2.2019
[142] Winkler-Prins, A. (ed.) (2017): Global Urban Agriculture. Boston 2017
[143] Smith, J., Jehlicka, P. (2013): Quiet sustainability: Fertile lessons from Europe’s productive gardeners. Journal of Rural Studies, 32, pp.148–157

humanity for long, especially because of its immense use of resources and its dependence on oil. Therefore, the recommendation of the current World Agricultural Report, which was written by 500 scientists on behalf of the United Nations and the World Bank, is to restore small-scale agricultural structures in cities, as well.[144] [145]

4.1.2 Sustainability

The multifaceted concept of sustainability, with its ecological, social, and economic dimensions, has become the guiding principle for a broad and undivided consensus within the international community despite differences and national specificities. Global megatrends such as urbanization, the demand for resources and energy, climate change, and demographic change create complex, multi-dimensional problems for states, societies, and economies, and they justify the need to incorporate sustainability as the guiding norm for all decisions and actions on the local, national, and global levels.[146] Common threats and interests as well as perceived requirements for action unite the international community in its efforts to make sustainability a priority in all areas of political, public, and private life.

The concept of sustainability first emerged in the 18th century in Hannß Carl von Carlowitz's discourse about forestry.[147] He pleaded for a moderate forest management system that aligned all economic activities with natural growth processes so that forests could regenerate by themselves or through afforestation. In international political publications, the term was first mentioned

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[144] Weltagrarbericht. https://upd-weltagrarbericht.zs-intern.de/index.php. Retrieved on 4.1.2019

[145] Wißmann, C. (2014): Stadtluft macht Blei. http://www.spiegel.de/wirtschaft/urban-gardening-die-versorgung-der-staedte-neu-organisieren-a-970305.html. Retrieved on 4.1.2019

[146] Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung: Die Agenda 2030 für nachhaltige Entwicklung. http://www.bmz.de/de/ministerium/ziele/2030_agenda/index.html. Retrieved on 8.6.2017

[147] von Carlowitz, H.C. (1713): Sylvicultura oeconomica, Leipzig 1713

in the Club of Rome study "Limits to Growth."[148] Its central thesis was that "absolute limits to growth would be reached for an assumed exponential growth in the areas of industrialization, population growth, malnutrition, environmental degradation, and the exploitation of primary resources in the course of the next century. A collapse could only be avoided and the environment preserved for future generations, if mankind will be capable to restore a balance between economy and ecology."[149]

Scientific expert reports and the introduction of new, environment-friendly technologies progressively instigated new political and economic concepts, especially in Western industrial nations.[150] In 1983, a panel of independent experts, the World Commission on Development and Environment (WCED), began to explore options for sustainable global development for the new millennium and beyond. Its final report, "Our Common Future," also called the "Brundtland report," was published in 1987, and its core statements remain valid today: "We define sustainable development in simple terms as paths of progress which meet the needs and aspirations of the present generation without compromising the ability of future generations to meet their needs."[151]

This document identifies three dimensions of sustainability that encompass all relationships and interactions in both public and private spheres. Sustainability in the ecological field, for example, includes targets for mitigating negative climate effects, reducing harmful emissions, and limiting continuous land and resource consumption without preventing the necessary economic growth.[152]Sustainable economic development must pursue its goals of increasing productivity,

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[148] Meadows, D., Meadows, D., Zahn, E. (1972): Die Grenzen des Wachstums. Bericht des Club of Rome zur Lage der Menschheit. Stuttgart 1972
[149] Masyk, T. (2013)
[150] Meadows, D., Meadows, D., Randers, J. (1992): Die neuen Grenzen des Wachstums – Die Lage der Menschheit: Bedrohung und Zukunftschancen. Stuttgart 1992
[151] Brundtland, Gro (1987): Report of the World Commission on Environment and Development: Our Common Future. www.un-documents.net /wced-ocf.htm. Retrieved on 12.2.2017
[152] Masyk, T. (2013)

profitability, and competitiveness without jeopardizing the quality of life for future generations. In practice, this means that renewable resources are only used to the extent that they can be regenerated, and environmental pollution must not exceed the absorption and assimilation capacity of the ecosystems. In principle, further exploitation of all non-renewable resources should be kept to a minimum and be compensated by renewable energy.[153] The last pillar of sustainable development is the social dimension, that is, the fight against poverty, the protection of social equality, and democratic principles. Without society's "social capital," which must be developed sustainably, successes in other areas may not endure: "What we need are new concepts, new values, and to mobilize will. We need a new global ethic."[154]

Brundlandt's definition of sustainability remains relevant, and it is still used in science as the basis for further concept development. For example, Ben-Eli[155] has supplemented or replaced the aforementioned three dimensions with five core principles: the material domain, the economic domain, the domain of life, the social domain, and the spiritual domain. Although the concept of cross-generation equity and welfare is of great importance, according to Ben-Eli, its disadvantage is that the needs of future generations can neither be determined nor measured. In contrast, the relationship between the current world population and the absorption power of ecosystems can be more easily determined and measured, so the necessary courses of action for maintaining a dynamic equilibrium can be deduced: "A dynamic equilibrium in the process of interaction between a population and the carrying capacity of its environment such that the population develops to express its full potential without producing irreversible, adverse effects on the carrying capacity of the environment upon which it depends."[156]

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[153] ibid.
[154] Brundtland, G. (1987), p. 3
[155] Ben-Eli, M. (2012): The Cybernetics of Sustainability: Definition and Underlying Principles. http://www.ethicalmarkets.com/wp-content/uploads/2012/08/The_Cybernetics_of_Sustainability.pdf. Retrieved on 4.2.2019
[156] ibid.

4.1.3 Resilience

The term “resilience” is derived from the Latin word “resilire,” which means to “jump or bounce back.” D.E. Alexander[157] has traced the concept of resilience to the writings of Seneca the Elder, Ovid, and Cicero; in connection with recovery after a natural disaster, R. Tomes first used the term after the earthquake in 1854 in Shimoda, Japan.[158] At the end of the 19th century, the concept of resilience was used in mechanics and engineering sciences in the context of material science to describe the ability of a material to repeatedly achieve the original state, even if its material is altered. In the 1960s, the term was introduced into psychology and medicine before Holling[159] placed it at the center of his ecological system theory.

Today, the scientific literature offers a variety of definitions, most of which are similar and differ only by emphasizing individual aspects, characteristics, and application options against various threats under different conditions. Greiving et al.[160] distinguish three forms of adaptive capacity, which is always aimed at future challenges. Sector-specific adaptive skills that are assessed by experts, generic skills that are based on social adaptation ability and finally cross-sectoral adaptive skills that extend to spatial, regional or urban areas and contribute to the adaptation to climate change. Increased "climate resilience" is an important component of sustainable development “because the transition towards a state that meets the needs of the present without compromising the ability to meet the

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[157] Alexander, D.E. (2013): Resilience and disaster risk reduction: an etymological journey. Nat. Hazards Earth Syst. Sci., 13, pp. 2707–2716

[158] Tomes, R. (1857): The Americans in Japan; An Abridgement of the Government Narrative of the U.S. Expedition to Japan Under Commodore Perry, D. Appleton, New York 1857, p. 57

[159] Holling, C.S. (2001): Understanding the complexity of economic, ecological, and social systems. Ecosystems, August 2001, 4, pp. 390-405

[160] Greiving, S. et al. (2015): Germany’s Vulnerability to Climate Change. Technical Report. https://www.researchgate.net/publication/329209976. Retrieved on 9.4.2020

future generations is prevented, if climate threats interrupt planning processes."[161]

Greiving, Fleischhauer et al.[162] come to similar conclusions. They determine redundancy, diversity, resilience and reliability as the most important structural features of a resilient city. [163] In order to be able to react adequately and proactively to threats and dangers, additional flexibility is required. This can best be achieved through integrated action concepts and intersectoral cooperation, which bundles competencies and accomplishes tasks together.

Today, it is generally accepted that a city's resilience is an important criterion for its future viability, that resilience cannot be a substitute for sustainability, and vice versa.[164] In all efforts to promote sustainability and resilience, cities are at the center because they have a high share of energy consumption and CO2 emissions and thus significantly contribute to climate change. Moreover, these densely populated areas are particularly vulnerable to climate changes and require concerted efforts to curb their negative impacts. "The road to sustainability runs through the world's towns and cities. By building sustainable towns and cities, you will build global sustainability."[165]

Cities represent complex systems that consist of thousands of economically, socially, institutionally, and environmentally relevant links. As the urban regions and their populations steadily grow, all threats and negative events could

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161 Schaefer, M, Thinh, N., Greiving, S. (2020): How Can Climate Resilience Be Measured and Visualized? Assessing a Vague Concept Using GIS-Based Fuzzy Logic, Sustainability. January 2020 DOI: 10.3390/su12020635, p. 635

162 Greiving, S. et al. (2016): Resiliente Stadt – Zukunftsstadt. Forschungsgutachten. https://epub.wupperinst.org/frontdoor/deliver/index/docId/6614/file/6614_Resiliente_Stadt.pdf. Retrieved on 20.4.2020

163 ibid. p.16

164 According to a UN study of 2011, more than 60% of all people living in the 450 largest cities in the world are at high risk of a natural disaster. The 5 mega cities that are at high risk from cyclones, tidal waves, droughts, earthquakes or a nuclear incident are Tokyo, Delhi, Mexico City, New York and Shanghai. United Nations Department of Economic and Social Affairs Populations Division: World Urbanization Prospects. New York 2012

165 Ramses: Urban adaptation effects on urban climate. www.ramses-cities.eu/. Retrieved on 12.2.2017

increase in intensity in the future. As a basis for urban resilience, the Organization for Economic Co-operation and Development (OECD) cites the ability to adapt, robustness, flexibility, inclusion, and integration, as well as sufficient resources and redundant urban systems.[166] This is the basis for the dynamic, flexible character of urban resiliency and the ability to choose multiple pathways. “Urban resilience refers to the ability of an urban system – and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales – to maintain or rapidly return in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity.”[167]

In resilient cities, people live more securely, and this is why the pursuit of resilience is so important. Since the vulnerability of a given technological social system is not completely predictable, cities must consider this uncertainty in all planning activities. For an intelligent, proactive mitigation strategy, urban planning and architecture need to adapt themselves to the requirements of an increased mitigation and adaptation to climatic effects and other possible hazards.[168] An infrastructure that is built today is usually designed for use over several decades. Therefore, it is important that alliances with urban networks, public organizations, and the private sector are collectively committed to supporting cities as they improve their resilience.[169] [170]

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[166] OECD: Resilient Cities - Policy Highlights. http://www.oecd.org/cfe/regional-policy/resilient-cities-policy-highlights-preliminary.pdf. Retrieved on 19.6.2017

[167] Meerow, S., Newell, J., Stults, M. (2016): Defining urban resilience: A review. Landscape and Urban planning, 147, p. 39

[168] Elmqvist, T. (2014): Urban Resilience Thinking. Solution, 5(5), 2014, pp. 26-30 https://www.thesolutionsjournal.com/article/urban-resilience-thinking/. Retrieved on 1.3.2017

[169] de Medellín, A. (2014): Seventh Session of the World Urban Forum. https://www.medellin.gov.co/irj/go/km/docs/wpccontent/Sites/Subportal%20del%20Ciudadano/Nuestro%0Gobierno/Secciones/Plantillas%20Gen%C3%A9ricas/Im%C3%A1genes/2013/WUF7/WUF7%20 Background%20Information%20.pdf. Retrieved on 28.2.2017

[170] UN-Habitat (2014): New Global Collaboration for Urban Resilience Announced At WUF7. https://unhabitat.org/new-global-collaboration-for-urban-resilience-announced-at-wuf7/. Retrieved on 28.2.2017

In this context, Schaefer, Tinh and Greiving[171] assess robustness and adaptiveness combined with interdisciplinary monitoring and evaluation as key components of urban climate resilience. Along with information and transparency, they form the indispensable requirements for a multilevel governance and social resilience that builds on participation, justice and identification of the actors with their city and neighborhood. This aspect is often underestimated, but social inequality and inadequate access to essential goods can increase the damage caused by extreme events in a dangerous manner.

When analyzing the threats posed by climate change, Greiving, Fleischhauer et al.[172] emphasize that not only possible sudden extreme events have to be taken into account, but also gradual climatic changes that can significantly influence the quality of life. With appropriate guiding principles for resilient spatial structures, urban development and urbanization programs can take on a “pioneering role” for comprehensive climate adaptation measures.[173]

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[171] Schaefer, M, Thinh, N., Greiving, S. (2020): How Can Climate Resilience Be Measured and Visualized? Assessing a Vague Concept Using GIS-Based Fuzzy Logic. Sustainability. January 2020 DOI: 10.3390/su12020635

[172] Greiving, S., Fleischhauer, M. et al. (2011): Klimawandelgerechte Stadtentwicklung Ursachen und Folgen des Klimawandels durch urbane Konzepte begegnen. https://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/ministerien/BMVBS/Forschungen/2011/Heft149_DL.pdf?__blob=publicationFile&v=2. Retrieved on 12.4.2020

[173] Greiving, S., Fleischhauer, M. (2010): ExWoSt Forschungsfeld „Urbane Strategien zum Klimawandel“ – Vorstudie, Forschungsfeld, Modellvorhaben. https://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/BBSRInfo/2009_2010/DL_2_2010.pdf?__blob=publicationFile&v=3, Retrieved on 13.4.2020

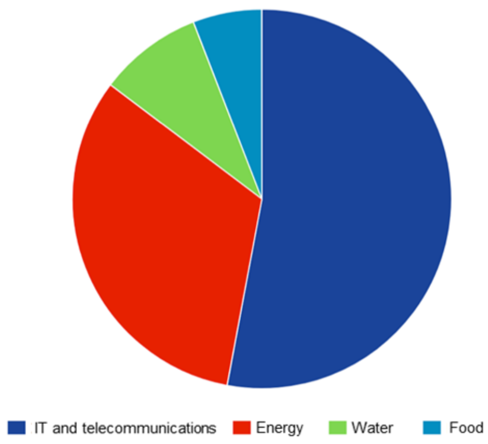

Figure 7 – Number of IT disruptions by sector reported to the BSI from March 2016 – June 2017, Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik)

4.1.4 Vulnerability

Resilience and vulnerability are closely related but represent different approaches to the analysis of the impacts of internal or external events. Both concepts are originally derived from ecology and are used in scientific literature to describe the threats to ecological, social, and economic systems. While resilience can be seen as a guiding principle and primarily as a structural and dynamic system feature in the sense of a positivistic epistemology, vulnerability is an aspect of resilience and its analytical basis.[174]

Vulnerability is generally defined as the degree to which a devastating event influences a system. As a concept, it implies a risk analysis of all physical, social, and economic aspects as well as the system's ability to overcome the threat.[175] [176] A more specific definition is that of the United Nations (International Strategy

[174] Miller, F., Osbahr, H. et al. (2010): Resilience and Vulnerability: Complementary or Conflicting concepts? In: Ecology and Society, 15(3), p. 11
[175] Fichter, K. et al. (eds.) (2010): Theoretische Grundlagen für Erfolg reiche Klimaanpassungsstrategien. Projektkonsortium ‚nordwest2050'. Delmenhorst 2010
[176] ibid.

for Disaster Reduction), which describes vulnerability as “conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of a community to the impact of hazards.”[177]

In the Hyogo Framework for Action, “hazard” has been defined as “[a] potentially damaging physical event, phenomenon, or human activity that may cause the loss of life or injury, property damage, social and economic disruption, or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro meteorological, and biological) or induced by human processes (environmental degradation and technological hazards).”[178]

Although vulnerability and resilience are closely linked, they differ in terms of their perspective on the subject of investigation. Resiliency can be understood as a dynamic process that must prove itself with flexibility, robustness, and adaptation in a case of crisis; vulnerability, meanwhile, is the general susceptibility of a system or some of its elements that can be measured in degrees. Reducing vulnerability does not automatically increase the resilience of a city or a given structure; rather, as two sides of the same coin, they have measurable parameters, such as exposure and sensitivity, in common.[179] [180]

Thus, a city can be both vulnerable and resilient at the same time because certain elements and structures may prove to be stable in a crisis, while others are not. Vulnerability can also be understood as the lower or higher susceptibility of the social and natural environment against external threats and changes, for example

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177 United Nations International Strategy for Disaster Reduction (UNISDR) (2004): Living with Risk. A Global Review of Disaster Reduction Initiatives. UN Publications. Geneva 2004

178 World Conference on Disaster Reduction: Hyogo Framework for Action 2005-2015. http://www.unisdr.org/2005/wcdr/intergover/official-doc/L-docs/Hyogo-framework-for-action-english.pdf. Retrieved on 12.6.2017

179 Proag, V. (2014): The concept of vulnerability and resilience. https://core.ac.uk/download/pdf/81134186.pdf. Retrieved on 20.7.2019

180 Miller, F. et al. (2017): Resilience and Vulnerability: Complementary or Conflicting Concepts? https://www.jstor.org/stable/26268184. Retrieved on 20.7.2019

those caused by climate change, while resilience is more of an adaptation strategy that ensures the functioning of the urban system on the basis of vulnerability assessments.[181]

Some scientists, such as Strunz,[182] Norris et al.,[183] Brand, and Jax[184] have criticized resilience as a vague concept that is not suitable for practice and not necessary as long as vulnerability assessments can provide information that can serve as a foundation for effective prevention and mitigation measures. However, according to Strunz, conceptual indeterminacy can also be advantageous for pragmatic and creative problem solving. Most governments accept the importance and necessity of urban resilience as an evident political goal, especially as appropriate measures show faster and more visible successes in reducing vulnerability.[185]

Birkmann, Greiving and Serdeczny[186] emphasize that people, infrastructure and ecosystems in different places are vulnerable to climate change in very different ways, since the possible damage results not only from external climate changes but also from socio-economic development processes. Within a risk concept tailored to the circumstances, the individual dangers, the exposure and the degree of vulnerability would also have to be determined with reference to future social developments in order to design an effective resilience strategy. Thus, when resilience is seen as the result of a recursive process and as a normative umbrella concept, it serves as a guiding principle that is an essential element of sustainability. As a widely accepted concept, resilience brings benefits for

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[181] Cote, M., Nightingale, A. (2012): Resilience thinking meets social theory: Situating social change in socio-ecological system research. Progress in Human Geography, 36(4), 2012, pp. 475-489

[182] Strunz, S. (2012): Is conceptual vagueness an asset? Arguments from philosophy of science applied to the concept of resilience. Ecological Economics, 76, pp. 112-118

[183] Norris, F.H. et al. (2008): Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. Am. J. Community Psychol. 2008, 41(1-2), pp. 127-150

[184] Brand, F., Jax, K. (2007): Focusing the Meaning(s) of Resilience: Resilience as a Descriptive Concept and a Boundary Object. Ecology and Society, 12(1), p. 23

[185] Brannon, B. (2012): Resiliency Buzzword of the Day or Tool for Relief? http://paperroom.ipsa.org/papers/ paper_9919.pdf. Retrieved on 8.6.2017

[186] Birkmann, J., Greiving, S., Serdeczny, O. (2017)

politicians and pragmatists because it places positive transformation processes at the forefront, while vulnerability alone without feasible problem-solving strategies leads to threatening associations that may be denied or rejected.[187]

Practical experience shows that most catastrophic damage occurs in cities that are located in already known dangerous areas, such as flood plains and earthquake and hurricane regions. The vulnerability of these locations especially in regard to drinking water and food supplies are often reinforced by inadequate management of population growth and illegal settlements in particularly vulnerable areas where serious ecological damage, such as deforestation and extreme soil sealing, significantly increase the dangers for the population.[188] "Evidence indicates that exposure of persons and assets in all countries has increased faster than vulnerability has decreased, thus generating new risks and a steady rise in disaster-related losses, with a significant economic, social, health, cultural and environmental impact in the short, medium and long term, especially at the local and community levels."[189]

In a seven-case study of the ESPON Climate Initiative and European Environment Agency,[190] a distinction was made between physical, environmental, social, economic, and cultural sensitivity in order to determine the vulnerability regarding the potential impact of climate change, together with the exposure values. The underlying assumption was "that a region with a high climate change impact may still be moderately vulnerable if it is well adapted to

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[187] Miller, F. et al. (2010): Resilience and Vulnerability: Complementary or Conflicting Concepts? Ecology and Society, 15(3), Art. 11, pp. 1-25

[188] Münchener Rückversicherungsgesellschaft, Geo Risks research, NatCat Service (2016): Loss events worldwide 1980-2015, March 2016. This report includes the 10 costliest flood events, the 10 costliest tropical cyclones, the 10 costliest winter storms, the 10 costliest storms, the 10 deadliest and 10 costliest earthquakes and the 10 deadliest and 10 costliest events worldwide.

[189] Hooke, W. (2015): Disaster experts send a message from Sendai. http://www.livingontherealworld.org/?p=1257. Retrieved on 14.6.2017

[190] European Commission: ESPON Climate Change and Territorial Effects on Regions and Local Economies.https://www.espon.eu/export/sites/default/Documents/Projects/AppliedResearch/CLIMATE/ESPON_Climate_Final_Report-Part_B-MainReport.pdf. Retrieved on 5.6.2017

the anticipated climate changes. On the other hand, high impacts would result in high vulnerability to climate change if a region has a low adaptive capacity."[191]

According to United Nations studies, cities will be strongly affected by the consequences of ongoing climate change if their mitigation strategies are not successful: "Out of a total of 1,692 cities with 300,000 inhabitants or more on 1 July 2014, nearly 56%, or 944 cities, were at high risk of exposure to at least one of the six natural hazards (cyclones, floods, droughts, earthquakes, landslides, and volcano eruptions). Slightly less than 15% of all cities, or 249 cities, were highly exposed to at least two of the six types of natural disaster and about 2%, or 27 cities, were exposed to three or more (or multiple) types of natural disaster."[192] [193]

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[191] Ibid., p. 5

[192] United Nations, Department of Economic and Social Affairs, Population Division (2015): Risks of Exposure and Vulnerability to Natural Disasters at the City Level: A Global Overview. Technical Paper No. 2015/2. https://esa.un.org/unpd/wup/Publications/Files/WUP2014-TechnicalPaper-NaturalDisaster.pdf. p. 4. Retrieved on 23.6.2017

[193] UNISDR (2017): National Disaster Risk Assessment. Governance System, Methodologies and Use of Results. https://www.unisdr.org/files/52828_nationaldisasterriskassessmentwiagu.pdf. Retrieved on 8.10.2018

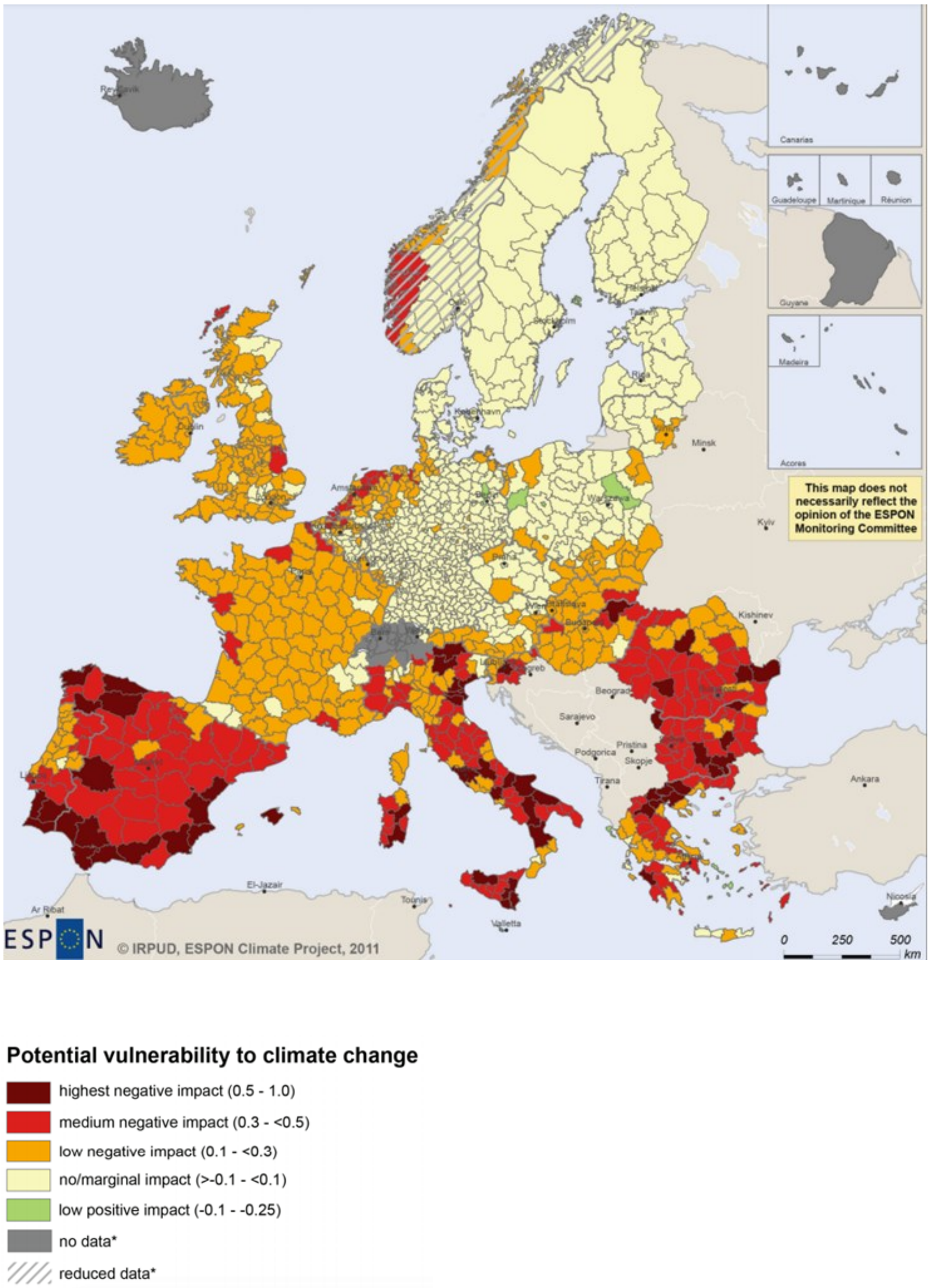

Figure 8 – Potential vulnerability to climate change, ESPON & IRPUD, Climate Change and Territorial Effects on Regions and Local Economies – Final Report, TU Dortmund (2011)

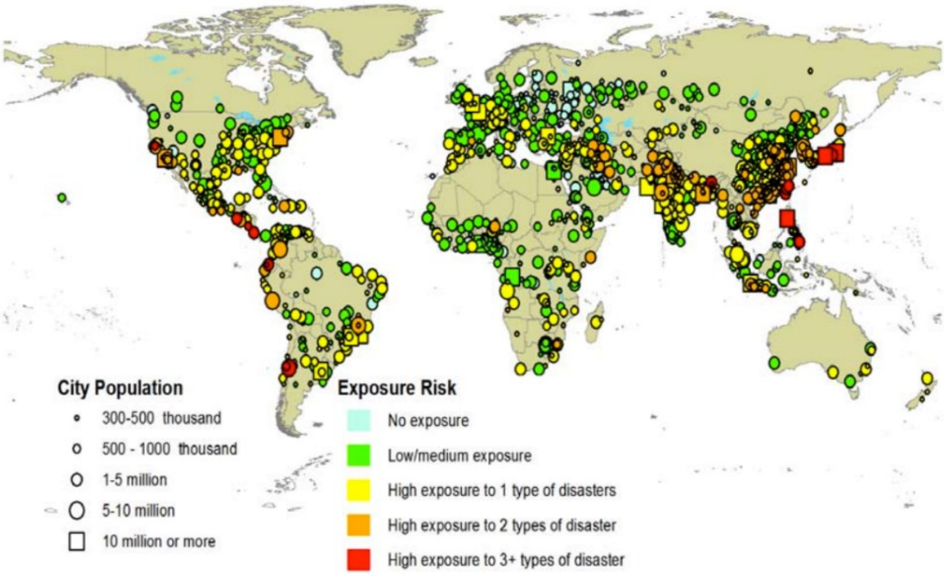

Figure 9 – Risks of Exposure and Vulnerability to Natural Disasters at the City Level: A Global Overview, Technical paper No. 2015/2. p. 6, UN, Department of Economic and Social Affairs, Population Division

Figure 10 – World natural catastrophes by continent in 2016, Munich Re, Geo Risks Research (2017)

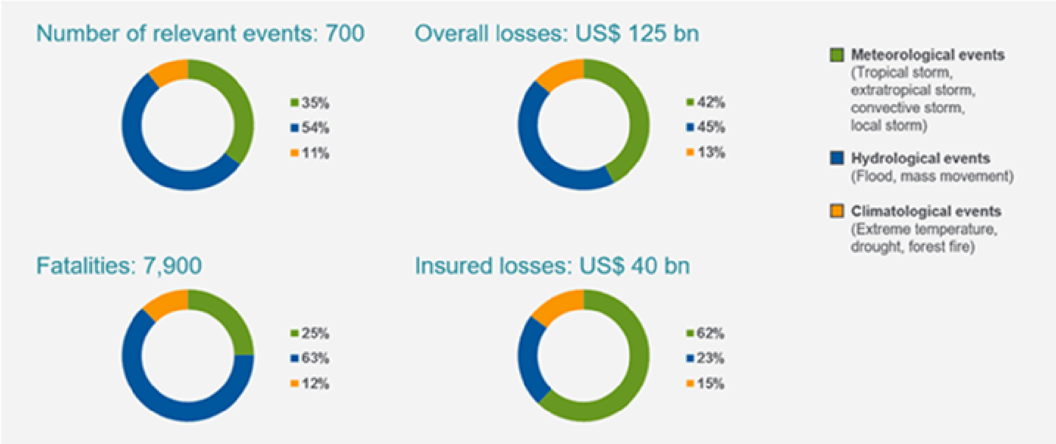

Figure 11 – World weather-related catastrophes by type of event 2016, Munich Re, Geo Risks Research (2017)

4.2 Mitigation and Adaptation

Each city consists of interconnected, interacting elements with the capacity to learn, i.e., they have the attribute of feedback reactions, self-organizational behavior, and emergence. Learning from experience leads to the spontaneous formation of new properties and structures due to the interaction of their elements.[194] New developments in societal and technical systems – such as the urban agricultural movement – result in new emergent structures, in which different stages can be determined: A "pre-developmental stage" with experimentation and a pilot project at the individual level, a "take-off phase" with the emergence of innovation, an "acceleration phase" with an organizational transformation, and a "stabilization phase," where a new dynamic equilibrium is achieved.[195] [196]

[194] The theory of complex adaptive systems is a focus of the research work of the Santa Fé Institute. https://www.santafe.edu/. Retrieved on 4.2.2017

[195] Nevens, F. et al. (2008): Urban Transition Labs: Co-creating Transformative Action for Sustainable Cities. Journal of Cleaner Production 2013, 50, pp. 111-122

[196] Colander, D., Kupers, R. (2014): Complexity and the art of public policy – Changing Society from the Bottom up. New Jersey 2014

The impact of climate change such as floods, heat waves, and droughts depends on the effectiveness of mitigation measures on the basis of cities' improved resilience and adaptability.[197] Adaptation, which can be defined as all measures to reduce vulnerability to the effects of climate change, requires an integrated approach "to conservation, restoration, and sustainable management of territories to enable people to adapt to climate change, and ultimately increase their resilience."[198] In a best-case scenario, sudden threats can be duly anticipated, and appropriate preventive measures can be taken to reduce vulnerability so that these threats do not materialize.[199] [200]

Mitigation measures, such as the creation of redundant resources, effective crisis management strategies, and protection measures for critical infrastructure have to complement the adaptation strategy of resilient cities. They aim to reduce the effects of an existing risk such as "deliver basic needs, safeguards human life, protects, maintains and enhances assets, and promotes knowledge. It also stimulates economic prosperity, supports livelihoods, and defends the rule of law and equity."[201]

Climate change adaptation and mitigation measures consist of technical and so-called "nature-based" solutions, which are based on a green urban infrastructure which includes urban agriculture. Such a green infrastructure requires technological solutions and the latest sustainable concepts in architecture and construction, while creating greener sanctuaries within cities to ensure the

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[197] EEA: Climate change, impacts and vulnerability in Europe 2016. An indicator-based report. Copenhagen 2017. http://www.eea.europa.eu//publications/climate-change-impacts-and-vulnerability-2016. Retrieved on 8.3.2017

[198] BfN (2015): Workshop documentation Expert Workshop on Nature-based solutions to climate change mitigation and adaptation in urban areas and their rural surroundings. https://www.bfn.de/fileadmin/BfN/ina /Dokumente/Tagungsdoku/2015/2015-Naturebased_solution-Workshop_report_Vilm_.pdf. Retrieved on 5.7.2019

[199] European Union: ET 2050 Territorial Scenarios and Visions for Europe. Final Report, 20.6.2014. https://www.espon.eu/library?filename=final+report. Retrieved on 15.5.2017

[200] Susca, T. et al. (2011): Positive effects of vegetation: Urban Heat Island and green roofs. Environmental pollution, 159(8), pp. 2119-2126

[201] The Rockefeller Foundation: City Resilience Framework. https://www.rockefellerfoundation.org/app /uploads/City- Resilience-Framework1.pdf. p. 4. Retrieved on 26.2.2017

survival of many endangered species.[202] [203] [204] Barriers to implementing a green infrastructure are often insufficient awareness of the problem, lack of knowledge of evident benefits of urban green spaces for human health and city climate, and existing bureaucracy.[205] [206]

4.3 Seed-Scale and Emergence

In this study, the Seed-Scale and Emergence Theory have been chosen as a suitable theoretical approach to explain the emergence and development process of today's UA movement. The reason for this is, that – as a socio-economic theory – the Seed-Scale and Emergence Theory is a comprehensive approach to social change that mainly focuses on human initiative and activity. The Seed-Scale and Emergence approach sees socio-economic development not as the result of a system input, but as an outcome of the interaction between system elements, actors, and their "capacity-focused development."[207]

Originally designed to promote entrepreneurship for sustainable development and reducing poverty in Third World countries, it also serves as a useful theoretical vehicle for explaining the phenomenon of urban gardening and farming in industrialized countries. The Seed-Scale and Emergence approach interprets human energy as a resource that is omnipresent in every community in the world. This energy can manifest itself in different forms and structures, such as individual labor, collaboration with others, creativity, and learning: "The

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[202] Set, K. et al. (2011): A Meta-Analysis of Global Urban Land Expansion. doi: 10.1371/journal.pone.0023777. Retrieved on 8.7.2019
[203] Haase, D. et al. (2014): A quantitative review of urban ecosystem service assessments: Concepts, Models, and Implementation. Ambio, 43(4), pp. 413-433
[204] European Commission (2013): Building a Green Infrastructure for Europe. http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructure_broc.pdf. Retrieved on 9.7.2019
[205] ibid.
[206] Intergovernmental Panel on Climate Change Climate Change 2014 Synthesis Report. Fifth Assessment Report, https://ar5-syr.ipcc.ch/topic_adaptation.php. Retrieved on 25.3.2019
[207] Kretzmann, J., McKnight, J. (1993): Building Communities from the Inside Out: A Path Toward Finding and Mobilizing a Community's Assets. Evanston, ILL. 1993

hallmark of emergence is this sense of much coming from little. Yet, emergence is a ubiquitous feature of the world around us. Mundane activities such as farming depend on rules of thumb for emergence for example, knowing the conditions that influence the germination of seeds."[208]

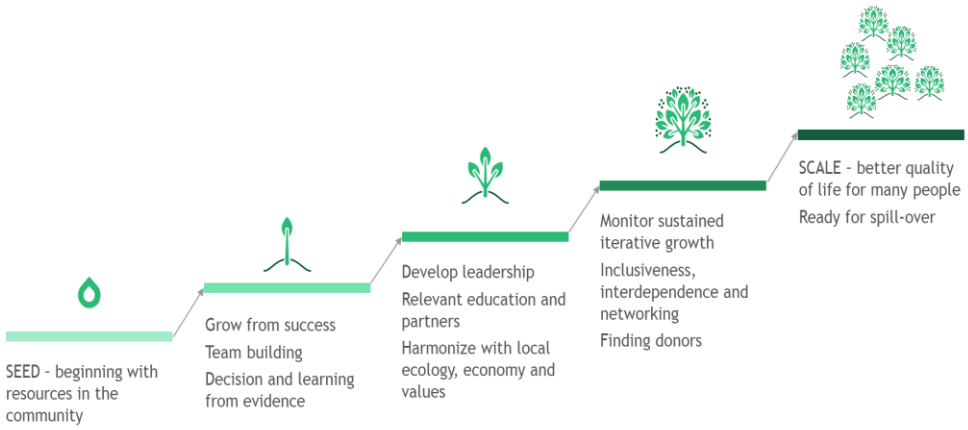

Figure 12 – Seed Scale and Emergence Theory, author of this study (2020)

The origins of the contemporary Seed-Scale and Emergence analytical framework date to 1992, when James P. Grant,[209] investigated how successful pilot projects ("seeds") for the well-being of the poor population and especially for children could extend to the national level with high impact ("scale").[210] After Grant's death in 1995, Carl and Daniel Taylor developed this into a pragmatic seed-scale and emergence approach. In their opinion, the goal of sustainable human development should be to bring together the "three primary environmental care objectives of ecosystem management, meeting basic needs, and community empowerment, so that: communities develop the capacity to solve their own problems by applying appropriate science-based interventions that are simplified

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[208] Holland, J. (1998): Emergence: From Chaos to Order. p. 2. Cambridge 1998
[209] SEED is an acronym for Self-Evaluation for Effective Decision-Making. SCALE is an acronym for Systems for Communities to Adapt Learning and Expand.
[210] UNICEF: The State of the World's Children 1992. pp. 5-11. New York 1992

and adapted for local use; and systematic extension is promoted by an evolving extension process in which communities learn from each other."[211]

In his proposal for scaling up with self-reliant social empowerment, Taylor cites the evolution from a "self-reliant understanding of local needs,"[212] the development of any action in a "combination of a bottom-up and top-down programming," and the anchoring of action in community reliance and self-reliance as basic principles for sustainable human development.[213] Seed-Scale usually starts at the local level, gains momentum, and expands into a larger framework. At the core of this process is the people's initiative, starting with what they have and moving forward with rising aspirations. In a feedback loop of success and improved quality of life, a scaling-up process begins with more participants joining the movement.[214] An important pre-condition for this scaling-up is the ability of the interconnected and interacting elements of a complex adaptive system to learn, which means that they have the properties of feedback, self-organization, and emergence.

Thus, Seed-Scale can also serve as a suitable theoretical analytical framework to explain the development of the trend towards urban gardening and urban agriculture. Unlike other frameworks, Seed-Scale provides guidelines that any community can follow because it does not presuppose significant investment, expert workers, or support from the government. Starting with the only resource that is always available, human energy, the surrounding local ecology, economy, and values can be influenced, and technologies, social systems, information, and financing subsequently join the movement.

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[211] Taylor-Ide, D., Taylor, C. (1995): Community Based Sustainable Human Development. Children, Environment and Sustainable Development Primary Environmental Care (PEC) Discussion Papers No. 1, February 1995
[212] ibid.
[213] ibid.
[214] Taylor, D., Taylor, C., Taylor, J. (2012) : Empowerment on an Unstable Planet: From Seeds of Human Energy to a Scale of Global Change. New York 2012

As the urban gardening trend in the USA and many European countries has demonstrated, the Seed-Scale approach provides a viable operating system that everyone can adopt: "Creative neighborhood leaders... are discovering that wherever there are effective community development efforts, those efforts are based upon an understanding, or map of the community's assets, capacities and abilities. For it is clear that even the poorest neighborhood is a place where individuals and organizations represent resources upon which to rebuild."[215]

In this context, emergence can be understood as the spontaneous formation of properties or structures that arise only through the interaction of the system's constituents. The origin or emergent behaviors can be intricate causal relations across different scales or cybernetic feedback processes, and the emergent property itself can be predictive or arbitrary and unique.[216] The system elements alone, however, do not possess the properties that emerge from mutual interactions that can produce stabilizing and amplifying feedback, thus either preserving or changing the state of the system.[217]

As a learning-by-doing framework, emergence leads to social change on the basis of community success, a process called "seed." The next phase is the expansion of activities among societal groups, which can unfold at the community, regional, and national levels, a process called "scale." This development from low-level manifestation to higher-level complexity is called "emergence" because the outcome of Seed-Scale is not caused by external inputs but emerges from system-inherent processes. As an empowering concept

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[215] Kretzmann, J., McKnight, J. (1993): Building Communities from the Inside Out: A Path Toward Finding and Mobilizing a Community's Assets. Skokie, IL. 1993.

[216] Mason, D., Knowd, I. (2017): The emergence of urban agriculture: Sydney, Australia, February 2010. https://www.researchgate.net/publication/233522162_The_emergence_of_urban_agriculture_Sydney_Australia. Retrieved on 3.11.2017

[217] Walker, B., Salt, D. (2006): Resilience Thinking: Sustaining Ecosystems and People in a Changing World. New York 2006, p. 164

for any initiative in a local community, equity, sustainability, and integrity should be the guidelines and assessment criteria for the seed and the scale phase.[218]

The example of urban garden projects shows how separate, local initiatives and projects are integrated into a network for the exchange of information and cooperation. This leads to the formation of communities and finally to a new, up-scaled system with stronger influences than the individual or small group had in the beginning: “Emergence has a life-cycle. It begins with networks, shifts to intentional communities of practice and evolves into powerful systems capable of global influence.”[219]

Thus, the emergence of further garden projects is based on four prerequisites according to the Seed-Scale and Emergence basic principles: First, the success of a pilot project enhances the confidence of the founders and participants and creates momentum for further initiatives. Second, three-way partnerships refer to the need for support from public authorities that create the legal framework for the projects as well as experts who function as advisers and develop new ideas. Third, according to Daniel, Carl, and Jesse Taylor,[220] further requirements are based on evidence-based decision-making and objective data. The fourth precondition is the willingness of community members to acquire new skills and to make management power-sharing flexible and capable of acting.

Change begins when local actions join together and become an emergent phenomenon, regardless of how small and invisible they may be at the beginning. Through its immanent dynamics, networking is a new, effective method of

[218] November 2012 SEED-SCALE training manual & toolkit - a manual prepared by Luke C. Taylor-ide drawing also on materials prepared by Nawang Singh Gurung Developed Based on A Task Force Commissioned by UNICEF with books written by Daniel C. Taylor, Carl E. Taylor and Jesse O. Taylor. https://www.seed-scale.org/sites/seed-scale.org/files/SEED-SCALE_TrainingManual.Final_.pdf. Retrieved on 2.3.2018

[219] Wheatley, M., Frieze, D. (2006): Using Emergence to take Social Innovations to Scale. www.margaetwheatley.com/articles/emergence.html. Retrieved on 8.03.2017

[220] Taylor, D., Taylor, C., Taylor, J. (2012): Empowerment On An Unstable Planet: From Seeds of Human Energy to a Scale of Global Change. New York 2012

organization that creates the conditions of emergence for independent individuals by dispensing with hierarchical structures and controls. When individuals ally themselves with friends, neighbors, and other like-minded individuals on the basis of a few basic interests and principles, simple rules can create complex behavior: “Emergent phenomena always have these characteristics: They exert much more power than the sum of their parts; they always possess new capacities different from the local actions that engendered them; they always surprise us by their appearance.”[221]

According to Holman,[222] the characteristics of emergence are coherence, wholeness, dynamism, and downward causation, whereby the leadership of the community of interests is either equally distributed among the individual sub-units or in the context of situation-induced leadership. A difference can be identified between weak and strong emergence; in the former, the properties result from the interaction on the elementary level and can be understandable to a certain extent with computer simulation. In the case of a strong emergence, the new properties are not traceable to the properties of the system components. Because of constant interactions between systems, their elements, and their environment, an unpredictable complexity develops exponentially with the number of system constituents.[223]

Emergence in the Seed-Scale process is intended to promote societal advancement that is not solely rooted in economic growth because profits from economic growth do not necessarily improve health, education, security, or the environment.[224] Most of the benefits of growth and progress are unequally distributed and favor those who have money, natural resources, and labor. Since

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[221] ibid.
[222] Holman, P. (2010): Engaging Emergence. San Francisco 2010
[223] Corning, P. (2002): The Re-Emergence of Emergence: A Venerable Concept in Search of Theory. Complexity, 7(6), pp. 18-30
[224] Taylor, D., Taylor, C., Taylor, J.O. (2012): Empowerment on an Unstable Planet: From Seeds of Human Energy to a Scale of Global Change. Oxford 2012

a disproportionate concentration on economic growth neglects the interests of communities, the Emergence and Seed-Scale approach provides a pragmatic concept with context-specific solutions that, until now, have successfully been applied in many projects.[225] [226] [227]

The Basque Declaration, which was adopted at the Eighth European Conference on Sustainable Cities and Towns in April 2016, fits into this context through its call for rethinking the boundaries between public and private sectors. Success can only be achieved through a socio-cultural, socio-economic, and technological transformation through innovative, pragmatic approaches and the active participation of citizens, as this is the case with the urban gardening movement: "Today, in order to meet these challenges, we will have to think outside of the box and find innovative ways to economically and socially engage our civil societies particularly on the local level. We will have to find sustainable solutions that increase the economic value that is captured in cities and regions for the benefit of the local population."[228]

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[225] Seed Scale Training Manual. http://www.seed-scale.org/sites/seed-scale.org/files/SEED-SCALE_TrainingManual.Final.pdf. Retrieved on 8.3.2017

[226] SEED program at UNO. https://www.seed.uno/. Retrieved on 8.3.2017

[227] Organization of the SEED Awards 2015-2016. https://www.adelphi.de/en/project/organisation-seed-awards-2015-2016. Retrieved on 8.3.2017

[228] Sustainable Cities Platform: Endorse the Basque Declaration. http://www.sustainablecities.eu/endorse-the-basque-declaration/. Retrieved on 3.6.2017

5.0 RESEARCH QUESTIONS AND LIMITATIONS

After briefly outlining the global developments and urban problem areas that provide the background for the topic of this paper and defining key terms such as "urban agriculture", "sustainability", resilience and "vulnerability", this study aims to answer the following question:

With which forms, technologies and implementation options can urban agriculture improve the sustainability and resilience of cities?

In order to be able to answer this complex question, four sub-questions were formulated.

1. How can the Seed Scale and Emergence approach explain the development of UA in Germany and to what extent can it be applied in an adapted version to the conditions in Singapore and the UAE?

2. What are the benefits of modern agricultural technologies and how can they be integrated into urban adaptation and mitigation strategies?

3. What role can the UA play in German sustainability policy and what is the acceptance among the population?

4. What insights gained from the two case studies are also relevant for the strategic integration of urban agriculture in Germany?

The subject of this study is comprehensive and not self-limiting, it is highly complex and involves many aspects from different scientific disciplines. The central terms "urban agriculture," “sustainability,” and “urban resilience” require complex questions in ecological, economic, and social areas. In order to remain within the scope of a limited-time study, it is necessary to focus on certain key issues, create a synopsis of the results obtained, and develop further questions for future studies.

For these reasons, the research refers to cities, concepts, and conditions of realization in the industrialized countries of Europe, Asia, and the USA. In every country and every culture, urban agriculture is practiced according to specific geographical, climatic, economic, and social conditions. The findings in this study possess only a limited significance for the function of urban agriculture and the problems of local urban resilience in poor, developing countries. Nevertheless, the study of sustainable, resource-saving technologies has shown that sometimes-modified versions can be used to benefit the environment and urban farmers around the world.

The brief outline of the historical development of urban agriculture is mainly limited to Germany and illustrated with examples from current manifestations in Munich. The selection of and visits to urban agriculture projects in Germany were limited to Munich, Ulm, Heidelberg, and Cologne, where the author had the best local accessibility and access to contact persons.

The projects of the two case studies, the UAE and Singapore, take place in countries where urban agriculture does not operate as a subsistence economy and where both advanced technologies and sufficient investment capital are available. The initial conditions for an improved food security are very specific in both case studies and cannot directly be transferred to European countries. Nevertheless, the results of Singapore in particular show different ways of integrating urban agriculture into a compact urban landscape which can be useful ideas for other urban planning strategies, also in Germany.

Interviews and the online survey were conducted with a limited number of participants. The results of the empirical investigations are compared and discussed with the results and findings of other research projects. Again, the number of selections must be limited to central studies only. In addition, the extensive online survey presents assessments of a participant collective that reflects the conviction of laypersons regarding the central statements of this study. Thus, research hypotheses are taken out of the isolation of the scientific community and can be compared with "public opinion," even if the source is not representative.

The advocacy of measures to improve urban sustainability and resilience is shown here with a numerically limited sample, but these questions can be useful for further empirical studies. Further subjective limitations resulted from the personal interest of the researcher, who has attributed great importance and relevance to the topic. He also made the decisions to use theoretical explanatory approaches and methods of analysis that he found most suitable for answering the research question. Despite these unavoidably subjective and essentially characteristic limitations of a scientific study, the investigation has provided important insights that are supported by other studies and provide direction for further research.

6.0 STRUCTURE AND RESEARCH DESIGN

The entire research study comprises ten chapters and is structured according to the sub-questions. In the introductory part, the predominant global trends of the 21st century are shortly outlined. They include the increasing urbanization worldwide, the continuing deterioration of the ecosystems, global climate change and the rising demand for food for the growing world population. These are the relevant national and international developments that are decisive for the design and practice of urban agriculture.

The following chapters show, that many of the current problems resulting from the above-mentioned megatrends are overlapping and concentrated in cities. More efficient solutions for current crises and sustainable adaptation and mitigation strategies are needed for a safer future. In order to explore the possibilities of urban agriculture making an important contribution to improving sustainability and resilience, the key terms of sustainability, vulnerability and resilience are defined in the theoretical part.

The Seed Scale and Emergence approach is used to explain the emergence and development process of today's UA movement. Its prerequisites for the social anchoring of the urban gardening movement and successful upscaling – in some cases right up to large commercial projects – run like a central theme throughout the entire research.

To answer the fourth sub-question, innovative agricultural technologies that can be applied in modern urban agriculture are presented in detail at the beginning of the analytical part. Subsequently they are assessed using a SWOT analysis of the vertical farm concept with regard to its ecological, social, economic and health benefits and its suitability for urban adaptation and mitigation strategies. A comprehensive overview of the current state of research and the results of some selected research projects serve to provide additional information and a scientific comparison.

Based on the previous analysis, the question what role the UA can play for the future German sustainability policy can be discussed by outlining the main objectives of the current strategy. Since a policy that fully integrates urban agriculture into its green infrastructure planning requires backing among society, an online survey was carried out to investigate the acceptance of the UA and the level of knowledge regarding its diverse forms and technologies. Interviews with experts and initiators of German gardening projects point out motives, goals and problems of the urban gardening practice.

The next section aims to answer the question of the options for a successful implementation of the UA and integration into a sustainable food system with two case studies, another SWOT analysis and an interview with a vertical farm operator. An extensive case study on the Singapore climate action plan, which aims to integrate the UA into an infrastructure to improve resilience, provides insights and ideas that can be implemented not only in Asia but also in many other cities around the world.

The discussion of the outcome with the findings of other researchers and the resulting conclusions of the previous chapters form the basis for a synthesis in the last part of the study. In a synopsis, the main results of the investigation are summarized to answer the main research question and formulate recommendations for future research.

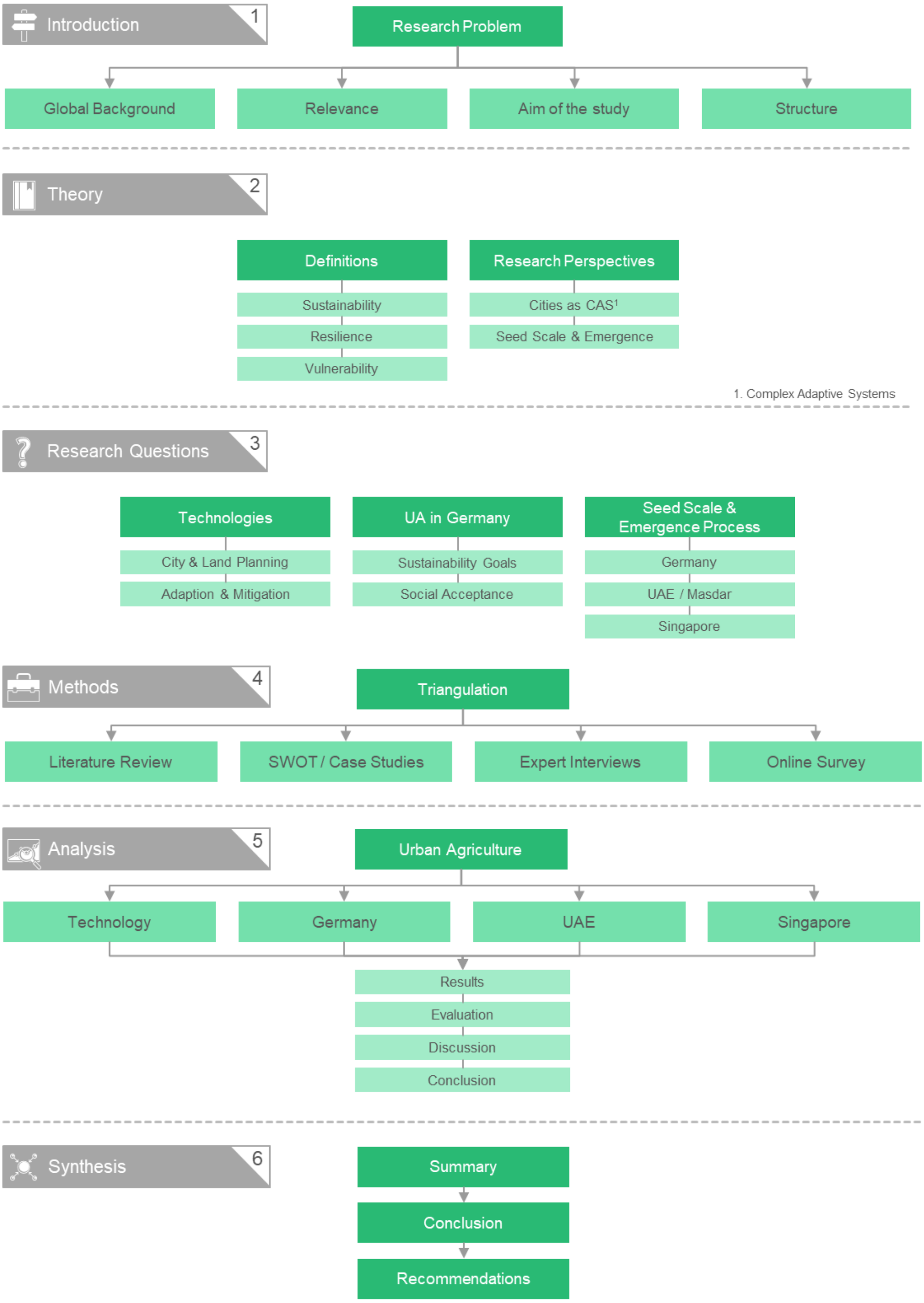

Figure 13 – Research Design, author of this study (2020)

7.0 METHODS AND DATA ACQUISITION

7.1 Triangulation of Research Methods

Scientific investigations on sustainability and resilience naturally transcend disciplinary boundaries because, due to technical and economic globalization, the current economic, social, and environmental problems of sustainability are so complex that a single discipline or method is not sufficient to develop comprehensive solutions.

In this study, a combination of quantitative and qualitative methods was applied. In order to answer the research questions of this study, different types of data were used from different sources and a scientific exchange was carried out at different times and in different places with a large number of people.[229] Thus, methodological triangulation as a research strategy can balance the weaknesses of one approach with the strengths of another and improve the quality of the research by a higher validity of the research results.[230] [231]

In practice, the triangulation of data and methods specifically means that, with regard to the different types of soilless cultivation methods, innovative technologies and their ecological, social and economic benefits, and interviews with experts (scientists, politicians, entrepreneurs) were performed. Additionally, comparisons with other research projects and on-site visits to vertical farms in Germany, UAE and Singapore were carried out. Also, several interviews were carried out in Ulm, Cologne, Heidelberg and in the Munich city administration for

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229 https://www.unaids.org/sites/default/files/sub_landing/files/10_4-Intro-to-triangulation-MEF.pdf. Retrieved on 10.12.2017

230 The theory of complete adaptive systems is a focus of the research work of the Santa Fé Institute. https://www.santafe.edu/. Retrieved on 4.2.2017

231 Hales, D. (2007): An Introduction to Triangulation. UNAIDS Monitoring and Evaluation Fundamentals. https://www.unaids.org/sites/default/files/sub_landing/files/10_4-Intro-to-triangulation-MEF.pdf. Retrieved on 10.12.2017

an exemplary presentation of urban gardens in Germany and the profiles and motives of urban activists.

The data obtained from interviews with garden activists, experts, and participants of an online survey, as well as from a comprehensive literature analysis, were evaluated statistically or interpretatively. Subsequently, the results of both the qualitative and the quantitative research were compared with the results of other research projects in the chapters on "State of Current Research".

The triangulation of methods and data was implemented according to the individual subject areas in this study:

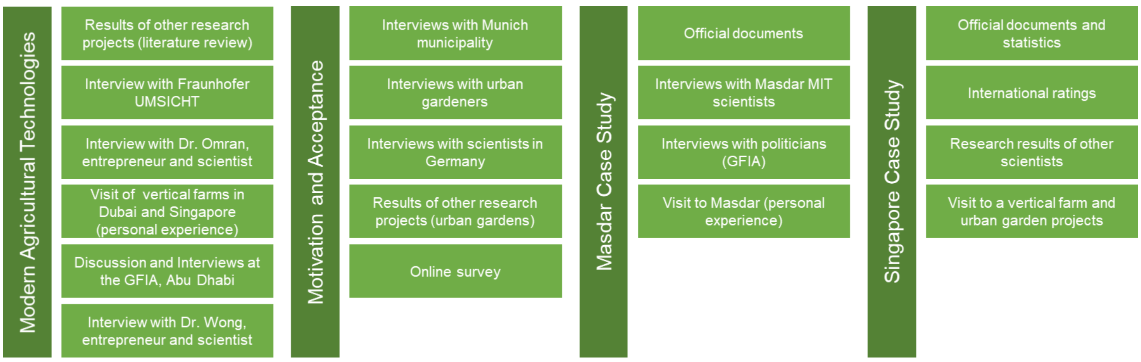

Figure 14 – Triangulation of research methods, author of this study (2020)

7.2 Literature Review

The starting point of the study is the author's personal interest based on previous studies in the field of sustainable economy.[232] [233] Thus, the preliminary stage started with browsing the Internet and looking for interesting articles about the new urban farming trend in Germany and across Europe. Websites, blogs, and video clips inspired the author to intensify his investigation by searching via Scopus and Google Scholar for the following topics: "urban agriculture," "urban sustainability and resilience," "agricultural technologies," "food security," "food security in UAE and Singapore," "climate change," "seed-scale and emergence theory," "Masdar," "Fraunhofer InFarming," etc. In addition to scientific studies, companies' and organizations' websites and government documents were also consulted and inspired the author to travel to Singapore and the UAE to visit vertical farms and talk with leading experts.

An overview of available sources and research showed that urban agriculture manifests in many forms all over the world and has also become a grassroots movement in Germany that differs from the historical forms of urban gardens. Extensive literature research has also shown that the most frequent topics in the scientific discussion are successful projects in low-income countries that use urban agriculture for subsistence, better nutrition, and family food security.

[232] Masyk, T. (2011): Nachhaltigkeitsspezifische Maßnahmen im Automobilvertrieb und deren Auswirkungen auf Kundenperzeption, Wirtschaftlichkeit und Umwelt. FH Deggendorf 2011

[233] Masyk, T. (2013): Sustainability as a key factor in modern marketing strategies. University of Economics, Prague 2013

This section provides only a few examples.[234] [235] [236] [237] [238] The study of Krishnan[239] is dedicated to the important, often-overlooked aspect of urban food deserts in industrialized countries. However, there are few publications on the benefits of urban agriculture for mitigation and adaptation strategies in the industrialized global North.[240] [241] [242] The author is aware of only two studies on the societal acceptance of urban agriculture [243] [244] and no study that considers urban agriculture from a Seed-Scale and Emergence theory point of view.

7.3 SWOT Analysis and Case Studies

7.3.1 SWOT Analysis

The concept of vertical farming and its importance for future agriculture is actively discussed in science since the publication of Dickson Despommier's bestselling book “The Vertical Farm in 2010. “ [245] Since then, numerous vertical farms have appeared, especially in non-European countries, proving that, in spite of the

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[234] de Bon, H. et al. (2010): Sustainable urban agriculture in developing countries. A review. Agronomy for Sustainable Development. https://hal.archives-ouvertes.fr/hal-00886446/document. Retrieved on 14.10.2016

[235] Hamilton, A.J. et al. (2014): Give peas a chance? Urban agriculture in developing countries. A review. Agronomy for Sustainable Development, 34(1), pp. 45-73. https://doi.org/10.1007/s13593-013-0155-8. Retrieved on 15.10.2016

[236] Magnusson, U., Bergman, K. (eds.) (2014): Urban and Peri-urban Agriculture for Food Security in Low-income Countries – Challenges and Knowledge Gaps. SLU Global, Swedish University of Agricultural Sciences, Uppsala, Sweden 2014

[237] Poulsen, M. et al. (2015): A systematic review of urban agriculture and food security impacts in low-income countries. https://www.sciencedirect.com/science/article/abs/pii/S0306919215000809. Retrieved on 11.12.2016

[238] Gonzalez-Corzo, M. (2016): Urban Agriculture in Cuba: An Update. https://www.ascecuba.org/asce_proceedings/urban-agriculture-in-cuba-an-update/. Retrieved on 4.4.2017

[239] Krishnan, S. et al. (2016): Sustainable Urban Agriculture: A Growing Solution to Urban Food Deserts. In: Nandwani, D. (eds.) Organic Farming for Sustainable Agriculture. Sustainable Development and Biodiversity, 9. https://link.springer.com/chapter/10.1007/978-3-319-26803-3_15#citeas. Retrieved on 4.2.2017

[240] Viljoen, A. et al. (2005): Continuous productive urban landscapes. Oxford 2005

[241] Balmer, K. et al. (2005): The diggable city: Making urban agriculture a planning priority. Portland State University 2005

[242] Van Veenhuizen, R. (ed.) (2014): Urban Agriculture for Green and Productive Cities. Leusden, NL 2014

[243] Sanye-Mengual , E. et al. 2015

[244] Specht, K. et al. 2015

[245] Despommier, D. (2010): The Vertical Farm. Feeding the World in the 21st Century. New York 2010

sometimes-considerable energy costs, vertical farming can operate profitably. Practical implementations exist now in numerous countries (the USA, Australia, Singapore, China, Germany, etc.).

As an analytical approach, the SWOT analysis is well suited for determining both a commercial or political strategy (UAE Food Security Strategy) and the chance of success of a product or business model (vertical farming). In a strengths, weaknesses, opportunities, threats analysis, the own position as well as that of competitors (traditional agriculture) can be weighed against each other. The overarching goal of the SWOT analysis is to define measures with which the identified opportunities can be exploited and risks avoided.

The analytical approach according to the SWOT guidelines makes it easier, e.g., for companies in the vertical farming sector, to consider internal and external factors with opportunities and risks in relation to each other and to develop formalized target-oriented strategies from this. The main focus is on the actual situation and the appropriate use of resources for maximum efficiency (see the Emirati Food Security strategy). For this reason, the SWOT analysis is a very helpful tool for strategic decision making, which can be easily applied for many purposes by communicating complex issues transparently with the SWOT matrix.

Disadvantages of the SWOT analysis consist in its character of a snapshot, which requires regular updates. In addition, its results naturally depend on the factors chosen and their assessment, which reflect the subjective understanding of the researcher. Since the large number of parameters used often makes objective evaluation difficult, SWOT analysis should only be used as an accompanying procedure complementary to targeted detailed analyzes.

The initial situation for Singapore and the UAE is characterized by similarities and stark contrasts, which can be made clear by a SWOT analysis. For reasons of comparability and the development of the vertical farming strategy, the Emirati government has selected Singapore as a role model and partner in the development of a more resilient food system.

In the SWOT analyses performed in this study, the approach had not been chosen too narrowly, as there are many influencing factors. A national food system is not just about food imports, exports and in-house production. The prerequisites are to a large extent the political system, available capital and investment conditions, geographical conditions, level of education and consumer behavior, acceptance of innovations and the willingness of entrepreneurs to take risks.

With the help of the SWOT Matrix, new technologies such as hydroponics, aquaponics, and InFarming are examined for their significance for urban sustainability and resilience. The objectives of the actors responsible for concept development and implementation, as well as resources and capabilities in a competitive environment, are investigated. Furthermore, factors that are conducive to or inhibitive of achieving the declared goals are identified. Both SWOT analyzes of the vertical farm concept and the food security strategy of the UAE are based on literature research, document reviews, interviews, on-site attendance at conferences (GFIA), discussions with MIT Masdar, and several visits to vertical farms.

7.3.2 Selecting Singapore and the UAE

According to the 2018 Food Security Index of the Economist Group (FSI),[246] the most secure country in the world is Singapore, followed by Ireland, the United Kingdom, the United States, the Netherlands, and Australia. Germany occupied the 11th rank, and the UAE the 31st. While Ireland, the United States, and many others among the top 20 have highly productive agricultural sectors and enjoy

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[246] The Economist (2018): Ranking and Trends. https://foodsecurityindex.eiu.com/index. Retrieved on 29.6.2019

favorable climatic conditions, Singapore represents a special case. Similar to the UAE, Singapore has very little arable land, insufficient domestic agricultural production, and is almost completely dependent on food imports. Sufficient water is a permanent problem, as neither country has its own natural freshwater sources.

Singapore and the UAE are ideal case studies because of comparable starting conditions. On the other hand, they are characterized by stark contrasts - such as climatic conditions, population structure and political strategies. Both countries have some similar components in their food security strategy, such as stockpiling, price subsidies, food source diversification, investments in agriculture abroad, and incentives for public-private partnerships. They both offer financing for farmers and new technologies, and they both have a research and development infrastructure. In spite of these common features, Singapore's food security strategy is a success story, while the UAE are still struggling to improve their food security. The aim of the case studies in this study is to examine the food security strategy of both countries in order to highlight the crucial differences that explain the success of the Singapore strategy, the partial success of the UAE policy and the failure of the Masdar concept.[247]

During his research, the author traveled to Singapore and the UAE, attended research institutions, conventions, and vertical farms and held discussions with scientists, experts, and politicians. Together with the online survey and interviews with urban garden activists and scientists, the two case studies are an addition to the urban agriculture as it is practiced in Germany. Although they have a singular, subjective character in principle, their results are verifiable in further investigations and serve to test the explanatory value of the Seed-Scale and

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[247] A new cooperation between the UAE and Singapore government in food security started in August 2018 "with the aim of identifying and adopting the most innovative practical and theoretical technologies". Alghoul, R., Basir, H. (2018): UAE, Singapore discusses cooperation in food security. http://www.ipsnews.net/2018/08/uae-singapore-discuss-cooperation-in-food-security/. Retrieved on 24.6.2019

Emergence principles. In addition, there are some very effective methods in Singapore for integrating the UA into a compact urban structure that could also be adopted by German cities.

7.4 On-Site Visits and Expert Interviews

7.4.1 On-Site Visits

The intention to conduct this research not only on the basis of desk research, but also through discussions with different experts and visits to vertical farming projects was one of the driving impulses and main motives. For this purpose, the author visited a number of local urban farming projects and spoke to the Department of Urban Planning and Building Regulations in Munich and the Fraunhofer UMSICHT Institute in Oberhausen,[248] where he was informed about the progress of urban agriculture in Germany. The direct contact with these experts provided useful background information that proved to be of great value for the central problems of this study and a critical assessment of public documents.

Additionally, the author participated in roundtable sessions of the Global Forum for Innovations in Agriculture in Abu Dhabi in 2016 and 2017, held talks with leading local Emirati politicians, visited the city of Masdar, Abu Dhabi and Dubai and met with university staff members from the Masdar Institute of Science and Technology. He also stayed two days at the first vertical farm in Dubai, where Ashraf Omran, President of the Arab Council for Water and Food Security, introduced him into vertical farming technology.

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[248] Fraunhofer UMSICHT: https://www.umsicht.fraunhofer.de/. Retrieved on 3.5.2017

The author acquired also further practical insights and valuable information during his stay in Singapore. There, he exchanged views with producers of vertical farming equipment and vertical farm operators and was introduced to the latest achievements in vertical farming technology by Lionel Wong, Founding Director of the Upgrown Farming Company.[249]

7.4.2 Expert Interviews

The selection of and the visits to urban agriculture projects in Germany were limited to Munich, Ulm, Heidelberg, and Cologne, where the author conducted interviews with urban gardeners. The questions for the urban activists were quite similar, and the questions for the experts were individually tailored to the interlocutor's respective expertise. During the preparation phase, the author developed key questions, which were then introduced to the conversation at the appropriate opportunity. After completing the dialogue, the contents were protocolled from memory and recorded in writing. Talking to urban gardeners about their motivation, the development of the garden project, and the realities of participating in a community garden provided valuable information that could later be compared to similar surveys by other researchers.

The semi-structured interviews with experts were helpful in raising the author's awareness of the research problem and in generating his research questions. Another important advantage of expert interviews was to gain insider knowledge at the source through personal contact, where the conversation partners openly described their personal assessments. These personal reviews and opinions must be distinguished from verifiable facts, but both belong to the achieved and usable results.[250]

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[249] Upgrown Farming Company. https://upgrownfarming.co/. Retrieved on 3.4.2017

[250] Meuser, M., Nagel, U. (2005): Expertinnen Interviews – vielfach erprobt, wenig bedacht. In: Bogner, A. et al. (eds.): Das Experteninterview – Theorie, Methode, Anwendung. Wiesbaden 2005

All of the selected experts the author interviewed had many years of experience in their fields and highly successful professional careers. The talks took place in a relaxed atmosphere and developed with positive momentum. Thus, what Mieg and Brunner[251] once defined as the goal of an expert interview, namely to "retrieve time-effective, experience-based expert knowledge from suitable persons," could be achieved.[252]

7.5 Online Survey

One precondition for a successful expansion and promotion of urban agriculture by urban planning agencies is the knowledge of how urban agriculture is valued by the population. Therefore, this online survey aimed at answering the following questions:

- To which extent is the use of fallow land, the expansion of community gardens, and the promotion of innovative farming technologies accepted and desired?
- Is an effectiveness of UA assumed for an improvement of urban resilience and sustainability and, if so, for what reasons?
- Which forms of UA are particularly popular and which are more likely to be rejected?
- What connection is there between the acceptance of UA and the current place of residence, the education and possibly own horticultural activities of the people interviewed?
- Which threats to urban resilience are perceived and how is UA's potential for mitigation and adaptation to these challenges assessed?

[251] Mieg, H., Brunner, B. (2004). Experteninterviews. Reflexionen zur Methodologie und Erhebungstechnik. Schweizerische Zeitschrift für Soziologie, 30, pp.1999-2022

[252] ibid, „geeigneten Personen zeiteffektiv erfahrungsgestütztes Experten-Wissen abzuholen“, translated by the author.

These questions represent the author's scientific cognitive interest and justify the conduct of an online survey. Currently there is only one survey, that of Schulz et al.[253] in Germany with a similar topic; the authors conducted a survey in 2012 with 386 participants in Berlin on the demand for and acceptance of urban agriculture in major German cities. Building on this survey, the article of Specht et al.[254] on socially acceptable urban agriculture businesses was published in 2016. Their results, together with those of Heuner's[255] study on urban gardeners' motivation and the outcomes of the author's own online research from 2013,[256] are put into a comparative context following the data analysis of this online survey.

Online questionnaires provide a flexible, convenient way to collect large amounts of data, determine the relationships between individual variables, and formulate generalized conclusions from them. With different types of questions (open, closed, multiple choice, etc.), the survey can be tailored to the participants of the selected sample.

Above all, the advantages of online surveys are that they cost nothing, can be implemented quickly, and the interviewer cannot exert any influence on the respondent. Participants in the survey can choose the timing of the questions themselves and can be sure of their anonymity. Without travel expenses, people distant from the researcher can also be included in the survey.

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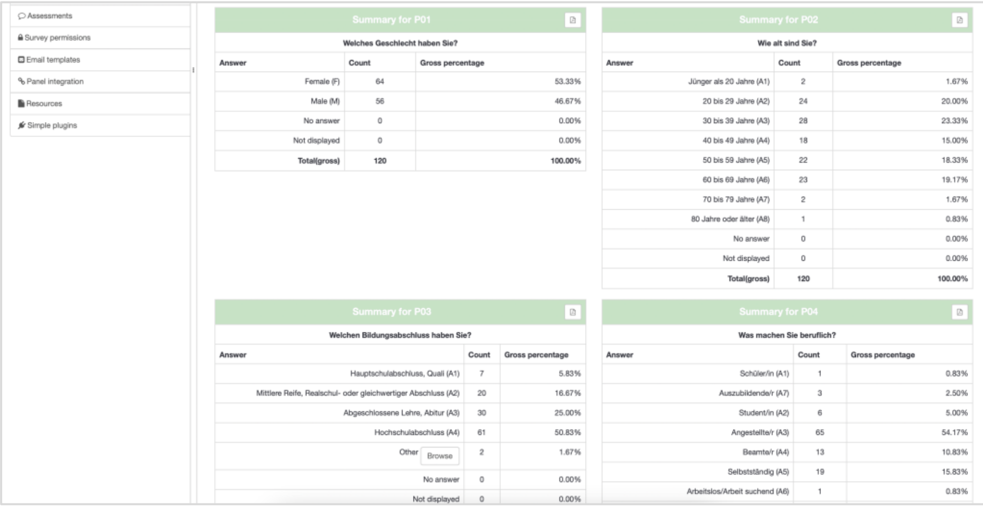
253 Schulz, K. et al. (2013): Urbane Landwirtschaft und „Green Production" als Teil eines nachhaltigen Landmanagements. Leibnitz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V. Diskussionspapier Nr.6, April 2013

254 Specht, K. et al. (2016): Socially acceptable urban agriculture businesses. Agronomy for Sustainable Development, March 2016, 36(17). https://link.springer.com/article/10.1007/s13593-016-0355-0. Retrieved on 25.5.2019

255 Heuner, S. (2016): Warum wird gegärtnert? Eine Untersuchung am Beispiel urbaner Gartenprojekte. Pädagogische Hochschule Karlsruhe. Institut für Biologie und Schulgartenentwicklung 2016

256 Masyk, T. (2013): Sustainability as a key factor in modern marketing strategies. University of Economics, Prague 2013

All data collected are immediately available for inspection on the server, together with an interim report (see chapter 12.2 for selected images from the author's online survey on the LimeSurvey Platform). [257]



Assessments
Survey permissions
Email templates
Panel integration
Resources
Simple plugins

Summary for P01

Welches Geschlecht haben Sie?

Answer	Count	Gross percentage
Female (F)	64	53.33%
Male (M)	56	46.67%
No answer	0	0.00%
Not displayed	0	0.00%
Total(gross)	**120**	**100.00%**

Summary for P02

Wie alt sind Sie?

Answer	Count	Gross percentage
Jünger als 20 Jahre (A1)	2	1.67%
20 bis 29 Jahre (A2)	24	20.00%
30 bis 39 Jahre (A3)	28	23.33%
40 bis 49 Jahre (A4)	18	15.00%
50 bis 59 Jahre (A5)	22	18.33%
60 bis 69 Jahre (A6)	23	19.17%
70 bis 79 Jahre (A7)	2	1.67%
80 Jahre oder älter (A8)	1	0.83%
No answer	0	0.00%
Not displayed	0	0.00%
Total(gross)	**120**	**100.00%**

Summary for P03

Welchen Bildungsabschluss haben Sie?

Answer	Count	Gross percentage
Hauptschulabschluss, Quali (A1)	7	5.83%
Mittlere Reife, Realschul- oder gleichwertiger Abschluss (A2)	20	16.67%
Abgeschlossene Lehre, Abitur (A3)	30	25.00%
Hochschulabschluss (A4)	61	50.83%
Other Browse	2	1.67%
No answer	0	0.00%
Not displayed	0	0.00%

Summary for P04

Was machen Sie beruflich?

Answer	Count	Gross percentage
Schüler/in (A1)	1	0.83%
Auszubildende/r (A7)	3	2.50%
Student/in (A2)	6	5.00%
Angestellte/r (A3)	65	54.17%
Beamte/r (A4)	13	10.83%
Selbstständig (A5)	19	15.83%
Arbeitslos/Arbeit suchend (A6)	1	0.83%

Image 1 – Interim report on LimeSurvey Platform, author's survey in 2019

The disadvantages of online surveys are that they require a minimum of computer skills, and therefore some people do not qualify for participation. Usually, there is a high dropout rate because the experimenter cannot control the interview situation. It is also possible that more complex questions can be misunderstood, and the participant may be afraid to ask the organizer of the survey for an explanation. In turn, open questions provide individual answers and are authentic, but they require personal evaluation and are not quantifiable.

Unavoidable sources of errors that occur in any written survey are partly based on the personality of the respondent, his environment during participation, and the effects that the sequence of answer alternatives, phrases, and the complexity of the questions produce for the participant.[258] The most common of these so-

[257] ibid.
[258] Schumann, S. (2018): Quantitative und qualitative empirische Sozialforschung. Mainz 2018

called "response tendencies" includes the halo or spill-over effect, the acquisition or approval tendency, and the primacy and regency effects.

In practice, this means that previous questions and answers can influence the subsequent ones (halo effect), that questions participants do not fully understand are approved (acquisition), the tendency to agree with the first satisfactory answers (primacy and regency tendency), or there may be an inclination to give basically average, favorable assessments (central tendency).[259] Further, once given, positive or negative judgments can determine the subsequent ratings (anchor effect).[260] Such sources of error cannot be ruled out in this online survey, but they do not unduly reduce the significance of the results obtained and interpreted because highly significant results represent verifiable opinion tendencies.

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[259] Bogner, K., Landrock, U. (2015): Antworttendenzen in standardisierten Umfragen. https://www.gesis.org/fileadmin/upload/SDMwiki/Archiv/Antworttendenzen_Bogner_Landrock_11122014_1.0.pdf. Retrieved on 10.6.2019

[260] Lipsmeier, G. (2004), Interrogare GmbH Bielefeld. http://eswf.uni-koeln.de/lehre/04/04_05/lipsmeier.pdf. Retrieved on 10.6.2019

8.0 ANALYSIS AND RESEARCH RESULTS

8.1 Modern Agricultural Technologies

In this research section, the benefits of modern agricultural technologies will be presented and the question answered, how they can be integrated into urban adaptation and mitigation strategies.

8.1.1 Soilless Types

8.1.1.1 Hydroponics

Hydroponics is a technology that allows plants to be cultivated without the use of soil by exclusively using water and mineral nutrients. For some techniques, a neutral growing medium is required. This method is particularly suitable for places with no appropriate soil or for confined spaces, such as on roofs and apartments. Since the water used can be completely recycled, this method is also suitable for dry areas and deserts, especially when a closed system is used to prevent strong evaporation. However, there are further advantages to hydroponics. Labor-intensive work such as tilting, fumigation, and watering is not necessary because simple technology for controlling automatic pumps for water and the nutrient supply is available, and it can also be coupled with computers. Without any prior knowledge, an urban gardener can successfully grow flowers or vegetables with such a hydroponic process.[261] [262] Four main types of hydroponic techniques can be distinguished:

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[261] USDA. https://www.nal.usda.gov/afsic/hydroponics. Retrieved on 11.19.2017

[262] Nguyen, N. et al. (2016): Hydroponics: A Versatile System to Study Nutrient Allocation and Plant Responses to Nutrient Availability and Exposure to Toxic Elements. J. Vis. Exp. 2016, 113. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5091364/. Retrieved on 15.10.2017

Image 2 – Ashraf Omran's farm in Dubai – Close picture of growing salad in nutrient solution, author's study trip to Dubai in 2015

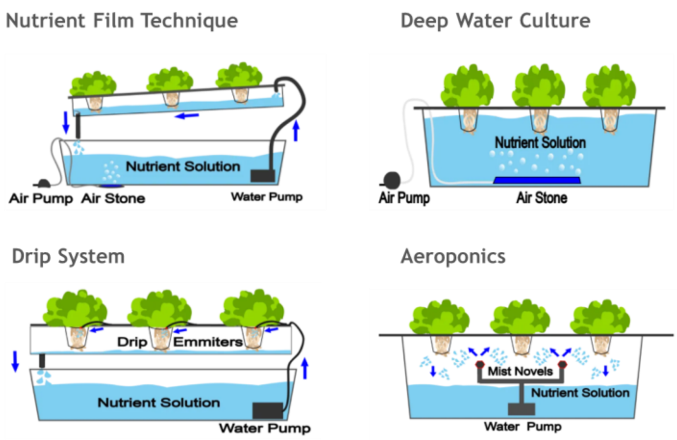

Figure 15 – Hydroponic variants, https://www.nosoilsolutions.com/

The Nutrient Film Technique

The Nutrient Film Technique is particularly suitable for plants with long roots, which are always surrounded by the nutrient solution, while the plants themselves are placed in an elevated position. A circular pumping system ensures that there is always sufficient nutrient solution to wet the roots. The advantages of this technique are the low water and nutrient consumption and the easy control of root quality and health. However, because the system and especially the pumps must always be monitored, it is not recommended for home gardeners or for use in developing countries.[263] [264]

The Drip or Dynamic Root Floating System

The most widely used system is the drip system or dynamic root floating system, which works with a simple submersed pump and a time controller. Occasionally, the nutrient solution is dropped onto the lower part of the plant, and excess liquid is returned to a reservoir. This technique is common in tropical and semi-tropical regions and is suited for developing countries because the pump is only occasionally engaged, and its use and installation do not require advanced knowledge.[265] [266]

The Wick System

The best-known and simplest system is the wick system, which completely dispenses with movable parts and absorbs the nutrient solution from a reservoir by means of a wick. The plants themselves grow on a medium that can consist

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[263] Epic Gardening: The Nutrient Film Technique Explained. http://www.epicgardening.com/nutrient-film-technique/. Retrieved on 11.9.2017

[264] Simply Hydroponics: Basic Hydroponic Systems and How They Work. http://www.simplyhydro.com/system.htm. Retrieved on 11.9.2017

[265] Faculty of Agriculture Department of Agronomy Kasetsart University: Dynamic Root Floating Technique. https://de.scribd.com/document/208543829/Dynamic-Root-Floating-Technique-DRFT. Retrieved on 11.9.2017

[266] Kao, Te-Chen et al. (2019): The Dynamic Root Floating Hydroponic Technique: Year-Round Production of Vegetables in ROC on Taiwan. http://www.fftc.agnet.org/library.php?func=view&id=20110801154442. Retrieved on 12.11.2018

of perlite, coconut fiber, vermiculite, and similar materials. However, the wick system is not efficient for larger plants that need more water and nutrients than most wicks can supply quickly enough.[267] Nonetheless, the yields that can be achieved by this simplified hydroponic growing method and the low operational and maintenance cost still outweigh the regular farming yields. It is useful for urban areas in every country and can be installed with inexpensive, easily available materials such as used tanks, ceramic pots, or aluminum containers.[268]

The Aeroponic System

Another, rather sophisticated hydroponic technology called aeroponics does not require any growing medium, only a pump with a short cycle timer that runs for a few seconds every couple of minutes. As with the nutrient film technology, the roots hang in the air, but here, they are not dipped into the nutrient solution; rather, a very fine mist moistens them.

This aeroponics system requires advanced technology and permanent supervision because the mister heads can easily be clogged, and any power outage or malfunction can lead to the plants drying out. Due to this relatively high vulnerability and the considerable investment costs, the aeroponics system is not ideal for developing countries but has proven highly efficient for professional farmers and vertical farming in a fully controlled, indoor environment.[269] [270]

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[267] Home Hydro Systems: Wick System. http://www.homehydrosystems.com/hydroponic-systems/wick-system_systems.html. Retrieved on 12.9.2017

[268] Powerhouse Hydroponics: Hydroponic Wick Systems For Beginners. http://www.powerhousehydroponics.com/hydroponic-wick-systems-for-beginners/. Retrieved on 12.9.2017

[269] AeroFarms: Our Technology. http://aerofarms.com/technology/. Retrieved on 11.9.2017

[270] Al-Khodmany, K. (2018): The Vertical Farm: A Review of Developments and Implications for the Vertical City. Buildings 2018, 8 (2), p. 24. https://doi.org/10.3390/buildings8020024. Retrieved on 25.2.2019

8.1.1.2 Aquaponics

Aquaponics is a biological system in which fish farming is symbiotically combined with the hydroponic cultivation of flowers, vegetables, or herbs. The symbiosis is achieved by using the precipitated ammonium from the nutrient-rich fish waste as fertilizer for plants.[271] Aquaponics was forgotten or neglected for a long time, but it is not new. Reportedly, 1,000 years ago, ancient civilizations such as the Aztecs successfully used it in their high-raised beds, the so-called "chinampas," and enjoyed the benefits of a reliable, fresh food supply.[272] [273] Further, in China, simultaneous fish breeding and plant cultivation in one system had been implemented for thousands of years in swampland areas.[274]

Image 3 – Aquaponics, https://youmatter.world

Fish is one of the most sustainable suppliers of animal protein because it is a high-quality feed conversion agent. To produce one kilogram of fish, only 1.2 to

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[271] Al-Khodmany, K. (2018)

[272] Tilapia.at: Tilapia in Aquaponik-Systemen. http://www.tilapia.at/aquaponik-hydroponik/. Retrieved on 11.9.2017

[273] UFarmer: Antike Vorläufer von Aquaponics – die Azteken als Überlebenskünstler. http://ufarmer.at/antike-vorlaeufer-von-aquaponics/. Retrieved on 11.9.2017

[274] Massachusetts Institute of Technology: Aquaponics. http://12.000.scripts.mit.edu/mission2914 /solutions/aquaponics. Retrieved on 12.9.2017

1.4 kilograms of feed is needed in aquaponic farming systems. Compared to the production of beef, which needs eight times more feed and produces high CO_2 emissions, the ecological, and only the ecological, production of fish can be considered a sustainable way of producing high-quality food for people.[275]

In practice, aquaponics is performed in a closed cycle, in which the fish droppings are sifted from the water. The ammonia is first converted into nitrite and then into nitrate, which is ideal for the plant nutrient solutions used in hydroculture. As the plants constantly clean the water, only the water necessary for the growth of the plants needs to be replenished. Thus, this method allows fish farming with a 90% reduced amount of freshwater and without the use of pesticides and antibiotics because the fish environment is constantly controlled and kept clean.

The advantages of aquaponics are impressive. It represents a pragmatic, robust, and sustainable solution to grow food in cities at the point of consumption, it offers a decisive contribution to food security and is resistant to unfavorable climatic conditions and events. Moreover, the aquaponics business concept is simple and easy to implement on urban rooftops, parking lots, private or community gardens, and in the urban periphery. Farmers do not need a costly distribution system, expensive logistics, or refrigeration, and the whole system is modular and expandable.

“We are only beginning to understand the vast potential of aquaponics rooftop farming in the city. I am convinced that it will prove a working, robust, and scalable solution to feed growing urban centers in the 21st century. It won’t replace our conventional food system but could achieve a sizeable urban market share. With

[275] ibid.

populations already large and still exploding, growing food in the city for the city makes sense not only environmentally but also commercially." [276]

Low-tech aquaponics is also well suited for urban contexts in developing countries and in industrialized countries because it only requires small amounts of water and no fertile land, and it provides an important source of fresh vegetables and animal protein. It can be operated with both freshwater and saltwater cultures and has a steady output that by far exceeds the yields of normal fish and plant breeding.[277] With one-kilogram fish, seven kilograms of vegetables can be produced, and only the water the plants absorb must be complemented. Aquaponics can easily be combined with alternative energies, such as photovoltaic or wind energy, and it allows a highly sustainable method of urban farming because of its environment-friendly recycling management.[278] [279]

Compared to traditional recirculating aquaculture, in which only fish is bred, aquaponics has many advantages. In traditional aquaculture, the water has to be discharged at a rate of 10%-20% daily because of the high concentration of ammonia in the tanks. The fish are prone to infections and often need to be treated with different medications and antibiotics. In aquaponics, which resembles a natural ecosystem, fish stay healthy in perfectly cleaned water, and there is no need to discharge the water, which saves water costs and keeps the environment unharmed. All hydroponic techniques can be combined in aquaponics, whereby the use of an inert planting media such as clay pellets,

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[276] Gaus, R. (2013): The Farming Technique That Could Revolutionize the Way We Eat. https://www.citylab.com/design/2013/03/farming-technique-will-revolutionize-way-we-eat/4880/. Retrieved on 11.9.2017

[277] Somerville, C., et al. (2014): Small-scale aquaponic food production. Integrated fish and plant farming. FAO Fisheries and Agriculture Technical Paper 589. http://www.aquacultuurvlaanderen.be/sites/aquacultuurvlaanderen.be/files/public/aquaponics_fao.pdf. Retrieved on 24.2.2019

[278] Mission 2014: Feeding the World. http://12.000.scripts.mit.edu/mission2014/solutions/aquaponics. Retrieved on 24.2.2019

[279] Konschel, K. (2014) (project founder of Aquaponics Africa). https://www.theguardian.com/global-development-professionals-network/2014/oct/02/aquaponics-a-sustainable-solution-to-food-security. Retrieved on 12.9.2017

shale, or coconut fiber is ideal for home and hobby scale systems where hobby gardeners want to grow a large variety of crops. In this case, the media works as a biological and mechanical filter by removing the solid waste and converting the ammonia to nitrate in the same system.[280]

Both hydroponics and aquaponics can produce 10 times more and 30% faster than traditional agriculture, and both systems are highly flexible regarding their location. Fish and plants can be produced everywhere, including on roofs, impermeable ground, brownfields, and in illuminated basements, thus allowing an adaptive use of the scarce resource land. With the vertical integration of the hydroponic and aquaponic production, the production can be maximized by a factor of nine compared to the horizontal application.[281] Operating costs such as rent and heating can be minimized and, at the same time, income is increased. Further, food is produced locally with aquaponics, and more employment opportunities are created, for example in engineering design, computer programming, crop management, and training programs that are required to apply this technology.

With aquaponics, the demand for fresh fish and sustainably grown vegetables can be satisfied to a high extent, and city dwellers have complete control over these food resources, which can serve as vital basis for a city's resilience and food security. "An increase in the availability of food in developing nations through the use of aquaponics would decrease the death rate, while also increasing the income of the farmer and improving the overall economy of the nation."[282]

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[280] The Aquaponic Source: What is aquaponics? https://www.theaquaponicsource.com/what-is-aquaponics/. Retrieved on 12.9.2017

[281] Triple Pundit: How Aquaponics Makes Commercial Urban Agriculture Possible. http://www.triplepundit.com/2013/12/future-sustainable-commercial-urban-agriculture-aquaponics/. Retrieved on 12.9.2017

[282] Abuta, T. (founder of Amsha Africa Foundation), ibid. Retrieved on 12.9.2017

8.1.1.3 The Fraunhofer InFarming Approach

The development of CO2-neutral, energy-efficient, and climate-friendly cities is the goal of a multidisciplinary research cooperation of 10 Fraunhofer Institutes with the Federal Ministry of Education and Research, entitled “City of Tomorrow” (Morgenstadt).[283] Based on the assumption that the need for urban space will double by 2050, as experts have assumed, concerted efforts are needed to further develop renewable energy generation and storage possibilities, electric mobility, and land use to optimize and integrate individual technologies within a holistic system approach. The Morgenstadt-initiative is such a strategic action model which synergistically combines previously unconnected systems and key technologies for the development of smart cities.[284] “Metropoles can become a pioneer of sustainable change. Because in the restructuring of existing cities and the better planning of new cities there is a huge potential to counter climate change and to improve the quality of life of urbanites.”[285]

With the intention to create more space for the production of food near the consumers, the Fraunhofer-Institute UMSICHT offers new solutions for the usage of roofs as places whose potential for agriculture has not yet been perceived. Therefore, researchers at the UMSICHT institute want to demonstrate that special greenhouses with hydroponic and aeroponic cultivation technologies represent a resource-saving, space-efficient solution for metropolitan areas. In their view, cities have unknown agricultural land reserves, as most flat roofs can be converted into vegetable gardens where a considerable part of a city’s demand for salads, tomatoes, cucumbers, and beans could be produced.[286] [287]

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283 Fraunhofer Institut: Innovationsnetzwerk Morgenstadt. http://www.fraunhofer.de/de/fraunhofer-forschungsthemen/innovationsnetzwerk-morgenstadt.html. Retrieved on 01.10.2017

284 ibid.

285 Bullinger, H.-J. (2012): President of the Fraunhofer Society. www.fraunhofer.de/de/presse/presseinformationen/2012/april/morgenstadt.html. Retrieved on 1.10.2017

286 Fraunhofer IAO. https://www.iao.fraunhofer.de/lang-de/presse-und-medien/aktuelles/2064-nahrungsmittel-fuer-die-stadt-aus-der-stadt.html. Retrieved on 24.7.2018

287 Pons, O. et al. (2015): Roofs of the Future: Rooftop Greenhouses to Improve Buildings Metabolism. https://www.sciencedirect.com/journal/procedia-engineering/vol/123/suppl/C. Retrieved on 22.3.2017

In order to integrate the components of the InFarming concept into the existing building structure, lightweight constructions with new materials and new plastics must be tested as supporting elements for use in new greenhouses.[288] One vision of the Fraunhofer future city-farm are office buildings with greenhouses on flat roofs for the cultivation of vegetables. In a closed circuit, all water is recycled, as is all waste, whereby the excess building heat can be used as an energy source. Using a special membrane method, the researchers can use grey and black water for irrigation. Essential nutrients for plant growth are retained in this membrane-filtering process, and thus little fertilization is necessary.[289] Additionally, the wasted heat generated by the building ventilation, computer rooms, or from the greenhouse is converted into thermal energy by using thermal storage.[290]

A first prototype for the inFarming concept is the Fraunhofer-inHouse Center in Duisburg, which has been developed with its American partner BrightFarms LLC.[291] Here, the focus is integrated energy generation through waste heat utilization, photovoltaics, and recycled water. "In addition, we develop materials for insulation and fire protection or particularly light material components. Bioplastics are increasingly being integrated on the basis of renewable raw materials." [292]

Another Morgenstadt-project directly related to the InFarming concept is the Decentral Urban Water Infrastructure Systems (DEUS), which is currently applied to roof-water farms.[293] Such farms can also integrate aquaponics, as shown by a

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[288] Agrobusiness Niederrhein e.V. http://www.agrobusiness-niederrhein.de/cms/front_content.php?idart=223. Retrieved on 1.10.2017

[289] Fraunhofer IKTS. https://www.ikts.fraunhofer.de/en/departments/environmental_process_engineering/biomass_technologies/me mbran_process_techmodeling.html. Retrieved on 4.11.2018

[290] Fraunhofer Gesellschaft. https://www.fraunhofer.de/en/press/research-news/2012/february/fresh-city-tomatoes-any-time.html. Retrieved on 23.10.2018

[291] Fraunhofer. https://www.inhaus.fraunhofer.de/en.html. Retrieved on 4.11.2018

[292] Keuter, V. (2012): https://www.euractiv.de/section/stadt-der-zukunft/opinion/urban-farming-in-der-stadt-von- morgen/. Retrieved on 30.9.2017

[293] Fraunhofer IGB. https://www.igb.fraunhofer.de/content/dam/igb/de/documents/Brosch%C3%BCren/DEUS21_Regeneratives_Wassermanagement.pdf. Retrieved on 24.2.2019

test site in Berlin-Kreuzberg funded by the German Federal Ministry of Education and Research (BMBF) through the Intelligent and Multifunctional Infrastructural Systems for a Future Urban Water Management (INIS) support initiative.[294] [295] There are several different types of water farms, but all use a high-performance membrane system that biologically purifies sewage, and its organic components are then converted into biogas in anaerobic bioreactors. Previous research results have shown that the technology used is structurally feasible, and the liquid fertilizer obtained from the black water is hygienically safe to cultivate vegetables.

8.1.2 Evaluation of Sustainability and Resilience

8.1.2.1 Hydroponics

Environmental Advantages

The application of hydroponics and aeroponics offers many benefits to the environment:

- Hydroponic plants are suitable for use in cities, in suburbs, on urban brownfields, in empty buildings, and in vertical farms. They consume only about one-fifth to one-eighth of the area compared to traditional agriculture.

- Hydroponic farms do not demand any soil and are thus suitable for difficult climatic conditions and even desert regions.

- No deforestation is necessary, nor is the destruction of existing green spaces. Hydroponic plants do not cause any soil erosion or agricultural run-off.

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[294] Federal Ministry of Education and Research (BMBF): Smart and Multifunctional Infrastructural Systems for Sustainable Water Supply, Sanitation and Stormwater Management (INIS). https://nawam-inis.de/en. Retrieved on 1.10.2017

[295] Federal Ministry of Education and Research: Smart and Multifunctional Infrastructural Systems. https://www.fona.de/en/smart-infrastructures-inis-9817.html. Retrieved on 1.10.2017

- There is much lower water consumption than in traditional agriculture, with closed systems using even 90% less.[296]

- Variable recycling methods can be used: wastewater (gray water) of households can be cleaned with simple gravel filters and used for plants.[297] [298]

- The non-recycled, nutrient-rich hydroponic waste solution for growing plants in greenhouses can be reused for certain plant species.[299]

- The environment is protected by the use of fewer food miles, less fossil fuel consumption, and lower CO2 emissions due to shorter transports.

- Pesticides and fungicides can affect humans and animals, and they are not necessary in closed systems. [300]

Economic Advantages

- There are low-tech and high-tech versions of hydroponics. In both cases, the hydroponic method requires much less work than traditional field agriculture. Nutrient content and pH levels are easily controlled, as are all other parameters such as lighting, humidity, and temperature, which are optimally adjusted for growth.[301]

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[296] Monaco, E. (2018): Is Hydroponics the Most Sustainable Type of Farming? https://draxe.com/hydroponics-sustainable/. Retrieved on 11.4.2019

[297] Instructables. https://www.instructables.com/id/Greywater-Recycling-Nutrient-Film-Hydroponic-Syste/. Retrieved on 11.4.2019

[298] Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V. (ed.) (2015): Es wächst etwas auf dem Dach. http://www.zalf.de/htmlsites/zfarm/Documents/leitfaden/dachgewaechshaeuser_leitfaden.pdf. Retrieved on 11.4.2019

[299] Kumar, R., Cho, J. (2014): Reuse of hydroponic waste solution. Environmental Science and Pollution Research, 21(16). doi: 10.1007/s11356-014-3024-3. Retrieved on 11.4.2019

[300] Orsini, F. et al. (2014): Exploring the production capacity of rooftop gardens (RTGs) in urban agriculture: The potential impact on food and nutrition security, biodiversity and other ecosystem services in the city of Bologna. Food Security, 6(6), pp. 781-792, December 2014. doi: 10.1007/s12571-014-0389-6. Retrieved on 8.4.2019

[301] Al-Kodmany, K. (2014): Green Retrofitting Skyscrapers: A Review. Buildings, 4(4), pp. 683–710

- An example of the scalability and variable applications of hydroponics are herbal farms networked with supermarkets, such as those of a Berlin start-up and the mini-farms of the supermarket chains Migros and Metro in Switzerland, Paris, and London.[302]

Possible Economic Disadvantages

- A disadvantage of hydroponics is the higher energy demand compared to conventional agriculture, where light and rainwater are free. However, when all other costs, such as agricultural work, machines, transport, fuel, packaging, and distribution are included in the total cost calculation and considered in relation to the generated income, the balance sheet for hydroponic agriculture appears promising.

8.1.2.2 Aquaponics

Experts consider aquaponics a model for sustainable food production based on the principles of emission reduction and recycling. In addition, it represents a particularly effective use of the synergy of two biological systems, thus producing environmentally friendly and sustainable plant and animal products in a connected system.[303] [304] [305]

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[302] Reintjes D. (2019): Edeka und Metro gehen unter die Gärtner. https://www.wiwo.de/unternehmen/handel/gemeinsam-mit-berliner-start-up-edeka-und-metro-gehen-unter-die-gaertner/23791512.html. Retrieved on 8.4.2019
[303] ID3AS. https://www.id3as.org/projekt.php?id=9. Retrieved on 10.4.2019
[304] König, B. et al. (2016): On the sustainability of aquaponics. doi: 10.19040/ecocycles.v2i1.50. Retrieved on 10.4.2019
[305] Morgenstern, R. et al. (2016): Pilotstudie "Nachhaltige Aquaponik Erzeugung für Nordrhein-Westfalen". https://www4.fh-swf.de/media/downloads/igreen/projektberichte/20170330-Projektbericht-43-USL-DinA5-final-mit-ISBN.pdf. Retrieved on 10.4.2019

Environmental Advantages

- Unlike conventional fish farming, the water is continuously cleaned, so there is no need for chemicals and additional fertilizer. The fish themselves produce an organic fertilizer for the plants.

- No antibiotics need to be used, the wild populations are spared, and within the cycle, no important nutrients are lost. [306]

- Due to the closed water cycle, the daily fresh water requirement is less than 3%, so that, for example, only 35 liters of water are consumed for one kilogram of tomatoes instead of 180 liters.

- Aquaponics consumes 90% less water compared to traditional aquaculture, and the area needed for tomatoes is only one-fifth of what is needed for free-range tomatoes.

- The aquaponics system is virtually emission-free, as the plants convert the CO2 emitted by the fish into oxygen.

- Aquaponics facilities are almost independent of location. They are usually built-in greenhouses and are also suitable for dry areas and regions where no conventional agriculture is possible due to the lack of arable land.

- The aquaponics system produces healthy food locally while creating new jobs. By eliminating long transports and fossil fuel, CO2 emissions are reduced.

[306] Becker, P., Beichele, U. (2012): Mensch, Fisch! Landesmuseum Natur und Mensch Oldenburg. pp. 95-98. In: Kloas, W.: Fisch als Nahrungsmittel der Zukunft, 90, Oldenburg 2012

- Thus, aquaponics strengthens food security and reduces the volume of imports.[307]

Economic Advantages

- Aquaponics has lower acquisition and operating costs because, in contrast to conventional aquacultures, all the nutrients involved are fully utilized in all their conversion stages, and no additional, complex filtering measures are necessary, as is the case with aquaculture.
- Due to the vertical structure, high productivity is achieved per land unit, and at the same time, land consumption is greatly reduced.

- Modern, high-tech applications are most efficient and sustainable when installed indoors, as they allow optimal environmental control. Indoor aquaponics is independent of climate, solar radiation, and weather events, and there is no evaporation or pollution from birds, insects, fungal spores, and the like.

- At the same time, the plants clean the air inside the building.[308]

- Indoor systems are scalable and suitable as microsystems for private households.

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[307] Seager, C. (2014): Aquaponics: a sustainable solution to food security? https://www.theguardian.com/global-development-professionals-network/2014/oct/02/aquaponics-a-sustainable-solution-to-food-security. Retrieved on 8.3.2019

[308] Aquaponics Design Company. https://aquaponicsdesign.co/aquaponics/top-10-modern-applications-of-indoor-aquaponics-farming/. Retrieved on 8.3.2019

Education and Food Security

- An example of aquaponics in school is the Knowledge-, Optimization-, Yield- and Activation (KOYA) - approach by Michael Hensel. Aquaponics is a particularly effective method of combating hunger and protein deficiency.[309]

- The children in a primary school in Phnom Penh are taught aquaponics so they can apply their knowledge at home in the villages.

- The goal of the KOYA - project is “to empower schools and communities suffering from food insecurity, water scarcity, poor soil, and extreme levels of poverty, with the self-sustaining food production education of aquaponics technology.” [310]

- Aquaponics is a hands-on learning tool for many schools to design, build, and operate aquaponics systems to acquire knowledge about eco-friendly food production.

8.1.2.3 Fraunhofer InFarming

The intention of the Fraunhofer InFarming concept is to integrate agriculture in cities and metropolises by using facades, roofs, and entire buildings as agricultural land. For this purpose, Fraunhofer UMSICHT develops special materials for lighting systems and circular processes for nutrients, water recycling, and alternative energy use.

[309] Sadidov, N. (2004): Evaluation and development of aquaponics production and product market capabilities in Alberta. http://www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/projects/reports-rapports/ca/CA-04-01-001.pdf. Retrieved on 13.3.2019

[310] Koyaproject. https://koyaproject.org/. Retrieved on 13.3.2019

Environmental Advantages

- With its resource-saving and space-efficient implementations, the InFarming concept represents an economically and ecologically advantageous approach that, through the use of material cycles, can reduce the consumption of resources and CO2 emissions in food production and in existing or new buildings.[311]

- Since the global reserves of phosphorus, which is indispensable for the production of artificial fertilizer, are limited, the Fraunhofer InFarming concept aims at nutrient recovery from secondary raw material sources. Wastewater and energy resources are recycled from the building and reused for plant cultivation.

- Rooftop farming on urban rooftops plays a central role in the innovative InFarming approach, which can help compensate for heavy rain, insulate buildings thermally, prevent noise, and reduce the urban heat island effect.

- The energy consumption of a skyscraper with roof-top farming is said to be reduced by up to 23%, and 20% in the case of air conditioning.[312]

Economic Advantages

- There can be significant savings for vertical farms on roofs by using the water surplus heat, cooling water, and carbon dioxide from the buildings below.[313] [314] The airflow of the building increases the ventilation of the greenhouse in

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311 Fraunhofer UMSICHT: Nachhaltige Konzepte für die Urbane Pflanzenproduktion. Gebäudeintegrierte Systemlösungen. https://www.umsicht.fraunhofer.de/content/dam/umsicht/de/dokumente/kompetenz/prozesse/infarming.pdf. Retrieved on 8.3.2019
312 Specht, K. et al. (2014)
313 Cicekli, M., Barlas, N. (2014)
314 Besthorn, F. (2013): Vertical Farming: Social Work and Sustainable Urban Agriculture in an Age of Global Food Crises. Australian Social Work, 66(2), pp. 187–203.

warm periods, and the CO2 contained in it is fed to the plants. Rainwater can be collected on the roof and used for irrigation, and the wastewater of the building can be cleaned and reused by the greenhouse.

- The population in the neighborhood is supplied with fresh vegetables, such as leafy greens, carrots, radishes, peppers, beans, beets, tomatoes, and herbs, which also make an important contribution to the resilience of the urban food system.

- Rooftop farms can be designed as horizontal greenhouses or vertical farms depending on the nature of the roofs, and, depending on equipment and automation, they can have economic returns comparable to other open or closed hydroponics facilities.

- With the integration of urban agriculture in buildings with advanced recycling technologies, the InFarming approach is an efficient, long-term strategy to supply the population with fresh food while improving the indoor comfort of buildings and the urban area without polluting the environment.

8.1.3 SWOT Analysis: The Vertical Farming Concept

8.1.3.1 Definition of a Vertical Farm

The concept of a vertical farm is not completely new, although modern approaches and futuristic constructions incorporate technological achievements of the 21st century. The term “vertical farming” first appeared in Gilbert Bailey’s book “Vertical Farming” in 1915, in which he described the economic and environmental benefits of vertical agriculture.[315] In the 1980s, a Swedish farmer

http://doi.org/10.1080/0312407X.2012.716448. Retrieved on 8.3.2019

[315] Bailey, G. (1915): Vertical Farming. Wilmington, USA 1915

named Ake Olsson invented a spiral rail system for growing food crops in vertical farms.[316] The rights to his vertical farming concept were sourced from a Swedish food-tech company that today builds vertical farms all over Europe, Asia, and North America “to meet the rising demand for locally grown food in cities all around the world. We minimize the use of transportation, land, energy and water – using waste products in the process but leaving no waste behind.”[317]

In principle, vertical farming is a simple concept that implies a vertical planting method instead of a horizontal one. Three different types have so far been distinguished. The first category of medium-sized, urban vertical farms already exists in numerous cities. They are built in old or new buildings or department stores and include several levels of growing beds on tower-like racks. These rotate so that all plants receive even natural light and also special artificial light. The second type is built with the same technology on the roofs of old or new buildings in residential areas, as well as supermarkets or restaurants. The third type consists of highly different, multiform, multi-story skyscrapers designed by visual architects for locations in the middle of the city, on artificial islands, or even on ships.[318] So far, however, none of these visionary types have been built.

Another highly sustainable version of a vertical farm was recently introduced by Square Roots, the company of Kimbal Musk.[319] This involves the use of discarded shipping containers that can be planted on multiple levels. These mobile vertical

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316 http://www.digitaljournal.com/tech-and-science/technology/plantagon-feeding-the-world-with-vertical-farming-technology/article/508590. Retrieved on 2.4.2018
317 http://www.plantagon.com/about/business-concept/business-concept/. Retrieved on 1.3.2019
318 Vyas, K. (2018): 13 Vertical Farming Innovations That Could Revolutionize Agriculture. https://interestingengineering.com/13-vertical-farming-innovations-that-could-revolutionize-agriculture. Retrieved on 12.3.2019
319 Square Roots. https://squarerootsgrow.com/. Retrieved on 12.3.2019

farms are particularly suitable for developing countries and are run by the owners themselves, while Square Roots provides advice and support. [320] [321]

Historically, the vertical farming concept, which was pioneered by the American ecologist and professor of public health Dickson Despommier, took on a new, central importance with the emergence of the modern urban farming movement starting with the first guerrilla gardeners in the U.S. Based on technologically advanced hydroponic and aeroponic agricultural technologies and computerized lighting, feeding, and irrigation systems, a vertical farm can, in principle, grow many vegetables and fruits and even breed fish and poultry.[322] As an extension and development of hydroponic greenhouses designed to solve the problem of land scarcity and soil degradation, the production of vegetable and partly also animal foodstuffs takes place in direct proximity to the consumers, thus saving on transport costs and transport times.

By shifting the production from the ground into the height and the associated use of several superimposed levels in a multi-story skyscraper, more food can be grown than on comparable floor space on the ground. In addition, crops can be cultivated throughout the year, as they can grow under optimal temperature, light, and humidity conditions.[323] This kind of agriculture can recycle gray water and requires much less water than traditional farming because less evaporation takes place in indoor cultivation. The closed-loop system recycles and reuses not only dirty water but also sewage, nutrients, and food waste, thus leading to a zero-waste outcome.

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[320] Besthorn, F. H. (2013): Vertical Farming: Social Work and Sustainable Urban Agriculture in an Age of Global Food Crises. Australia Social Work, 66(2), pp. 187–203

[321] Kozai, T., Niu, G. (2016): Conclusions: Resource-Saving and Resource-Consumption Characteristics of PFALs. In: Kozai, T., Niu, G., & Takagaki, M. (eds.): Plant Factory: An Indoor Vertical Farming System for Efficient Quality Food Production, pp. 395–399. London 2016

[322] Despommier, D. (2010): The Vertical Farm: Feeding the World in the 21st Century. New York 2010

[323] Benke, K., Tomkins, B. (2017): Future food-production systems: vertical farming and controlled-environment agriculture, Sustainability: Science, Practice and Policy, 13(1), pp. 13-26. doi: 10.1080/15487733.2017.1394054. Retrieved on 16.3.2018

Image 4 – Ashraf Omran's farm in Dubai – Vertical farm, author's study trip to Dubai in 2015

Independent of skilled labor, seasons, and soil fertility, and protected from severe weather events, pest infestation, and fungal diseases, a vertical farm can produce nutritious, high-quality fresh food year-round. Since the core principle behind the vertical farm concept is the optimal use of resources such as water, land energy, capital, and labor, it can be deployed anywhere in the world to achieve maximal yields with minimal environmental impacts.[324]

8.1.3.2 Strengths

Environmental Strengths

- Re-use of nutrient solution
- High space efficiency
- No greenhouse gas emission
- No food wastes
- Waste and water recycling
- Minimal water demand

[324] Padilla, M. et al. (2018): Urban farming in the city of tomorrow. http://publica.fraunhofer.de/documents/N-506944.html. Retrieved on 24.3.2019

- Short transport routes
- Reduced disease transmission
- No pesticides, fungicides, or pests
- No soil erosion
- No agricultural run-off
- No deforestation
- Organic production without pesticides is easier than on open fields
- No air pollution by mechanical equipment
- Protection of biodiversity
- Use of renewable energy
- Remediation of anthropogenic eutrophication

Economic Strengths

- Year-round crop production
- Flexible use of natural and artificial light
- Great variety of products
- Protection from extreme weather events
- Regular growing cycles and reliable harvests
- Minimal production overheads such as crop washing, refrigeration, and transport
- Higher productivity compared to single-level greenhouses
- Cost savings for reducing environmental damages
- Stimulus for urban economy

Health and Social Strengths

- Fresh vegetables and fruits without long transport times
- No use of fungicides or pesticides
- Transparency of producer and location
- Safer and hygienically produced food
- Opportunities for social interaction and integration

- New jobs in the city
- Stimulation of new technological developments
- Educational and leisure possibilities

Environmental Advantages

Vertical farming is meant to be an innovative, sustainable, and controlled-environment agricultural technology for the mass production of plants and animal products in metropolitan areas. In its most compact form, it operates in multi-story buildings, so-called farmscrapers.[325] [326] Using the most advanced, resource-saving agricultural technologies, the vertical faming concept aims at avoiding the environmental mistakes of conventional agriculture and fulfills all the requirements of a truly sustainable, resilient food production system.

To date, the global ecosystem has been severely damaged by traditional agriculture. Monocultures in conventional outdoor farming are highly sensitive to diseases and pests and often require high use of agrochemicals. Overcultivation and excessive use of fungicides and pesticides have led to progressive soil degradation and the eutrophication of rivers, lakes, and oceans. In 2008, 405 dead zones were identified, where safe food production is no longer possible.[327] In vertical farms, plant cultivation takes place without these auxiliaries and according to organic-ecological specifications. Should problems with microorganisms or other plant diseases occur, natural, harmless remedies can combat these phenomena.[328]

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[325] Warnes, S. (2013): Farmscrapers take eco-friendly architecture to dizzying heights in China. http://www.independent.co.uk/news/world/asia/farmscrapers-take-eco-friendly-architecture-to-dizzying-heights-in-china-8546568.html. Retrieved on 13.9.2017
[326] Deutsche Bauzeitung: Gemeinschaftsgärten, Fischtanks und Farmscraper. http://www.db-bauzeitung.de/db-themen/energie/gemeinschafts-gaerten-fischtanks-und-farmscraper/. Retrieved on 13.9.2017
[327] Cho, R. (2011)
[328] ibid.

Traditional and, above all, primitive farming techniques have caused a massive loss of topsoil and excluded the cultivation of trees, which are indispensable for long-term CO_2 sequestration. According to the FAO, “25% of the earth’s land are degraded”[329] and in a very poor condition;[330] “farming has upset more ecological processes than anything else – it is the most destructive process on earth.”[331] In most regions of the world, over 70% of freshwater is used for agriculture. As climate change will likely result in warmer temperatures and droughts in the future, the global water crisis will intensify.

By using sustainable technologies such as hydroponics and aquaculture, which, in large urban projects, may also be combined with small animal husbandry and poultry farming, vertical farming can contribute to restoring ecosystem functions and agricultural services.[332] Aeroponics and hydroponics enable the most efficient use of water because up to 95% less water can be used in a closed system, while avoiding harmful agricultural run-off.[333] Vertical farms do not require agricultural equipment for activities such as plowing, sowing, harvesting, and manuring, which, in traditional agriculture, consume up to 20% of all fossil fuels.[334] [335] The local consumption of locally produced foods can drastically reduce the costs for cooling and storage and reduce the travel miles of most foods, thus leading to further fossil resource savings.[336] Due to very short

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[329] FAO. http://www.fao.org/news/story/en/item/95153/icode/. Retrieved on 31.3.2019

[330] Säumel, I. et al. (2012): How healthy is urban horticulture in high traffic areas? Trace metal concentrations in vegetable crops from plantings within inner city neighborhoods in Berlin, Germany. Environ. Pollut. 2012, 165, pp. 124–132

[331] Despommier, D., cited by Cho, R. (2011)

[332] Despommier, D. (2015): The Vertical Essay. http://www.verticalfarm.com/?page_id=36. Retrieved on 3.3.2019

[333] Germer, J. et al. (2011): Skyfarming an ecological innovation to enhance global food security. Journal für Verbraucherschutz und Lebensmittelsicherheit, 6(2), pp. 237–251. http://doi.org/10.1007/s00003-011-0691-6. Retrieved on 28.2.2019

[334] Caplow, T. (2009): Building integrated agriculture: Philosophy and practice. Urban Future 2030, pp. 54–58. https://www.researchgate.net/publication/312442295_Building_integrated_agriculture_philosophy_and_practice_Urban_Futures_2030. Retrieved on 16.3.2019

[335] Despommier, D. (2011): The vertical farm: Controlled environment agriculture carried out in tall buildings would create greater food safety and security for large urban populations. Journal für Verbraucherschutz und Lebensmittelsicherheit, 6(2), pp. 233-236

[336] Cicekli, M., Barlas, N. (2014): Transformation of today greenhouses into high technology vertical farming systems for metropolitan regions. J. Environ. Prot. Ecol. 2014,15, pp. 1779–1785

transport distances, CO2 emissions and harmful particulate matter concentrations are also significantly reduced.[337] [338] On the transport route alone, up to 30% of all food spoil, and in developing countries even up to 50%, which represents a major economic and world-burdening problem.[339] [340] In the summer in particular, expensive refrigerated transportations are required for perishable foodstuffs, and more than 100,000 people are nevertheless diagnosed each year with infections caused by bacteria, viruses, or parasites found in food in Germany.[341]

Vertical farms are characterized by high area efficiency and are particularly suitable for sustainable land use management. On one acre of land, a vertical farm can produce four to six times more than conventional agriculture on 30 outdoor acres. Another advantage of vertical farming is that it is highly adaptable, does not require fertile soil, and can be practiced almost anywhere in the world.[342] To feed the world's growing population of nine to 10 billion, the FAO estimates that, by 2050, 60% more agricultural produce will have to be produced. This would require around 300 million acres of additional farmland, but the conversion of remaining soil in developing countries and additional agricultural water use would destroy the already fragile balance of the entire ecosystem.[343] Due to the clearing of rainforests, nature and the global climate have already suffered irreparable damage. With vertical farms, the ecosystem could slowly recover, and farmland could be restored**.** Once the ecological system recovers, its natural

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[337] Umweltbundeamt. https://www.umweltbundesamt.de/service/uba-fragen/warum-ist-feinstaub-schaedlich-fuer-den-menschen. Retrieved on 25.3.2019
[338] Lungenärzte im Netz. https://www.lungenaerzte-im-netz.de/news-archiv/meldung/article/feinstaub-ist-noch-schaedlicher-als-bisher-angenommen/. Retrieved on 25.3.2019
[339] Welthungerhilfe. https://www.welthungerhilfe.de/fileadmin/pictures/publications/de/fact_sheets/topics/2018-factsheet-lebensmittelverschwendung.pdf. Retrieved on 22.3.2019
[340] Slow Food. http://www.teller-statt-tonne.de/wp-content/uploads/2015/06/TsT_Einf%C3%BChrung_LMV_SEK.pdf. Retrieved on 25.3.2019
[341] Deutsche Gesellschaft für Ernährung e.V. https://www.dge.de/presse/pm/bei-sommerhitze-verderben-lebensmittel-schneller/. Retrieved on 30.3.2019
[342] Despommier, D. (2013)
[343] FAO. http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf. Retrieved on 30.3.2019

mitigation and adaptation abilities will be restored, a process of utmost importance for the future of mankind: “The protection of biodiversity will lead to an increase in genetic varieties of plants and animals and the reduced stress on the land will help natural ecosystems flourish.”[344] [345] [346]

Economic Advantages

Vertical farms can achieve greater yields than traditional farms because they can be harvested year-round regardless of weather, climate, day, and season.[347] [348] In contrast, conventional farming only allows a maximum of three crops per year.[349] Since the plant waste and biological waste can be recycled, it is possible to save much of the phosphate-based mineral fertilizer. Phosphate is a finite resource, and its careful use is a necessity for sustainable food production.[350]
A study by Perez[351] has reported that 23 times more lettuce (470 tons per acre) was harvested on a vertical farm than on the same area with traditional agriculture. This high productivity is largely due to the fact that a vertical farm offers ideal growth conditions for a wide variety of plants that can be harvested regardless of weather conditions.[352] Since planting in a vertical farm is done on several levels that are superimposed, large areas of land can be saved in

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344 Germer, S. et al. (2011)
345 Gorbachevskaya, O., Hendrikje, S., Kappis, C. (2007): Wissenschaftlicher Erkenntnisstand über das Feinstaubfilterungspotential von Pflanzen (qualitativ und quantitativ). Ergebnisse der Literaturstudie. Berliner Geographische Arbeiten 109
346 Bruse, M. (2003): Stadtgrün und Stadtklima – Wie sich Grünflächen auf das Mikroklima in Städten auswirken. LÖBF-Mitteilungen, 1/2003, pp. 66 - 70
347 Stopyra, D. (2016): High times: Vertical farming is on the rise — but can it save the planet? https://www.salon.com/2016/09/25/high-times-vertical-farming-is-on-the-rise-but-can-it-save-the-planet/. Retrieved on 3.9.2017
348 Sivamani, S. et al. (2013): A Smart Service Model Based on Ubiquitous Sensor Networks Using Vertical Farm Ontology. International Journal of Distributed Sensor Networks, 9(12). http://doi.org/10.1155/2013/161495. Retrieved on 7.3.2019
349 Despommier, D. (2013)
350 Dubbeling, M. (2011): Integrating urban agriculture in the urban landscape. Urban Agriculture Magazine, 25, pp. 43–46
351 Perez, V. M. (2014): Study of The Sustainability Issue of Food Production Using Vertical Farm Methods in An Urban Environment Within The State of Indiana. https://docs.lib.purdue.edu/dissertations/AAI1565090/. Retrieved on 5.3.2019
352 ibid.

comparison to conventional agriculture and used for other purposes or naturalized.

Great advances in LED lighting technology, which is specifically geared towards the needs of plants, allow constant optimal lighting conditions that encourage rapid growth in plants.[353] Today, more than 80 varieties of leafy greens, microgreens, and strawberries are cultivated in vertical farms, and other plant species are constantly added. “To feed a population of 100,000, each individual would need 1 m² of space, hence a vertical farm would need to be 100m x 100m x 10 layers with the top floor acting as a simple greenhouse.”[354] [355]

The initial costs of constructing and equipping a vertical farm are undoubtedly high, but existing vertical farms indicate that the investment costs are amortized in a relatively short time.[356] This is possible because the yields are much higher than in ordinary greenhouses, the consumption of water and nutrients in a closed system is minimized, there are no crop losses, and there are few transport, storage, and cooling costs. However, the costs of energy for lighting and possibly air conditioning represent an important factor that varies greatly from country to country and that can be significantly reduced through the use of solar and wind energy. Overall, experts consider the economic business potential of vertical farming quite high, also because it is scalable from small to large food production installations. They have estimated the global vertical farming market in 2015 to

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[353] Stopyra, D. (2016): High times: Vertical farming is on the rise - but can it save the planet? https://www.salon.com/2016/09/25/high-times-vertical-farming-is-on-the-rise-but-can-it-save-the-planet/. Retrieved on 20.03.2018

[354] Perez (2014)

[355] Banerjee, C., Adenaeuer, L. (2014): Up, Up and Away! The Economics of Vertical Farming. Journal of Agricultural Studies, 2(1). http://www.macrothink.org/journal/index.php/jas/article/view/4526. Retrieved on 4.4.2019

[356] Abel, C. (2010): The vertical garden city: towards a new urban topology. CTBUH Journal, 2, pp. 20–30. http://www.et2050.eu/et2050_library/docs/ tech/land_uses/Vertical_garden.pdf. Retrieved on 7.3.2019

be worth $1.15 billion and project it to reach $6.31 billion by 2022 based on its current growth rate of over 27% to 30% a year.[357]

Health and Social Advantages

The construction and operation of urban vertical farms also create many jobs in the city; architects, engineers, scientists, horticulturists, marketers, environmentalists, economists, managers, and computer specialists, among others, are needed for the construction and operation of a vertical farm. In addition, vertical farms can also be connected to shops, restaurants, supermarkets, cafes, and workshops, which create additional work opportunities.[358] Consumers can buy their food directly at the place of production and thus enjoy transparency concerning the origin and producer of their food; they can also discover the proximity to food, natural processes, and a conscious diet.[359] [360] Thus, vertical farming can "provide a recreational purpose to improve the quality of social life and to increase well-being in a society."[361]

According to a study by the WHO, worldwide, over half of all farms still use untreated animal and human excrements, which result in a high rate of infection by the plants themselves or by flies.[362] In vertical farms, all food is grown using the best technical possibilities, thus virtually eliminating health risks from fungal

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357 Garden Culture Magazine: Vertical Farming Market Growth (2016). https://www.gardenculturemagazine.com/techno-gardens/vertical-gardening/vertical-farming-market-growth/. Retrieved on 13.9.2017

358 Besthorn, F. (2013): Vertical Farming: Social Work and Sustainable Urban Agriculture in an Age of Global Food Crises. Aust. Soc. Work, 66, pp.187–203. https://www.researchgate.net/publication/263334886_Vertical_Farming_Social_Work_and_Sustainable_Urban_Agriculture_in_an_Age_of_Global_Food_Crises. Retrieved on 10.3.2019

359 Al-Kodmany, K. (2012): Sustainable Tall Buildings: Toward a Comprehensive Design Approach. Int. J. Sustainable Design, 2(1), pp. 1-23. https://www.researchgate.net/publication/263485796_Sustainable_tall_buildings_toward_a_comprehensive_design_approach. Retrieved on 16.3.2019

360 Germer, J. et al. (2011)

361 Despommier, D., Ellingsen, E. (2008): The Vertical Farm: The sky-scraper as vehicle for a sustainable urban agriculture. https://www.researchgate.net/publication/241325575_The_Vertical_Farm_The_sky-scraper_as_vehicle_for_a_sustainable_urban_agriculture. Retrieved on 26.3.2019

362 Al-Kodmany, K. (2018): The Vertical Farm: A Review of Developments and Implications for the Vertical City. Buildings, 8(2), 24. doi: 10.3390/buildings8020024. https://www.mdpi.com/2075-5309/8/2/24/htm#B1-buildings-08-00024. Retrieved on 22.3.2019

infestation or fertilizers. Closed vertical systems can also dispense with genetically modified plants, since possible pests would be detected early by permanent monitoring. Since the vertical systems are operated under laboratory conditions, pest infections would be almost impossible.[363] [364]

In the future, there will be more citizens in cities and metropolises who have no or only limited access to fresh, healthy food. Experts are convinced that, with a corresponding number of farming skyscrapers, food could be produced for the entire urban population.[365] [366] [367] It is estimated that a 30-story building could produce food for 50,000 people.[368] [369] Even in poor weather, disasters, blocked transport routes, or in times of crisis, food could be produced in the vertical farms, thus making an important contribution to the population’s food security.

Mobile vertical farms could also maintain a basic supply of fresh, healthy food for refugee camps and crisis areas abroad. In developing countries, small-scale “vertical gardens” can help poor families earn a modest income and produce essential nutrition for the whole family. “While vertical farming won’t elevate a poor household to middle class, it will offer some security for their owners and provide them with a resource that can add to their incomes.”[370]

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[363] Despommier, D. (2011)
[364] The Greens/EFA Group in the European Parliament (2016): 6 Gründe, den Gentechnik-Anbau in der EU zu verbieten. https://www.greens-efa.eu/de/artikel/news/id-6-reasons-to-ban-gm-plant-cultivation-in-the-eu/. Retrieved on 4.3.2019
[365] Despommier, D. (2010)
[366] Germer, S. et al. (2011)
[367] Specht, K. et al. (2014)
[368] Despommier, D. (2009)
[369] Wagner, C. (2010): Vertical Farming: An Idea Whose Time Has Come Back. Futurist, 44(2), pp. 68–69
[370] Pires, E. (2014): Agriculture Vertical Farming: Fighting Poverty and Food Insecurity in Kibera, Kenya. http://innovatedevelopment.org/2014/03/30/vertical-farming-fighting-poverty-and-food-insecurity-in-kibera-kenya. Retrieved on 5.4.2019

8.1.3.3 Weaknesses

High Investments Costs

- High initial costs
- High land prices in and around large cities
- High energy requirements because of artificial lighting
- Site-specific complexity
- Heating and/or cooling systems required
- Constant monitoring required
- Limited crop variety
- Not all plants are suitable for cultivation in vertical farms
- Need for skilled architects, engineers, and civil planning
- Information and awareness among the population is highly limited
- Skepticism because of unnatural farming methods
- Products have an exclusive image and are mainly sold to restaurants

Space Scarcity

In major cities such as London, New York, and Hong Kong, extremely high land prices can be an obstacle to establishing a vertical farm and subsequent upscaling. Since there are hardly any fallow areas in such places, the solution could be the use of vacant buildings or suitable flat roofs.[371] For this purpose, in some places, it may be difficult to find skilled architects and biotechnologists who are experienced in the peculiarities of this new, growing technology, and it could be necessary to “import” them from abroad.

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[371] Sivamani, S. et al. (2014): A Rule Based Event-Driven Control Service for Vertical Farm System. In: Park, J. et al. (eds.): In Future Information Technology, 276, pp. 915–920. Berlin 2014. http://doi.org/10.1007/978-3-642-55038-6_138. Retrieved on 8.3.2019

Costs for Lighting Equipment

In vertical farms, daylight is usually insufficient, and special, artificial plant lighting must be used, as well as rotating shelves that ensure photosynthesis for all levels. The resulting equipment and energy costs are not insignificant and can be an obstacle to the spread of vertical farms.[372] [373]

Constant Monitoring

In addition, vertical farms require continuous, real-time monitoring of temperature, humidity, CO_2 concentrations, light intensity, air supply, pH values, irrigation, and fertilization. Depending on the geographic location, running a vertical farm can also cause heating or cooling costs that cannot be fully compensated by the use of wind turbines and solar cells.

Limited food variety

Of course, vertical farming has also its limits, for example when it comes to grains or fruits that grow on trees, which are difficult or even impossible with hydroponic techniques. Thus, "urban farming will not replace but will complement the conventional methods of growing our food which will need to become more sustainable."[374]

Exclusivity of Products

Another disadvantage of the vertical farming products is that, in the initial phase, they do not reach underserved sections of the population due to high production

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[372] Banerjee, C., Adenauer, L. (2014): Up, Up and Away! The Economics of Vertical Farming. Journal of Agricultural Studies, 2(1), p. 40. http://doi.org/10.5296/jas.v2i1.4526. Retrieved on 5.3.2019

[373] Specht, K. et al. (2014): Urban agriculture of the future: an overview of sustainability aspects of food production in and on buildings. Agriculture and Human Values, 31(1), pp. 33–51. http://doi.org/10.1007/s10460-013-9448-4. Retrieved on 5.3.2019

[374] Tidona, M., Managing Director of aponix.eu in Heidelberg, inventor of the vertical barrel concept. http://www.aponix.eu/. Retrieved on 23.3.2018

costs; therefore, purchase agreements with restaurants and hotels are necessary. Currently, as Despommier correctly notes, vertical farming "is a technology whose time has come for the rich," [375] and is especially suitable for countries that want to reduce their dependence on food imports.

Little Awareness and Information among People

Most people have little or no understanding of vertical farms and modern agricultural technologies, and many consider plant production in a high-rise building unnatural.[376] [377] Visitors to a vertical farm can easily have the impression that it is a laboratory or a high-tech factory. Since plants are cultivated without a natural environment or farmland and under the control of sensors, the food can be associated with "artificial products". This would achieve the opposite of what vertical farms aim to achieve, namely, the shift to organic and unencumbered, environmentally friendly crop cultivation. Currently, there is a lack of broad awareness campaigns and information events aimed at consumers, entrepreneurs, farmers, families, and the entire food industry to convey a positive image of vertical farms.

8.1.3.4 Opportunities

- Remediation of anthropogenic eutrophication
- Food market will grow to 9.2 billion consumers by 2050
- 70% of the world population will live in cities
- No seasonal restrictions

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[375] Despommier, D. (2016). https://www.theguardian.com/environment/2016/aug/14/world-largest-vertical-farm-newark-green-revolution. Retrieved on 13.9.2017

[376] Abel, C. (2010): The vertical garden city: Towards a new urban topology. http://global.ctbuh.org/resources/papers/download/390-the-vertical-garden-city-towards-a-new-urban-topology.pdf. Retrieved on 23.3.2019

[377] Specht, K. et al. (2014): Urban agriculture of the future: An overview of sustainability aspects of food production in and on buildings. Agriculture and Human Values, 31(1). doi: 10.1007/s10460-013-9448-4 Retrieved 23.3.2018.

- Adaptability to climate change
- Vertical farming will become a necessity
- Use of renewable energies
- Employment possibilities for urban people
- A larger variety of food on vertical farms
- Advanced, closed-loop system for more sustainability
- Development platform for new crops
- Vertical farming as educational instrument
- Sustainable image
- Additional income through leisure facilities and new partners.

Food Security

Today, more than 800 million hectares of soil-based agriculture are farmed, which equals about 38% of the total land mass; thus, according to Despommier, only the construction of urban food production centers can reliably feed the growing human population in the future and promote the sustainability and resilience of regions and cities.[378] A wide variety of produce can be harvested in high-rise vertical farming buildings in sufficient quantity to supply even large cities with enough food and make them independent from large imports. Large animals such as cattle, horses, sheep, and goats need to be raised in the urban periphery, but small animals could be integrated into a vertical farming complex.[379]

A Larger Variety of Food

Vertical farming is not limited to microgreens, strawberries, and lettuces. According to scientists of the University of Hohenheim in Stuttgart, rice is also a suitable commodity that can successfully be grown 365 days a year in a “sky

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[378] Despommier, D. (2011): The vertical Farm. Feeding the world in the 21. Century. The vertical Essay. http://www.verticalfarm.com/?page_id=36. Retrieved on 12.9.2017
[379] Despommier, D. (2011): The Vertical Farm. New York 2011

farm."[380] [381] There, it would be protected against drought, frost, rain, diseases, insects, and the emission of greenhouse gases associated with conventional rice agriculture could be completely avoided in a closed-circuit system. Contrary to the traditional, soil-based method, which uses 500 to 1,000 liters of water to produce one kilogram of rice, only 10 liters absorbed by the rice are needed in a sky farm.

As the most important food crop worldwide, rice currently provides approximately one-fifth of the global food requirement, but it is uncertain whether rice production can increase by 17% until 2035. This would be necessary to feed the growing population, especially in Asia, where the rice consumption is high, but the arable land for increased production is not available.[382] Thus, in the near future, there will be no alternative but growing rice in vertical greenhouses, which also will have positive side effects for the environment and the damaged ecosystem: "If vertical farming in urban centers becomes the norm, then one anticipated long-term benefit would be the gradual repair of many of the world's damaged ecosystems through the systematic abandonment of farmland. In temperate and tropical zones, the re-growth of hardwood forests could play a significant role in carbon sequestration and may help reverse current trends in global climate change."[383]

Closed-loop System and Advanced Recycling Techniques

Large-scale vertical farms like the ones of the company AeroFarms[384] will profit from their innovative aeroponics technology, which has only minimal water

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380 Asch, F. (2016): http://campus.region-stuttgart.de/chapters/view/5/article:45. Retrieved on 25.9.2017
381 Böhm, W. (2012): Uni entwickelt Reis-Hochhaus gegen Welthunger. https://www.welt.de/wissenschaft/article106361205/Uni-entwickelt-Reis-Hochhaus-gegen Welthunger.html. Retrieved on 8.8.2018
382 Alone in Tokyo, about 5.500 tons of rice are consumed each day by its inhabitants, which need 450.000-hectare acreage. In: ibid.
383 ibid.
384 http://aerofarms.com/. Retrieved on 13.9.2017

demand. Although the investment for a 70,000 square foot farm is said to be $30 million USD, investors are confident about achieving amortization within an acceptable time frame.[385] The technology that AeroFarms applies its aeroponics in a closed-loop system, which moistens the roots with nutrients, water, and oxygen, thus using 95% less water compared to field farming and 40% less than normal hydroponics.[386]

A specially developed smart and patented substrate in the form of a cloth medium for seeding, germinating, growing, and harvesting is one of the key components of AeroFarms success. It is made out of recycled plastic bottles, is re-usable and sanitizable, and works as a barrier between the mist and roots. A comprehensive monitoring of more than 130,000 data points per harvest allows the vertical farm to produce superior quality products without the risks that can confront conventional outdoor farming.[387] According to AeroFarms, this customizable system is 60 times more productive and needs 97% less land than conventional agriculture and 80% less water than hydroponic systems.

Lighting Technologies

One of the most important factors for a successful vertical farm is the optimal use of daylight and artificial lighting with special LED plant lamps. In order to use them cost-effectively for vertical farms, they must have at least 50% to 60% efficiency.[388] Meanwhile, Philips' plant lamps already achieve 68% efficiency, thus dramatically reducing the cost of lighting. In addition, the Dutch company PlantLab has developed a particularly low-cost LED technology for vertical farms,

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[385] The Guardian (2016): World's largest vertical farm grows without soil, sunlight or water in Newark. https://www.theguardian.com/environment/2016/aug/14/world-largest-vertical-farm-newark-green-revolution. Retrieved on 13.9.2017

[386] http://aerofarms.com/. Retrieved on 13.9.2017

[387] ibid.

[388] Eve, L. (2015): PlantLab Could Grow Fruit and Vegetables for the Entire World in a Space Smaller than Holland. Inhabitat, 17 March 2015. http://inhabitat.com/dutch-company-plantlabs-agricultural-revolution-could-grow-the-worlds-fruit-and-veg-in-a-space-smaller-than-holland/. Retrieved on 19.3.2019

and it only produces the blue, red, and infrared light spectrum necessary for plant photosynthesis.[389]

Another new induction light technology allows the use of argon gas as a light source and thus achieves a double life compared to LED lights. These inexpensive argon gas lamps generate enough heat to create an ideal growth climate for the plants without additional heating.[390] The need for artificial lighting for vertical farms is a weakness, but these energy costs must be balanced against other areas, such as reduced transportation and fuel costs, air pollution, storage, refrigeration, and packaging costs.[391] [392]

Efficient Use of Renewable Energies

For sustainable and resilient food production systems, vertical farms must take every opportunity to use renewable energy to reduce energy costs and make production more profitable and environmentally friendly. Options for the use of geothermal, solar, or wind energy exist in almost all regions in the world, and they need to be used for operation even more than before. Efforts have already been made to build a 100% sustainable and energy self-sufficient vertical farm, for example Metropolis Farms in Philadelphia: “We are pushing the envelope by attempting to build a zero-carbon farm. Through water recapture techniques, renewable energy production, advanced energy systems, and most importantly by farming locally, we are on the right track.”[393]

If there is a shortage of empty buildings or brownfields, it is possible to construct multi-story vertical farms above the water, as the French company Studio NAB

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[389] Levenston, M. (2011): Philips Lighting Promotes City Farming. City Farmer News, 10 December 2011. http://www.cityfarmer.info/2011/12/10/. Retrieved on 13.3.2019

[390] Al-Kodmany, K. (2018): The Vertical City: A Sustainable Development Model. Boston 2018

[391] Cicekli, M., Barlas, N. (2014)

[392] Miller, A. (2011): Scaling Up or Selling Out? A Critical Appraisal of Current Development. https://curve.carleton.ca/748f35ee-2799-4ff4-80b6-de3032dd65f7. Retrieved on 29.1.2019

[393] Clean Technica. https://cleantechnica.com/2017/10/03/worlds-first-solar-powered-indoor-vertical-farm-comes-philadelphia/. Retrieved on 8.4.2019

has proposed with the model of "Superfarms." According to this approach, the Superfarm not only produces leafy greens, microgreens, and fruits with aquaponics, but it also produces various seaweeds, edible insects, honey, ginseng, and aloe vera. The intention is to exclusively use energy that is generated by wind turbines and solar cells.[394] [395]

Saving Costs through Upscaling and Automatization

Another promising vision of vertical farming is in progress by a young startup in Silicon Valley, which is currently building a 100,100 square foot vertical farm in Washington and plans to build vertical farms outside of major cities. Their products should reach consumers within hours rather than days. By fully automating farms with robots, which will also take over work such as sowing and harvesting, the profitability of the business will increase, and the investment will be amortized after three to five years. Scaling-up, cost savings for staff, and radically declining costs of LED lighting are the prerequisites that this young company wants to use.[396]

In the near future, vertical farms could be fully automated. Special sensors control the exact water, fertilizer, and temperature requirements of the plants, and chromatographers can analyze the flavonoid content to determine the best harvest time.[397] The trend is that several farms can be monitored remotely at the same time, and essential functions such as fertilization, pH values, and moisture can be controlled with smartphones, PCs or tablets, and intelligent software.

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[394] Hydroponics Highway. https://www.hydroponicshighway.com/superfarm-by-studio-nab-proposes-a-vertical-farm-concept-to-combat-land-shortage/. Retrieved on 9.4.2019

[395] Malone, D. (2019): Studio NAB's Superfarm project creates an entire ecosystem in an urban environment. https://www.bdcnetwork.com/studio-nab%E2%80%99s-superfarm-project-creates-entire-ecosystem-urban-environment. Retrieved on 9.4.2019

[396] Cosgrove, E. (2017): Vertical Farming Startup Plenty Acquires Bright Agrotech to Scale. https://agfundernews.com/breaking-vertical-farming-startup-plenty-acquires-bright-agrotech-scale.html. Retrieved on 10.4.2019

[397] Al-Kodmany, K. (2018): The Vertical Farm: A Review of Developments and Implications for the Vertical City. Buildings, 8(2), p. 24. doi: 10.3390/buildings8020024. Retrieved on 10.4.2019

Integration into the Urban Infrastructure / InFarming Approach

Although land prices are high in megacities and cities, many houses are suitable for vertical farming according to the InFarming concept, provided there is support from the city council.[398] Cost reductions through innovative strategies are possible when roof-top farms and buildings interact, for example when using the waste heat of the building for vertical farming, recycling the building waste, energy cost sharing, processing, etc.[399] The vertical roof-top farms can use organic waste, CO2, and animal fertilizer and turn them into biogas for heating or cooling. In the future, vertical farms can also be used as an effective sound insulator by lowering sound reflection.[400] According to research reports, plants can absorb the noise of traffic, aircraft, and machinery, and the interior noise level can be reduced by up to 60 decibels through green roofs.[401] [402] [403] [404]

Expansion of Education and Marketing Functions

Vertical farms can take advantage of opportunities to share knowledge about modern agricultural technologies with a broad population in close collaboration with schools, universities, and research institutes. These include seminars, lectures, guided tours through the vertical farm, experimental fields, and events that are also suitable for families. Most urbanites know little about how their food is produced. Here, they could have direct contact with the producer and inspect the entire production process.

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398 Fletcher, O. (2012): The Future of Agriculture may be up. The Wall Street Journal, 13 October 2012. https://www.wsj.com/articles/SB10000872396390443855804577602960672985508. Retrieved on 13.3.2019

399 Safikhani, T. et al. (2014): A review of energy characteristic of vertical greenery systems. Renewable and Sustainable Energy Reviews, 40, pp. 450–462. http://doi.org/10.1016/j.rser.2014.07.166. Retrieved on 22.3.2019

400 ibid.

401 Specht, K. et al. (2014): Urban agriculture of the future: An overview of sustainability aspects of food production in and on buildings. doi: 10.1007/s10460-013-9448-4. Retrieved on 6.4.2019

402 https://www.gebaeudegruen.info/. Retrieved on 6.4.2019

403 Fletcher, J. (2015): 7 Benefits of Rooftop Gardens. https://treescience.com.au/blog/7-benefits-of-rooftop-gardens/. Retrieved on 5.4.2019

404 https://livingroofs.org/noise-sound-insulation/. Retrieved on 5.4.2019

Finally, the management of vertical farms can take advantage of the location in or on the outskirts of the city to increase the popularity of products while generating additional income by connecting cafeterias, restaurants, or cooking workshops to the vertical farm. Novel ideas for producing food and sustainable ways of structuring city life and consumption patterns are now realized in a number of vertical farms. These initiatives are often carried out and supported by research institutes as well as private organizations. In order to advertise and promote their concepts and attempts, they usually let the public view their work. This is done through arranging visits or tours to their sites.[405]

8.1.3.5 Threats

- Electricity failure can cause fatal damage
- Image of a laboratory product
- Eco-groups reject the new cultivation method
- Farmers' unions and the greenhouse industry reject vertical farms
- Heavy subsidies to conventional agriculture
- Limitations to high-value crops
- Skepticism from businesses and academia
- Greater regulatory requirements
- No support from government and municipalities
- Not enough customers
- New, competing users.

The most significant threat to an existing vertical farm that cannot fully or partially power itself from renewables would be a total power outage. A long-term failure

[405] Kalantari, F. et al. (2017): Opportunities and Challenges in Sustainability of Vertical Farming: A Review. Journal of Landscape Ecology, June 2017. https://www.academia.edu/34397493/Opportunities_and_challenges_in_sustainability_of_vertical_farming_a_review. Retrieved on 26.3.2019

of important system components such as irrigation, lighting, and nutrition could lead to high or total damage to the plants.[406]

Critics of the vertical farming concept often argue that the dependence of vertical farms on artificial lighting causes too much of an environmental footprint, although this objection is only the result of the isolated consideration of lighting costs and not the entire food production chain. Nevertheless, such a judgment could lead to a negative attitude towards vertical farms in politics and mass media.[407] Since urban development plans do not yet include the construction of vertical farms, city councils could reject their construction on fallow land or in empty houses in the city and in the immediate periphery. Brownfields are in particularly great demand, for example, by urban gardeners, who prefer to use these spaces as community gardens rather than for economically oriented companies. If there are no official permits, this would pose a significant threat.

Neither farmers nor traditional greenhouses want to compete with vertical farms that offer higher-quality and healthier products. Farmers' associations, trade unions, and other lobbyists can be strong opponents of spreading vertical farms and can influence the public in their favor. Furthermore, substantial subsidization of conventional agriculture by the EU is a serious economic obstacle that leads to price distortions on the free market. If vertical farms are not competitive in price, they have to adapt to a small clientele such as restaurants, hotels, and customers who are willing to pay higher prices. This situation will change in a food security crisis when food production has to assume a vital function for society.

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[406] Sarkar, A., Majumder, M. (2015): Opportunities and Challenges in Sustainability of Vertical Eco-Farming: A Review. http://www.joaat.com/uploadfile/2015/0907/20150907104134985.pdf. Retrieved on 9.4.2019

[407] Khandros, M. (2018): The Promise and Peril of Vertical Farming. http://economyleague.org/providing-insight/regional-direction/2018/08/10/the-promise-and-peril-of-vertical-farming. Retrieved on 3.4.2019

There are also social and psychological barriers to the products of vertical farms; these are largely based on ignorance, prejudice, and misinformation. Vertical farms can easily create the impression that genetic engineering occurs or that the products are not natural; in reality, however, the products are not chemically contaminated and are far fresher than the competitive ones. Here, entrepreneurs and supporters of vertical farms still need to do significant educational work and build a positive image of their products and the entire production process. A failure in these necessary information and marketing campaigns would be a threat to further development and upscaling.

8.1.4 State of Current Research

8.1.4.1 Urban Vertical Farms

A study published by the Fraunhofer IAO in 2018[408] on the importance of urban indoor farms for a self-sufficient, integrated, and sustainable urban food and resource system has shown that they can significantly contribute to urban sustainability and resilience by returning food production to close proximity to consumers.[409] Other researchers and experts have indicated that urban indoor farms act as an important platform for the development of innovative technologies, mainly the areas of water recycling[410] [411] [412] and energy production by burning methane from compost.[413] [414]

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408 Padilla, M. et al. (2018): Urban farming in the city of tomorrow. http://publica.fraunhofer.de/documents/N-506944.html. Retrieved on 24.3.2019
409 ibid.
410 Despommier, D. (2011)
411 Safikhani, T. et al. (2014): A review of energy characteristic of vertical greenery systems. Renew. Sustain. Energy Rev. 2014, 40, pp. 450–462
412 Miller-Robbie, L. et al. (2017): Wastewater treatment and reuse in urban agriculture: exploring the food, energy, water, and health nexus in Hyderabad, India. https://iopscience.iop.org/article/10.1088/1748-9326/aa6bfe. Retrieved on 16.4.2019
413 Sivamani, S. et al. (2014): An OWL-Based Ontology Model for Intelligent Service in Vertical Farm. Lect. Notes Electr. Eng. 2014, 279, pp. 327–332. Retrieved on 12.4.2019
414 Lehmann, S. (2010): The Principles of Green Urbanism: Transforming the City for Sustainability. Earthscan, London 2010

Al-Kodmany[415] has emphasized the socio-economic benefits of vertical farms that offer numerous employment opportunities. Building a vertical farm requires a multi-disciplinary team of different experts. Saadatian,[416] Glaser,[417] and Holt [418] have reached the same conclusions in their analyses.

Molin and Martin,[419] Healey and Rosenberg,[420] and Kalantari et al.[421] have argued, that the high space efficiency of vertical can curb the expansion of conventional agriculture by means of grubbing valuable rainforests (for example in South America), regenerating the vacant farmland in Western industrialized countries, and transforming it into natural habitats.

Graber et al.,[422] Dubbeling,[423] Sivamani et al.,[424] and Specht et al.[425] have investigated the particular environmental friendliness of urban indoor farms. As they do not use pesticides, fungicides, and other chemicals that can cause surface and groundwater pollution and degradation of the environment, they are currently the only alternative for environmentally friendly food production, along with ecological city gardens and rooftop facilities.

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[415] Al-Kodmany, K. (2018): The Vertical Farm: A Review of Developments and Implications for the Vertical City. February 2018. doi: 10.3390/buildings8020024. Retrieved on 16.4.2019

[416] Saadatian, O. et al. (2013): A state of the art review of solar walls: Concepts and applications. J. Build. Phys. 2013, 37, pp. 55–79

[417] Glaser, J.A. (2012): Green chemistry with nanocatalysts. Clean Technol. Environ. Policy, 14, pp. 513–520

[418] Holt, S. (2016): Food and Farm Labour, Urban Agriculture. https://civileats.com/2016/01/05/not-your-dads-farm-job-millennials-look-to-high-tech-farms-for-careers/. Retrieved on 19.3.2019

[419] Molin, E., Martin, M. (2018): Reviewing the energy and environmental performance of vertical farming systems in urban environments. https://www.ivl.se/download/18.2aa2697816097278807e72d/1522310465773/C298.pdf. Retrieved on 13.4.2019

[420] Healy, R.G., Rosenberg, J.S. (2013): Land Use and the States. Routledge, New York 2013

[421] Kalantari, F. et al. 2017): Opportunities and Challenges in Sustainability of Vertical Farming: A Review. J. Landsc. Ecol. 2017, 2(2). DOI: 10.1515/jlecol-2017-0016. Retrieved on 13.4.2019

[422] Graber, A., Schoenborn, A., Junge, R. (2011): Closing water, nutrient and energy cycles within cities by urban farms for fish and vegetable Production. Int. Water Assoc. Newsletter, 37, pp. 37–41

[423] Dubbeling, M. (2011): Integrating urban agriculture in the urban landscape. Urban Agric. Mag., 25, pp. 43–46

[424] Sivamani, S., Kwak, K., Cho, Y. (2014): A Rule Based Event-Driven Control Service for Vertical Farm System. In: Park, J. et al. (eds.): Future Information Technology. Berlin/Heidelberg 2014, pp. 915–920

[425] Specht, K. et al. (2015): Zero-Acreage Farming in the City of Berlin: An Aggregated Stakeholder Perspective on Potential Benefits and Challenges. Sustainability 2015, 7, pp. 4511–4523

The studies by Germer et al.[426] and Kozai[427] have shown that vertical farms can not only purify wastewater and use it to grow crops, but that drinking water can be produced by evapotranspiration. In addition, up to 95% of water can be saved with a closed-loop system compared to traditional agriculture. However, Thomaier[428] has noted that, despite the great benefits such as energy savings, waste reduction, and biodiversity conservation, vertical farms are not a panacea for the current environmental problems; they are merely a viable, environmentally friendly complement to conventional agriculture.

The innovative method of aquaponics, which can also be practiced in vertical or horizontal rooftop farms, has received special appreciation in the scientific literature in terms of sustainability, resilience, and profitability. “It can offer a sustainable food-production model that supplies crop year-round with no interruption due to climate change, season, or adverse natural events (e.g., hurricane, drought and flood.” [429] [430]

Runke et al.[431] and many others[432] have called aquaponics a promising strategy with a high potential for success that ideally combines two technologies and is therefore particularly suitable for combating hunger in the world: “It is our conviction that this technology has the potential to play a significant role in food production in the future.”[433]

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426 Germer, J. et al. (2011)

427 Kozai, T. (2015): Plant Factory: An Indoor Vertical Farming System for Efficient Quality Food Production. N.Y. 2015

428 Thomaier, S. et al. (2015): Farming in and on urban buildings: Present practice and specific novelties of Zero-Acreage Farming (ZFarming). Renewable Agriculture and Food Systems, 30(1), pp. 43–54

429 Rakocy, J. et al. (2010): Update on tilapia and vegetable production in the UVI aquaponic system. https://www.researchgate.net/publication/237308635_Update_on_tilapia_and_vegetable_production_in_the_UVI_aquaponic_system. Retrieved on 26.3.2019

430 Abel, C. (2010): The vertical garden city: Towards a new urban topology. CTBUH J.2010, 2, pp. 20–30. http://global.ctbuh.org/resources/papers/download/390-the-vertical-garden-city-towards-a-new-urban-topology.pdf. Retrieved on 14.3.2019

431 Runge, R. et al. (2017): Strategic points in Aquaponics. https://www.researchgate.net/publication/314205280_Strategic_Points_in_Aquaponics. Retrieved on 14.3.2019

432 Mchunu, N. et al. (2017): Food Sovereignty for Food Security, Aquaponics System as a Potential Method: A Review. J. Aquac. Res. Development, 8(7). doi: 10.4172/21559546.1000497. Retrieved on 17.4.2019

433 Runge, R. et al. (2017)

Ideally, aquaponics operates with a rooftop or vertical farm. Advanced systems can integrate organic waste as feed and efficiently and sustainably connect the waste recycling with protein production. For this reason, Takahashi and Kolasa[434] have argued that the aquaponics method has the potential for food production that is superior to that of traditional agriculture.

Kloas[435] has reached similar conclusions in his collaborative research project Innovative Aquaponics for Professional Application (INAPRO), which is supported by the EU and is the first of its kind in Spain, Germany, Belgium, and China. With the INAPRO system, which can be adapted to any local conditions, sustainable, resilient food production can be operated with nearly zero emissions, while being highly resource-efficient and effectively improving food security: “The INAPRO system responds to the global challenge of food security by producing local, healthy and sustainable food with a low water and carbon footprint alongside with a drastic reduction of nitrogen and phosphorus emissions.” [436]

8.1.4.2 Urban Roof-Top Farms

The results of the Fertile City project of the research group Sanyé-Megual et al.[437] in Barcelona have confirmed the optimization of resource consumption (energy, water, and CO2) in the interaction between greenhouse and building. In this project which is similar to the Fraunhofer InFarming approach, the roof-top greenhouse integrates energy, water, and CO2 flows into the building's metabolism. Due to its location on the roof, the higher temperatures resulting from

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[434] Takahshi, M., Kolasa, J. (2018): Sustainable Aquaponics. https://macsphere.mcmaster.ca/handle/11375/23464. Retrieved on 17.4.2019

[435] European Commission. https://ec.europa.eu/eip/agriculture/en/news/inspirational-ideas-aquaculture-hydroponics-aquaponics. Retrieved on 17.4.2019

[436] Kloas, W. (2017): Aquaculture + hydroponics = aquaponics. https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/field_core_attachments/nw_aquaponics _10012017_en.pdf. Retrieved on 2.4.2019

[437] Sanyé-Megual, E. et al. (2015): The ICTA-ICP Rooftop Greenhouse Lab (RTG-Lab): Closing metabolic flows (energy, water, CO2) through integrated Rooftop Greenhouses. doi: 10.13140/RG.2.1.5016.7206. Retrieved on 4.3.2019

the building's heat below contribute to maintaining ideal growth rates in the greenhouse.[438]

Pons et al.,[439] researchers in the same project, have shown that, when analyzing the entire cradle-to-consumer process, locally produced tomatoes are cheaper and have a lower environmental footprint than conventional tomatoes. Their conclusion from the findings thus far is that urban agriculture brings many benefits: “It promotes sustainable development, food safety and affordability, environmental and food education, local economy, biodiversity… and therefore it should be included in cities urban and management plans.”[440]

In New York, Susca et al.[441] have studied four areas and found a difference of 2°C between rooftop and non-planted areas. They determined the surface albedo effect, i.e., the reflectivity of non-self-illuminating, diffusely reflecting surfaces[442] by comparing black, white, and green roofs. The results show that the green roofs were the least heated because of the biological activity of the plants, which also reduced the effects of the urban heat island.

The research by Oberndorfer et al.[443] reveals similar results. In particular, the dark, impermeable surfaces of streets and roofs are responsible for the urban heat island effect. Increasing the albedo can reduce this urban heat build-up. Additionally, green roofs are particularly suitable for urban storm-water management, as they delay the runoff. By protecting the roof from UV damage

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[438] ibid.
[439] Pons, O. et al. (2015): Roofs of the Future: Rooftop Greenhouses to Improve Buildings Metabolism. https://www.sciencedirect.com/journal/procedia-engineering/vol/123/suppl/C. Retrieved on 12.12.2018
[440] ibid.
[441] Susca, T. et al. (2011): Positive effects of vegetation: Urban heat island and green roofs. Environmental Pollution, 159(8–9), pp. 2119–2126. https://doi.org/10.1016/j.envpol.2011.03.007. Retrieved on 12.2.2019
[442] Akbari, H. et al. (2012): The long-term effect of increasing the albedo of urban areas. Environmental Research Letters, 7(2). https://iopscience.iop.org/article/10.1088/1748-9326/7/2/024004. Retrieved on 20.4.2019
[443] Oberndorfer, E., Lundholm, J., Bass, B. (2007): Green roofs as urban ecosystems: Ecological structures, functions, and services. BioScience, 57, pp. 823–833. https://doi.org/10.1641/B571005. Retrieved on 25.2.2019

and extreme temperature fluctuations, they improve the longevity membrane and produce a significant cooling effect in the summer. They lower the heat transfer through the roof, cool the buildings, and promote evapotranspiration.[444]

The experiments of Marasco[445] confirm the essential role of evapotranspiration for the summer cooling effect: “Green roofs (roofs with a vegetated surface and substrate) provide ecosystem services in urban areas, including improved storm-water management, better regulation of building temperatures, reduced urban heat-island effects, and increased urban wildlife habitat.”[446]

The qualitative and quantitative study on the particulate matter filter potential by the research group Kappis et al.[447] and Körner[448] (Humboldt University Berlin) assessed the performance of various types of vegetation on roofs, gardens, walls, roadsides, and city parks. The leaf surfaces of the plants bind the fine dust, and their self-cleaning surface structure causes clumping to coarse dust. In addition, leaves can directly bind and neutralize gaseous air contaminants. An indirect cleaning effect by the plants takes place through the change of the airflow, which distributes and minimizes air pollution.

De Zeueuw et al.[449] and Flournoy et al.[450] have confirmed that urban agriculture, and roof top plants in particular, can improve urban sustainability and resilience

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[444] ibid.

[445] Marasco, D. et al. (2006): www.researchgate.net. Marasco_et_al-ET_from_Urban_Green_Roofs-March09.pdf. Retrieved on 13.4.2019

[446] Oberndorfer, E., Lundholm, J., Bass, B. (2007): Green roofs as urban ecosystems: Ecological structures, functions, and services. BioScience, 57, pp. 823–833. https://doi.org/10.1641/B571005. Retrieved on 25.2.2019

[447] Kappis, C. (2007): Studie zum wissenschaftlichen Erkenntnisstand über das Feinstaubfilterungspotential (qualitativ und quantitativ) von Pflanzen, Forschungsprojekt Nr. 06HS021

[448] Körner, S. (2007): Feinstaubfilterungspotential von Pflanzen. Anmerkungen zu einem Workshop an der Humboldt Universität zu Berlin

[449] Zeeuw, H., van Veenhuizen, R., Dubbeling, M. (2011). The role of urban agriculture in building resilient cities in developing countries. The Journal of Agricultural Science, 149(S1), pp. 153 - 163. https://doi.org/10.1017/S0021859610001279. Retrieved on 4.3.2019

[450] Flournoy, R., Hagey, A., Rice, S. (2012): Urban Agriculture: Equitable Strategies and Policies for Improving Access to Healthy Food and Revitalizing Communities. https://www.policylink.org/sites/default/files/URBAN_AG_FULLREPORT.PDF. Retrieved on 12.3.2019

through multiplier and indirect effects on the local economy: “Urban agriculture has the potential to support other local businesses, thereby creating multiplier and indirect economic benefits.[451] Examples of resource reinvestment include the purchasing of farming equipment and supplies, including compost, from local vendors.”[452] [453] [454]

Van Veenhuizen and Danso[455] have noted that some countries are particularly suitable for the installation of rooftop farms: “Countries with large urban areas and crop mixtures suitable for both the climate and urban cultivation could produce millions of tones from UA (Urban Agriculture).”[456] The available area in the USA is estimated at 2 million hectares and that of China at 1.4 million hectares. This is followed by Brazil, India, Russia, Germany, and Japan.

Clinton et al.[457] have estimated that, in the USA, around 40 million tons of food can be produced annually with rooftop plants and 20 million tons in China, followed by Germany and Brazil. These countries are characterized by a combination of favorable production factors and could benefit most from urban agriculture, both in terms of income generated and ecosystem services obtained. The value of ecosystem services through existing plantings is reported at $33 billion annually: “Food production, nitrogen fixation, energy savings, pollination, climate regulation, soil formation, and biological control of pests could be worth as much as $80 - 160 billion annually in a scenario of intense UA implementation.”[458] Such an intensified urban agriculture could generate 98 to 178.3 million tons of food – according to the FAO.[459]

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[451] ibid.
[452] ibid.
[453] ibid.
[454] Wagner, C. (2010): Vertical farming: An idea whose time has come back. Futurist 2010, 44, pp. 68–69
[455] van Veenhuizen, R., Danso, G. (2007): Profitability and Sustainability of Urban and Periurban Agriculture. http://www.fao.org/3/a-a1471e.pdf. Retrieved on 13.2.2019
[456] ibid.
[457] Clinton, N. et al. (2018): https://doi.org/10.1002/2017EF000536. Retrieved on 19.4.2019
[458] Clinton, N. et al. (2018)
[459] http://www.fao.org/faostat/en/#home. Retrieved on 19.4.2019

According to studies by Martelozzo et al.,[460] about one-third of the total urban area would have to be used for urban agriculture in order to provide the global supply of urban dwellers with vegetables. It is not only megacities, but smaller metropolitan areas that are especially suitable for this purpose*:* “We also show that smaller urban clusters (i.e., <100 km^2 each) together represent about two-thirds of the global urban extent; thus, UA discourse and policies should not focus on large cities exclusively, but should also target smaller urban areas that offer the greatest potential in terms of physical space.”

The integration of urban agro-systems into the urban infrastructure means that more habitats will be created for invertebrate and avian communities, as they will find their nesting and breeding areas there as well as their food. The studies by Brenneisen,[461] Köhler et al.,[462] and Goddard [463] have shown that planted roof systems are populated by numerous insects, such as spiders, bees, and grasshoppers, and that on older roofs, rare plants and lichens are likely to develop spontaneously. Thus, the protection of biodiversity allows an increase in the genetic variants of plants and animals, as well as a regeneration of natural ecosystems.[464]

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[601] Martellozzo, F. et al. (2014): Urban agriculture: A global analysis of the space constraint to meet urban vegetable demand. Environmental Research Letters, 9(6). https://doi.org/10.1088/1748-9326/9/6/064025. Retrieved on 7.3.2019

[461] Brenneisen, S. (2006): Space for urban wildlife: Designing green roofs as habitats in Switzerland. Urban Habitats, 4, pp. 27 - 36. www.urbanhabitats.org/v04n01/index.html). Retrieved on 11.4.2019

[462] Köhler, M. et al. (2002): Green roofs in temperate climates and in the hot-humid tropics - far beyond the aesthetics. https://www.emeraldinsight.com/doi/abs/10.1108/09566160210439297?fullSc=1&journalCode=emh. Retrieved on 13.4.2019

[463] Goddard, M., Dougill, A., Benton, T. (2010): Scaling up from gardens: Biodiversity conservation in urban environments. Trends in Ecology & Evolution, 25(2), 90 98. https://doi.org/10.1016/j.tree.2009.07.016. Retrieved on 23.2.2019

[464] Kalantari, F. (2017)

According to Koohafkan and Altieri[465] and Bailkey et al.,[466] roof-top gardens and farms also fulfill the important role of being a repository of agricultural knowledge. Since modern agriculture, which endangers the transfer of important knowledge, is no longer accessible to large parts of the population, open, roof-top farms combine the pursuit of horticultural activities for a broad spectrum of interested parties with the provision of horticultural know-how. At the same time, nutritional knowledge is improved, the daily diet is enriched with fresh fruits and vegetables, and a new bond between man and nature is created.[467] [468] [469] [470]

8.1.5 Conclusion

This chapter introduced new, innovative agricultural techniques such as hydroponics, aquaponics, modern rooftop farming, and vertical farming based on the aforementioned technologies. The subsequent SWOT analysis highlighted the multiple benefits and opportunities for developing these new technologies in urban vertical farms, as well as the weaknesses and potential problems. The technologies used in the vertical farms and rooftop farms were evaluated for their significance for urban sustainability and resilience in the areas of the environment, economy, and society.

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[465] Koohafkan, P., Altieri, M. (2010): Globally Important Agricultural Heritage Systems: A Legacy for the Future. http://www.fao.org/fileadmin/templates/giahs/PDF/GIAHS_Booklet_EN_WEB2011.pdf. Retrieved on 13.2.2019

[466] Bailkey. M., Campbell, M., Hodgson, K. (2011): Urban Agriculture: Growing Healthy, Sustainable Places. http://growingfoodconnections.org/gfc-reader-entry/urban-agriculture-growing-healthy-sustainable-places/. Retrieved on 2.3.2019

[467] McClintock, N., Cooper, J., Khandeshi, S. (2013): Assessing the potential contribution of vacant land to urban vegetable production and consumption in Oakland, California. Landscape and Urban Planning, 111, pp. 46–58. https://doi.org/10.1016/j.landurbplan.2012.12.009. Retrieved on 4.1.2019

[468] Turner, B. (2011): Embodied connections: Sustainability, food systems and community gardens. Local Environment, 16(6), pp. 509–522. https://doi.org/10.1080/13549839.2011.569537. Retrieved on 5.1.2019

[469] McCormack, L. A. (2010). Review of the nutritional implications of farmers' markets and community gardens: A call for evaluation and research efforts. Journal of the American Dietetic Association, 110(3), pp. 399–408. https://doi.org/10.1016/j.jada.2009.11.023. Retrieved on 4.3.2019

[470] Boeing, H. et al. (2012): Critical review: vegetables and fruit in the prevention of chronic diseases. doi: 10.1007/s00394-012-0380-y. Retrieved on 7.1.2019

Numerous quantitative and qualitative studies, surveys, and international research projects support the findings of the SWOT analysis.

Urban Gardening Has Multiple Benefits for Society, the Environment and Food Security

In Europe, almost one-third of the greenhouse gas emissions are caused by food production, which is also responsible for biodiversity loss and deforestation. In addition to impressive CO2 emissions through food-related logistics, what is eaten and how much is wasted are as significant as food miles.[471] By consuming food that is both in season and locally produced, transport emissions and the need for refrigeration in stores can be reduced. Traditional urban gardening has significant benefits in all its manifestations for improving urban air quality, preserving biodiversity, and providing fresh, mostly organic food. Garden plots are usually more productive than rural holdings, and vegetables that are not intended for personal use can be sold directly to consumers without middlemen and thus save substantial costs on transport, packaging, storage, and refrigeration.

Short, direct markets have become increasingly popular across Europe and the U.S., as consumers associate local products with higher and fresher quality, greater health and nutritional value, and more environmentally friendly production. At the same time, they prefer direct contact with the manufacturer and want to support the local economy with a fair price. According to a 2016 Eurobarometer survey, four out of five respondents believe that buying from local farmers has great benefits, and that it is important to support local farmers.[472]

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[471] Shrink that footprint: The tricky truth about food miles. http://shrinkthatfootprint.com/food-miles#ZUSrJ4Yv7sebr4xO.99. Retrieved on 5.9.2017

[472] http://ec.europa.eu/COMMFrontOffice/publicopinion/index.cfm/Survey/getSurveyDetail/instruments/SPECIAL/ surveyKy/2087. Retrieved on 10.9.2017

Resistance to crises is an important component of sustainability, and agriculture and food security are its key components. International organizations have advocated improvements in urban food security through the expansion of urban agriculture for some time. In their opinion, this can only be achieved through diversified, small-scale, organic agriculture, which in practice means that the development would have to be exactly the opposite of a totally globalized lifestyle.[473]

Modern Agricultural Technologies Can Improve the Ecosystem

Currently, European agriculture accounts for more than 10% of total CO2 emissions (2015: 426,473 kilotons of CO2). A shift to less CO2-intensive production and land conversion into forests would be essential to regenerate the global ecosystem. Such a scenario could produce at least an 80% reduction in emissions by 2050, according to the Institute for European Environmental Policy (IEEP) calculations.[474] The prerequisite for this net-zero agriculture would be the self-sufficiency of the EU with regard to the production of plant and animal foods and an end to the strong export orientation. Instead, production would have to take place on less land to create space for the necessary reforestation. No known method other than extensive rooftop farming and vertical farms could facilitate such a change in agricultural production and restore the damaged ecosystem.

Vertical Farming Increases Food Security

Since fertile farmland will become a scarce commodity in the future, it makes sense to integrate food production into urban infrastructure and planning as much as possible. The productivity of rooftop and vertical farms that produce modern,

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[473] FAO: FAO's work on agroecology. A pathway to achieving the SDGs. http://www.fao.org/3/i9021en/i9021en.pdf. Retrieved on 11.5.2019

[474] Gillman, S. (2019): How to Reduce Greenhouse Gas Emissions from EU Agriculture by 81%. http://www.arc2020.eu/reduce-greenhouse-gas-emissions-from-eu-agriculture-81/. Retrieved on 22.4.2019

soilless food is far greater than that of conventional agriculture, it is independent of climate and seasons and can therefore guarantee, with appropriate dissemination and upscaling, a reliable supply of fresh food for the urban population. Urban agriculture cannot completely replace conventional agriculture, but it can effectively complement and even outperform it in some areas. Livestock husbandry could take place on normal farms in the urban perimeter in order to reduce transport routes and resource consumption as much as possible.

Urban Rooftop Farms and Vertical Farming Can Mitigate the Effects of Climate Change

The previous assessment of new agricultural technologies and the establishment of urban roof-top farms and vertical farms have shown that both concepts provide workable solutions for a sustainable environmental, economic, and social agenda. Rooftop farms and vertical farms can effectively cool their environments, sequester large amounts of CO2, and significantly reduce the urban heat island effect. As a result of climate change, ever-increasing dry spells and droughts will threaten agriculture, which may result in reduced yields and lead to drastic price increases. By contrast, vertical farms are characterized by the sparing use of drinking water and the cleaning and usage of processed water. Proximity to consumers reduces transport distances to a minimum, and operations are performed without the use of large agricultural machinery, thus significantly reducing the consumption of fossil fuels and protecting the environment. With a closed production system, vertical farms have a minimal ecological footprint and can allow the naturalization and regeneration of former farmland in the future.

Vertical Farms are a Promising Business Model for the Future

Provided that the vertical farms are designed with circular, energy-efficient business cycles, the previous SWOT analysis showed that there will be strong new market opportunities for this business model. With the high, sustainable quality of their products, vertical farms have a clear competitive advantage over imported foods. The multiple strengths and opportunities of vertical farms can be used to successfully counteract weaknesses and potential threats.

Above all, broad awareness campaigns must ensure that consumers are informed about the health benefits of the food produced, the environmentally friendly technology, and the associated food safety. Increased interdisciplinary research and collaboration is needed to foster a better collective understanding of these new agricultural methods. Since vertical farms could supply a large portion of the population with food in the future, economic full-cycle analyzes are needed to accurately determine the ROI of various types and sizes of vertical farms, to enable economically secure upscaling, and to develop a robust business model that is competitive in the global economy.

Currently, the concept of a high-tech vertical farm is not viable for poorer, developing countries. However, as they suffer from a lack of water, low-fertile farmland, and low resources, developing low-tech, flexible vertical farm models for these countries is an important task. On the basis of local conditions, the affordability of rooftop and vertical farming would have to be determined with quantitative analyzes and feasibility studies.

A New Orientation of Agriculture is Indispensable

It is a fact that 821 million people in the world are starving, while 1.9 billion suffer from obesity and debilitating obesity. It is also undisputed in the scientific community that conventional agriculture and the current food system are among the most important causes of climate change, species extinction, pollution, and water scarcity. Therefore, the decisive international commissions of the UN and the EU have begun to realize that continuing as before is not a realistic option.[475] Although the population density and structure have significantly changed in the last decade, and progressive urbanization produces more and larger cities, our agriculture concept has not adapted to this change. “Instead of rethinking the place of agriculture relative to changing demographics, new storage, processing and distribution methods have evolved to shuttle food over ever-growing distances across the country. This widening gap between producer and consumer requires greater energy consumption, higher transportation costs, increasing use of synthetic preservatives and more pollution. It makes fresh, nutritious agricultural foodstuffs accessible only to those who have access and who can afford it.”[476]

8.2 Urban Agriculture in Germany

In this research section, the question is to be clarified what role the UA can play in German sustainability policy and what the acceptance is among the population.

8.2.1 Germany’s Sustainability Strategy

After environmental protection was institutionalized in Germany with its own ministry in the 1970s, the country has been a pioneer in environmental policy within Europe. Important laws from this early period were the Water Resources Act (Wasserhaushaltsgesetz, 1957), the Federal Nature Protection Act 1976 (Bundesnaturschutzgesetz), the Air Pollution Control Regulations (1983), and the

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[475] European Parliament: Briefing. September 2016. EPRS | European Parliamentary Research Service. Author: Marie-Laure Augère-Granier. Members' Research Service. EN. PE 586.650. Short food supply chains and local food systems in the EU. http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/586650/EPRS_BRI(2016)586650_EN.pdf. Retrieved on 23.4.2019

[476] Kuhn, T. (2009): Urban Agriculture in Wisconsin: A Survey and Discussion of Land Use and Planning Practices in High Density Counties. http://familyfarmers.org/wp-content/uploads/2011/07/Urban-Agriculture-in-Wisconsin-A-Survey-and-Discussion-of-Land-Use-and-Planning-Practices.pdf. Retrieved on 30.3.2019

Recycling and Waste Management Act (Kreislaufwirtschafts- und Abfallgesetz) of 1994.[477]

In the Federal Nature Conservation Act, the tasks of landscape planning are defined in detail, which – together with regional, agricultural and forestry planning – form the land planning system of Germany. Landscape planning aims to implement the goals of nature conservation and landscape maintenance and thus to secure the habitat functions for plants and wildlife, as well as nature experience and recreational functions (Art. § 6 (1) BNatSCHG).[478] Instruments for achieving these tasks are landscape programs, landscape framework plans, landscape plans and green structure plans.[479]

A newly drafted Federal Nature Conservation Act came into force in 2010 – in addition to the original provisions – which regulates the compensatory and replacement measures that are necessary when interfering with nature. According to §14 (1) BNatSCHG, "interventions" are to be understood as changes in surface areas, the living soil layer and the groundwater table, which can impair the performance and functionality of the natural balance or the landscape. Settlement and traffic route structures are an example of frequent interventions. The originator of such interventions is obliged to refrain from an avoidable impairment of nature or – if this is not possible – to compensate with equivalent measures of nature conservation and landscape management (compensation obligation).

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[477] Jänicke, M. (2009): Geschichte der deutschen Umweltpolitik. https://www.bpb.de/gesellschaft/umwelt/dossier-umwelt/61136/geschichte?p=all. Retrieved on 2.2.2019

[478] Gruehn, D., Kenneweg, H, (2001): Kritische Evaluation der Wirksamkeit der Landschaftsplanung im Rahmen der Bauleitplanung in Rheinland-Pfalz. Abschlussbericht im Auftrag des Landesamtes für Umweltschutz und Gewerbeaufsicht sowie des Ministeriums für Umwelt und Forsten des Landes Rheinland-Pfalz. https://www.edoweb-rlp.de/resource/edoweb:3657969. Retrieved on 3.5.2020

[479] Gruehn, D. (2006): Landscape Planning as a Tool for Sustainable Development of the Territory - German Methodology and Experience. In: Vogtmann, H. & Dobretsov, N. [Ed.]: Environmental Security and Sustainable Land Use - with special reference to Central Asia, pp. 297-307. Springer. The Netherlands

In practice it has been shown that with increasing development and provision of valid data, local landscape planning can have significant positive effects on land use plans. “In comprehensive plans with a landscape plan as basis, nature conservation and landscape management objectives have been considered two times higher than in comprehensive plans without landscape plan“.[480] Since landscape planning not only has a food security mandate but also offers strategies for future development (§9 (3) BNatSCHG), a stronger integration of urban agriculture concepts could be beneficial. Urban agriculture is strongly associated with the urban environment and landscape, the entire urban metabolism and society. Therefore, it can give important impulses for the city and regional planning.[481]

In 1997, the concept of sustainability was integrated as a valid legal guideline in the revision of the Federal Planning Act (Raumordnungsgesetz). As a result, new regional plans at the federal and regional levels were developed with corresponding sustainable guiding principles, and cities and municipalities supplemented these with local Agenda 21 programs.[482]

Today, Germany’s sustainability policy is based on the EU Sustainable Development Strategy,[483] which was first endorsed in 2001 and modified by adding 17 strategic areas of action with specific objectives and measures, such as climate change and renewable energies, “sustainable transport, sustainable consumption and production, natural resources, public health”[484] services, social integration, population development and migration, global challenges in terms of

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[480] ibid.

[481] Lohrberg, F. (2018): Urbane Landwirtschaft als Impulsgeber für die Landschaftsplanung. In: Marschall, I. (ed.) pp 93-98 https://www.bfn.de/fileadmin/BfN/service/Dokumente/skripten/Skript_498.pdf. Retrieved on 19.6.2019

[482] Christmann, G., Ibert, O. et al. (2012): Vulnerability and Resilience from a Socio-Spatial Perspective. Erken 2012. http://www.resilience-berlin.de/download/wp_vulnerability.pdf. Retrieved on 17.2.2017

[483] Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU): EU-Nachhaltigkeitsstrategie. http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Nachhaltige_ entwicklung/ eu_nachhaltigkeitsstrategie_neu.pdf. Retrieved on 23.5.2017

[484] ibid.

poverty, and sustainable development and transversal measures as a contribution to the knowledge society (education, research, and development).[485] [486] Meanwhile, the EU directives from 2006 were perceived as outdated due to the unchecked progressive damage to the environment and increasing changes in the terrestrial climate, and the member states therefore requested a new European sustainability strategy in June 2017, which should serve as a framework for implementing the Sustainability Agenda 2030.[487]

The objectives of the German Sustainability Policy New Edition 2016 which are oriented towards the targets of Agenda 2030, include the goals that cities and settlements should become safe, sustainable, and resilient, and that renewable natural products should only be used according to their regeneration capacity. Food security should be guaranteed by promoting sustainable consumption and production patterns and by implementing effective measures to protect terrestrial ecosystems and biodiversity. In order to ensure the sustainability and resilience of the food system, climate-smart agriculture has to be supported, which includes new farming technologies such as hydroponic farming, vertical farming, and urban gardening on brownfields or any other suitable surface.[488]

Concerning sustainable water management, the quality of groundwater in Germany is not as high as it could be. According to the findings of Water Framework Directive (WFD) controls, about 36% of the 1,000 groundwater bodies are rated as “not in a good state” because of transverse structures blocking, straightening, and interpenetrating flowing waters. A very favorable ecological condition could be found in only 8.2% of all water bodies, and 36% are in a

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[485] ibid.
[486] ibid.
[487] ibid.
[488] Die Bundesregierung: Deutsche Nachhaltigkeitsstrategie. Neuauflage 2016. https://www.bundesregierung.de/resource/blob/975292/730844/3d30c6c2875a9a08d364620ab7916af6/deutsche-nachhaltigkeitsstrategie-neuauflage-2016-download-bpa-data.pdf?download=1. Retrieved on 30.5.2017

moderate state.[489] In the past, the German government has done too little to combat the nitrate pollution of groundwater; the European Court of Justice condemned it in the nitrate dispute in 2018 and required making the fertilizer ordinance more stringent.[490] The aim of the federal government is to return rivers, lakes, coastal waters, and groundwater to a high-quality condition by 2027 at the latest, a timeframe that the European Commission considers unsatisfactory.[491]

The results of a recent analysis of German environmental policy and the status of 2019[492] show that natural areas are threatened on a large scale, limits have been exceeded, and environmental targets have been missed. Every day, approximately 69 hectares are re-listed as settlements and traffic areas in Germany.[493] However, as the German Sustainability Strategy from 2016 shows, the federal government wanted to reduce land consumption to fewer than 30 hectares per day. By 2050, this requirement should be replaced by a net zero-area consumption which would imply the introduction of a land-cycle management that effectively manages brownfields, including land conversion, recycling, de-sealing, and renaturation activities.

In agriculture, German policy continues to focus on an increased use of pesticides and fertilizers that guarantee increasing yields but also lead to nitrogen surpluses, biodiversity loss, and water pollution. Relevant targets have not been met regarding the protection of biodiversity and air and soil quality. According to Jacob's and Wolff's analysis, the reason for this insufficient environmental policy

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[489] Umweltbundesamt (2015): Die Wasserrahmenrichtlinie – Deutschlands Gewässer 2015. https://www.umweltbundesamt.de/publikationen/die-wasserrahmenrichtlinie-deutschlands-gewaesser. Retrieved on 30.5.2017

[34] Zeit online (2019): EU mahnt Deutschland wegen Nitratbelastung. https://www.zeit.de/wissen/umwelt/2019-07/nitrat-grundwasser-eu-kommission-deutschland. Retrieved on 25.7.2019

[491] ibid.

[492] Jacob, K., Wolff. F. (2019): Veröffentlichung des 6. Globalen Umweltberichts (GEO-6) 2019: Analyse der Implikationen für Deutschland. Hintergrundbericht. https://www.umweltbundesamt.de/publikationen/veroeffentlichung-des-6-globalen-umweltberichts-geo. Retrieved on 20.7.2019

[493] ibid.

is the lack of its integration into individual sector policies and a small-scale implementation modus.[494]

8.2.2 Agenda 21 and Agenda 2030

A prominent assumption in the Brundtland report was that local actions can have a significant impact on a global scale and vice versa; global change may directly affect the local level. On this basis, the action program "Local Agenda 21" was adopted at the Summit in Rio, and it calls on urban and municipal administrations to develop sustainable action programs in cooperation with citizens, civil society organizations, and the private sector under the motto "Think Globally – Act Locally." In this context, all members of the European Conference on Sustainable Cities and Towns signed a "Charter of European Towns and Cities Towards Sustainability" in 1994, thus committing themselves "to sustainable and future-oriented social, economic, environmental, land, spatial, and budgetary policies, as well as to the participation in the Local Agenda 21-process."[495]

Under the motto "Agenda 2030," the 193 member states adopted a new version of the UN sustainability strategy in New York on September 25, 2015. At the heart of the Agenda 2030 are 17 Sustainable Development Goals (SDGs) that outline a strategy to eradicate hunger, poverty, and inequality in the world while adapting to climate change and preserving natural ecosystems.[496] [497] [498]

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[494] ibid.

[495] Portal Územniho Planovani (1994): Charter of European Cities & Towns towards Sustainability. http://portal.uur.cz/pdf/aalborg-charter-1994.pdf. Retrieved on 23.3.2017

[496] UN, Division of Sustainable Development Goals: Sustainable development goals. https://sustainabledevelopment.un.org/. Retrieved on 5.2.2018

[497] Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung: Die Agenda 2030 für nachhaltige Entwicklung. http://www.bmz.de/de/ministerium/ziele/2030_agenda/index.html. Retrieved on 16.3.2018

[498] Basis für die Umsetzung der SDGs in Deutschland ist die im Januar 2017 von der Bundesregierung verabschiedete Deutsche Nachhaltigkeitsstrategie. BMU (2016): Deutsche Nachhaltigkeitsstrategie – Neuauflage 2016. https://www.bmu.de/themen/nachhaltigkeit-internationales/nachhaltige-entwicklung/strategie-und-umsetzung/nachhaltigkeitsstrategie/. Retrieved on 15.12.2017

Figure 16 – 17 SDGs, https://ec.europa.eu/

SDG target 11.3[499] emphasizes the need for a comprehensive, long-term strategy to make cities more sustainable. With innovative methods of urban agriculture (community roof gardens, edible walls, vertical farms, roof gardens, etc.), the participation of citizens in food production is enabled, and urban resilience should be strengthened.[500] [501] In this context, the FAO has called for the involvement of the private sector to increase food production while protecting natural resources and the improvement of living conditions through inclusive economic growth.[502] “Unlocking the potential of the private sector is fundamental to progress. Engaging with entrepreneurs and tapping into the know-how of the private sector, including agricultural producer organizations, cooperatives, small and medium-

[499] UN, Division of Sustainable Development Goals: Sustainable development goals. https://sustainabledevelopment.un.org/. Retrieved on 5.2.2018

[500] Hernandez, M., Manu, R. (2018): Growing Greener Cities. Urban agriculture and the Impact on SD 11. https://sdg.iisd.org/commentary/generation-2030/growing-greener-cities-urban-agriculture-and-the-impact-on-sdg-11/. Retrieved on 6.7.2019

[501] Forster, T., Escudero, A. (2014): City Regions as Landscapes for People, Food and Nature. Washington, D.C. 2014

[502] FAO (2018): Transforming Food and Agriculture to achieve the SDGs. http://www.fao.org/3/I9900EN/i9900en.pdf. Retrieved on 5.2.2018

sized enterprises as well as international corporations is a pre-requisite for implementation of the 2030 Agenda."[503]

However, the global comparative study guided by the Bertelsmann Stiftung on implementing SDGs[504] in industrialized and developing countries shows that no country has yet fulfilled all 17 goals. Sweden, Norway, and Denmark occupy the top places in the ranking, while Germany is in sixth place, the USA is in 29th place, and China is in 54th place. "Their inability to fight the growing social divide combined with their overuse of resources therefore shows that today's high-income countries in their current shape can no longer serve as role models for the developing world."[505]

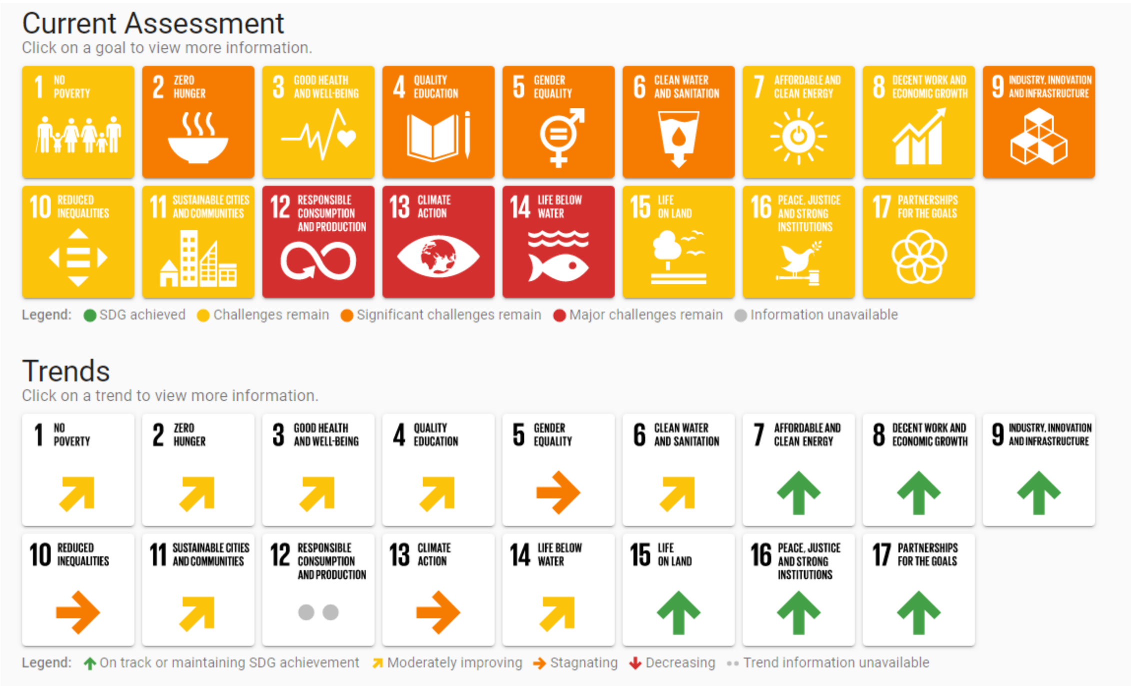

Figure 17 – Current state of Germany, SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK (SDSN) GERMANY

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[503] ibid., p. 8
[504] Bertelsmann Stiftung (2018): Sustainable Development Goals Index. https://www.bertelsmann-stiftung.de/de/unsere-projekte/sustainable-development-goals-index/. Retrieved on 25.5.2019
[505] ibid.

8.2.3 Interviews: Urban and Peri-Urban Farming in Munich

In the course of the research work, numerous interviews with experts were carried out to apply the triangulation and interdisciplinarity method in practice. These specialists were urban employees, scientists, entrepreneurs, urban garden initiators and project managers.

In Munich the task of the Department of Urban Planning and Building Regulations, Greenplaning (Referat für Stadtplanung und Bauordnung, HA II/542 Grünplanung) is to include potential sites for urban gardeners, as tenant gardens, community gardens, and allotments within the concepts of city planning, especially in new urban development projects. For this purpose, the communal department acquires land for new garden allotments on the basis of the land use plan and strives for ecological cultivation in lease agreements. The department is also responsible for the continuing development of Munich’s herb gardens, as well as various forms of community gardens by offering more locations to citizens.

Here, the author received extensive information about both topics and received internal documents of the department.

Gardens and Schrebergartens

In comparison to other German cities, the city of Munich has few private gardens because fewer than 2% of households possess an own garden. In Cologne, Nuremberg, Hamburg, and Dortmund, 2% to 4% have a small garden; in Bremen and Hannover 6% - 8%; in Dresden 10%; in Halle and Leipzig 11%; and in Magdeburg more than 11% have a garden.[506] [507]

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[506] Appel, I., Grebe, C., Spitthöver, M. (2011): Aktuelle Garteninitiativen. Kleingärten und neue Gärten in deutschen Großstädten. Kassel 2011

[507] Universität Kassel: Aktuelle Garteninitiativen. http://www.uni-kassel.de/upress/online/frei/978-3-86219-114-7.volltext.frei.pdf. Retrieved on 17.7.2017

In Munich, there are 80 municipal allotment gardens, as well as gardens of the rail-agriculture union, of the state and private facilities with a total of 8,425 tenants (Schrebergärten). Between 1984 and 2005, a total of 952 allotment garden plots were redeveloped, i.e., each year, an average of 45 plots.[508] Munich citizens' demand for small gardens is still high, and there are long waiting lists. In recent years, a change in the age structure among users could be noticed because, unlike in the past, it was not only retirees who wanted to have their own plots for gardening activities, but also many families with children. Therefore, about 60 hectares are reserved for the future development of small gardens in the zoning plan with integrated landscape planning. In addition, in order to create more parcels, the city of Munich has started dividing large lots and creating plots with a target size of 200-250 m².

Although Munich has the fewest allotments per inhabitant after Stuttgart and is the German city with the highest land prices and rents, it places a high importance on the preservation and further development of allotments. Besides the traditional Schrebergarten, open spaces for gardeners in a densely populated city like Munich are scarce. Therefore, an important goal of the municipality is to provide the residents of multi-story houses with green areas as tenants' gardens, like the unused space in the Messestadt Riem where a "Green Workshop" (Grünwerkstatt) has been established. The workshop advises and supports initiatives that use this land for horticultural activities.[509]

Cooperation with Guerilla Gardeners

There is also an official cooperation between the Department for Building and Horticulture (Baureferat) and the Guerrilla Gardeners Munich, as well as the Green City e.V. for the cultivation of potential green areas along roads. The

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[508] Referat für Stadtplanung und Bauordnung: Urbanes Gärtnern in München. Analyse und Grundsatzbeschluss. München 19.2.2014, p. 10

[509] ibid.

Building Department "provides to 'Green City' the necessary plants and helps them with the planning and selection of appropriate species for the sites. The subsequent maintenance by the 'godparents' (Green City) mainly includes regular watering, weeding and cleaning, and informing passersby to pay attention to the planted areas. In addition to the greening and beautification of streets, the promotion of social contacts in the quarter is an important goal of these projects."[510]

School and Therapy Gardens

The Pedagogical Institute in Munich, as well as the Network School Gardens Munich e.V. and the Department for Building and Horticulture, support the supervisors of school gardens with information and training activities. In addition, the Munich Child and Youth Farm e.V. offers two Youth Farms for school classes and children from the neighborhood who can acquire basic knowledge in these vegetable gardens.

Furthermore, in the seven Herb Gardens (Krautgärten) of the city of Munich, plots are assigned to kindergartens, schools, senior groups, and therapy facilities, an offer that is used extensively. Since the high therapeutic value of working with plants and animals has long been recognized in medical and elderly care, the Horst Salzmann Center (AWO Munich) has created a 3,000 m^2 garden with raised beds and fish ponds for cultivation by senior citizens and geronto-psychiatric patients, as well as raised beds where wheelchair users can exercise horticultural activities and look at the plants at eye level.[511]

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[510] Referat für Stadtplanung und Bauordnung: Urbanes Gärtnern in München. Analyse und Grundsatzbeschluss. 19.2.2014, p. 24

[511] AWO Horst-Salzmann-Zentrum. https://www.awo-muenchen.de/senioren/seniorenwohn-und-pflegeheime/einrichtungen-in-ihrer-naehe/horst-salzmann-zentrum-neuperlach/ueber-uns/. Retrieved on 30.8.2017

Participatory Community and Intercultural Gardens

In Munich there are now 13 intercultural gardens that successfully serve as meeting places for people of different nationalities and backgrounds. Some of them have certain admission criteria and focus on special groups of participants, like the neighborhood garden in Berg am Laim, the multi-generation garden in Milbertshofen, the bee-garden in Hadern, or the intercultural women's garden in Englschalking, but most of them are open to everyone.[512]

Roof Gardens

The Munich City Council considers the development and sustainable use of roofs an important resource for the future which can be used for the ecological, economic, and social benefits of residents. Here, solar systems for the production of renewable energy can be built as well as multiform spaces for recreation and gardening activities. Green roofs help improve the air quality; they balance extreme temperatures in the city and can also extend the lifespan of roofs. As far as the static capacity is assured and security conditions are in place, raised beds are an ideal solution for flat roofs, and sandboxes or playgrounds can be installed in conjunction with other community areas, too.

Common gardening and recreational activities are considered as an ideal option for commercial and municipal buildings whose roofs are well suited for this purpose. In addition to the possibility of cultivating food and flowers, roof gardens improve the building climate because the plants act as a filter for contaminating particles and as an acoustic barrier, and to a certain degree, they help prevent

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[512] Bewohnergarten an der Gotteszeller Straße (Berg am Laim), Interkulturelle Frauengärten (Englschalking), Waben-Garten, (Englschalking), Bienengarten (Hadern), Kulturgarten (Hadern), Interkultureller Garten München-Lochhausen (Lochhausen), Generationengarten (Milbertshofen), Internationales Gartenprojekt „Treffpunkt Garten“ (Neuaubing), Münchner Garten der Kulturen e.V. (Neuhausen), O'pflanzt is! Interkultureller Nachbarschaftsgarten (Neuhausen), Zusammen aktiv in Neuperlach (Neuperlach), Interkultureller Nachbarschaftsgarten am Ackermannbogen (Schwabing), Interkultureller Garten an der IG Feuerwache (Schwanthalerhöhe). Urbanes Gärtnern in München. Analyse und Grundsatzbeschluss. Referat für Stadtplanung und Bauordnung, 19.2.2014. p. 20

flooding in the streets. Because of the environmental and social advantages of cultivated roof gardens, the Munich Department of Building sees many opportunities to design flat roofs in holdings and newly developing areas of the city.

Micro-gardens

The smallest type of garden can mostly be found in the form of containers on terraces, balconies, patios, or private rooftops. Such micro-gardens can easily be managed by almost anyone – women, men, children, elderly people – and they can be highly productive.[513] Intensive micro-garden cultivation is especially suitable for cities because it uses environment-friendly technologies such as rainwater harvesting and household waste management. If there is no soil or land available, micro gardens can be created with all kinds of containers and substrates consisting of local materials, such as glass wool, lava stones, brick chippings, sawdust, and recycled plastic fibers.

The Agropolis Concept

The Department of Urban Planning and Building Regulations of Munich is currently planning the new district Freiham on an area of 350 hectares, where 20,000 inhabitants will live and 7,500 people will work in the future. A compact, green, urban residential area will be built on about 190 hectares and consist of a community center, an educational campus with a sports park, and 8,000 apartments neighboring a 55-hectare landscape park. Various neighborhoods with different types of houses for families, single people, and seniors with high environmental standards are meant to enable different working and living models

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[513] FAO studies have shown that a micro garden of one square meter can produce either 30 kg of tomatoes per year or 100 onions every 120 days or 10 cabbages every 90 days or 36 lettuces every 60 days. Food and Agriculture Organization of the United Nations: With micro-gardens, urban poor "grow their own". http://www.fao.org/ag/agp/greenercities/en/microgardens/. Retrieved on 13.7.2017

and to encourage the inhabitants to pursue social communication and participation.[514]

The Agropolis concept won the first prize in an urban development and landscape-planning competition for the first phase of realization which called for innovative proposals to create opportunities for the population to meaningfully connect nature and urbanity.[515] Here, the main challenge was the creation of a public sphere in a development on Munich's last "green meadow," which allows an urban atmosphere with diversity, spatial orientation, and residence for active and lively neighborhoods that identify themselves with the new part of the city.

The future citizens of Freiham should live in Munich and, at the same time out in the country, thus enjoying the advantages of both the urban variety and the close proximity to nature. By considering all aspects of a future-oriented, sustainable city design and ecological approach, a sophisticated architecture should be implemented in the sense of a compact city comprised of residences and working places, ground floor zones, mobility systems, and social inclusion.

Innovative designs of higher construction densities for short commuting distances, multi-purpose roof-landscapes, and attractive private and public open spaces were supposed to be essential elements of Freiham as a compact and green "garden city," similar to Ebenezer Howard's garden concept from the 19th century.[516] The new city district should be completely integrated into green areas, and gardens shall be fully integrated into the compact urban structure. Additionally, there should be private gardens, community gardens, Krautgartens,

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514 Stadt München: Freiham. https://www.muenchen.de/.../2017_Sustainable%20Freiham.pdf. Retrieved on 26.9.2017

515 Stadt München: Planungsreferat Werkbericht. https://www.muenchen.de/rathaus/dam/jcr:a4133074-5032-46af-a411-532d41191754/LHM_Planungsreferat_Werkbericht14_RZ_ENG.pdf. Retrieved on 29.9.2017

516 Landeshauptstadt München, Referat für Stadtplanung und Bauordnung (ed.): Freiham. München 2014

and roof-top gardens for self-harvesting, as well as mobile supermarkets and plant nurseries.

By focusing on the promotion of self-cultivation and a sustainable use of land resources, Agropolis as a model project also aims to stimulate a metropolitan food strategy that provides users and operators direct experiences in the production of healthy food. For this purpose, the areas in Freiham should be used for temporary ecological farms between the building phases, which were able to move forward according to the progress in the building sector.

As a combination of urban agriculture and urban gardening, growing vegetables and fruit on roof tops was planned as an intermediate or long-term use by both professional gardeners as well as residents.[517] These farms should produce, process, and market their own products and, at the same time, act as a communicative and participatory platform for the citizens.[518] Under the motto “the rediscovery of harvesting in everyday urban life,” educational and training programs should be offered for self-cultivation, harvest, and processing in order to convey experience and skills in producing one’s own food. After the completion of Freiham, the remaining areas of the farm should continue to be used for urban agriculture and complement the roof gardens and backyard fields. The fresh products should be transported daily with a new tram, the “Viktualien-Tram” from Freiham, toward the center of Munich where they could also be sold directly to the customers at individual stops.[519]

In sum, the Agropolis Concept is characterized by valuable synergies between high living and residential quality, modern urban development, and technical infrastructure. All aspects of sustainable and ecological planning were taken into

[517] Referat für Stadtplanung und Bauordnung, Beschluss der Vollversammlung und des Stadtrates vom 19.2.2014
[518] Agropolis München. https://www.agropolis-muenchen.de/index_de.html. Retrieved on 10.9.2017
[519] Detail: Münchner als Landwirte. http://www.detail.de/architektur/tehemen/agropolis-muenchner-als-landwirte-000903.html. Retrieved on 24.9.2017

account in order to maximize the attractiveness of the new city district and serve as a showcase project for further sustainable developments.

Unfortunately, the original plan could not be implemented. Agropolis, as an ideal ecological model for the integration of urban agriculture in future urban developments, was conceived by a team of architects without the participation of engaged citizens. As operators of urban agriculture, they were not involved in the concept development and planning phase. A Seed-Scale and Emergence process could not develop in this way, because that would have required the commitment of motivated Freihamer citizens. As confirmed by the authorities, there was no lack of exciting ideas and interest, but there was a lack in terms of time, money, public support and feasibility, mainly because of the missing leading individuals who invested their personal energy. Therefore, Agropolis has remained just a collection of ideas. Only a small part of the concept, such as mobile gardening on the land according to the development plan, an open-air supermarket, and the installation of roof gardens on the apartments have been realized.

Another interview was conducted with the Munich Municipal Department (Stadtgüter). This conversation was mainly about the so-called "Krautgartens," in which Munich plays a pioneering role, as it has many compensation areas and a good stock policy.

In 1999, the first Munich Krautgarten was opened as a pilot project in the field of a farmer in Johanniskirchen. In subsequent years, two more gardens were created in Trudering and Riem, and they allow all interested citizens to grow vegetables, flowers, and herbs for their own use. In addition to the known integrative, educational, and social objectives, the state capital wishes to intensify cooperation with green-belt farmers and promote the shift towards sustainable agriculture. Since the Krautgartens are in close proximity to the city or located on the outskirts, they also represent an easily perceived contribution to climate protection that enjoys a high degree of acceptance among the population. The great popularity of the Krautgartens led to large demand for such plots, which caused the Department of Urban Planning and Building Regulations to decide that, every year, a new Krautgarten site should be developed.

Currently, there are 19 Krautgartens in Munich with approximately 1,300 plots of 30-60 m². The principle is the same in all gardens. In the spring, the farmer sows and plants on his area of arable land, whereas partial areas remain free for planting according to the wishes of the Krautgardeners. From May to November, the Krautgardeners are responsible for maintaining and harvesting, and all organic farming has to be done without artificial fertilizers, pesticides, and fungicides. The contracts with the active Krautgardeners are reassigned for every gardening season, so that on the one hand the gardeners remain flexible in their commitment and, on the other hand the farmer receives a secure income by providing his land at the beginning of the season.

The advantages of these herb gardens are that the organic vegetable garden is fully prepared and planted with regional vegetable varieties. The gardeners do not enter into a multi-year commitment and can harvest fresh, organic vegetables with only a few hours of work per week throughout the season. Based on a close partnership between city dwellers and farmers, the Krautgarten concept is a cost-effective way to implement a close collaboration between urban farmers and the farmers who own the arable land. After the gardening season, the farmer resumes the preparation of the soil for the next season. The farmer has the advantage that the tenants pay for the area and not for the harvest, and he receives the rent in the spring. Thus, the risk of harvesting posed by weather events and pests lies with the hobby gardener who has to undertake the labor-intensive control of the weeds himself, in which the farmer advises him.

The success of Munich's Krautgartens has inspired many other cities in Germany to initiate similar projects. In order to guide the further development of new

Krautgartens, the Munich Department helps with the planning and land selection while seeking an even distribution of the sites on the urban fringe, including a special priority supply to locations with increased social demand.

8.2.4 Expert Interviews

8.2.4.1 Volkmar Keuter, Head of Fraunhofer inHaus Center, Group Manager Urban Production, Fraunhofer UMSICHT Institute

As one of the pioneers of integrated food production in Germany, the Fraunhofer UMSICHT Institute has developed the inFarming concept which connects urban farming with the flexible use of material and energy flows in metropolitan regions. The goal of the inFarming concept is to show that the cultivation of special greenhouses on the roof or on facades can provide a resource-conserving and area-efficient horticultural option. In order to obtain more information about this concept and about the general approach of the Fraunhofer UMSICHT Institute towards urban agriculture, Mr. Keuter was asked about the reasons for and benefits of food production in metropolitan regions. Other questions in this semi-structured interview concerned the specific characteristics of building-integrated agriculture and the potential of urban farming for improving the sustainability and resilience of cities.

According to Dr. Keuter, urban horticulture is not only an important topic for megacities. It is equally significant for almost every city in Germany, regardless of its number of inhabitants. If vegetables are cultivated directly in the vicinity of the consumer, no long transports are necessary, the environment is spared via lower CO2 emissions, and the consumer has the advantages of obtaining fresher, better quality goods at stable prices. In addition, many old varieties of vegetables could be grown that are not suitable as an international import product.

Local, building-linked food production can be a profit-oriented, efficient farming method if it uses a closed production cycle. Urban greenhouses allow year-round cultivation, use only biological plant protection, and maintain consistently high quality. By using hydroponic modular systems with low weight, they achieve 10-20 times higher revenues than ground-based agriculture. In peri-urban flat roofs, these greenhouses can use the building heat, rain, and purified waste water for operation. The supply of electricity can be secured by photovoltaic systems. In this way, rooftop farming on 1,000 m² can produce around 45,000 kg of vegetables per year and bind eight tons of CO_2.

Despite all these impressive advances in inFarming technology, Dr. Keuter expressed his skepticism about the concept of resilience because, in his opinion, even the concept of sustainability is not yet fully dispersed among the population. In his view, many people simply do not want to confront the issues of sustainability and resilience. As far as food production is concerned, there is a lack of transparency towards the public. Therefore Dr. Keuter advocates the creation of many social, participatory urban gardening projects that may lead to a change of awareness in society.

Without explicitly mentioning the Seed Scale and Emergence Process, Mr. Keuter nevertheless lists the necessary conditions for the success of the InFarming concept. Here, too, the public and especially the residents concerned must be informed in detail about the possibilities, for example, of urban gardens on flat roofs. Ideally, this happens when a new building is planned or an existing building is planned to be converted. Only the involvement of the future users creates the basis for a fruitful exchange of thoughts and ideas, sustainable motivation and the application of environmentally friendly cultivation methods. With a nucleus of InFarming houses and gardens, an upscaling process can emerge that leads to local and supra-regional communities.

8.2.4.2 Philipp Stierand, Author[520] [521] [522], Blogger, and Spatial Designer

The blog “Speiseräume“ is an online magazine on municipal nutrition policy and urban nutrition planning. It develops ideas and strategies for a sustainable urban food supply and promotes concepts for the debate about healthy nutrition. For the cognitive interest of this study, the author asked Mr. Stierand about the social benefits of urban agriculture for society and the measures necessary for a more resilient urban food system. How can cities take more responsibility for their food supply rather than leaving it entirely to the market? In this context, it was also asked which tasks should and could be controlled by the nutrition councils Philipp Stierand propagates.

According to Stierand, urban agriculture is a social glue that brings people together and promotes social participation by creating living communities and neighborhoods. For the general public it provides communal, well-kept green areas and offers opportunities for individual development. Urban agriculture also acts as a spatial designer and mobilizer because the production of food in urban areas concerns space acquisition and personal engagement. The empowerment of the urban gardening movement allows citizens to experience new working and living forms as well as a better quality of life.

In order to create more awareness of the importance of healthy nutrition and sustainable food production, more local garden projects should be initiated and promoted, possibly with European political support programs. According to Stierand, today’s food system is de-localized, and the city has lost control over

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520 Stierand, P. (2014): Speiseräume. Die Ernährungswende beginnt in der Stadt. München 2014

521 Stierand, P. (2016): Urbane Wege zur nachhaltigen Lebensmittelversorgung. Potentiale und Instrumente kommunaler Ernährungspolitik. In: Steven Engler, Oliver Stengel, Wilfried Bommert (eds.): Regional, innovativ und gesund. Nachhaltige Ernährung als Teil der großen Transformation, pp. 117-136

522 Stierand, P. (2012): Stadtentwicklung mit dem Gartenspaten. Umrisse einer Stadternährungsplanung. https://speiseraeume.de/downloads/SPR-Stadternaehrungsplanung-Stierand.pdf. Retrieved on 4.2.2018

its food security and supply. The local retail is made up of national, multi-branched systems for which the individual city as a place of consumption or production is completely interchangeable. In contrast, regional food systems can regain influence on the food supply, strengthen agriculture, and protect the environment. They give consumers safety and provide product knowledge, i.e. they create nutritional competence with consumers.

Stierand is convinced that the global food system is resilient and that the greatest threat to a city's resilience comes from producing oligopolies. Nonetheless, cities should invest in sufficient stockpiling in order to reduce their vulnerability to nutritional bottlenecks of any origin.

The tasks of a nutrition council are to create and disseminate information about the food system for all citizens with the aim of anchoring the food system with its peculiarities, effects, dangers, and opportunities, in everyone's consciousness. As local platforms, they are well suited to address necessary changes in the urban food system by connecting consumers, local food producers, and environmental and health experts. In this sense, a nutrition council can be the ideal forum to discuss and evaluate economic, cultural, health, and sustainability issues with regard to a more sustainable city development.

The advantages of a Nutrition Council as a local platform for communication and connection between consumers and ecological food producers are important for the development of upscaling structures in terms of the seed scale and emergence approach. Individual initiators or associations are offered numerous options for networking and cooperation from which citizens and city administration benefit equally. Another important benefit is the professional advice and training organized by the Nutrition Council, which is essential for individual entrepreneurial initiatives to contribute to a more resilient urban food system.

8.2.5 Urban Gardens in Germany: Interviews and On-Site Visits

8.2.5.1 Various Garden Profiles

The author of this study conducted interviews with managers of garden projects in Ulm (Neunkirchengarten, Quartiersgarten), Cologne, and Heidelberg; these were designed as semi-structured interviews, and brief notes were taken to help remember them. Immediately after the interviews, the author recorded his notes in writing from memory. The aim of these interviews was to determine to what extent these gardening projects had a genuine origin in the inhabitants of the respective districts, which objectives the initiators pursued, and by what means their ideas were implemented. Another goal was to investigate the resonance in the neighborhood of these garden projects and learn about the profiles and motivation of the hobby gardeners involved.

Other topics in the conversation related to the characteristics of the community garden, such as location, legal status, management, and cooperation with the authorities. Costs, types of cultivated products and cultivation method and the time spent by amateur gardeners in the garden were also the subject of the conversation.

Neunkirchengarten in Ulm[523]

The idea for the Neunkirchen community garden came from a school project in the 11th class of a local college and then developed into a working group of 150 people within their neighborhood. The goal of the collaborative project is to slow down everyday life and overcome the separation from nature.[524] In support of this project, the Green Space Department (Grünflächenamt) of the city of Ulm

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[906] Urban Gardening Ulm. http://urban-gardening-ulm.de/. Retrieved on 17.10.2017
[524] ibid.

provided a small area of 100 square meters with a free usage contract of two years, which could be extended repeatedly. The management of the garden, which was founded in 2013, is the responsibility of the work group, which is open to everyone.

The garden is not mobile and consists of traditional flowers and vegetable beds. Additionally, herbs, strawberries, wolfberry, goji berries, sloe, and barberry are organically cultivated, and the gardeners themselves decide what to grow. Modern agricultural techniques, such as vertical farming and aquaponics, are known but were judged as not suitable for such a small project. Instead, the participants prefer a traditional garden. Most of the hobby gardeners spend about three to four hours per visit in the garden and participate in regular workshops and barbecue meetings.

The garden community currently pays a small lump sum for water access to the city, but all other costs, primarily for water and seeds, are covered by donations and private funds. The products, which are intended exclusively for the gardeners' own consumption, are cultivated on the existing soil and on purchased soil. The necessary seeds and seedlings are bought at the hardware store or the nursery.

The project provides important knowledge of food production as well as healthy vegetable nutrition. Moreover, the garden project creates a vibrant, inclusive community that consists of people from different social and ethnic backgrounds. For a continuous exchange of experience, the working group also has connections with other activists and project operators. Overall, the garden enjoys a positive response from the neighborhood and is particularly popular with families with children.

The work group attaches high importance to urban agriculture for urban life, especially with regard to regional food supplies, food security, social benefits, and the improvement of the urban climate. It is therefore the group's wish that, in the future, more and possibly financially supported urban gardens with larger planting areas will be created to further contribute to the unsealing of cities.

Quartiersgarten in Ulm[525]

The idea for this project came from its coordinator, who worked as a district manager in the poets' quarter (Dichterviertel) and requested state funding together with the Rehabilitation for Youth, Welfare, and Social Work in Ulm West (Sanierungstreuhand Ulm and the AG West). Starting with its first gardening season in 2018, cucumbers, tomatoes, squash, pumpkins, and carrots have been grown for the self-consumption of the gardeners on a paved parking lot behind the train station in the poets' quarter. Great emphasis is placed on organic vegetable cultivation without pesticides and artificial fertilizers. The offer to become actively engaged is aimed at all residents, regardless of age or nationality.

The Ministry of Economics, Labor, and Housing Construction (Ministerium für Wirtschaft, Arbeit und Wohnungsbau) supports the project with € 66,000, and a gymnasium also participates, as do the Spanish Association and the Treatment Center for Tortured Victims. At first, the initiators had to convince the city of Ulm that community gardens were necessary and useful. The community garden project is coordinated and accompanied by a team of staff that consists of three employees and one trainee.

The project area is initially free for five years, and the money for gardening, seeds, soil, plants, and raised beds comes from donations and the personal resources of the hobby gardeners. As the approximately 500 m^2 parking area

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[525] Quartiergarten ULM. https://www.quartiersgarten-dichterviertel-ulm.de/. Retrieved on 11.11.2018

remains sealed, nesting aids for birds and insects have been installed, and the plants are grown in sacks, pallets, containers, and raised beds.

In addition to the common gardening activity and regular gardener meetings, parties and common events like shared cooking and beekeeping take place there. The new project has received overwhelming support from the population. The interested parties come from all walks of life, often the elderly, who used to have a garden themselves but could no longer manage it alone. Important aspects in the concept of the redesigned poets' quarter neighborhood are coexistence with the neighborhood, socializing, and becoming familiar with the social environment. With new roads, parking lots and new sidewalks, public and private space will merge, and residents are encouraged to relocate part of their lives outside.

Edible Heidelberg (Essbares Heidelberg)[526]

The origin of this project lies in the participation in the study initiative "Greening the University" in Tübingen and the urban garden projects in Berlin and the Edible City Andernach approach,[527] which served as a role model. The stated aim of the non-profit organization is to demonstrate that, even within the city borders, green islands can be created for edible plants while improving the city's carbon footprint. Additionally, local self-sufficiency should be increased, and knowledge about sustainable development and nutrition should be conveyed through workshops, lectures, and guided tours. To this end, a constant exchange of experience and cooperation with other environmental initiatives and local institutions is conducted.

In January 2013, the non-profit association Edible Heidelberg received the first bed of private property in Heidelberg-Rohrbach. Private owners and the allotment

[526] Essbares Heidelberg. www.essbaresheidelberg.wordpress.com. Retrieved on 2.12.2017

[527] Stadt Andernach. Essbare Stadt. http://www.andernach.de/de/leben_in_andernach/essbare_stadt.html. Retrieved on 2.12.2017

garden association helped with advice, and the group was able to produce seedlings itself. For the large garden (250 m^2) the city gave a contract of use in 2014, according to which the association only has to pay for the water used, but not for a lease.[528]

Image 5 – Urban garden in city center of Heidelberg, author's study trip in 2017 (1/2)

[528] Ecoguide. https://www.ecoguide.de/gemusebeete-in-der-stadt-initiative-essbares-heidelberg-sucht-mithelfer/. Retrieved on 11.11.2018

Image 6 – Urban garden in city center of Heidelberg, author's study trip in 2017 (2/2)

The Edible Heidelberg Club currently consists of 15 members who take care of five gardens, including a small neighborhood bed, flower and vegetable beds at a refugee camp, a planted car park, a new garden under construction, and a large communal garden. The gardens are not mobile, except for a few beds. Modern technologies, such as vertical farming and aquaponics, are considered as interesting, future-oriented technologies, and the association has already performed its first permaculture experiments.

The products (zucchini, cucumbers, tomatoes, salads, beets, fennels, bush beans, chilies, and much more) are not sold but are consumed by the gardeners and visitors. The gardeners usually spend one to three hours per week in the garden. Open garden meetings are held twice a week, in which residents are also involved, as are kindergartens and schools. Additionally, the Edible Heidelberg Club offers garden tours, book events, exhibitions, tent festivals, seeding actions, webinars, and bike tours. The response to the gardens and events is extremely positive among the neighborhood and in the public press. Urban gardening is seen as a movement that has already triggered a change in the mainstream relationship between nature, farming, food, and consumption.

Kölner Neuland e.V.[529]

The original idea for the community garden came from a guerrilla action to embellish a fallow land in the neighborhood and a flash-gardening mob of 200 people. Since 2008, the citizens of the neighboring district had lived with the sight of this neglected urban area in Köln-Bayenthal which belongs to the construction and real estate business of the state, Nordrhein-Westfalen. The entire fallow area is about one hectare in size, and an urban garden project was the ideal solution for intermediate use until the beginning of the construction activities. In 2011, the association Kölner Neuland e.V. was founded with the aim of promoting education, environmental and nature conservation, and civic engagement through a meaningful interim use of this fallow area.

The project is managed by the association Kölner Neuland e.V., which pays the costs for insurance, seeds, tools, toilets, and water infrastructure with the generated income for the individual beds (€24 per year). The garden is financed almost entirely through these revenues, as well as by funding and donations, and it does not aim to make any profit.

In order to keep the garden mobile and flexible when the area is built, everything is planted in movable boxes, buckets, and sacks. Most of the mobile containers belong to everyone and are cared for by the community. There are also plots that gardeners can plant individually, and where half of the products are for the gardener, while the other half belongs to the community.

[529] Kölner Neuland e.V. www.neuland-koeln.de. Retrieved on 2.11.2017

The garden is operated with up- and recycled elements according to the principles of organic farming. Since the soil is contaminated with pollutants that could also enter the air, the Cologne Environmental Department (Umweltamt) has required the application of a 10-cm thick protective layer of pollutant-free brick sand on top. In the mobile raised beds, tomatoes, strawberries, lettuce, herbs, beans, rice, and soybeans, are grown, which the gardeners consume themselves.

On average, the participants spend two to three hours per week in the garden. Much of the work is performed jointly, such as the production of seed boxes, the production of seedlings, the care of the terrain, and the construction of the water infrastructure. Additionally, all participants can enhance their knowledge of cultivation, sustainability, and related topics in one of the following workshops: children and environmental education, bees, irrigation, eco-gastronomy, permaculture, herbs, refugees, botany, and composting.

The Kölner Neuland e.V. is integrated into the framework of the Edible City of Cologne Initiative, which is currently organized in workgroups on the WECHANGE project platform.[530] There are workgroups on the following subject areas: edible public greens, community gardens, allotments, orchards, social and educational institutions, company gardens, participatory agriculture, biodiversity and urban development, and gardening on private land. In the summer season, a weekly "gardening with a contact person" is offered, as are garden consultations with professional biologists, who provide information about ecological gardening.

The garden is well accepted by the neighborhood as the former fallow land now contributes significantly to the beautification of the city quarter. There are always

[530] WeChange. https://wechange.de. Retrieved on 2.11.2017

many guests in the garden who enjoy guided tours and informative events on ecological food production and the importance of regional products. The Cologne Neuland e.V. association is well networked among other activists and project operators and wishes to become accepted by the city as a competent partner in its green and environmental education planning.

8.2.5.2 Urban Gardeners' Profile

The answers concerning the urban gardeners’ profile and their motivation to participate in a community garden project were similar in all four interviews. The founding idea of all four gardens came from committed citizens who wanted to beautify their district and create a garden for themselves and their fellow citizens on unused brownfields. Most of the participants in community gardens were women, frequently single parents with children and low incomes. Another group of clients were parents with several children, low-income residents, and those seeking asylum. The majority had no balcony, terrace, or garden where they could practice gardening as a hobby. It is interesting to note that many of the community gardeners come from groups who, historically, have not had close connections to agricultural activities, such as musicians, artists, authors, and architects. For this clientele, urban gardening is not a function of subsistence or food security, but rather an activity of socio-cultural, environmental, therapeutic, recreational, and educational value.

The motives for community gardening are the people’s interest in contact with their neighbors, community spirit, a space for children to play and learn gardening, and the possibility of self-supply with healthy, fresh fruits and vegetables. Since most of the gardeners are beginners with no gardening skills, training programs and accompanying counseling are the prerequisites for the success of the community garden.

Just about all of the amateur gardeners had high demands for the quality of their food and preferred fresh, organic products, which they learned to cultivate themselves. In addition, practically all the gardeners were convinced that their outdoor gardening activity considerably contributed to their personal health and led to a certain degree of independence from the food industry. In this context, it is important for the participants that these gardens serve as a meeting point for like-minded people regarding healthy, organic nutrition and nature conservation. Workshops, common cooking and dinners, seminars, and social events are popular among the gardeners, who consider these joint activities a way to escape the anonymity of city life by shaping the living environment in their own quarter.

8.2.5.3 Evaluation

The Seed-Scale and Emergence Approach, which focuses on human initiative and activity, is particularly suited to the system-structural evaluation of the results. The phenomenon of urban gardening and the emergence of urban gardens on brownfields, public areas, and private areas is primarily based on human creativity and energy that manifests in individual creativity, cooperation, and common learning. Single individuals or smaller groups initiate appropriate processes for basic needs and community empowerment, as well as suitable solutions for the local environmental design.

The results of the interviews with the managers of the individual garden projects clearly show common characteristics in the sense of a seed scale and emergence process. Networking with other projects and with the municipal authorities developed particularly well in the urban gardens visited. All urban garden projects studied in this investigation had their seed-start at the local level, and feedback loops of success used a scaling-up process that integrated more and more participants into the project. The prerequisites for this scaling-up development in urban gardening projects are active communication and networking of like-minded people who have the capacity for self-organization, adaptation through learning-by-doing, and feedback. All of this is done on the basis of perceived community assets, capacities, and abilities with egalitarian management and without strict rules. Since all individual local garden initiatives are linked by information and cooperation networks, new community projects can emerge at a higher level of scale with far greater influence than the founding group.

In all four garden projects, there were strong similarities regarding the answers in the semi-structured interviews:

- On average, participants spent about three hours per stay in the garden.
- The gardeners themselves, individually or in groups, decided which vegetables or fruits they wanted to grow and consumed their home-grown products themselves or together with other gardeners.
- Organic farming was practiced in all gardens.
- The horticultural activities are low-cost, as were water and the purchase of soil and seeds.
- The workshops, courses, seminars, and lectures offered were very popular with gardeners and external visitors alike.
- Participants were recruited from all social classes and occupational groups.
- Unanimously, participants wanted more community gardens in their city and cooperation and consultation with city authorities on the further de-sealing of urban land or use of fallow land.

The reasons to participate in a community garden were described as follows:

- The beautification of the district through an attractive use of fallow land
- Opportunities to create new social practices and acquire horticultural knowledge
- Opportunities to spend leisure time with the whole family
- The desire for a healthy diet with fresh fruits and vegetables
- The health-promoting effect of hobby gardening
- The protection of nature and an improvement of the air.

8.2.5.4 Discussion

Publications on urban agriculture are numerous, but so far, there are few interviews with urban gardeners or initiators of urban garden projects. Lin Ying-Tzu[531] conducted semi-structured interviews with 12 participants from three urban gardens on public grounds in Amsterdam for her case studies. Her key finding is that urban farming is an alternative tool for improving urban quality of life by creating opportunities for recreation, education, and sustainable leisure activities. Numerous researchers have reached similar conclusions, only a few of which are listed as exemplary because they do not contain interviews.[532] [533] [534] [535] [536]

When citizens expand their day-to-day activities into public spaces on their own initiative and interact with members of their neighborhood at the same time, according to Lin, they change their city and their living conditions. In the sense of a seed-scale and emergence spill-over, this process can affect other citizens who claim and exercise their "right to the city" both individually and as a community.

Lin understands this "right to the city" as defined by Harvey[537] as "a right to change ourselves by changing the city. It is, moreover, a common rather than an individual right since this transformation inevitably depends upon the exercise of a collective power to reshape the processes of urbanization. The freedom to make and remake our cities and ourselves is, I want to argue, one of the most

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[531] Lin, Ying-Tzu (2017): Farming the Right to the City: Case Studies of Community-based Urban Farming on Micro-urban Public Space in Amsterdam. www.sustasis.net. Retrieved on 5.11.2018

[532] Hou, J., Johnson, J., Lawson, L.J. (2009): Greening cities, growing communities: learning from Seattle's urban community gardens. Landscape Architecture Foundation. Washington, D.C. 2009

[533] Knight, L., Riggs, W. (2010): Nourishing urbanism: a case for a new paradigm. In: Pearson, C. et al. (eds.): Urban agriculture: diverse activities and benefits for city society. Routledge 2016

[534] Clauzing, N., Clauzing, H. (2016): Urban farming. Tiel (NL) 2016

[535] Licka, L., Lohrberg, F. (2015): Urban Agriculture Europe. Berlin 2015

[536] Rosan, C., Pearsall, H. (2017): Growing a Sustainable City? The Question of Urban Agriculture. Toronto 2017

[537] Harvey, D. (2012): Rebel Cities. From the Right to the City to the Urban Revolution. London, New York 2012

precious yet most neglected of our human rights." [538] In this sense, according to Lin and Scheromm,[539] the collective operation of urban gardens aligns with the principles of participatory democracy while improving security and social cohesion in neighborhoods.

Gardening is a popular activity, especially among the older generation. Studies from Park et al.,[540] Armstrong,[541] Nicklett et al.,[542] and Soga et al.[543] have shown that moderate gardening has beneficial effects on cholesterol, blood pressure, mental well-being, and overall mortality. Cormack et al.[544] and Boeing et al.[545] have interpreted these effects as the results of an effective but moderate physical activity as well as a shift of the dietary intake toward more fresh fruits and vegetables.

Among the motives for participation in community gardens and the benefits of urban agriculture, the results of the interviews in this study coincide with those of the interviews conducted by Mamar[546] with Irene Nitsch from the environmental

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[538] Harvey, D. (2012): The right to the City. https://davidharvey.org/media/righttothecity.pdf. Retrieved on 20.10.2018

[539] Scheromm, P. (2015): Motivations and practices of gardeners in urban collective gardens: The case of Montpellier. Urban Forestry and Urban Greening, 14(3), pp. 735-742

[540] Park, S. et al. (2008): Gardening Provides Recommended Physical Activity For Older Adults. https://www.sciencedaily.com/releases/2008/12/081229104702.htm. Retrieved on 10.5.2019

[541] Armstrong, D. (2000): A survey of community gardens in upstate New York: implications for health promotion and community development. https://www.ncbi.nlm.nih.gov/pubmed/11027957. Retrieved on 10.5.2019

[542] Nicklett, E. (2016): Gardening Activities and Physical Health Among Older Adults: A Review of the Evidence. J Appl Gerontol. 2016, 35(6): pp. 678–690. doi: 10.1177/0733464814563608. Retrieved on 10.5.2019

[543] Soga, M. et al. (2016): Gardening is beneficial for health: A meta-analysis. doi: 10.1016/j.pmedr.2016.11.007. Retrieved on 12.5.2019

[544] McCormack, L.A. et al. (2010). Review of the nutritional implications of farmers' markets and community gardens: A call for evaluation and research efforts. Journal of the American Dietetic Association, 110(3), pp. 399–408. https://doi.org/10.1016/j.jada.2009.11.023. Retrieved on 4.3.2019

[545] Boeing, H. et al. (2012): Critical review: Vegetables and fruit in the prevention of chronic diseases. European Journal of Nutrition, 51(6), pp. 637–663. https://doi.org/10.1007/s00394-012-0380-y. Retrieved on 3.3.2019

[546] Mamar, A.-M. (2017): Grüne Freiräume für München. Ein Interview mit Irene Nitsch von der Umweltorganisation Green City e.V. über Geschichte, Probleme und Formen des Urban Gardening in München. 13. Oktober 2017. http://www.journalistenakademie.de/dossiers/eigensinn/urban-gardening-green-city/. Retrieved on 21.10.2018

organization Green City e.V. and those of Vehreschild[547] with Christa Müller. For the urban population, it is increasingly important to acquire a degree of food sovereignty, to grow organic vegetables, and, at the same time, to contribute to improving the air quality in the city: “Every square meter of green contributes to the stabilization of the city's climate.”[548] In a similar context, Müller[549] [550] notes in her interview that cooperation with nature and a new philosophy of life of "do-it-yourself" are some of the main motives for the growing trend of urban agriculture. Urban gardens are ideal meeting places for people of all ages and backgrounds to share and exchange knowledge about healthy nutrition, seed production, and organic farming methods.

The same motives, but with a slightly different weights, were also the results of Tobisch’ online study with 93 participants.[551] For 75%, lacking a garden “was one of the main reasons” for participating in urban gardening. For 90%, the community aspect was important, and 75% wanted primarily produce organic for themselves and to follow the food cycle from seed to harvest. More than 70% felt that the urban garden brought more nature to the city, and 87% thought it had beautified the area. For over 92%, the area has been socially revived, and for 42%, the quality of life in the area has increased.

The interviews with 156 allotment gardeners in an URBES case study about allotment gardens in Salzburg performed by Breuste and Artmann confirm the

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[547] Evidero. https://www.evidero.de/interview-mit-der-autorin-des-buches-urban-gardening. Retrieved on 21.10.2018

[548] Nitsch, I., ibid.

[549] Müller, C. (2009): Urbane Agrarkultur und neue Subsistenz. https://sozialeoekonomie.org/wp-content/uploads/wissensgrundlagen/Urbane-Agrarkultur-und-neue-Subsistenz_Christa-M%C3%BCller.pdf. Retrieved on 11.11.2018

[550] Müller, C. (ed.) (2011): Urban Gardening. Über die Rückkehr der Gärten in die Stadt. München 2011

[551] Tobisch, C. (WS 2012/2013): Oasen im Beton. Urban Gardening als Instrument zur Attraktivierung und Belebung von Brachflächen. TU Dortmund. http://www.urban-gardening.eu/wp-content/uploads/2013/11/oasen-im-beton_carlos-tobisch.pdf. Retrieved on 23.5.2019

core of these statements.[552] That study showed that 47% of the gardeners who produced food did so for health benefits. The majority of the gardeners interviewed (66%) responded “that they had learned about nature through allotment gardening,” and 31% said that they had acquired new knowledge about ecological behavior and 28% about horticulture. Further, 78% of the participants were convinced that the allotment garden was important or very important, especially for the younger generation, because it offered the possibility of learning about nature and observing birds, small mammals, and amphibians.[553]

8.2.5.5 Conclusion

An important finding from the talks with founders of and participants in urban garden projects were that not only the activists enjoy the advantages of the gardening projects but as well the inhabitants of the respective districts. Especially through numerous organized activities such as guided tours, seminars, garden parties, and training programs, all urban farming projects, whether herb gardens, community, hospital, or school gardens, enjoyed high popularity among the population. The aspects of organic food production, independence, working in the fresh air, and the acquisition of horticultural knowledge inspired the people and stimulated their engagement.

The city is being rediscovered as a space for food production that can be completely “controlled” by its consumers because what they eat is their decision in terms of their health and political affiliations. By changing attitudes towards sustainability, healthy living, and organic food production, urban agriculture creates a significant spill-over effect on consumer behavior and individual lifestyle habits. Common solutions to problems are accepted not for their existential

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[552] Breuste, J. H., Artmann, M. (2014): Allotment Gardens Contribute to Urban Ecosystem Service: Case Study Salzburg, Austria, 2014. http://www.urbanallotments.eu/fileadmin/uag/media/members _publications/Breuste _Artmann_2014_JUPD.pdf. Retrieved on 30.8.2017

[553] ICLEI - Local Governments for Sustainability: Urban Biodiversity and Ecosystem Services. http://www.iclei.org/details/article/urbes-urban-biodiversity-and-ecosystem-services.html. Retrieved on 4.12.2017

necessity but for reasons of solidarity and common ecological values. An egalitarian operational framework for ecological interactions, political contacts, and close networking of all activists as well as a special sense of belonging significantly facilitate the process of propagation.

As a global renaissance of urban agriculture is underway, the new food philosophy aims at contributing sustainable food production for a sustainable development and personal health by placing trust and fairness against the currently anonymous food production and supply chains. Urban gardening offers experiences of citizenship, public space, land ownership, and community identity-processes that seemed to be lost or forgotten in daily urban routines. Since most individuals seek opportunities for self-realization and development, the joint organization of processes and self-determination concerning their own living environment can easily be found in garden communities.

Food security is not only a top issue on the agenda of municipalities and communities worldwide, it is also an important personal decision for many people to acquire a certain degree of independence from the global food system. The local supply with imported food can become unstable in times when the demand rises sharply or other factors, such as spikes in fuel prices or disastrous climatic events, threaten millions with an insufficient food supply. Even with no immediate threats, an increasing number of individuals engage in food production in cities based on a genuine emotional need for better health, environmental sustainability, and self-sufficiency benefits that can be derived even through small-scale productive systems. Thus, “urban farming goes beyond the scope of growing food and has a great community development potential, serving as an important ‘agent of change’.”[554]

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[554] Padilla, M. et al. (2015): Urban Farming in the City of Tomorrow. http://publica.fraunhofer.de/documents/N-506944.html. Retrieved on 6.1.2019

8.2.6 Online Survey: UA Acceptance and Preferences

8.2.6.1 Analytical Framework

In the period from January 1, 2019 to April 30, 2019, 144 persons participated in the online survey on the LimeSurvey Platform of the Service Portal of the TU Dortmund (service.t-dortmund.de), and 120 participants finished it. At the beginning of the survey, there was a short introduction and explanation of the terms “urban agriculture,” “sustainability,” and “resilience.”

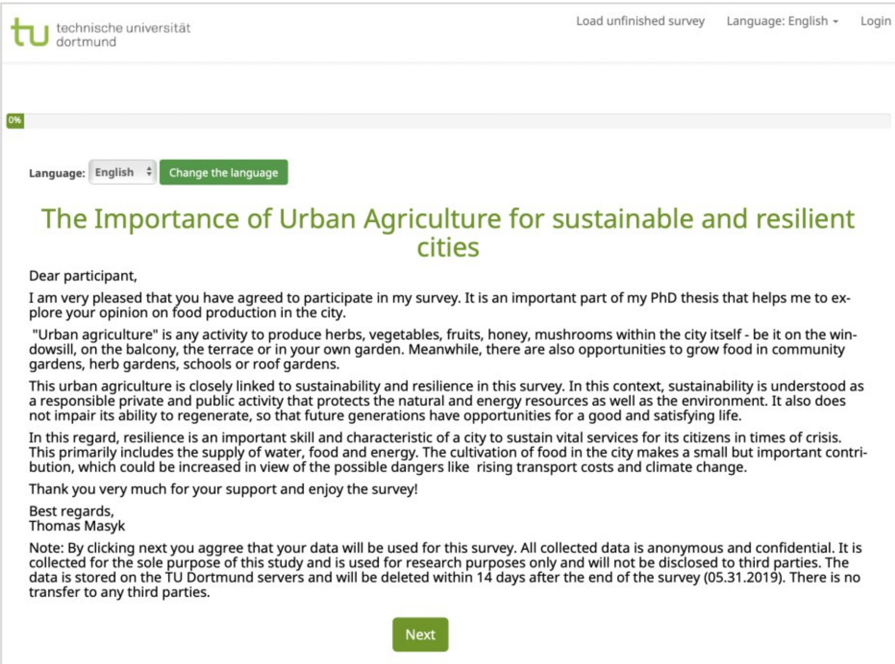

Image 7 – Survey's introduction page on LimeSurvey Platform, author’s survey in 2019

The relatively long required response time of about 20 minutes and the complexity of the last subject area, may explain the premature termination of some participants. Some people were inadequately accustomed to the survey design, so they opened the link and answered only the questions on the first page. However, they did not notice the “continue” button for the following pages, and therefore the rest of the questionnaire remained unanswered. In addition, although complete anonymity was guaranteed, a minority of respondents did not provide any information about gender, age, or other topics. [555]

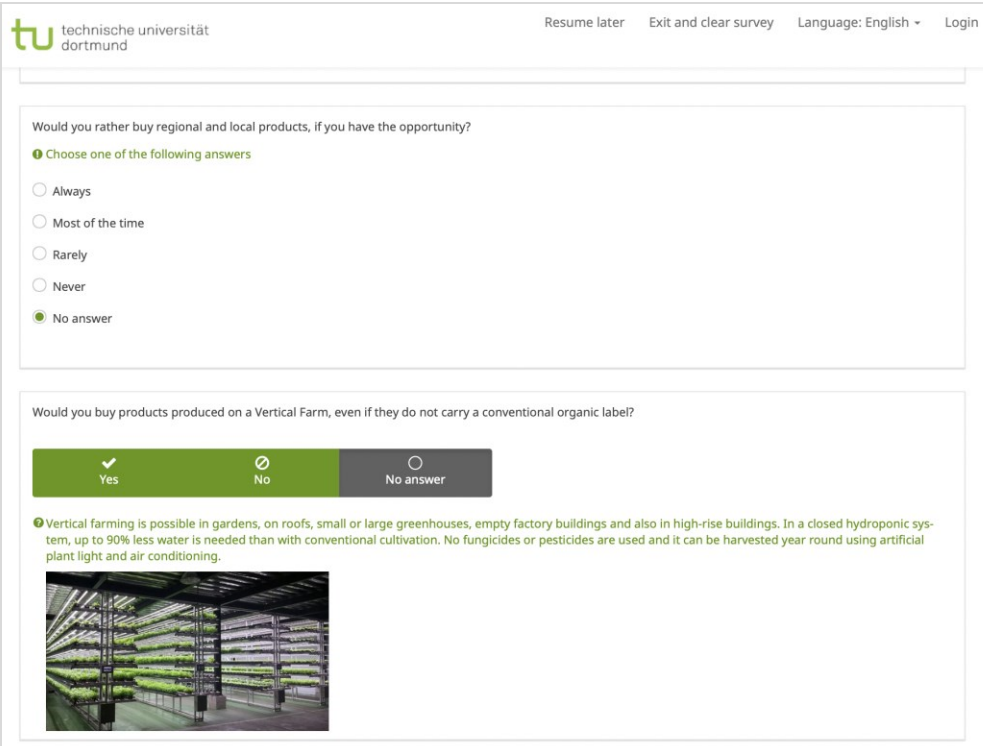

Image 8 – Questions on LimeSurvey Platform, author's survey in 2019

In total, 10 people completed the English version of the survey, and 110 chose the German version. The data sets of the fully answered tests were exported and analyzed with the help of IBM SPSS analytic software.[556]

All the subjects selected were friends, acquaintances, work colleagues, and family members of the author, who in turn acted as multipliers and invited their family and friends to participate. Selection criteria were an age over 20 years and an assumed interest in the subject. The sample is not representative of the demographic structure of Germany in terms of age, residence, or education.

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[555] Masyk, T. (2013). The author's online survey in 2013 was similarly complex and the same difficulties were encountered there.

[556] IBM SPSS software. https://www.ibm.com/de-de/products/spss-statistics. Retrieved on 13.04.2019

Of course, the survey on urban agriculture not only asked people who live in the city. Like the author, who was born in the city, grew up in the countryside and is living now in the city again after his education, there are rarely people who spend their entire lives only either in the city or in the country. There are also many people who live in the country or peri-urban, but commute to work in the city. Many retired people choose to move out of the city and live in the country-side. In any case, the views of all groups of people, no matter where they live, are relevant to this study.

Before the survey in English and German was available on the Internet, a preliminary test was conducted with several people to determine whether the questions were understandable. In addition, all participants were specifically requested to contact the author by telephone or via email in case of any ambiguity.

The online survey consisted of a total of 33 questions. Personal questions (gender, marital status, place of residence, etc.) were formulated as nominal questions. These were supplemented with quantitative questions on age, income, private food storage, etc., and ordinal questions with graduated assessments (horticultural knowledge, shopping behavior, etc.). The majority of the questions were closed questions with multiple choice answers, and, due to the expressed interest of the participants, it was important that thematically unreasonable answers were not available. This question type allowed faster evaluation and comparability of the results.

8.2.6.2 Objectives

The focus of interest were the following topics:

- A general exploration of the horticultural knowledge and eventual gardening activities of the participants, as well as their knowledge about forms and types of urban agriculture.
- The influence of the regionality of food on consumer and shopping behavior.
- Acceptance and preferences regarding the different manifestations of urban agriculture.
- Awareness of resilience and sustainability in the urban food system.
- Assessment of urban agriculture as a means of mitigating and adapting to climate change and potential crises.

8.2.6.3 Questions[557]

The set of questions (attached in appendix) was divided into four subsections.

Personal Questions

Detailed data were collected on gender, age, education, occupation, income, and place of residence. Questions also addressed horticultural knowledge and activities and the reasons for growing one’s own vegetables.

Consumer Behavior

In this section, the participants answered questions about their personal shopping habits, as well as their attitude towards local products and those that come from vertical farming.

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[557] See complete list of questions under 12.1 Interview questions

Acceptance and Preferences Regarding Urban Agriculture

The questions in this key area focused on existing knowledge of the forms and types of urban agriculture; the social, environmental, and health benefits of community gardens; the acceptance of community gardens in their own neighborhood; and the willingness to engage in such a community.

Urban Sustainability and Resilience

The fourth and most comprehensive question area was formulated to provide insights into the participants' overall level of information on sustainability and resilience in their country, city, and immediate living environment. In particular, participants were asked what urban resilience means, what measures should be taken to improve resilience, and how a green infrastructure could mitigate the negative effects of climate change. Hazards for urban food security were to be evaluated for their likelihood as well as the relevance of urban agriculture for adaptation to climate change. Finally, participants were asked to assess possible measures that cities and communities can use for a better promotion and support of urban agriculture.

8.2.6.4 Results and Evaluation

After completing the survey on the Internet, all the data obtained were carefully recorded and analyzed. Of particular interest were the correlations of personal variables (sex, occupation, education, age, income, place of residence, environmental awareness) with answers on the acceptance of urban agriculture, preferences, consumption and purchasing behavior, and knowledge about sustainability and resilience.

Using a conjoint analysis, the benefits of urban agriculture and their ranking could be determined with respect to their importance for the participants. In combination with a discriminant analysis, the differences between two or more defined groups were determined and, in addition, the priorities in the allocation of certain results within specific groups could be ascertained.[558]

Descriptive statistics and its instruments are particularly suitable for determining the laws and causes that explain the data and central questions. It allows the display of absolute, relative, and cumulative frequencies in tables and graphs.

In order to determine the significance of the relationship between two categorical variables answers (e.g., age and awareness of climate change) the Chi-Quadrat-Test integrated in the SPSS software was used. With $p<0,05$ being selected as significant, any value for p below 0,05 means, that there is a positive relation between the two categorical variables answers.

Personal Characteristics (Questions 1-11)

Gender, Age, Education, Income, and Profession

53% of the 120 participants were women, and 47% were men. Almost half of the people were younger than 40 years (45%). People between 40 and 70 accounted for 52%, and those above 70 years for only 3%.

[558] Masyk, T. (2013) Both types of analyses were performed by the author in his 2013 online survey and in the survey of this study.

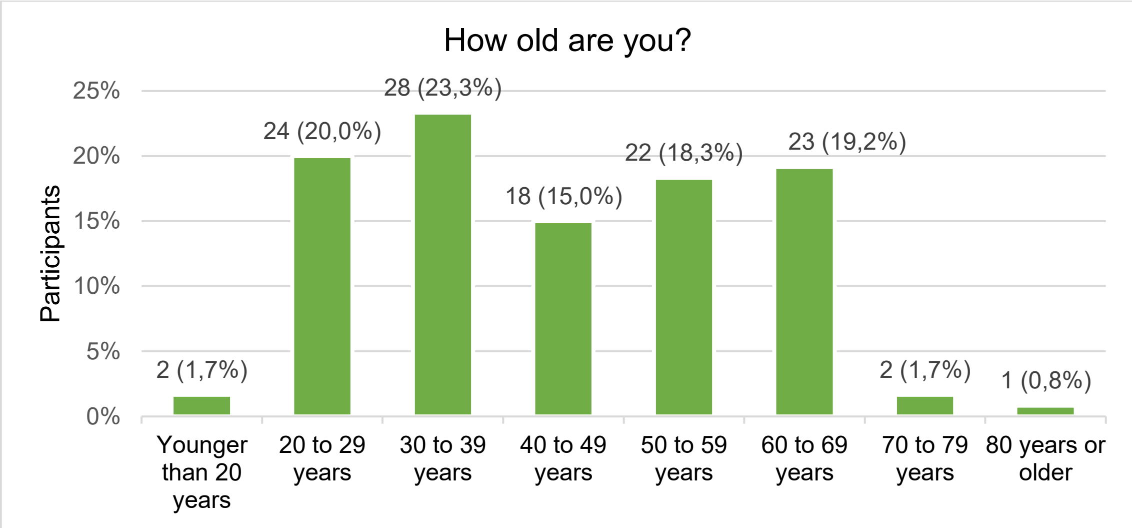

Table 1 – Personal characteristics – age, conducted survey

The predominant part of the participants had higher education, and 50% had university diplomas. This number is not representative for the population but due to the fact that the author had asked mainly people of his acquaintance.[559]

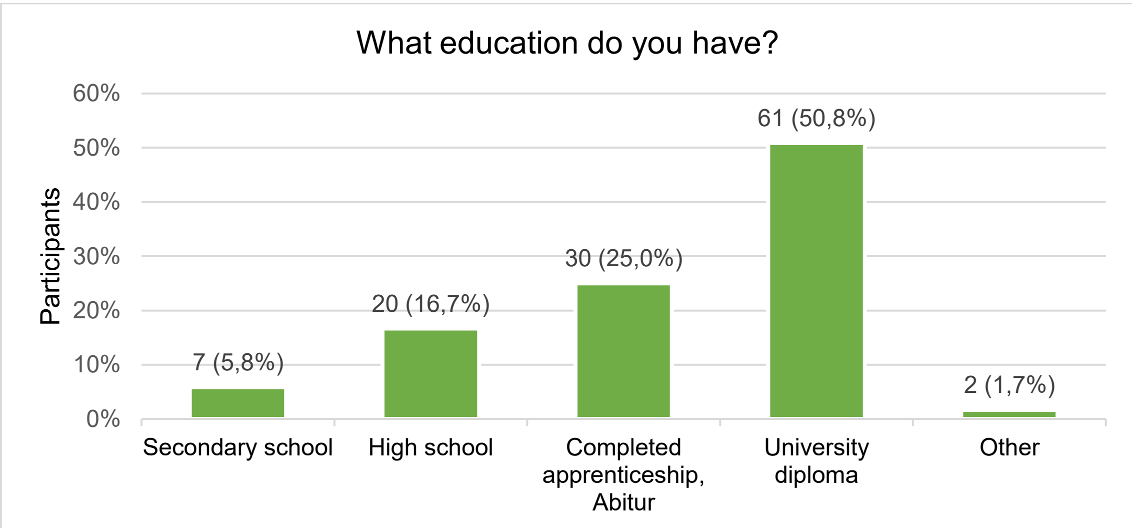

Table 2 – Personal characteristics – education, conducted survey

More than half of the candidates (54%) work as employees, and 20% are self-employed. The rest (26%) were evenly distributed among housewives, retired

[559] This refers to both surveys of the author in the same way.

persons, civil servants, or those still receiving education (apprentices or students).

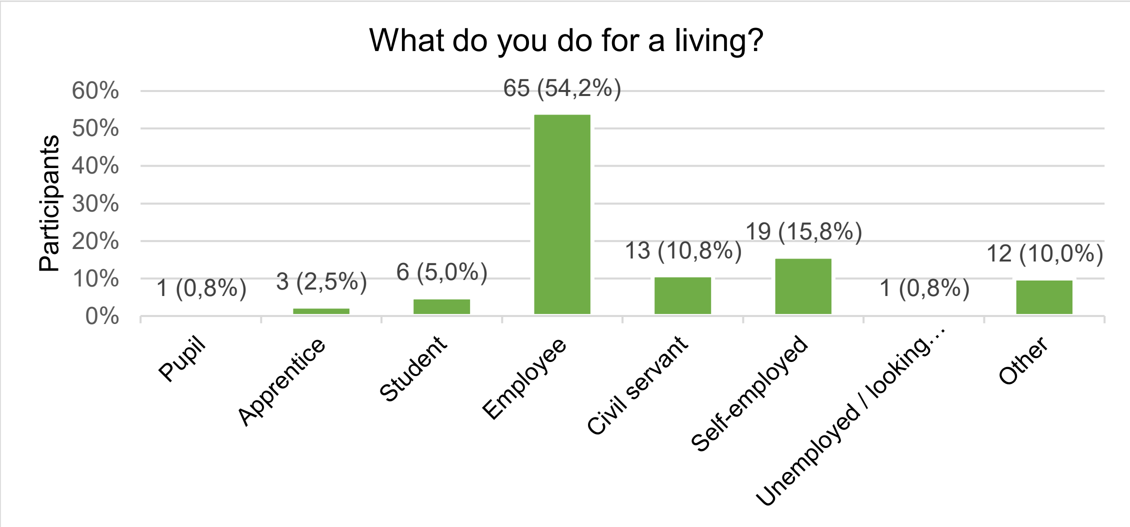

Table 3 – Personal characteristics – living, conducted survey

Concerning monthly income, the groups with €1,000 - 2,000, €2,000 - 3,000, and €3,000 - 4,000 were almost equally distributed, and each accounted for approximately one-quarter of the participants. Fifteen participants had a monthly net income of more than €5,000, and eight refrained from answering this question.

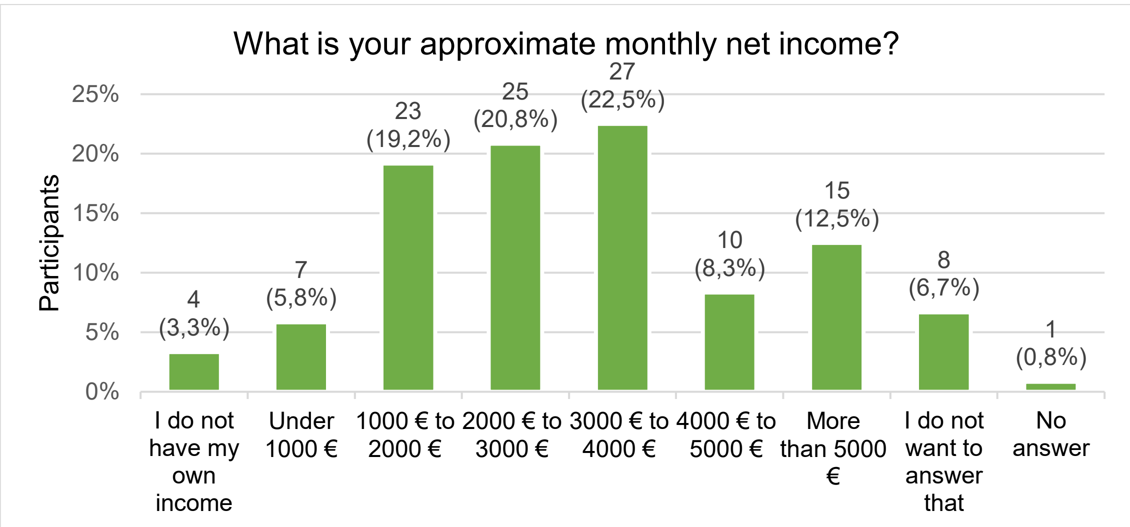

Table 4 – Personal characteristics – monthly income, conducted survey

Domicile, Environmental Awareness, Gardening Skills, and Activities

66% of the contestants lived in the city or in a suburban area, and one-third lived in the countryside.

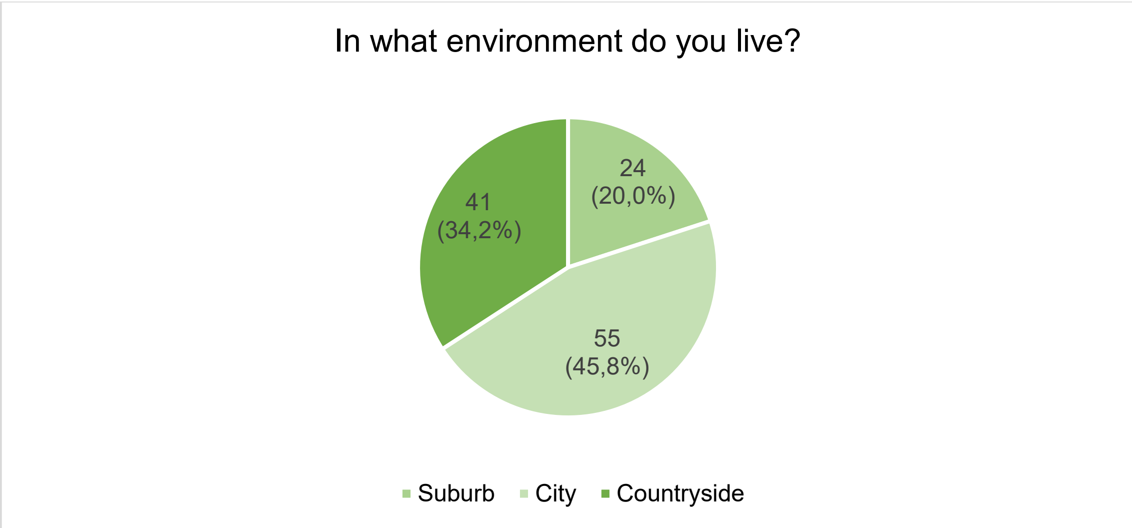

Table 5 – Personal characteristics – living environments, conducted survey

Most participants (57%) rated themselves as "rather environmentally conscious," 12% as "very environmentally conscious and critical," and only 2 (1.6%) of the 120 participants said that sustainability was not an issue for them at all.[560]

[560] Same question in the 2013 and 2019 online survey

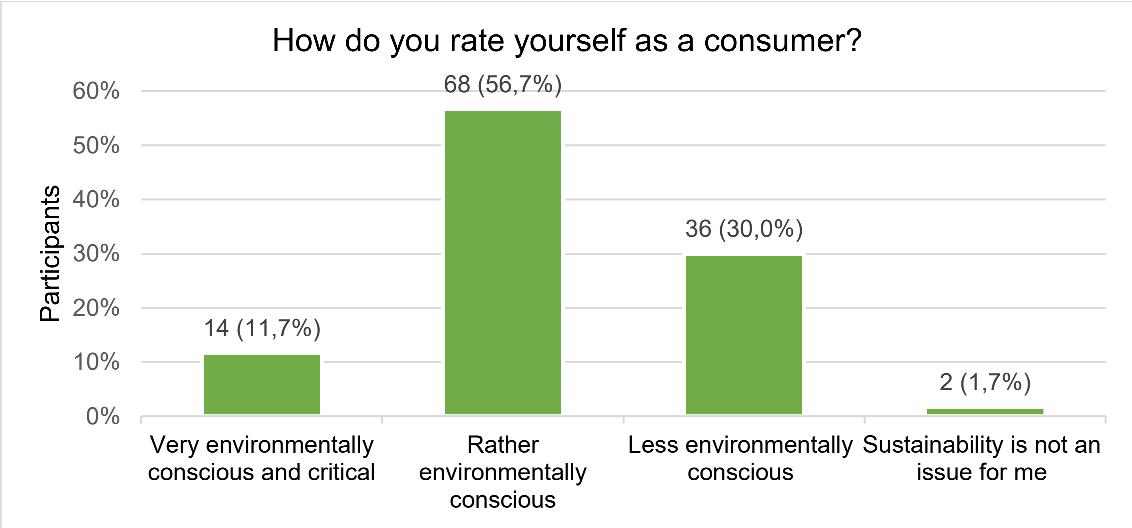

Table 6 – Personal characteristics – consumers' level of environmental consciousness, conducted survey

Half of the participants assessed their gardening skills as "good" (45%) or even "very good" (6%).

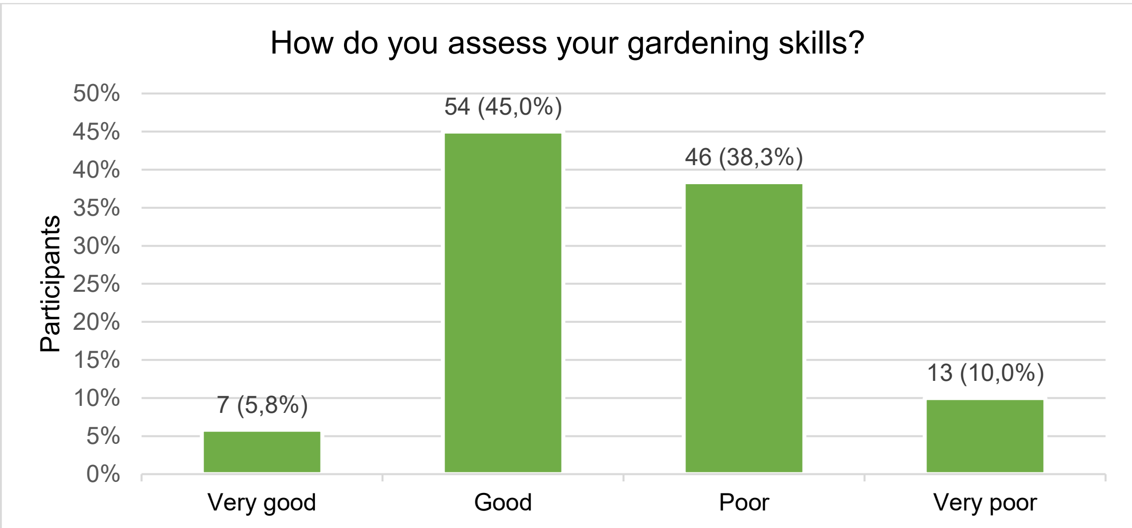

Table 7 – Personal characteristics – gardening skills, conducted survey

Growing food is mostly done in the garden (69%), or on the terrace (28%), window ledge (27%) or balcony (24%). No one was part of a community garden or had an allotment or rooftop garden. For this question, multiple answers were allowed. As the reason for growing one's own food, 77% of the answers were "self-produced food is healthier and safer than the purchased one," followed by "home-grown vegetables taste better" with 66%, and "because I love gardening activities" with 60% of the answers. Only 20% grow their own food to save money. For this question, multiple answers were allowed.

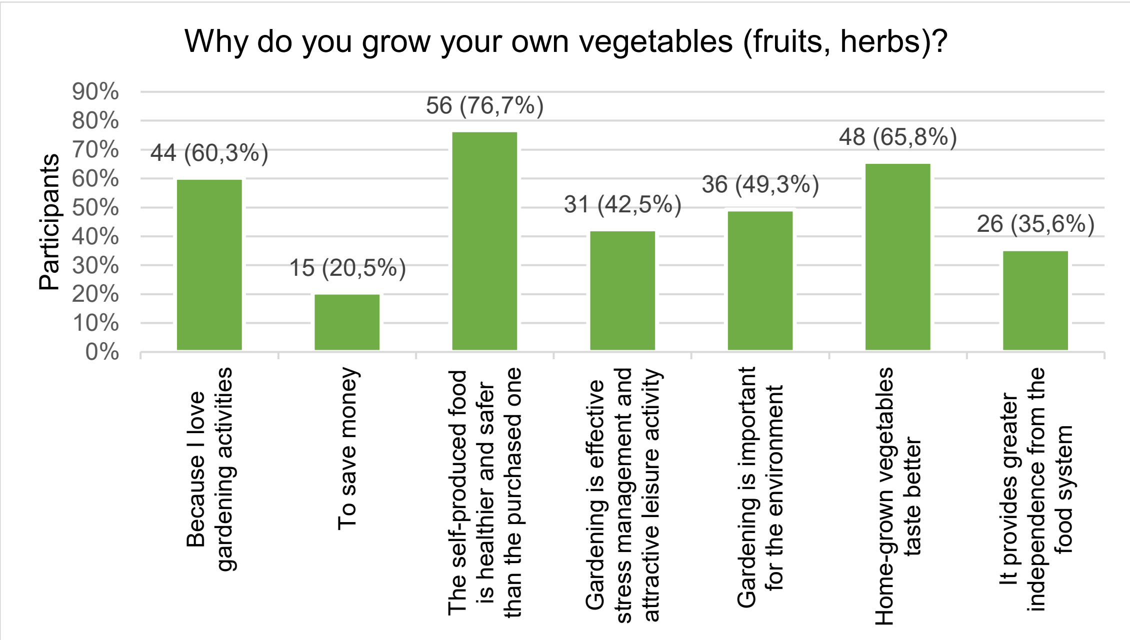

Table 8 – Personal characteristics – reasons for growing own food, conducted survey

The conjoint analysis showed that age[561] played no significant role in terms of environmental consciousness (61% of the younger age group, 74% of the older age group, p = 0,124).[562]

561 Younger age group: Age <40 years; older age group >40 years

562 Significance was calculated using the Chi-Quadrat-Test integrated in the SPSS software with p<0,05 being significant

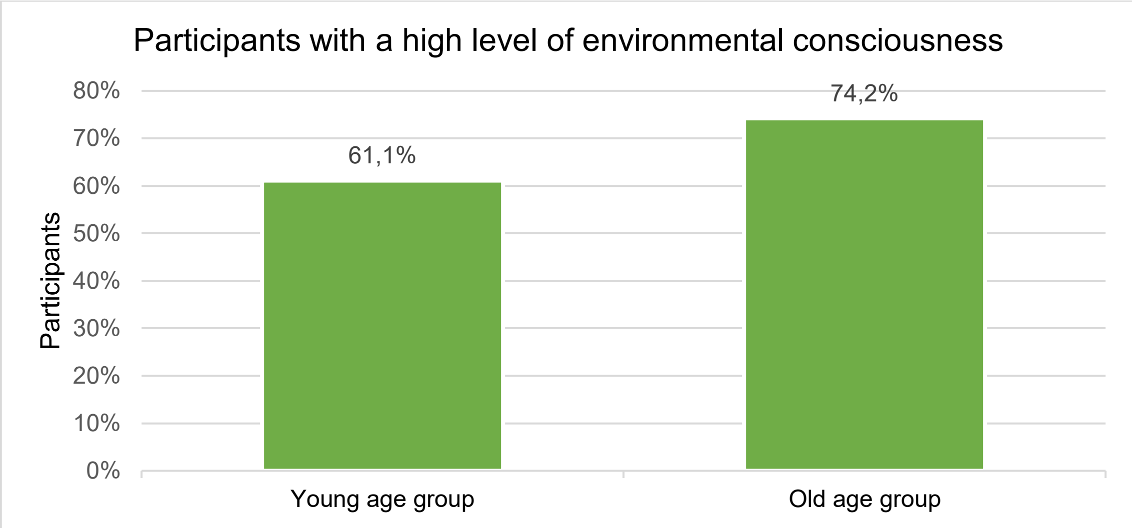

Table 9 – Personal characteristics – age and level of environmental consciousness, conducted survey

However, participants with higher education had a significantly higher environmental consciousness (56% versus 79%, p = 0,02).

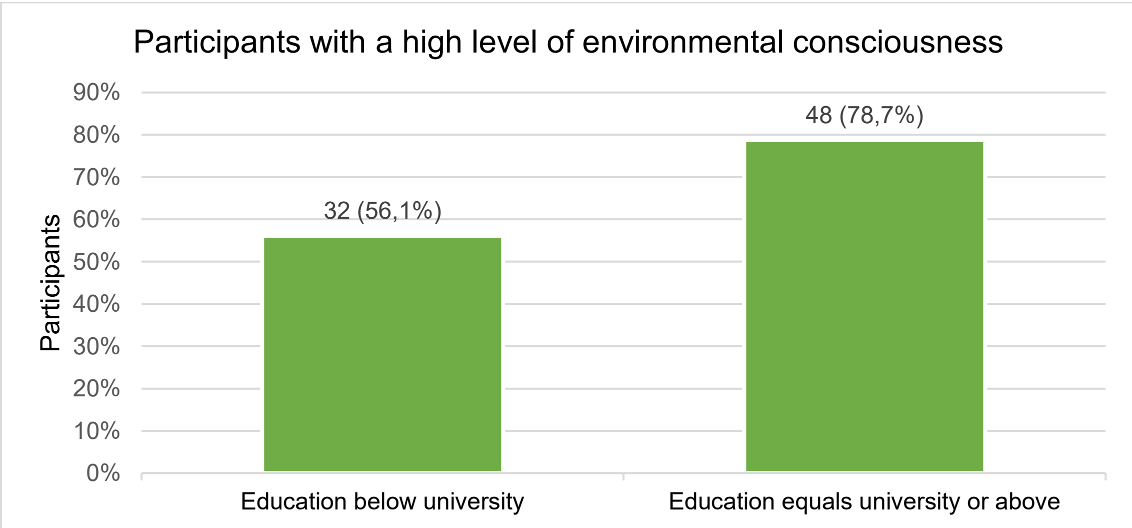

Table 10 – Personal characteristics – education and level of environmental consciousness, conducted survey

No significant difference (4%, p = 0,674) could be found between participants living in cities and those who lived in the countryside regarding their environmental consciousness.

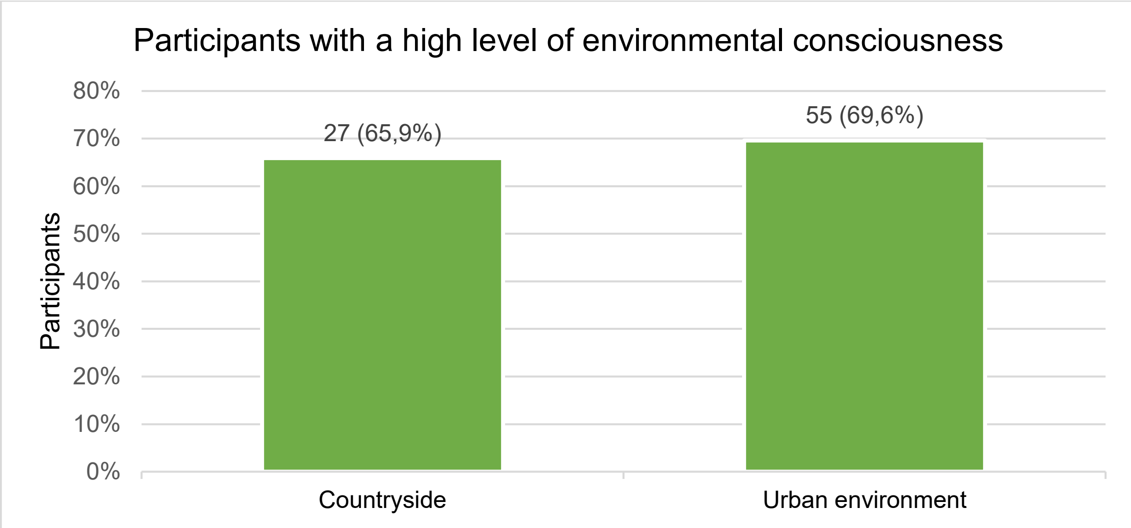

Table 11 – Personal characteristics – place of living and level of environmental consciousness, conducted survey

However, people in the countryside were significantly more likely (20%, p = 0,034) to grow their own food, and women were significantly more likely (19%, p = 0,036) to grow vegetables, fruits, or herbs compared to men.

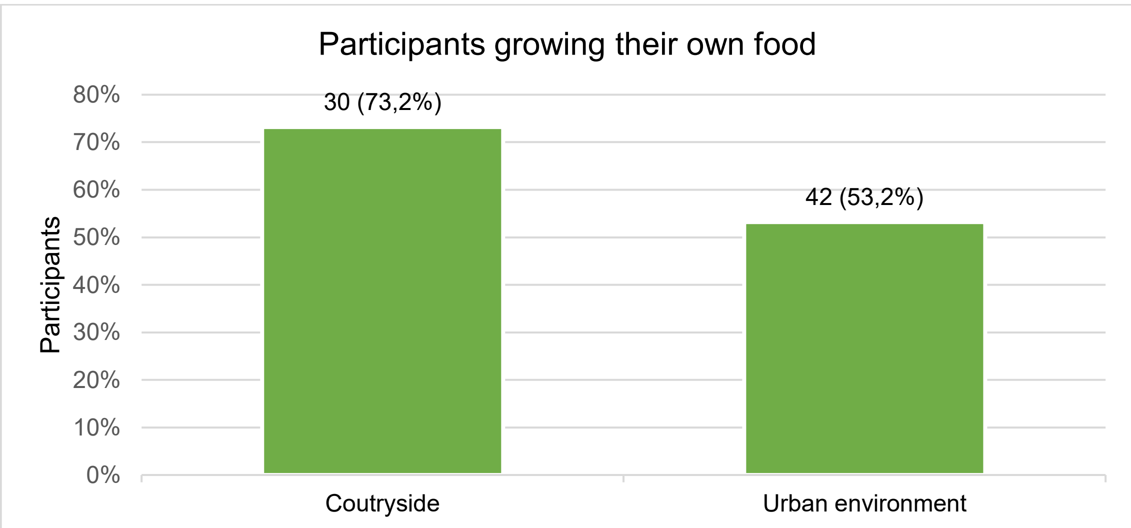

Table 12 – Personal characteristics – living environment and growing own food, conducted survey

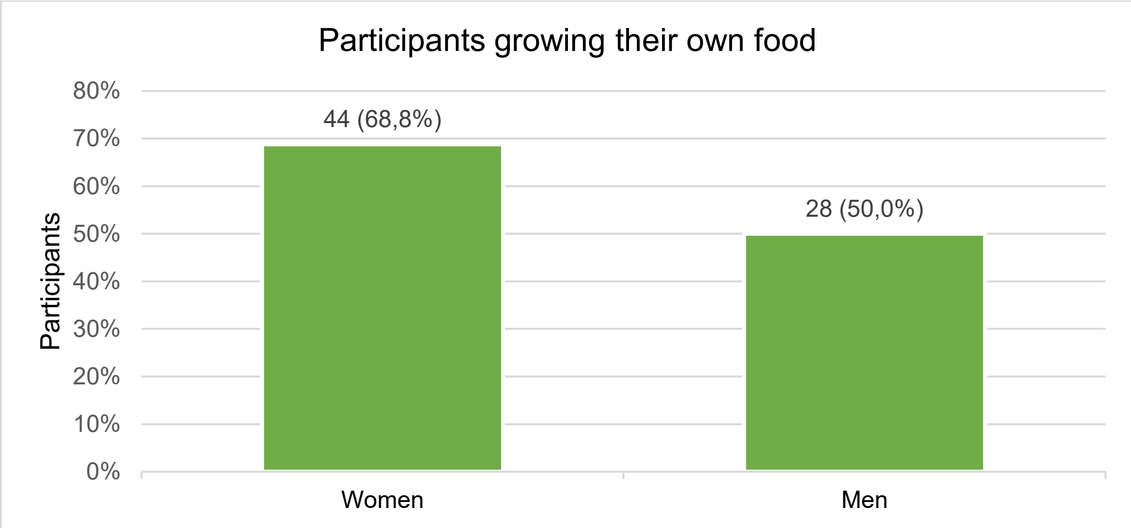

Table 13 – Personal characteristics – gender and growing own food, conducted survey

Highly environmentally conscious participants (76%) were significantly ($p < 0{,}001$) more likely to grow their own food than their counterparts with lower environmental awareness.

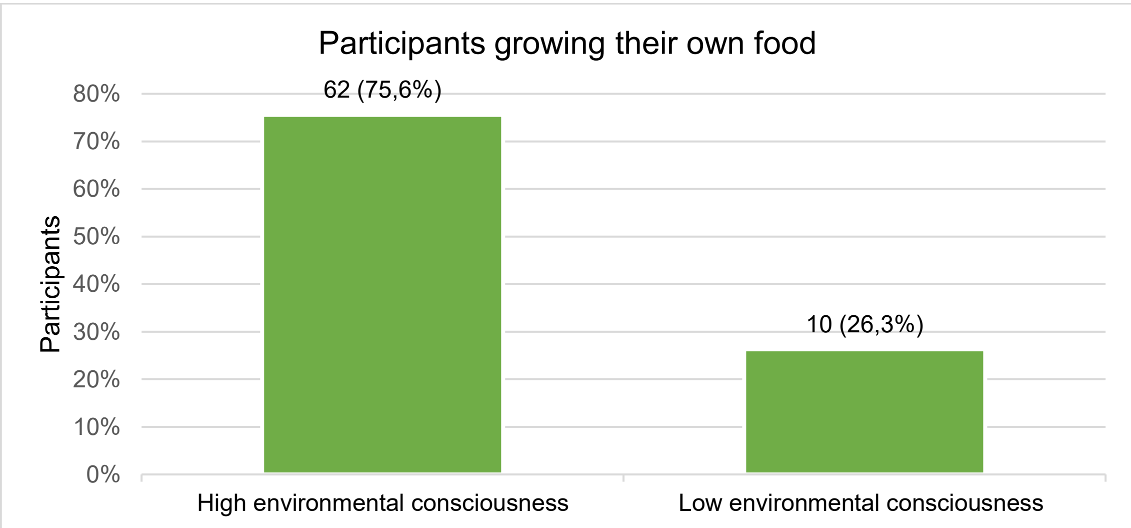

Table 14 – Personal characteristics – level of environmental consciousness and growing own food, conducted survey

Significantly ($p < 0,001$) more older people (76%) than younger ones (41%) grow their own food, but income[563] levels played no significant ($p = 0,625$) role (1%) in this respect.

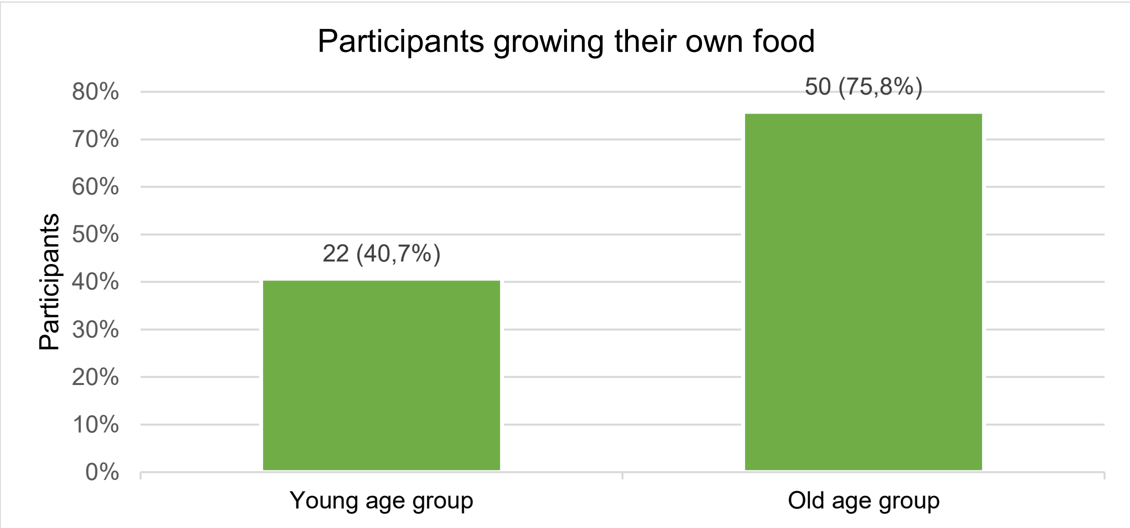

Table 15 – Personal characteristics – age and growing own food, conducted survey

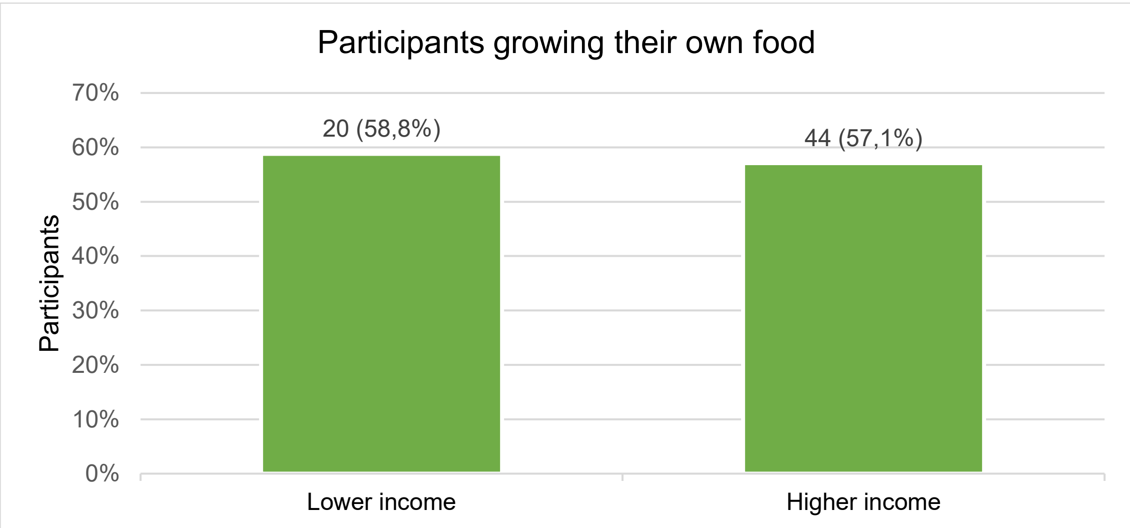

Table 16 – Personal characteristics – income and growing own food, conducted survey

563 Low income <3.000 €, Higher income >3.000 €

Consumer Behavior (Questions 12-16)

Shopping Behavior and Product Preferences

Nearly 88% of the participants regularly bought their fruits, vegetables, and herbs in the local supermarket. Farm shops (directly from the producer), specialty shops for healthy food, and farmers' markets were the next most common sources at around 30% each. Here, multiple answers were also allowed.

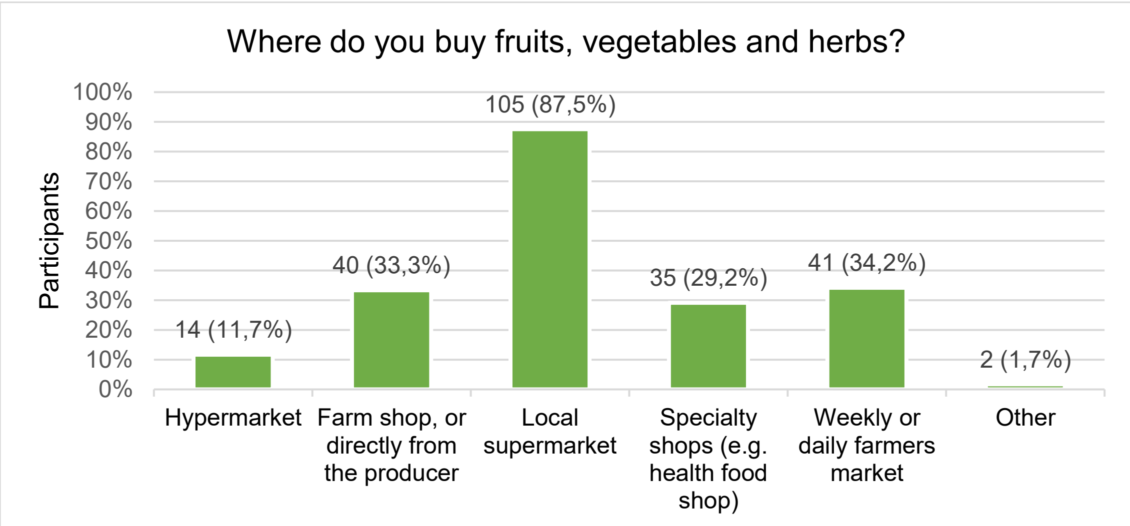

Table 17 – Consumer behavior – favorite shopping place, conducted survey

Most of the time, the participants (62%) bought regional and local products if they had the opportunity; of these, 29 % always did so, but 10% did so rarely or never.

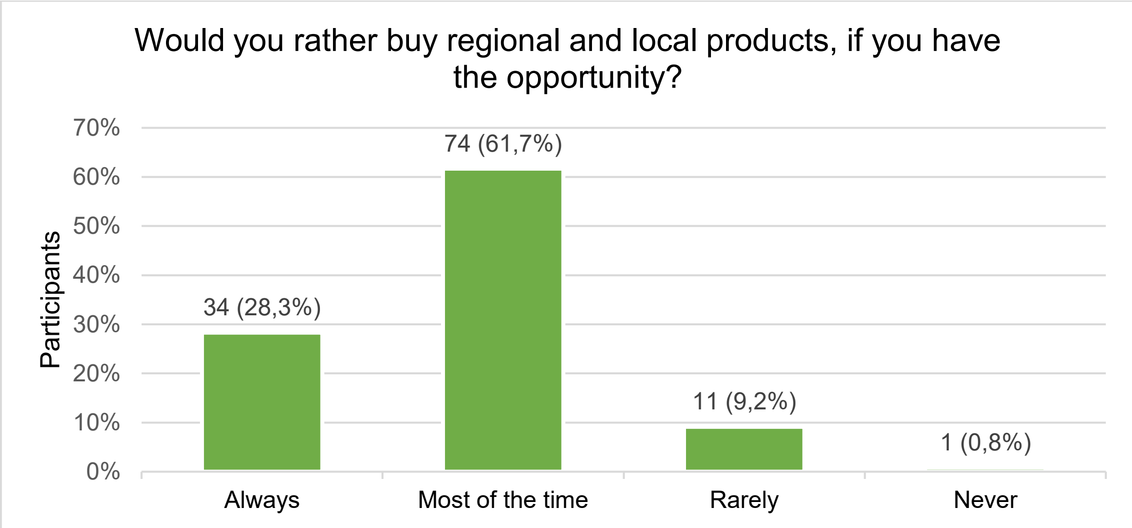

Table 18 – Consumer behavior – regional and local products, conducted survey

When asked about the reason for buying local products, the top answers were that “products are fresher” (87%), “doing so strengthens the local economy” (75%), and that “there is a better transparency regarding manufacturer and place of production” (65%). Almost half of the participants (48%) thought that the “product quality is safer.” Multiple answers were allowed in this case.

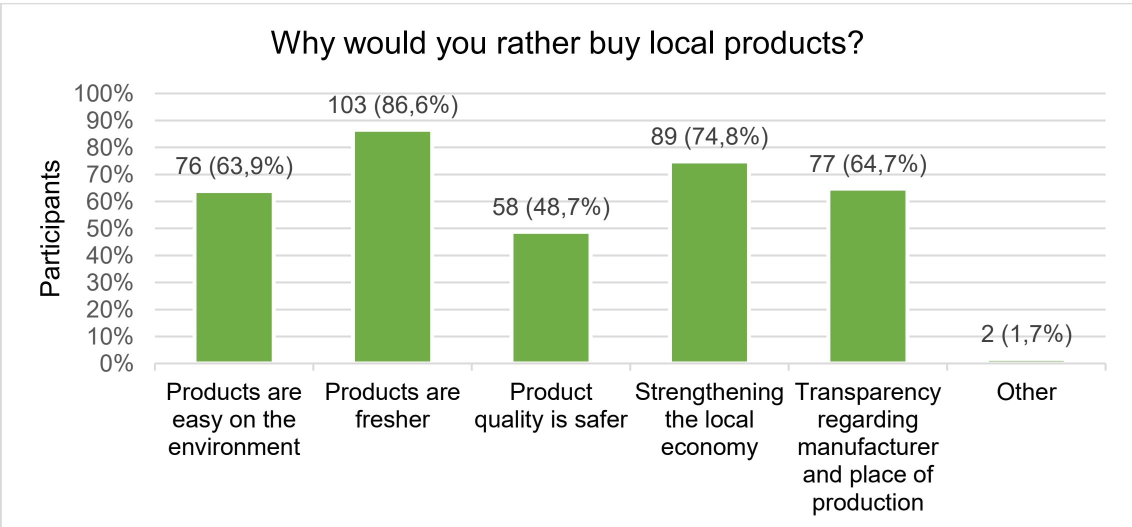

Table 19 – Consumer behavior – buying regional and local products, conducted survey

In total, 83% of the participants would buy products produced on a vertical farm, even if they did not carry a conventional organic label.

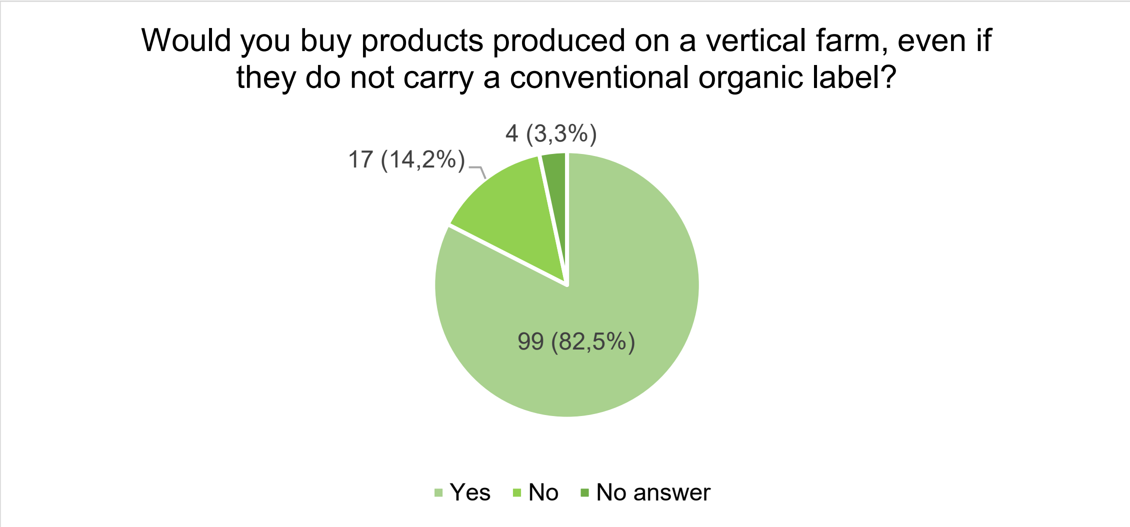

Table 20 – Consumer behavior – vertical farm products, conducted survey

For the remaining 14% (four did not answer this question) who would not buy such products, the main reason was that vertical farming is not natural cultivation (77%). Other arguments were "competition for conventional agriculture" (33%), "wasting energy for air conditioning and lighting" (33%), and "use of artificial fertilizer instead of bio fertilizer" (33%).

Multiple answers with regards to the arguments against vertical farm products were allowed. One free comment concerned the lack of product testing of food produced in vertical farms.

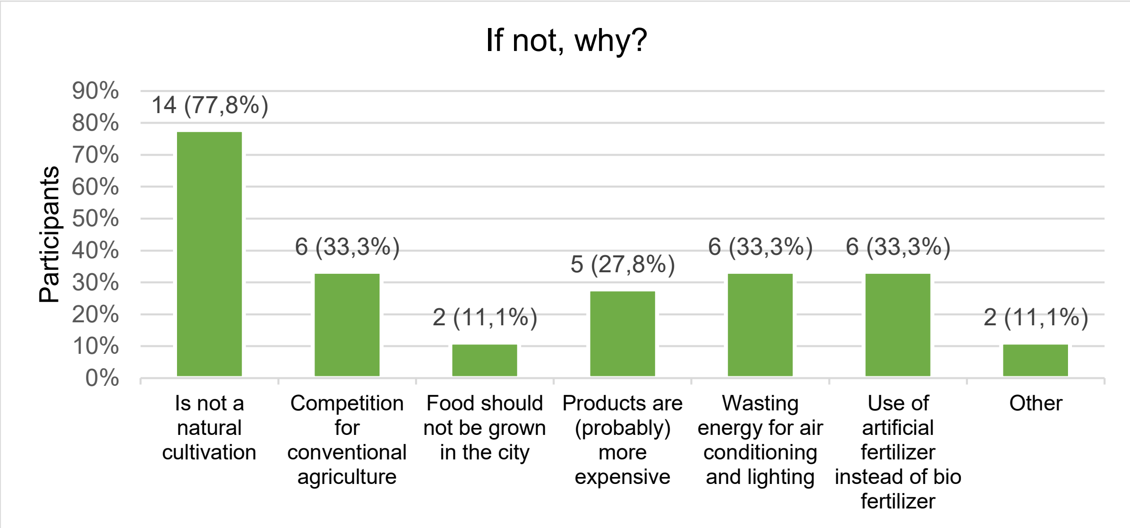

Table 21 – Consumer behavior – not buying vertical farm products, conducted survey

Here, the conjoint analysis revealed that participants with a high environmental consciousness were more likely to buy their fruits, vegetables, and herbs in either farm shops (20%) or at farmers' markets (20%) than participants with a low environmental consciousness (7% and 9%).

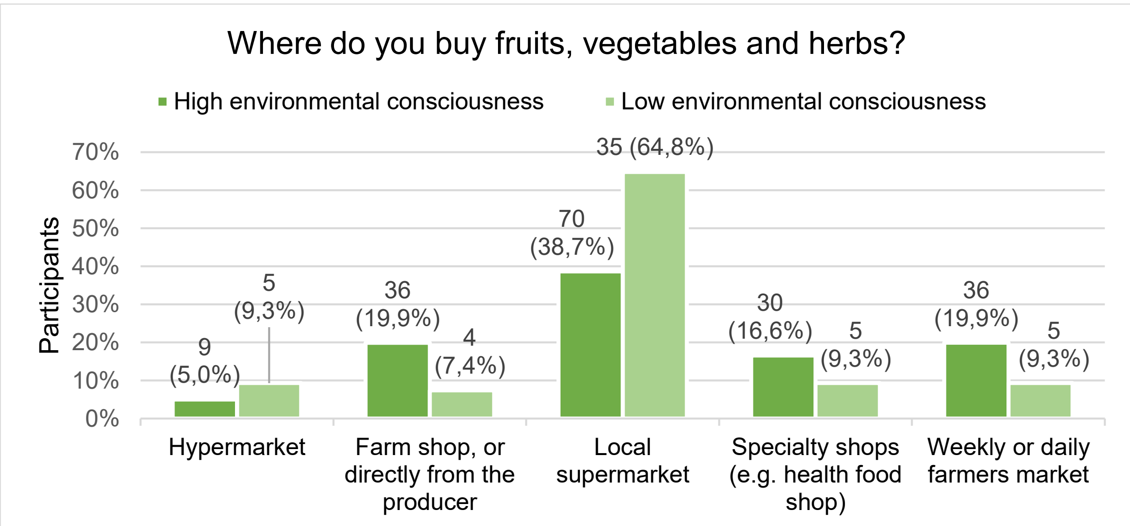

Table 22 – Consumer behavior – buying fruits, vegetables and herbs, conducted survey

When asked about the tendency to prefer regional and local products if available, age played almost no role (younger with 85% and older participants with 93%).

When comparing highly environmental conscious participants with those with a low environmental consciousness, the latter were significantly less likely (27%, p > 0,001) to prefer buying regional and local products.

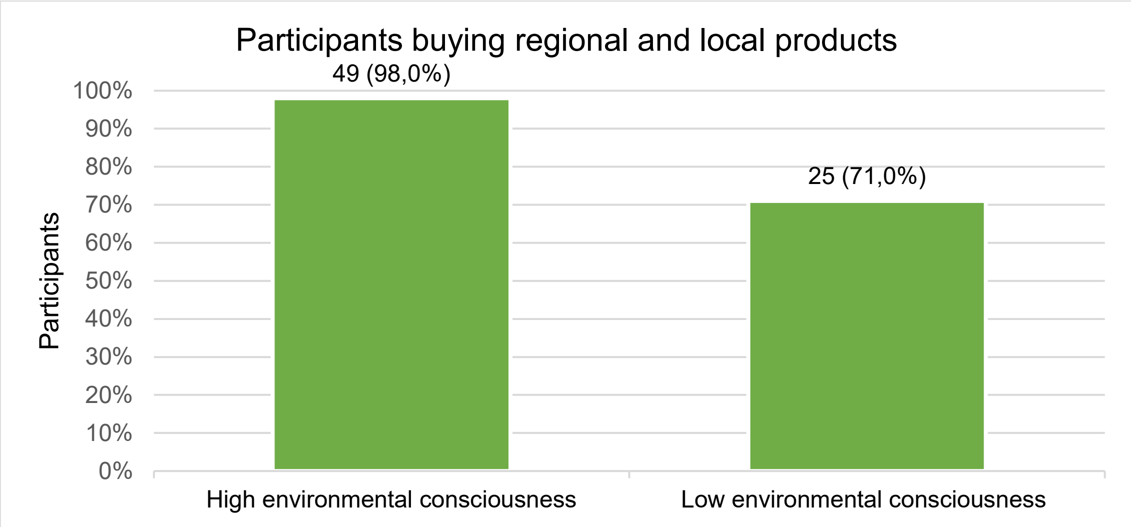

Table 23 – Consumer behavior – buying regional and local products and level of environmental consciousness, conducted survey

Living environment (p = 0,342), education (p = 0,673), and age (p = 0,960) had little to no significant impact on buying food produced on a vertical farm (tables 22, 23, 24).

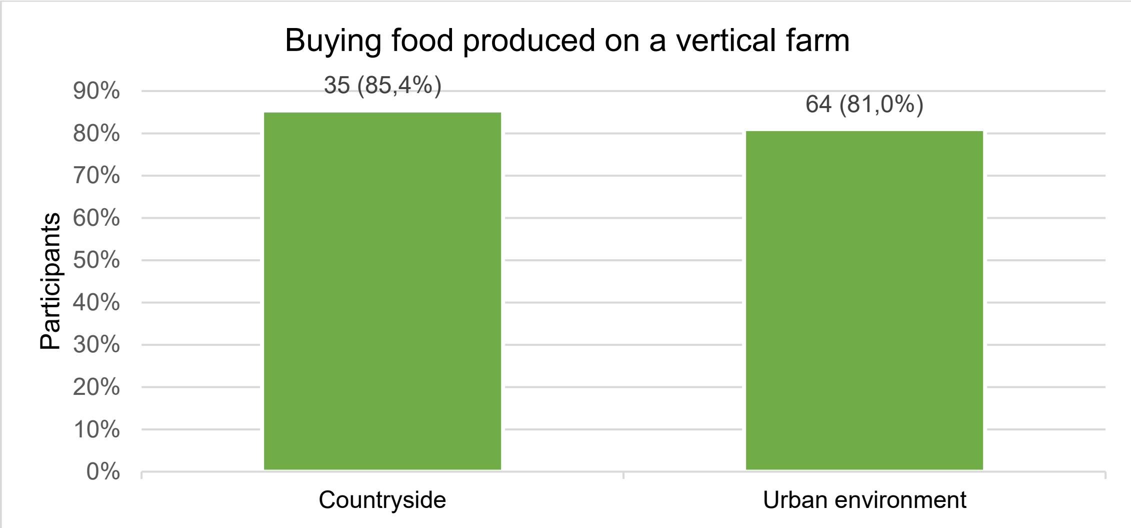

Table 24 – Consumer behavior – buying food produced on a vertical farm and living environment, conducted survey

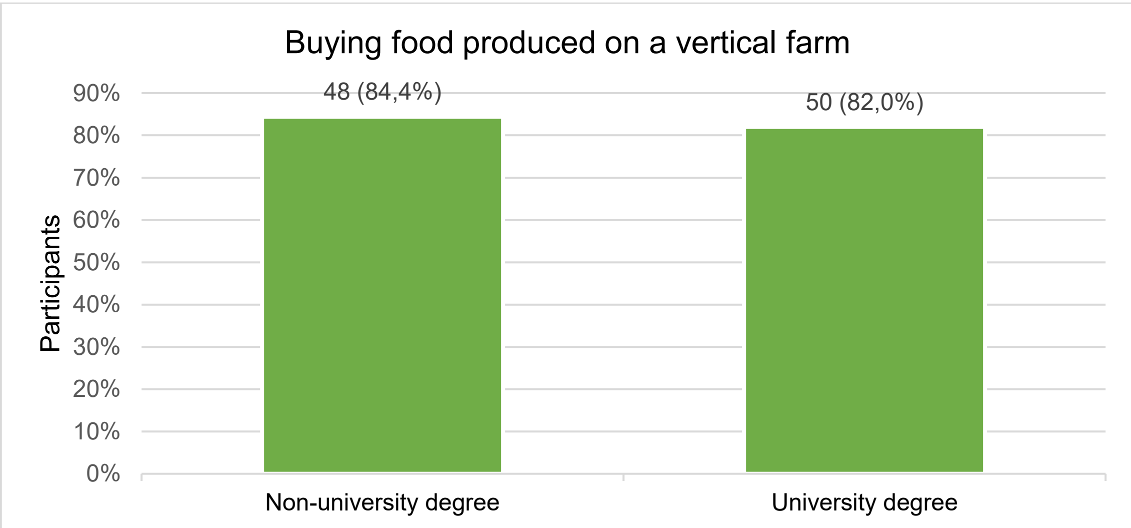

Table 25 – Consumer behavior – buying food produced on a vertical farm and education, conducted survey

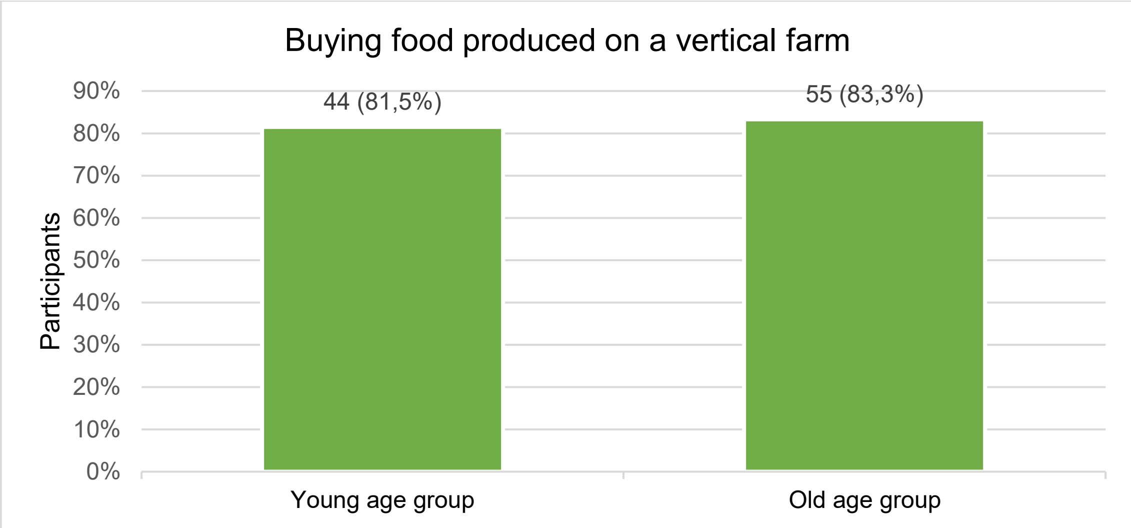

Table 26 – Consumer behavior – buying food produced on a vertical farm and age, conducted survey

Urban Agriculture: Acceptance and Preferences (Questions 17-23)

Knowledge about Forms and Types of Urban Agriculture

The great majority was familiar with the traditional forms of urban agriculture, 88% of all participants with “balconies/terraces,” 83% with “allotments,” 83% with “roof gardens,” and 80% with “greenhouses.” “garden plots” (78%), “community gardens” (73%), “private gardens” (72%), and “herb gardens” (60%) were also well known. Newer forms of urban agriculture, such as “self-harvest projects” and “vertical farms,” were only known by 36% and 33%, respectively.

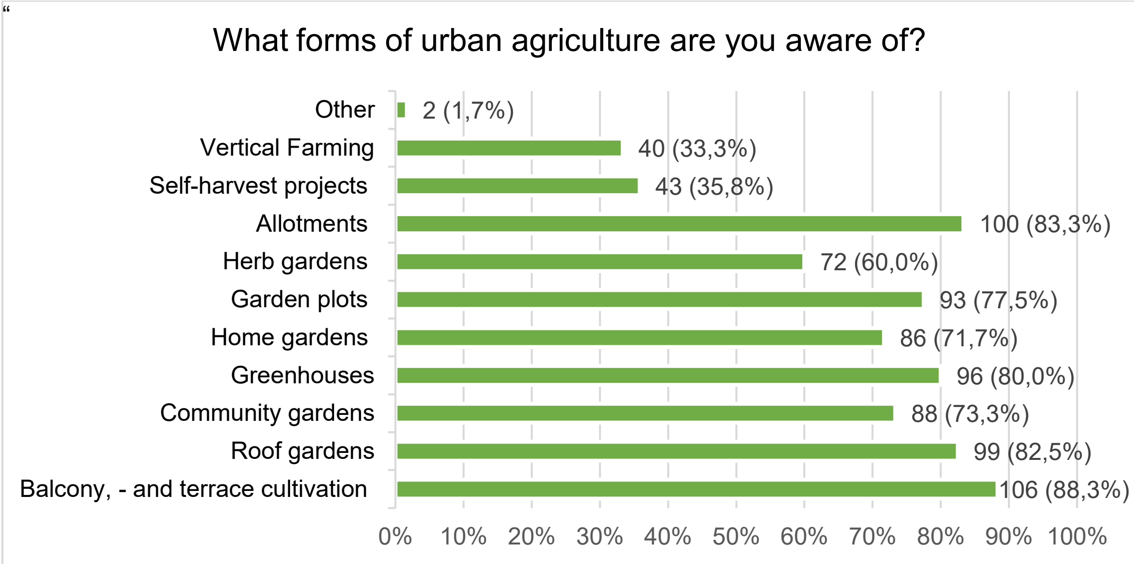

Table 27 – Urban agriculture: acceptance and preferences – forms of UA, conducted survey

Social, Ecological, and Health Benefits of Urban Agriculture

Regarding the social benefits of participating in a community garden, the top answers selected were “common gardening” (84%), followed by the “opportunity to make new friends” (73%), “to organize family leisure activities” (79%), and “beautification of the neighborhood” (63%). Other benefits included “the enhancement of the quarter” (63%), “image improvement of the neighborhood” (48%), and “the integration of migrants” (42%).

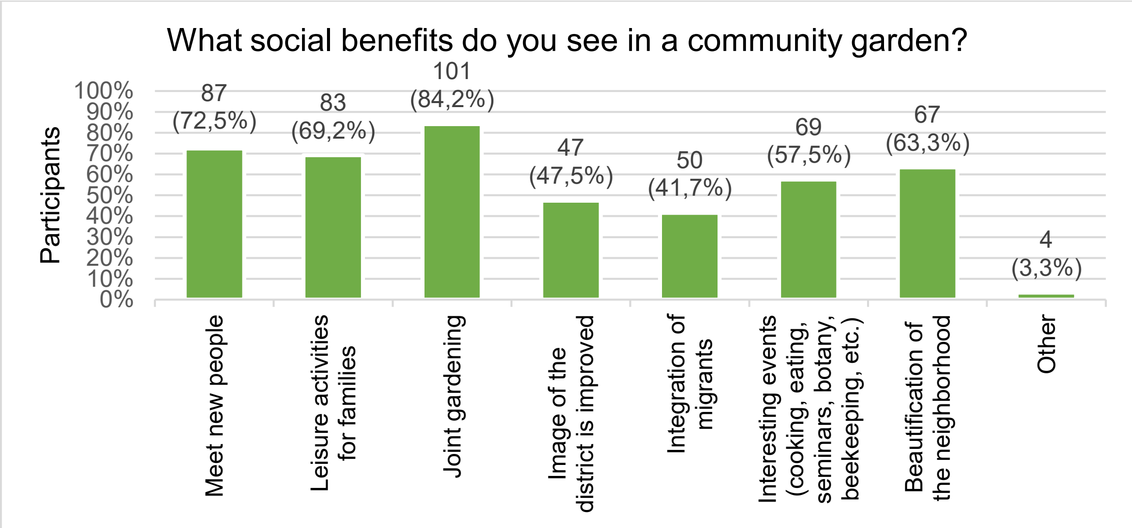

Table 28 – Urban agriculture: acceptance and preferences – social benefits, conducted survey

At the top of the list of environmental advantages was the "creation of a natural environment for pollinating insects" (84%), followed by the "possibility of organic cultivation" (75%), "air quality improvement" (67%), "protection of biological diversity" (65%), and "preservation of plant and seed varieties" (63%).

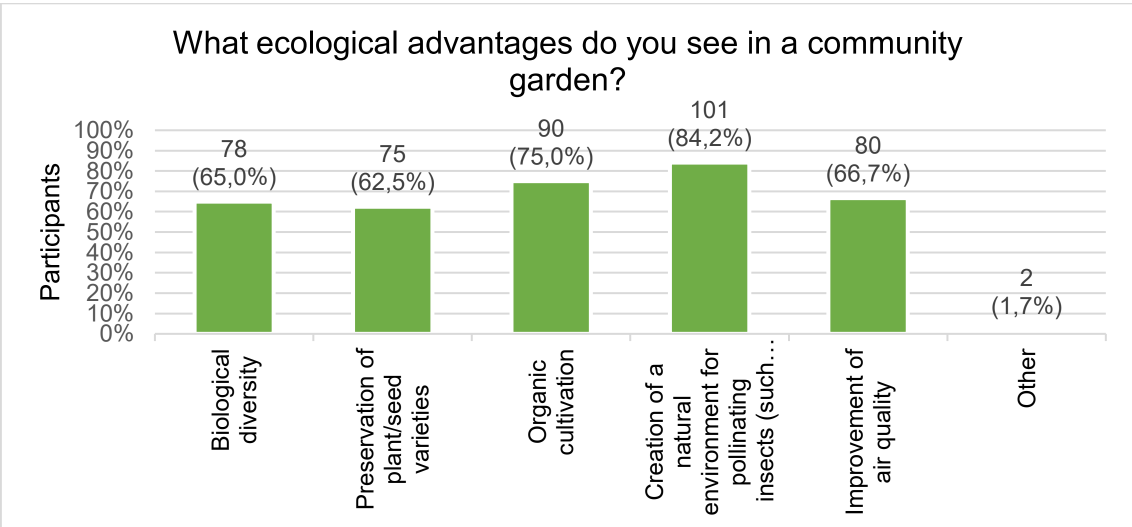

Table 29 – Urban agriculture: acceptance and preferences – ecological advantages, conducted survey

Here, 86% confirmed "various health benefits resulting from the horticultural activity in a communal garden." More than 70% cited "recreational activity in nature is relevant to health,” as well as the “resulting improvement in quality of life and nutrition,” especially for “low-income hobby gardeners.” “Raised beds for old or handicapped people” were considered beneficial by 65% when exercising a health promoting activity.

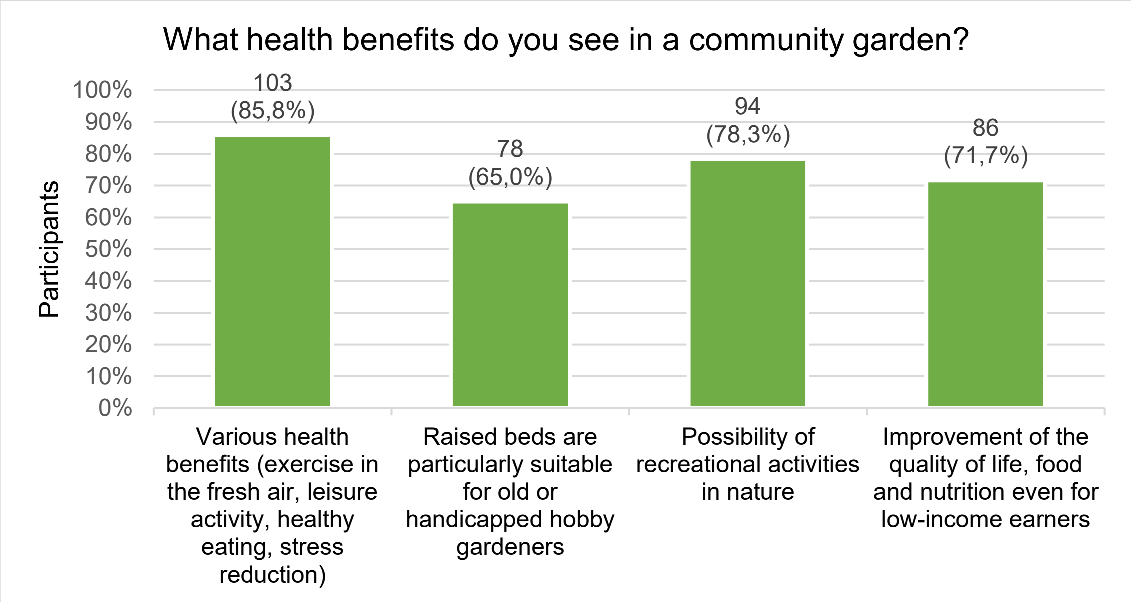

Table 30 – Urban agriculture: acceptance and preferences – health benefits, conducted survey

Acceptable Forms of Urban Agriculture in the Neighborhood (suburban and urban people only)

“Commercial agro-parks in the urban periphery*”* would be very gladly or gladly accepted by 62% of respondents. For 35%, this variant of urban agriculture was a less preferred institution, and 2% considered it unacceptable. 91% of the participants would like to have “roof gardens for house residents” in their neighborhood, whereas 6% would like them less, and 1% found them unacceptable. 54% of the participants had very positive or positive attitudes towards “fish farming and aquaponics;*”* 32% however, preferred to reject it, and 6% completely rejected it. “Gardens for hospitals” were accepted by 92% of participants with pleasure and gladly, while 6% did not approve.

“Intercultural gardens, mobile gardens on brownfields and public community gardens” were very well or gladly accepted by 81%, 86%, and 93%, respectively in their immediate surroundings, while 5% would like fewer public community gardens, 10% would like fewer intercultural gardens, and 8% would like fewer mobile gardens on brownfields in their vicinity. Between 1% and 5% did not want any form of urban agriculture in their neighborhood. School gardens and vertical agriculture in empty buildings are accepted by 92% with pleasure, and 86% of the participants would gladly welcome vertical agriculture in empty buildings.

Information Status about Urban Gardening Possibilities (suburban and urban people only)

For this question, 71% of the respondents answered with "not sufficiently informed” and 29% with "sufficiently informed.”

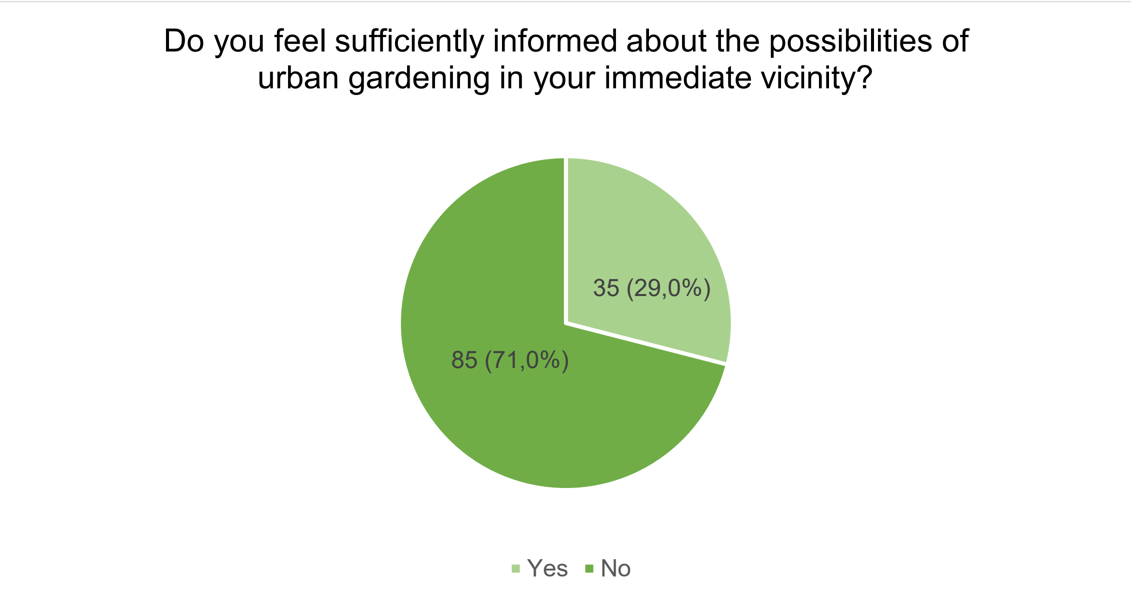

Table 31 – Urban agriculture: acceptance and preferences – feeling informed the possibilities of urban gardening, conducted survey

The results of the conjoint analysis show that older participants (26%) felt significantly (p = 0,002) more informed about the possibilities of urban gardening in their immediate vicinity than younger participants (7%).

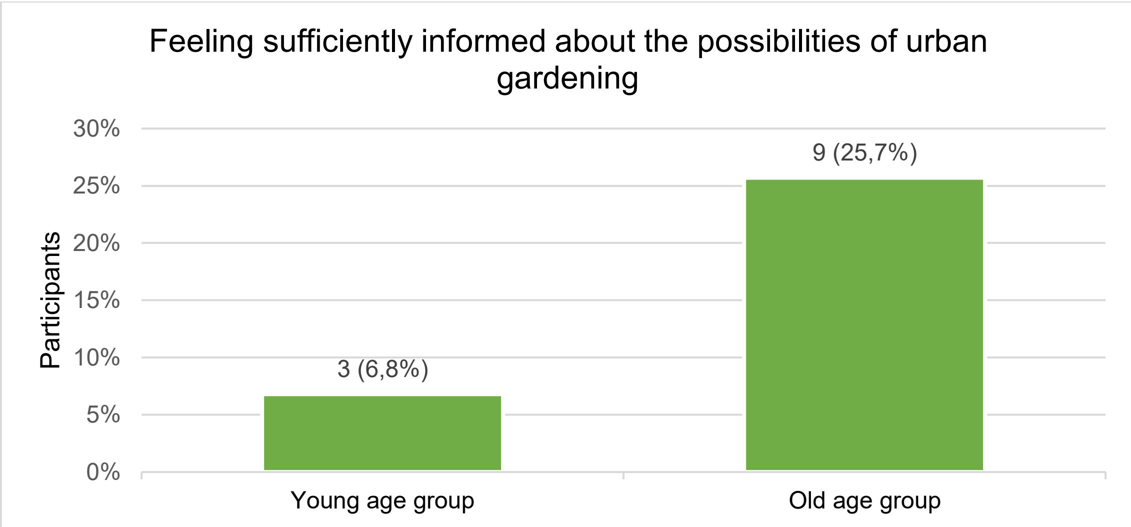

Table 32 – Urban agriculture: acceptance and preferences – age groups and feeling informed the possibilities of urban gardening

Environmental consciousness and education played little (p = 0,423) to no significant role (p = 0,762).

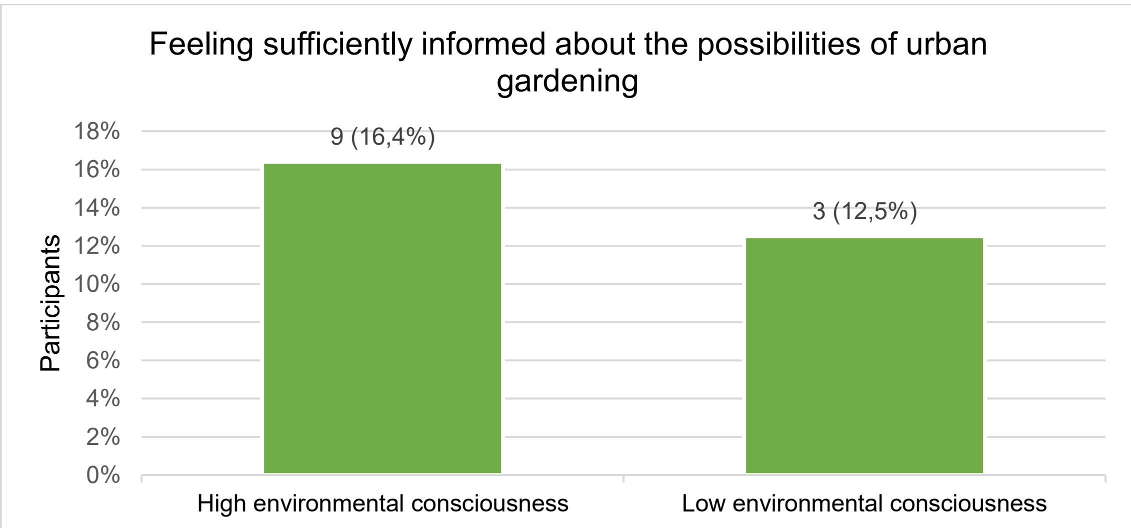

Table 33 – Urban agriculture: acceptance and preferences – level of environmental consciousness and feeling informed the possibilities of urban gardening

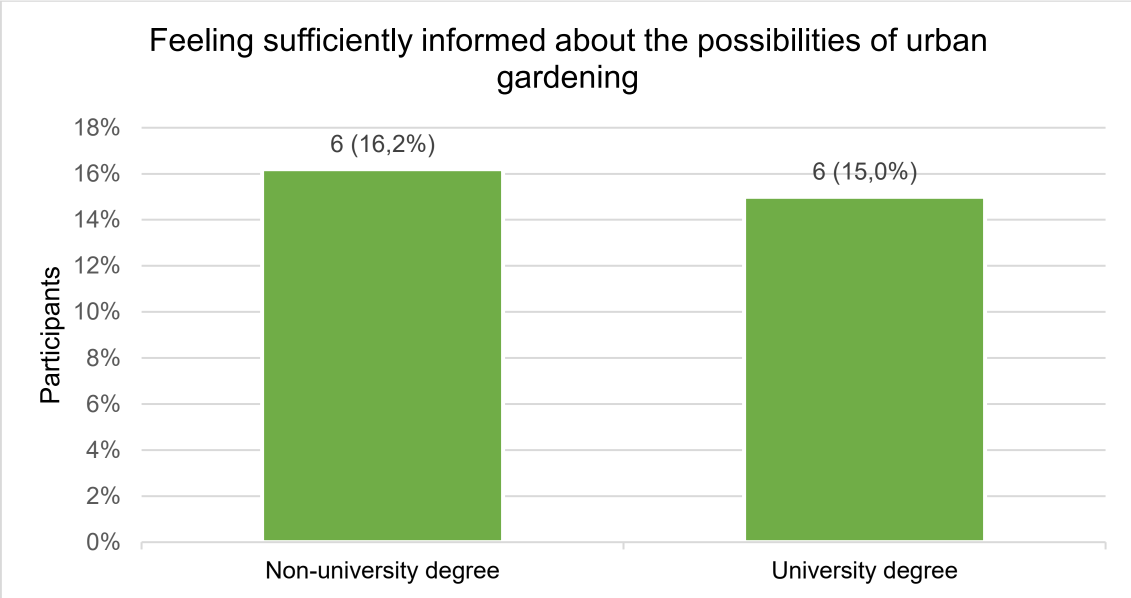

Table 34 – Urban agriculture: acceptance and preferences – level of education and feeling informed the possibilities of urban gardening

Personal Reasons to participate in a Community Garden (suburban and urban people only)

The majority (63%) stated that their motivation would be the "enjoyment of own vegetable production," followed by "learning from other hobby gardeners" (60%) and “attractive community events” (54%). For more than 40%, it would be crucial to be able to work in a community garden as “an ideal and healthy leisure time activity,” and for 61%, the reason for participating in a community garden would be the fact that the respondents “did not have their own garden.”

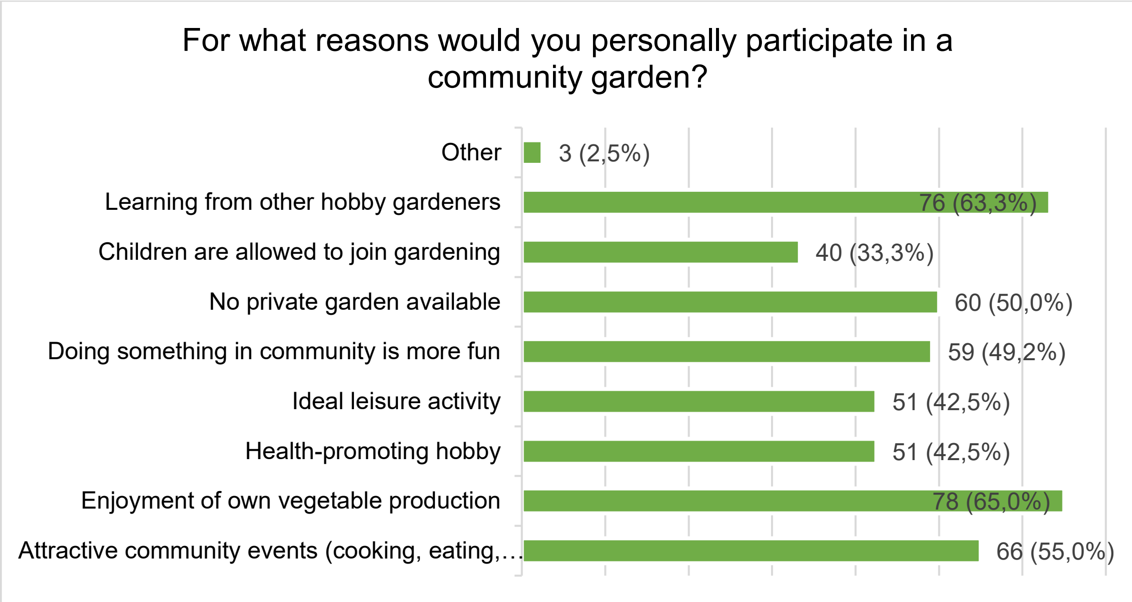

Table 35 – Urban agriculture: acceptance and preferences – community gardens, conducted survey

Resilience and Sustainability (Questions 24-33)

Knowledge of Sustainability

As all response options were closely related to the definition of sustainability, high approval rates were found for "raw material recycling and waste prevention" (87%), "use of renewable energies" (83%) and "environmentally friendly technologies" (82%), "economic use of fossil resources" (81%), "conservation of biodiversity" (79%), and "all measures of environmental protection" (69%). "Responsible, proactive planning social policy" received 49%, and the "promotion of local social and economic projects" received 40% of all responses.

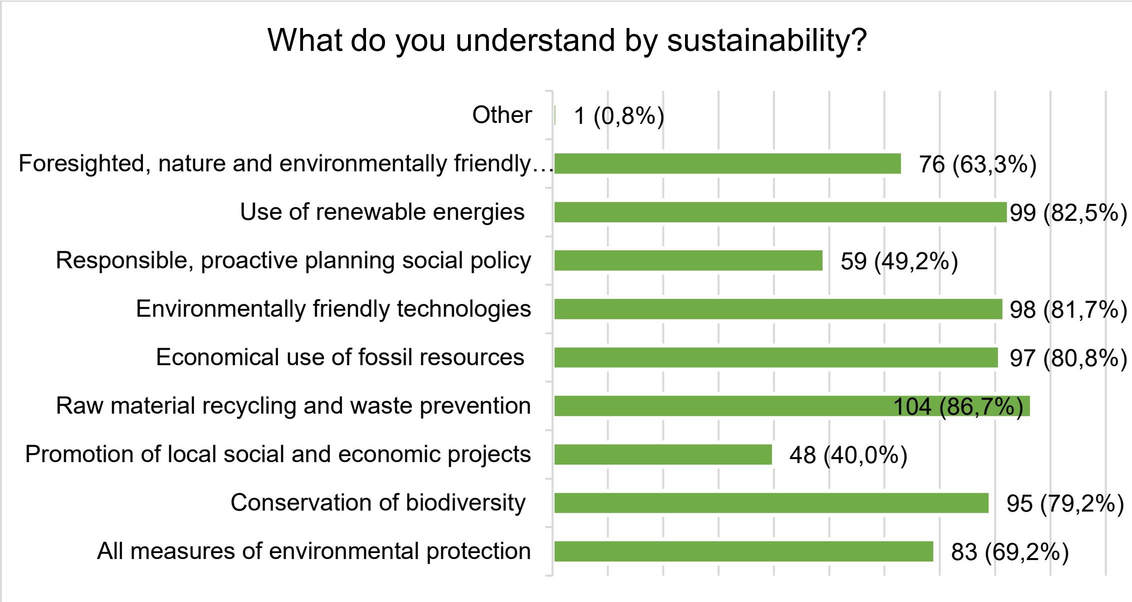

Table 36 – Resilience and Sustainability – sustainability, conducted survey

Awareness of Possible Threats due to Climate Change

57% of the participants described themselves as “very well or reasonably well informed,” and 42% said that they had “little or no knowledge” on this topic (2% gave no answer).

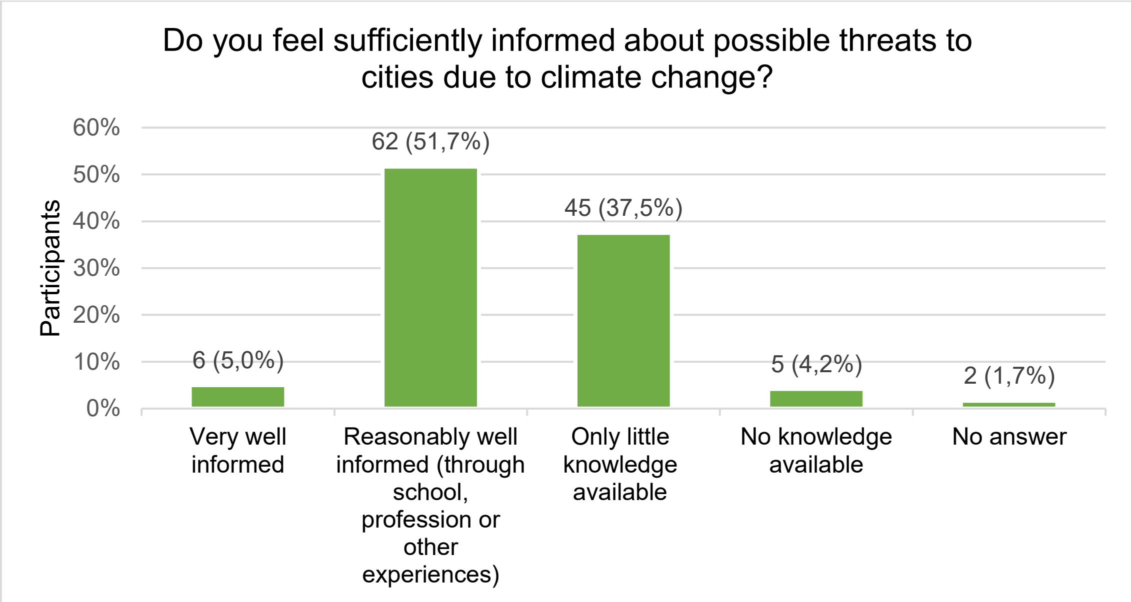

Table 37 – Resilience and Sustainability – informed about climate change

The Importance of Resilience for the Fight against Climate Change

On this question, all the answers were basically related to urban resilience, but the answers show a strong priority setting. 87% of the participants considered “water, food, and medicine” most important, while 85% chose “maintaining the functionality of the public help systems (medicine, fire, police).” Also rated as important, with over a 50% approval rating, was the “rapid restoration of damaged infrastructure,” the “fulfillment of normal governmental responsibilities,” and “the assurance of the citizens' confidence in urban crisis management.”

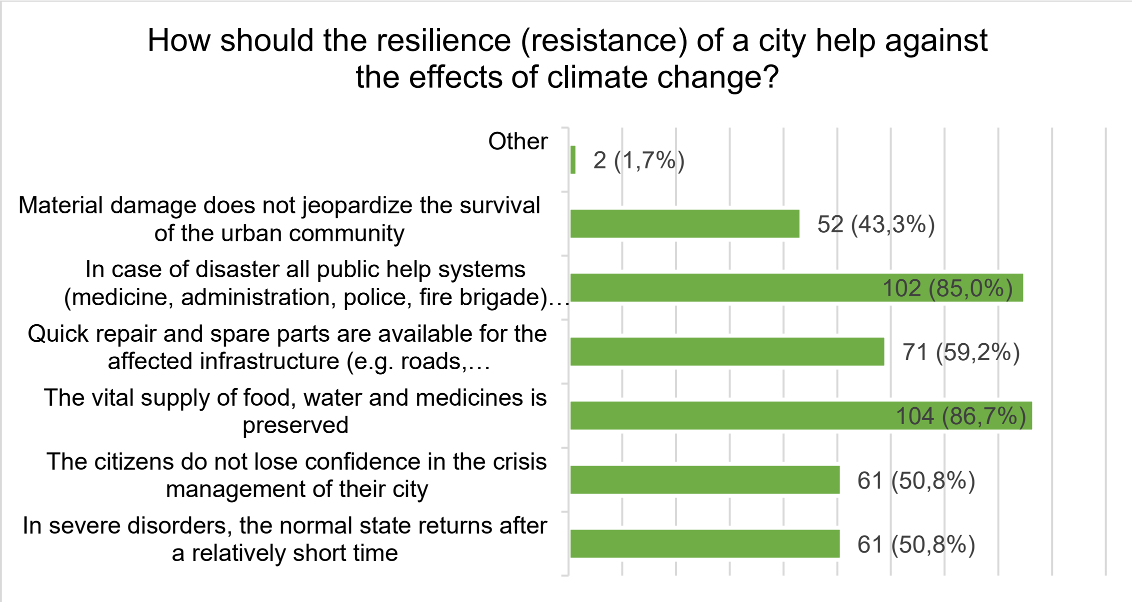

Table 38 – Resilience and Sustainability – resilience, conducted survey

Ways to Improve Urban Resilience

About 80% of the participants were convinced that, in the event of a crisis, “alternative supplies must be created for the provision with water and food.” In addition, “effective civil protection against natural disasters” must be performed. More than 70% agreed to “security measures and relocation strategies in case of power outages,” “preventive measures against water and food shortages,” and “structural measures against natural catastrophes like fires, floods, etc.”

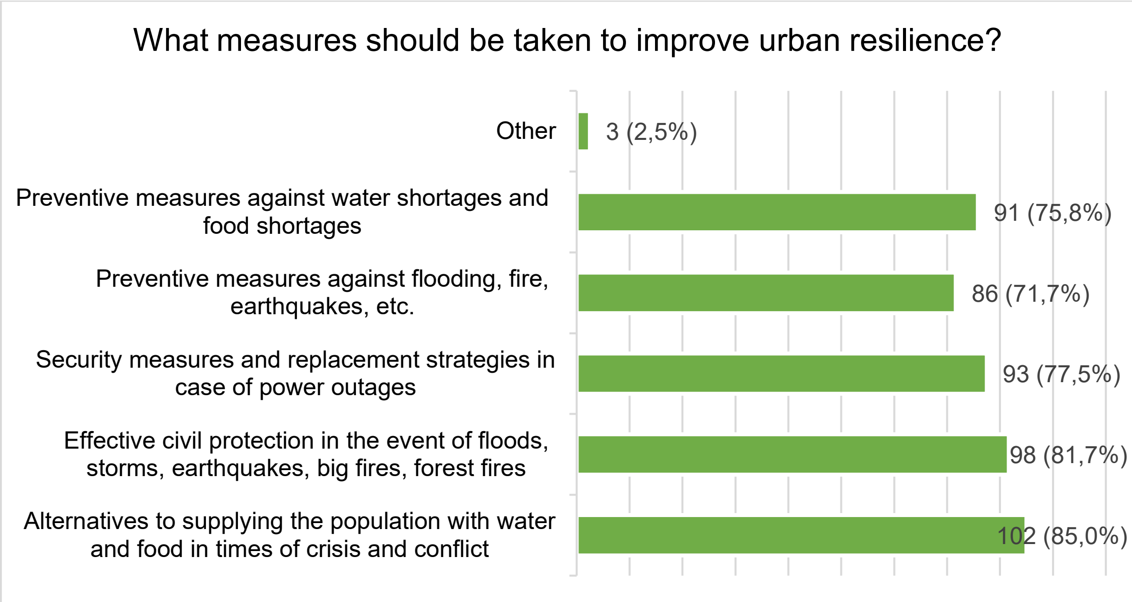

Table 39 – Resilience and Sustainability – ways to improve urban resilience, conducted survey

Rating of Green Infrastructure Measures to Fight Climate Change

The measures that received the highest approval ("very important" or "important"*)* were as follows:

- "tree planting to improve the city and capture CO2 emissions" (95%),
- "creation of as many green spaces as possible to replenish the groundwater" (91%),
- "parks for climate improvement and local recreation" (90%),
- "reduction of soil sealing" (86%),
- "greening of the streets with shady trees" (82%),
- "community gardens on brownfields" (78%),
- "the use of polder areas for urban agriculture" (70%),
- "roof gardens" (77%), and
- "porous road surfaces to avoid flooding" (65%).

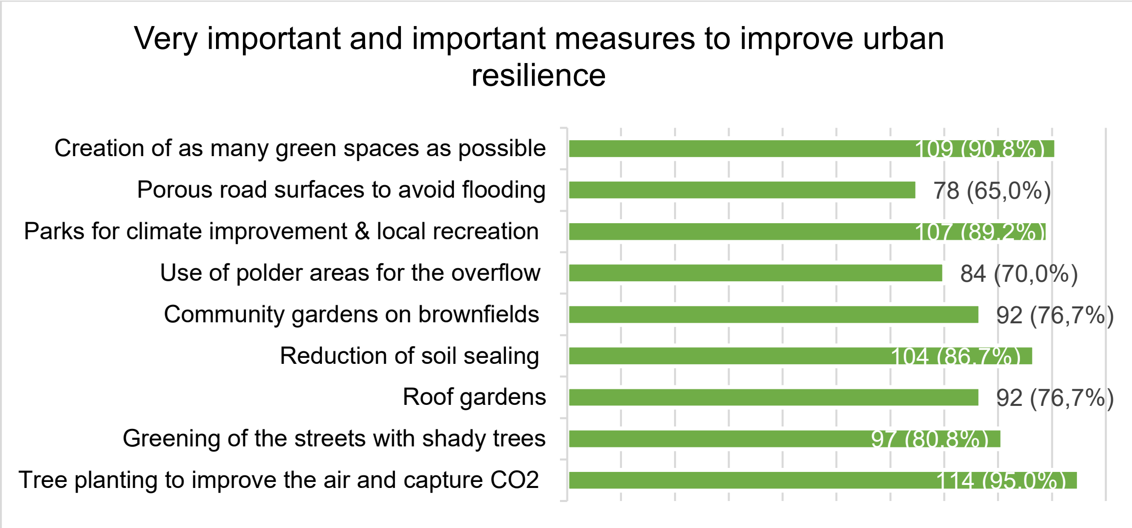

Table 40 – Resilience and Sustainability – resilience measures, conducted survey

Perceived Dangers to the Current Urban Food System

- 54% of respondents felt that the "lack of imports endangers the entire food supply of the population," while 45% considered it "less likely" or "unlikely"
- 66% are convinced that a "failure of the Internet would make cashless shopping impossible," while 31% did not agree
- 85% agreed with the statement that "rising commodity process would lead to higher food prices," and 13% disagreed
- 81% believe that “disruptions of transport routes would jeopardize replenishments for the supermarkets,” while 15% thought this was ″less likely" or "unlikely"
- 66% of participants agreed that "power outages could make selling in stores impossible," while 30% did not share this view
- 75% shared the fear that "shortages endanger social security and can lead to unrest," while 23% considered this "less likely" or "unlikely.”

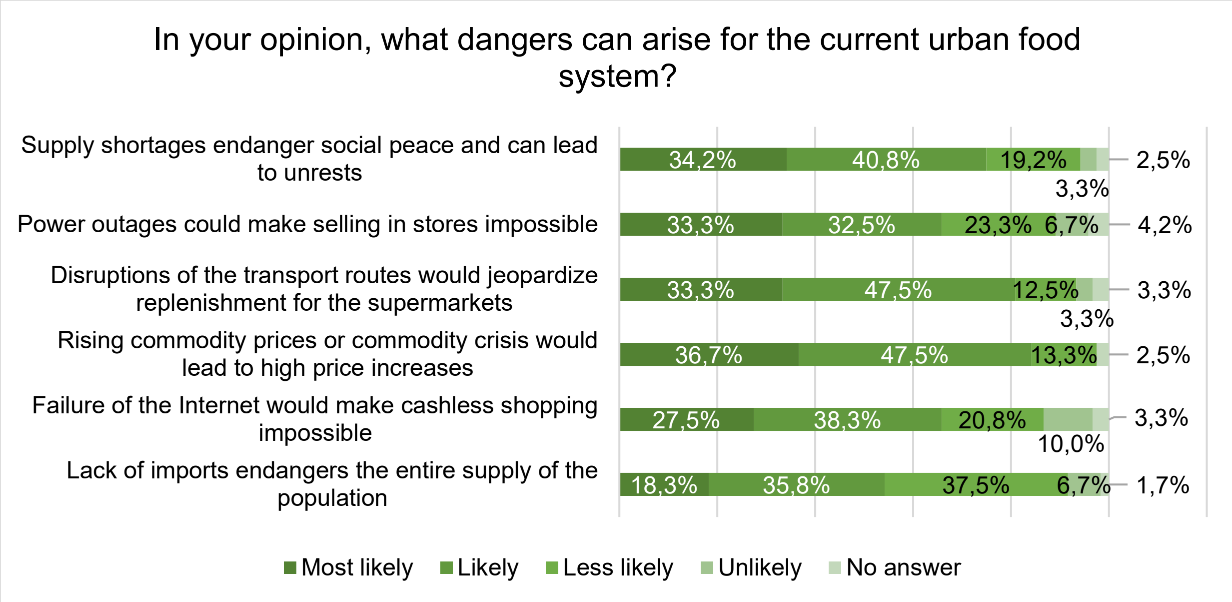

Table 41 – Resilience and Sustainability – dangers for urban food system, conducted survey

Mitigation Effects of Urban Agriculture

More than 70% of the participants responded that the following features of urban agriculture help adaptation to climate change:

- “no long transport routes and expensive cooling” (74%)
- “conservation of resources” (73%)
- “food for birds, bees, and other insects” (73%)
- “promoting biodiversity and preserving plant/seed varieties” (73%)
- “recycling organic waste and composting” (71%)
- “improvement of the urban climate” (71%)
- “greater independence in food supply” (71%).

Somewhat less frequently, the following answers were chosen:

- “low water consumption” (63%)
- “absorption of CO2 emissions” (61%)

- “indoor farms allow continuous harvests independent of the weather” (58%)
- “urban gardens increase the quality of life and living” (55%)
- “urban gardens strengthen social cohesion in the neighborhood” (53%)
- “promoting health through gardening and healthy eating” (53%)
- “passing important gardening knowledge to the next generation” (51%)
- “extra income and self-care for families and low-income earners” (39%).

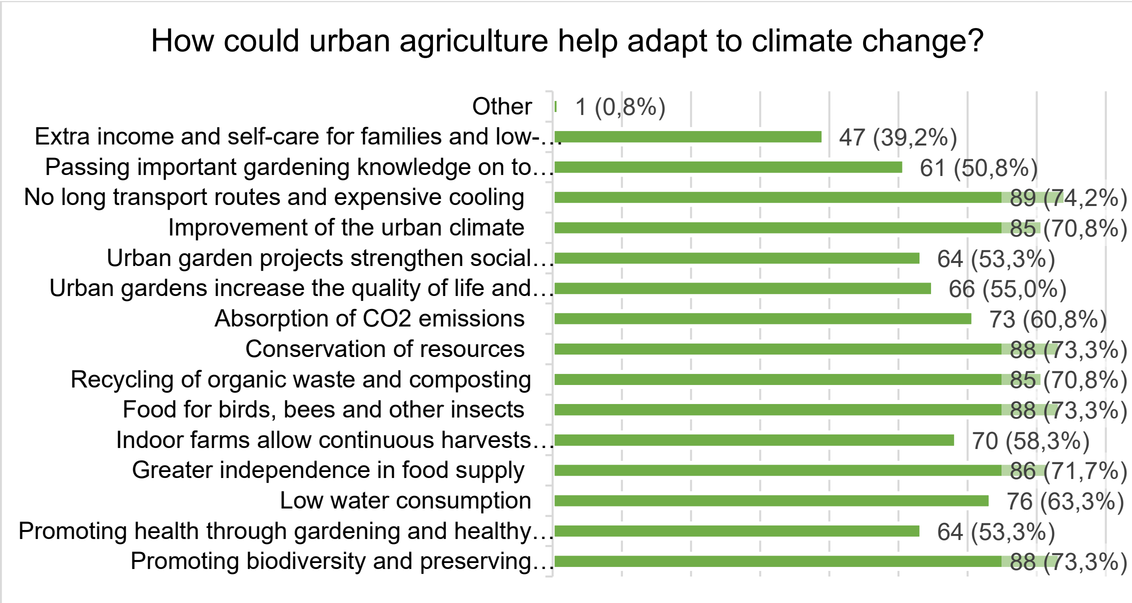

Table 42 – Resilience and Sustainability – adaption to climate change, conducted survey

Use of Urban Brownfields and Unused Land for Agriculture

Here, a large majority of 92% approved the use of brownfields and unused land for urban agriculture, while only 4% did not.

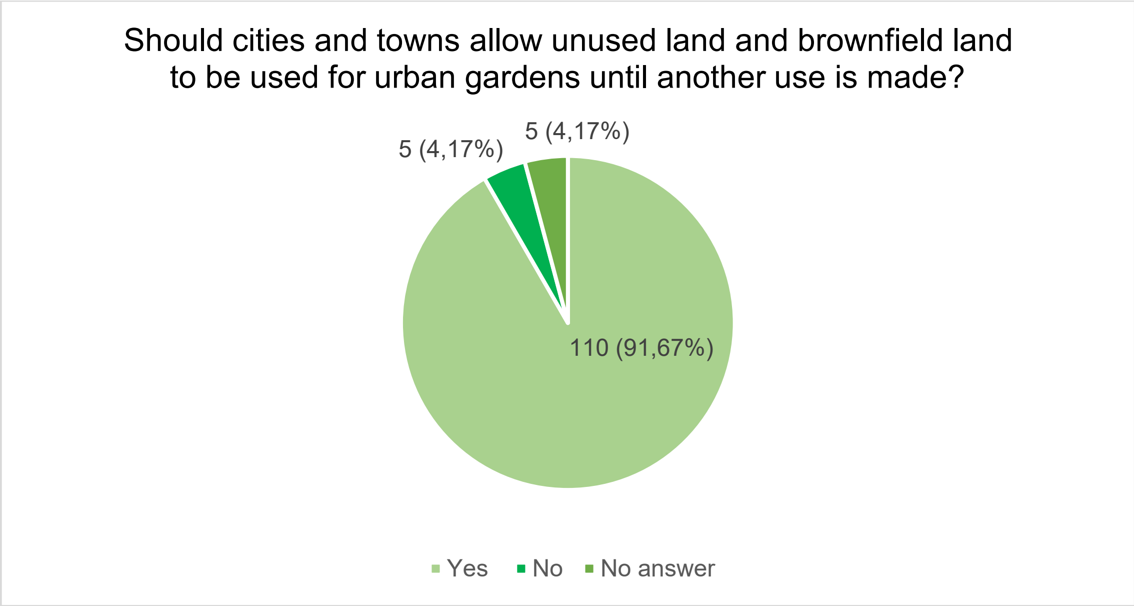

Table 43 – Resilience and Sustainability – usage of brownfields and unused land, conducted survey

The conjoint analysis proves that the level of environmental consciousness made no significant (p = 0,788) difference when asked whether cities and towns should allow unused land and brownfield land to be used for urban gardens until another use is made.

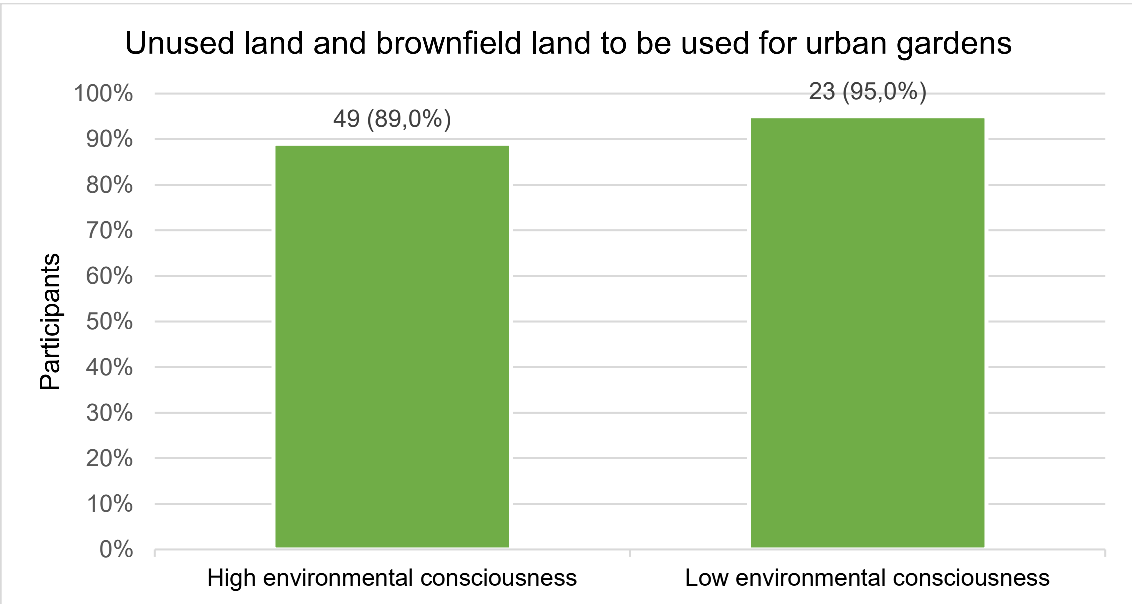

Table 44 – Resilience and Sustainability – usage of brown fields and environmental consciousness, conducted survey

Personal Food Supply in the Respondents' Homes

The participants' stocking of food had the following distribution:

- "fewer than three days" (23%)
- "three days" (13%)
- "one week" (34%)
- "two weeks" (17%)
- "three weeks" (4%)
- "one month" (9%).

Table 45 – Resilience and Sustainability – personal food supply, conducted survey

Older participants tended to have food supplies in the house for significantly ($p < 0,001$) more days (two weeks to one month, 80%) than younger ones (two weeks to one month, 44%).

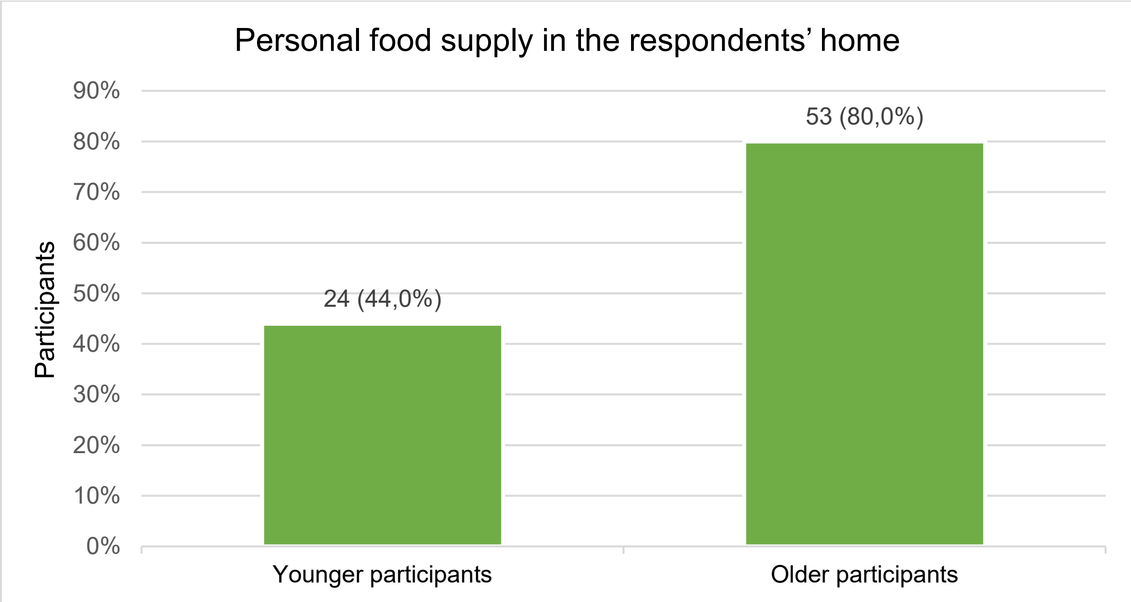

Table 46 – Resilience and Sustainability – personal food supply and age, conducted survey

Participants living in the countryside tended to have food supplies in the house for significantly ($p < 0,001$) more days (two weeks to one month, 90%) than participants living in urban areas (two weeks to one month, 53%).

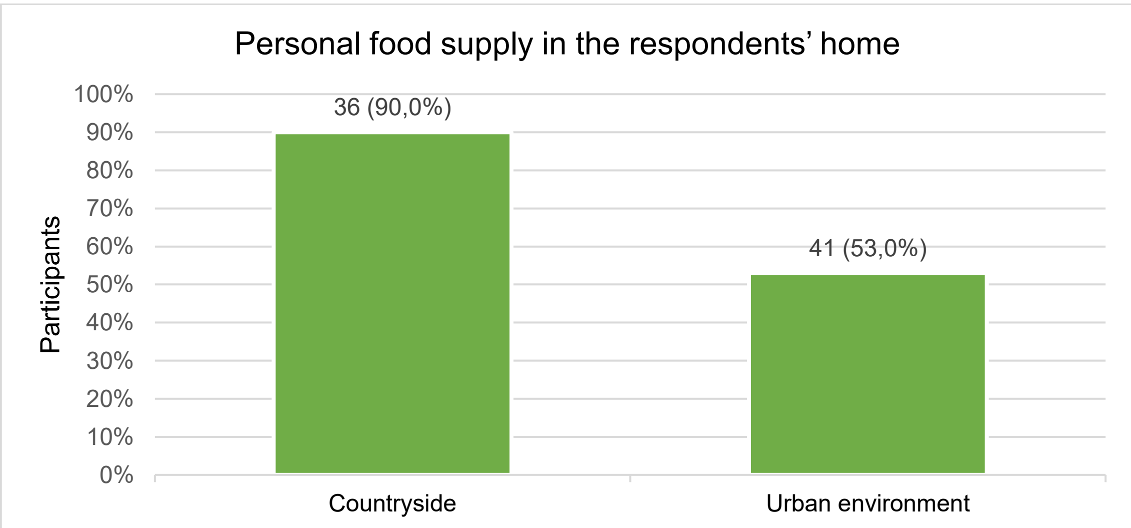

Table 47 – Resilience and Sustainability – personal food supply and living environment, conducted survey

Looking at the level of environmental consciousness, participants with a high consciousness were significantly (p = 0,025) more likely to have food supplies in the house for more days (two weeks to one month).

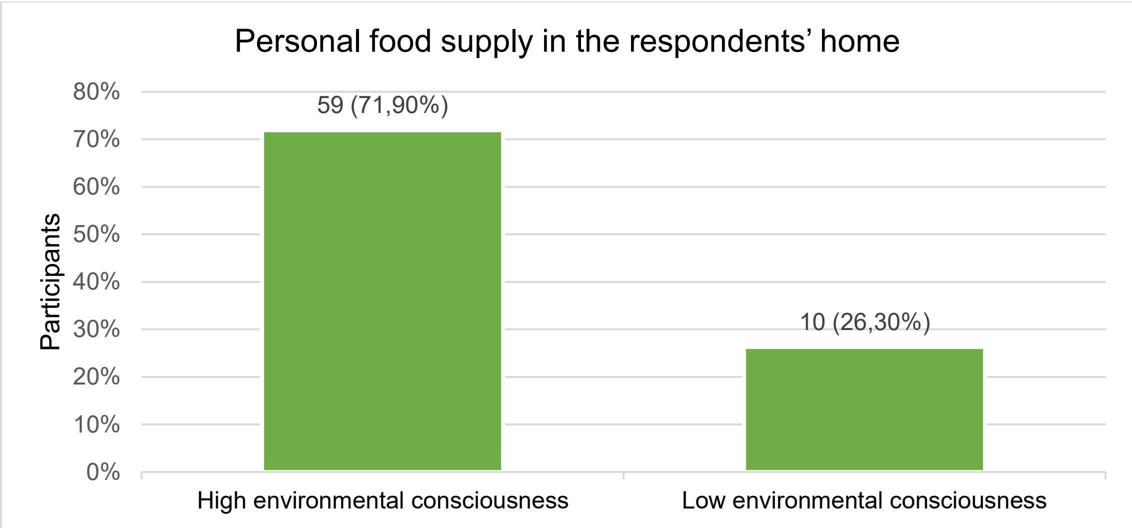

Table 48 – Resilience and Sustainability – personal food supply and environmental consciousness, conducted survey

Supportive Measures for Urban Agriculture

The following measures received a high level of approval:

- "greening flat roofs of urban buildings" (81%)
- "creation of gardens for kindergartens" (81%)
- "provision of land (brownfields)" (80%)
- "integration of urban agriculture in urban planning" (79%)
- "allow or support street markets for urban agriculture" (72%).

The lowest approval with 62% was received for the measure "providing project funding for intercultural and educational" gardens.

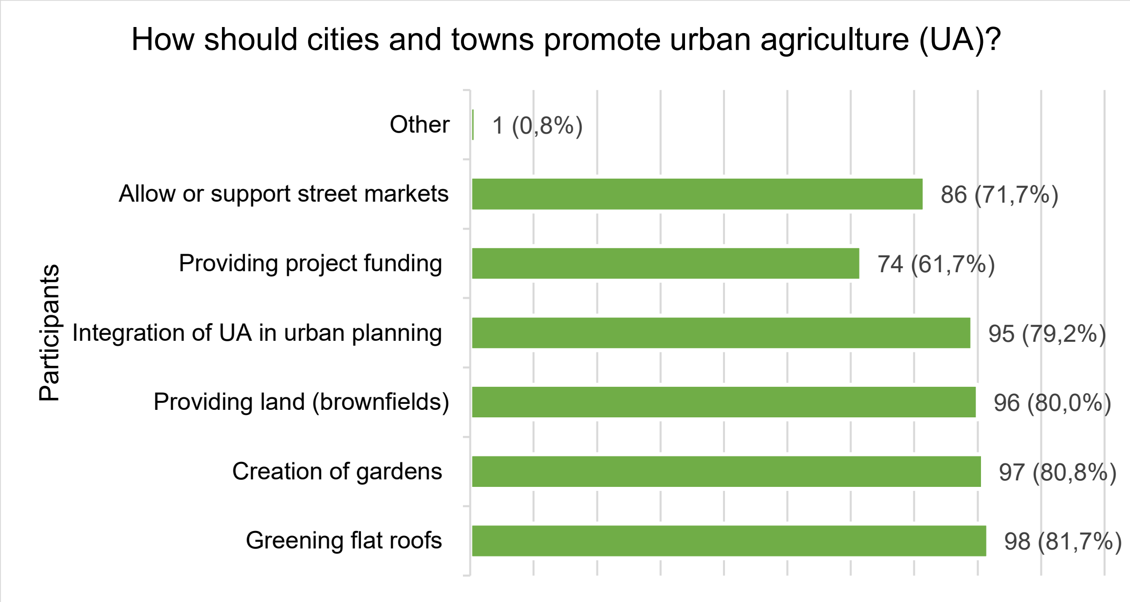

Table 49 – Resilience and Sustainability – promotion of UA, conducted survey

8.2.6.5 Discussion

To discuss the results of this online survey, the survey by Schulz et al.[564] from 2012 on the acceptance of urban agriculture, the study by Heuner[565] on the motivation of urban gardeners, and the author's[566] 2013 online survey on the importance of sustainability in consumer behavior and modern marketing were used.

In 2012, Schulz et al. conducted a non-representative survey with 386 participants in Berlin as part of their case study on "Urban agriculture and green production as part of sustainable land management." The purpose was to identify general preferences regarding land use, urban forms of organization, and their

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[564] Schulz, K. et al. (2013): Urbane Landwirtschaft und „Green Production“ als Teil eines nachhaltigen Landmanagements. Diskussionspapier Nr. 6. Leibnitz-Zentrum für Agrarlandforschung e.V., Müncheberg 2013

[565] Heuner, S. (2016): Warum wird gegärtnert? Eine Untersuchung am Beispiel urbaner Gartenprojekte. PH Karlsruhe. https://ufer-projekte.de/wp-content/uploads/2016/05/Sonja-Heuner-Warum-wird-gegaertnert.pdf. Retrieved on 14.5.2019

[566] Masyk, T. (2013): Sustainability as a key factor in modern marketing strategies. University of Economics, Prague 2013

products. Their findings were that about 50% of respondents were in favor of the urban production of vegetable products, less than 33% for animal products, and only about 18% for urban meat production. Here, the endorsement of the forms of production was equal to the willingness to buy (over 50%).

For land use, the majority (60%) preferred roof gardening, outskirts, fallow land, backyards, self-harvesting, and rented land. There was a high level of agreement (58%) for particularly environmentally sound production methods, but intensive forms of farming were rejected (2% to 18%).

The preferred characteristics of the products were as follows: high quality (29%), regionality (28%), organic production (19%), and animal welfare (16%). Social aspects received a low rating (8%). Only 25% would spend more on urban agricultural products.

Foremost among the uses and benefits of urban gardens, recreational functions were designated, followed by nature and landscape conservation and social integration in community gardens. More than 80% wanted access to public green spaces, intercultural gardens, and rooftop gardens. High rejection (65%) was reported by Schulz et al. for the operation of urban agriculture in multi-story houses, agro-parks or aquaponic farms. 67% of the respondents felt that urban agricultural products would be contaminated by urban fumes, and 50% considered soil contamination a problem.

The vast majority (75%) assessed urban agriculture as a contribution to improving the image of the city with positive effects on the environment, society, education, and leisure activities. Summarizing the results of Schulz et al., it can be said that the highest acceptance was found for multifunctional urban agriculture with ecological and social objectives.
Heuner performed another online study with 141 participants in 2016, focusing on the motivation of urban gardeners, the benefits of 81 urban gardening projects

and their effects on the environment. Her online survey revealed the lack of a personal garden and a strong desire to garden as the most common motive for joining a community garden. For 63% of the participants, environmental aspects played the decisive role; for 42%, it was social reasons, and for 22% health and leisure reasons were the primary factor. The majority of respondents (74%) indicated that participating in an urban gardening project improved or somewhat improved their knowledge of gardening. With about 86%, the respondents agreed or somewhat agreed with the thesis that the urban garden project had improved biodiversity in the area. A large majority, 92%, was convinced that the garden project had significantly beautified the environment, and 81% of the participants claimed that gardening had improved their mental well-being.

The author's own online survey in 2013 included 143 participants who, however, did not constitute a representative sample in terms of age and education. In the field of “consumer behavior and information,” 64% of respondents said they were not adequately informed about sustainable products; 67% said that they obtained their information from friends and family members, and 58% looked for product information on the Internet or on certification seals or labels. “Being asked about their expectations concerning a good sustainability marketing, the listing of ingredients, transparency, and verifiability were rated as ‘most important’. As also ‘important’ were seen specific information about environmental friendliness and life cycle of the product.”[567]

Concerning the assessment of sustainability and its importance in purchasing decisions, 59% answered with “very important” or “important.”

[567] Masyk, T. (2013)

“The vast majority of the older age group (40 – 65 years, 69%) and the younger age group (15 – 39 years, 55%) believed that sustainability is an ‘important’ or ‘very important’ decision factor.

When asked about the importance of a sustainable development for the planet and future generations, the overwhelming majority of the younger age group answered with ‘important’ or ‘very important’ (94%). Almost 100% of the older age group gave the same answer with the accent on ‘very important’ (76%).”[568]

Regarding sustainability awareness, 74% described themselves as “very environmentally conscious” or “rather environmentally conscious.” In the younger age group, 66% rated themselves as “very or pretty environmentally conscious,” while this answer was given by 94% in the older age group. “The question about sustainable products that are bought by the respondents, was answered that sustainable food is bought ‘whenever available’ by young (21%) and ‘regularly’ by older persons (20%).”[569]

The following reasons for buying sustainable products had the highest approval:

- “60% chose sustainable products because of their ‘harmlessness to the environment’.
- 56% of the persons associated with the purchase of a sustainable product a feeling of ‘doing something good for the environment’.
- The same percentage (56%) want to ‘do something good for their families and friends’ with sustainable products.
- 47% demonstrate with their shopping behavior their ‘rejection of factory farming and animal cruelty.’ ” [570]

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[568] ibid.
[569] ibid.
[570] Masyk, T. (2013)

“83% of all the participants would pay a higher price for sustainable and eco-friendly products, with whose acquisition they connect consistently positive feelings. Over 90% of participants would choose sustainable products if they have the same price and quality – a proof that the importance of sustainability has arrived in the consciousness of the consumers.”[571]

The survey also included an “assessment of corporate philosophies. Here, almost all pre-set options concerning desired sustainable business practices such as ‘energy efficient production,’ ‘promoting health and safety,’ ‘innovation and research,’ ‘local production,’ ‘protection of animal rights,’ and ‘fair trade’ were chosen by the respondents as ‘important.’ 20% rated a company’s philosophy and ethical position as ‘very important’ for their purchase decision, 61% as ‘important’ and 19% as ‘less important.’ Of all given factors, ‘quality’ and ‘sustainability’ were rated as the most important factors for a good reputation. They were followed by ‘attractiveness as employer,’ ‘company management,’ and ‘company philosophy.’ ”[572]

8.2.6.6 Summary and Conclusion

The overwhelming majority of the participants in this online survey referred to themselves as environmentally conscious or very environmentally aware, and most of them produced part of their food in the garden, on the terrace, or on the balcony. Compared to all responders, significantly more people ($p < 0,001$) grow their own food in this group compared to those who consider themselves less environmentally conscious.

Significantly more old people than young people grow their own food ($p < 0,001$). Also, significantly more people in the countryside grow their own food than people in the urban environment ($p = 0,034$) and significantly more women than men

[571] ibid.
[572] Masyk, T. (2013)

(p = 0,036). The level of income plays no role for the gardening hobby, and there are significantly more participants with higher education (p = 0,02).

Environmentally conscious people also have different shopping habits and purchase their local or regional food more often in farm shops and farmers' markets than in supermarkets, independent of age, residence, or education. The reasons given for this are the higher quality of the products, greater transparency concerning origin and production method, and strengthening the local economy. Generally, locally produced food is preferred because of higher freshness, safety, and shorter transport routes. People with a low environmental consciousness are significantly less likely to prefer buying regional and local products (p < 0,001).

The comparison with the 2013 author's online survey showed a high degree of consonance regarding the importance of sustainability in production, buying behavior, and self-awareness, with a somewhat stronger sustainability orientation among the older participants. Sustainability and resilience orientation in a company's philosophy and production practice were much appreciated by customers and represent a strong purchase incentive.

With few exceptions, all respondents were familiar with traditional forms of urban agriculture, but only one-third were aware of self-harvesting farms and vertical farms.

Vertical farms are an unknown farming concept for most people. Those who reject the products are afraid that the production method is unnatural and the outcome must be artificial factory food. Of course, these people have no knowledge about the ecological production processes and the superior quality of the products. Nonetheless, the vast majority of participants would buy the products from vertical farms, even if they did not carry a conventional organic label. Living environments, education and age had no significant influence on the decision to buy vertical farm products.

The vast majority highly appreciated gardening together with other people in a community garden or similar activity, above all because of the health benefits as an enjoyable outdoor activity. In accordance with the results of Heuner and Schulz, further benefits include knowledge, biodiversity protection, and enhancement of the quarter.

In their own neighborhood, people would love to have roof gardens, and they would also accept fish farming. However, agro-parks would be only well accepted in the urban periphery, in contrast to the results of the Schulz survey, where agro-parks were almost completely rejected. The highest acceptance in the survey was for hospital and school gardens and vertical farms in vacant buildings.

As a rule, older people considered themselves better informed than the younger generation, with a good understanding of sustainability and an average knowledge about the threats of climate change. The higher the environmental awareness, the more the people were informed about sustainability, resilience, and climate change, regardless of age.

The importance of resilience for the fight against climate change has been assessed as very high, whereby food, water, and medicine and maintaining the functionality of public help systems (medicine, fire, police) are considered most vital. For these reasons, alternative supplies for the provision of water and food and preventive measures against water and food shortages are identified as the most important measures to improve urban resilience.

In rating green infrastructure measures to fight climate change, the top ranks were the planting of trees to reduce CO_2 emissions, the creations of more green spaces for replenishing the ground water, parks for an improved micro-climate and recreational areas, and a reduction of soil sealing.

As probable threats to the current urban food system, the participants indicated rising food prices, disruptions of transport routes, and food shortages, which could trigger social unrest.

A high level of approval was found for the mitigation effects that urban agriculture can achieve, in particular the conservation of resources, the protection of biodiversity and especially pollinators, the recycling of organic waste, the improvement of urban climate, and the greater independence of urban food supply. Similar to Schulz's survey, a large majority in this survey favored the use of brownfields for urban agriculture as well as other supportive measures, such as the integration of urban agriculture into urban planning, greening flat roofs of urban buildings, and street markets for urban agriculture. In this respect, the environmental consciousness played no significant role.

This synopsis of the findings clearly shows that urban agriculture is a positive and environment-improving addition to the urban landscape among all age groups, urbanites, and people living in the periphery of cities or rural areas. Against the background that the survey's participants are not representative of the German population, it can be concluded from the results that there is a definite need for more green spaces and tree plantations for leisure and climate regulation, and that urban, hands-on gardens, roof gardens, and other forms of urban agriculture are very well accepted.

The participants mentioned 7 different reasons for their gardening hobby. They named 15 general benefits and specifically 4 health, benefits, 5 ecological and 7 social benefits of gardening. Of course, there is a difference between liking urban agriculture and liking to practice urban agriculture oneself. Many people do not have a terrace or balcony or any other option to do urban gardening, but nonetheless they support the UA concept and prefer to have more urban gardens.

Neither this study nor any other has so far found a genuine rejection of urban agriculture. There are certain understandable concerns about small animal breeding in inner city areas, but there would be sufficient space in the urban periphery for these projects so that the most important parameters, such as nature conservation, saving resources, and short transport routes can be met. The cultivation of one's own vegetables, flowers, and herbs, albeit often only on a small scale, is back in vogue, and this is not just a short-term trend, but a real need, above all for city dwellers, who bring a piece of nature home with them.

In rural areas the older generation is characterized by the fact that it generally has a significantly larger supply of food ($p < 0{,}001$) and has higher food sovereignty through its own food crops. People with a high environmental consciousness are significantly more likely to have food supplies for two weeks to one month ($p = 0{,}025$).

Younger people in the city often lack the gardening know-how and, above all, the necessary conditions, such as a private balcony or garden. Community gardens in the city districts could provide a welcome remedy and contribute to the neighborly integration of all sections of the population.

Regarding necessary sustainability and resilience measures against potential threats from climate change or other external crises, it is evident that, regardless of age, education, and place of residence, important actions to improve urban resilience receive undivided support. In particular, the positive effects of integrating urban agriculture into urban structures are recognized, and their extension is advocated. The mitigation effects and adaptation potential of green infrastructure, including various urban agricultural manifestations, are considered vital for a city's resilience and must be supported in the best possible way.

8.3 Case Study: UA in the Emirati Food Security Strategy

8.3.1 SWOT Analysis of the Current Food System

8.3.1.1 Strengths

- Political stability
- Economic power
- Excellent international rating
- High GDP
- Good transport and logistic structures
- Viable trade partnerships
- Good access to qualified human resources
- Modern infrastructure
- Good investment conditions
- Abundant energy resources
- Stable currency
- Low tariffs and trade barriers.

In recent decades the small desert state called the United Arab Emirates has become one of the wealthiest countries in the world, primarily due to the wealth created by the country's abundant oil deposits. With the world's seventh-largest oil reserves,[573] the country achieved an increase of its GDP from $46 billion USD in 1995 to $382.58 billion USD in 2017.[574] In order to diversify its economy as much as possible and reduce the dependency of its wealth on oil revenues, the UAE have heavily invested in infrastructure and services, as well as in profitable

[573] OilProduction. http://oilproduction.net/files/especial-BP/bp-statistical-review-of-world-energy-2016-full-report.pdf. Retrieved on 10.1.2019
[574] Trading Economics. https://tradingeconomics.com/united-arab-emirates/gdp. Retrieved on 11.1.2019

companies abroad; today, the non-oil sectors already account for 75% of its GDP.[575]

Political stability, a strong economy, and a high gross domestic product have contributed to the fact that, within a short time, an archaic society has become a successful modern state.[576] According to the Arab Youth Survey 2016, the UAE is the top country worldwide to live in because it is considered a safe, secure country with excellent opportunities to start a business."[577]

Extreme climatic conditions pose major challenges for the desert state and can only be overcome with strategically secure import and trade policies. Access to energy and capital is unlike that in any other country. The UAE's economy is largely based on the import of low-wage workers from Asia as well as highly qualified professionals from all over the world; the latter in particular have made the Emirates of Abu Dhabi and Dubai highly developed economic centers.

In 2015, together with the FAO, the UAE developed a strategic concept for sustainability and food security that should be fully implemented within a period of 15 years. Because the country needs to import at least 85% of its food from abroad, there are few or low import restrictions on food and no tariffs on staple food. In order to be less vulnerable to high price volatility and delivery shortfalls, the government pursues a diversified import policy with numerous states, as well as direct agricultural investments in foreign countries. As a reaction to the 2007-2008 food price crisis, the UAE started buying and leasing land abroad in order to reduce its dependence on traditional exporters.[578] The relocation of production

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[575] ibid.

[576] Fischbach, T. (2018): Strengthening Resilience: Advancing Food Security in the UAE. https://www.mbrsg.ae/getattachment/859ddec7-f5ed-48dd-99dd-4e1b8f326112/Advancing-food-security-in-the-UAE. Retrieved on 4.1.2019

[577] Khaleej Times. https://www.khaleejtimes.com/nation/dubai/uae-is-the-top-country-to-live-in-arab-youth-survey-1. Retrieved on 10.1.2019

[578] Gornall, J. (2016): Inside the UAE's quest for food security and why the West is wrong about land acquisitions. The National, Jan. 21, 2016. www.thenational.ae/arts-life/the-review/inside-the-uaes-quest-for-food-security-and-why-the-west-is-wrong-about-land-acquisitions#full. Retrieved on 7.1.2019

to countries such as Namibia, South Africa, and Sudan provides the advantage that, in the future, the UAE will be able to dispense with the production of wheat in their own country due to its high water demand. Additionally, a planned cooperation with Japan will allow the UAE to monitor planting projects via satellite and modern sensing technology.[579] [580]

A highly successful import policy in many areas enables the UAE to export food processed in the UAE back to other countries, thus becoming one of the world's largest re-exporting countries.[581] [582] Cheap workers from the Far East; available capital; inexpensive, abundant energy; and excellent port and airport facilities are the comparative competitive advantages that the Emirati government uses to secure and maintain a high level of food supply for the country. However, it should also be noted that the imported food would be unaffordable for most people if the government did not strongly subsidize it.[583] Such a heavily subsidized food supply system provides unrealistic prices, lowers incentives for sustainable consumption, and weakens resilience. This system is feasible only because of the country’s wealth. In order to be prepared for crisis situations, the Emirati government pursues a consistent stockpiling strategy with the storage of a six-month supply of barley, rice, wheat, and four months of corn stocks.[584]

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[579] Space.com. https://www.space.com/42280-japan-khalifasat-gosat-2-satellite-launch-success.html. Retrieved on 9.1.2019

[580] Ponce de Leon, J. (2018): UAE-built satellite launched from Japan. https://gulfnews.com/uae/science/uae-built-satellite-launched--from-japan-1.2294969. Retrieved on 9.1.2019

[581] Lowe, A. (2012): Ensuring Food Security of the UAE. Gulf News, 19 Feb. 2012. gulfnews.com/business/sectors/features/ensuring-food-security-of-theuae-1.982693. Retrieved on 9.1.2019

[582] Abdul Kader, B. (2017): Food processing sector supports UAE’s food security; officials say. Gulf News. 20 March 2017. www.gulfnews.com/ news/ uae/environment/food-processing-sector-supports-uae-s-food-security-officials-say-1.1997356. Retrieved on 5.1.2019

[583] Bailey, R. Willoughby, R. (2013): Edible Oil: Food Security in the Gulf. BP ed., ERR, Chatham House, 2013. https://www.chathamhouse.org/publications/papers/view/195281. Retrieved on 5.1.2019

[584] Fischbach, T. (2018): Strengthening Resilience: advancing Food Security in the UAE. https://www.mbrsg.ae/getattachment/859ddec7-f5ed-48dd-99dd-4e1b8f326112/Advancing-food-security-in-the-UAE. Retrieved on 4.1.2019

With the average food consumption in the UAE rising 12% a year, the government in Abu Dhabi has decided to complement its food security strategy with innovative agricultural cultivation methods. These are primarily soilless farming solutions like hydroponics and new greenhouse technologies such as vertical farming and roof-top farming. For this purpose, the government has made several agreements with other states that have advanced agricultural techniques and correspond to the specific climatic conditions in the UAE. Its goal is to build several large pilot projects that consume 90% less water and up to 50% less energy than conventional farming methods.

The use of UV-treated recycled water and cooling systems is intended to enable the growth of future UAE agriculture crops regardless of climatic conditions.[585] [586] [587] In order to reduce its ecological footprint, the government also increasingly focuses on organic agriculture and has reserved 46,900 acres for the growing demand for ecological and environment-friendly products: "Organic products bear a distinctive mark to enhance consumer confidence and the ministry is creating new marketing opportunities for organic products in co-operation with competent local authorities to encourage organic farmers."[588]

8.3.1.2 Weaknesses

- Very limited amount of arable land (7%)
- High dependency on fossil-fuel exports
- Extremely hot and dry climate in summer

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[585] Reinisch, L.: Farming in the Middle East 2050. http://static1.squarespace.com/static/5100ecebe4 b0b2093b3de5b6/t/51025693e4b091edd3f0e934/1 3591077 31457/brownbook_farmingME2050.pdf. Retrieved on 5.10.2017

[586] The National, 8 July 2018: Dubai government agrees on deal to start up to 12 vertical farms in the city. https://www.thenational.ae/uae/environment/dubai-government-agrees-on-deal-to-start-up-12-vertical-farms-in-the-city-1.748247. Retrieved on 4.1.2019

[587] Gray, A. (2018): Emirates is building a giant vertical farm to feed airline passengers. https://www.weforum.org/agenda/2018/08/emirates-is-building-a-giant-vertical-farm-to-feed-airline-passengers/. Retrieved on 7.1.2019

[588] Bin Ahmed Al Zeyoudi, T., UAE Minister of Climate Change & Environment. https://www.visitdubai.com/en/business-in-dubai/why-dubai/news-and-insights/agriculture-sector-innovation-dubai. Retrieved on 9.1.2019

- Short growing season
- Insufficient research on agricultural technologies
- High level of food waste
- Dependency on desalination
- Salient intrusion of freshwater resources
- Wasteful use of freshwater
- Lack of environmental awareness.

Although food security in the UAE is considered high because of its economic and political stability, it is a central task for the government of the desert state.[589] Currently, 85% to 90% of total food is covered by imports and the country's strong purchasing power could compensate for larger price volatility with even higher government subsidies.[590]

Due to the low economic diversification and the absolute dependency on oil exports, the UAE for the most part pays with oil export revenues. This makes the country sensitive to price fluctuations in the oil business. In addition, food imports must be permanently subsidized by the state to keep prices affordable and avoid social dissatisfaction. According to a recent report by the UAE government, the Emirates' food consumption is expected to reach 59.2 million tons by 2021, which means that the UAE's food imports will reach a new maximum.[591]

With only 7% of arable land available, extreme summer temperatures and an average annual rainfall of only 120 mm, UAE can produce only a small percentage of the food it needs with traditional agriculture. To promote local agriculture, indigenous farmers are supported by generous subsidies and technical assistance in line with the 2015 National Policy for Food guidelines.

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[589] Mohammed bin Rashid School of Government. https://www.mbrsg.ae/getattachment/859ddec7-f5ed-48dd-99dd-4e1b8f326112/Advancing-food-security-in-the-UAE. Retrieved on 7.1.2019

[590] Fischbach, T. (2018)

[591] Best food importers. https://bestfoodimporters.com/de/uae-food-imports-2018-getting-in-touch-with-importers-in-order-to-export-to-this-ever-growing-market/. Retrieved on 7.1.2019

These measures, however, cannot solve the main problem of UAE agriculture, the water shortage.[592] Currently, conventional water resources in the United Arab Emirates include “125 million cubic meters per year from seasonal floods, 3 million cubic meters per year from permanent springs, 22 million cubic meters per year from seasonal springs, 20 million cubic meters per year of falaj discharges, and 109 million cubic meters per year of aquifer recharge.”[593]

The high dependency on non-renewable water resources, coupled with a high per capita water consumption and increasing salinization of the natural freshwater reservoir, represents a serious problem. Groundwater levels have already fallen by up to 60 meters, and the complete drying up of the groundwater in the UAE cannot be ruled out.[594] According to official data, the agricultural sector alone is responsible for about 60% to 75% of the total water consumption in the country, and this proportion constantly increases. Of this total, 39% is consumed for conventional agriculture, 11% is used for greening and landscaping, and 10% is used for forestry, mostly with traditional methods that do not justify the wasteful use of water for a relatively small benefit.[595]

Another factor that complicates the food security situation in the UAE is the extreme population growth that has risen from 775,122 (1978) to 9,649,432 (2018) over the last four decades.[596] This rapid population growth is accompanied by an equally large amount of food waste, with more than 3.5 million tons of food thrown away in the UAE each year, at a cost of up to AED 15 billion ($ 4.1 billion). According to Ivano Ianelli, CEO of Dubai Carbon, compared with Europe, this

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[592] http://siteresources.worldbank.org/INTMNAREGTOPWATRES/Overview/20577193/GCCWater SectorReport–Englishversion.pdf. Retrieved on 14.3.2018

[593] Malek, C. (2015): UAE’s first agricultural policy to benefit farming sustainability and profitability. The National. December 2015. www.thenational.ae/uae/environment/uaes-first-agricultural-policy-to-benefit-farming-sustainability-and-profitability. Retrieved on 14.12.2018

[594] The National. https://www.thenational.ae/uae/study-cites-rapid-depletion-of-groundwater-in-uae-1.62486. Retrieved on 14.12.2018

[595] Ministry of Environment and Water (2015): UAE State of Environment Report. www.moew.gov.ae. Retrieved on 7.1.2018

[596] Country meters. https://countrymeters.info/de/United_Arab_Emirates. Retrieved on 7.1.2019

means that “an average person in Europe generates around 1.2 kg of waste a day, which is less than half the per capita waste generation of 2.7 kg per day in the UAE. This doubles to 5.4kg a day during Ramadan in the UAE.”[597] [598]

The population has little awareness of this problem. Although the Emirati government has begun to address this issue and attempts to encourage initiatives and campaigns at the national level with the aim of reducing food waste by three-quarters by 2021, the current strategy to combat food loss has thus far proved to be ineffective. The hospitality industry in particular is a major source of food waste, and the government does not exert enough pressure to change the situation or at least limit landfilling with discarded food through composting and recycling.[599] [600]

Since high price increases in global markets in 2007 also temporarily jeopardized the supply of staple food in the UAE, the importance and necessity of a viable, effective long-term strategy to improve food security has moved to the center of government efforts.[601] However, the increasing scarcity of freshwater resources, high water use, rising costs of desalination, a limited supply of arable land, and extended periods of drought caused by climate change are almost insurmountable challenges for a food security policy aimed at reducing import dependency.

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[597] Time out Dubai. https://www.timeoutdubai.com/aroundtown/news/75099-uaes-new-food-banks-the-solution-to-food-waste-issue. Retrieved on 7.1.2019

[598] Baldwin, D. (2016): Food Worth $ 4b Going to UAE Landfill. Gulf News, 23 Aug. 2016. www.gulfnews.com/news/uae/environment/food-worth-4bgoing-to-uae-landfill-1. 1883853. Retrieved on 17.11.2018

[599] Gulf News. https://gulfnews.com/going-out/society/zerofoodwaste-dubai-wages-war-against-food-waste-on-world-food-day-1.2106098. Retrieved on 2.1.2019

[600] Arabian Business. https://www.arabianbusiness.com/culture-society/398300-middle-east-becoming-more-aware-of-food-waste-impact-survey-shows. Retrieved on 2.1.2019

[601] Wam: Food security tops UAE’s priorities, says Abu Dhabi Crown Prince. Emirates 247 News. 7 Feb. 2017. www.emirates247.com/news/emirates/foodsecurity-tops-uae-s-priorities-says-abu-dhabi-crown-prince-2017-02-07-1.647735. Retrieved on 4.10.2018

Thus far, the UAE has been able to compensate most of these climatic and natural restrictions thanks to its focus on open trade as well as market interventions and subsidies. However, these measures alone cannot make the national food system sustainable and crisis-proof. Therefore, the UAE now seeks to improve the resilience of its food supply by expanding trade relations with other countries and investing heavily in research on innovative agricultural technologies.[602] [603] [604]

8.3.1.3 Opportunities

- Strategic location as gateway to Africa, the Middle East, and the Far East
- Economic diversification strategy
- Adoption of new agricultural technologies
- Research and education facilities
- Cooperation with leading international experts
- Expanding re-export market
- Excellent investment conditions
- Access to the global labor market
- Green initiatives and projects
- Excellent infrastructure and service sector.

Because agricultural research has long been neglected in the United Arab Emirates, sustainable ideas have been integrated relatively late into their policies, and they almost completely relied on the unlimited import possibilities of the global market. Over the past decade, however, the Emirati government has launched a series of comprehensive research initiatives and established

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[602] Visit Dubai. https://www.visitdubai.com/en/business-in-dubai/why-dubai/news-and-insights/agriculture-sector-innovation-dubai. Retrieved on 13.12.2018

[603] Oxford Business Group (2016): Abu Dhabi Taking Action on Food Security. www.oxfordbusinessgroup.com/analysis/ securing-supply-food-security-issue-and-government-and-private-sector-are-deploying-strategies. Retrieved on 1.1.2019

[604] Gueganic, P. (2015): Understanding UAE Food Security Strategy & Potential Investment Opportunities Related. LinkedIn, 9 June 2015, linkedin.com/pulse/ understanding-uae-food-security-strategy-potential-related-gueganic. Retrieved on 4.10.2018

corresponding public institutions with the aim of increasing domestic agricultural productivity. In parallel, public/private partnerships for scientific research are funded through state resources to develop effective alternative methods of food production in marginal and saline environments.[605]

One example is the International Center for Biosaline Agriculture[606] which conducts research with international partners on new technologies for the use of conventional and non-conventional water and land management concepts and remote monitoring techniques for climate change adaptation. In addition, the Sharjah International Center for Agricultural Research increasingly relies on international collaboration with renowned technology experts to increase food safety and security through significant structural changes in UAE agriculture. These relate primarily to closed, multistory vertical farms that can produce staple food for the country with water-saving methods.[607] [608]

In April 2020, the Abu Dhabi Investment Office announced a 272 million USD investment program to support Agritech companies and their new technologies. In the first phase a 53,000 square feet vertical farm (Aerofarm) is to be built in the desert, supplemented by several facilities for research and development. A similar development is taking place in Dubai at the same time, where the establishment of 12 vertical farms and additional aquaponic indoor farms for salmon farming has been decided.[609] “Agritech will be part of the solution to how

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[605] Chelali, T. (2017): Food security is this region’s urgent priority. The National, 8 Jan. 2017. www.thenational.ae/opinion/comment. Retrieved on 29.12.2018

[606] The ICBA was founded by the Islamic Development Bank (IDB), the Organization of the Petroleum Exporting Countries (OPEC) Fund, the Arab Fund for Economic and Social Development (AFESD), and the Government of the United Arab Emirates (UAE). www.biosaline.org. Retrieved on 9.9.2018

[607] Malek, C. (2013): Sustainable Farming Ideas Spread across UAE. The National, 21 August 2013. www.thenational.ae/uae/sustainable-farmingideas-spread-across-uae-1. Retrieved on 10.12.2018

[608] Zriqat, T. (2014): Water takes farming to cutting edge. The National, 17 Dec. 2014. www.thenational.ae/uae/environment/water-takes-farmingto-cutting-edge-1.452578. Retrieved on 10.12.2018

[609] Tariq Bin Hendi, the Director General of the Abu Dhabi Investment Office, quoted in: Peters, A.: Abu Dhabi is investing $100 million in indoor farming as it tries to become more resilient. https://www.fastcompany.com/90485666/the-united-arab-emirates-is-100-million-in-indoor-farming-as-it-tries-to-become-more-resilient. Retrieved on 10.4.2020

we can better utilize water, how we can be more efficient, and how we can drive yield in farms," said Tariq Bin Hendi, the Director General of the Abu Dhabi Investment Office. "We're embracing technology because we know it's the future."[610]

In order to promote the modernization of traditional farming methods and crops, the government started training programs for farmers on adopting sustainable farming techniques for water conservation and post-harvest techniques. This includes the control of a more efficient desalinated water use and the fight against the illegal use of groundwater with new water laws and the obligation to install water meters.

Many of the active Emirati greenhouses, which currently operate at low or medium technological levels, are now being retrofitted or replaced with new hydroponic facilities. These have shading systems, and temperature and humidity sensors to automatically adapt all processes for ideal growing conditions.[611] The government of Abu Dhabi is convinced that new, hydroponic technologies may be the key to overcoming the core challenges to its agricultural sector such as climate, land, and water constraints.[612]

Traditional agricultural practices have no future in the UAE and are not part of the National Strategic Plan (Vision 2021)[613] to transform the country with science, technology, and creative entrepreneurship into an innovation-based economy.[614] In order to be successful with new technologies such as hydroponics, vertical

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[610] ibid.

[611] Hortibiz. http://www.hortibiz.com/item/news/greenhouse-industry-is-growing-in-uae/. Retrieved on 7.1.2019

[612] Ahmed Al Zeyoudi, T., Minister of climate change and environment for the UAE. https://oxfordbusinessgroup.com/news/investment-sustainable-farming-and-new-technology-supports-abu-dhabi%E2%80%99s-efforts-boost-local. Retrieved on 6.1.2019

[613] Vision 2021. https://www.vision2021.ae/en. Retrieved on 18.11.2018

[614] Chelali, T. (2017): Food security is this region's urgent priority. The National, 8 Jan. 2017. www.thenational.ae/opinion/comment/food-security-is-this-regionsurgent-priority. Retrieved on 18.11.2018

farming and roof-top farming, both farmers and the population as a whole need to perform a comprehensive review that recognizes agriculture as a modern, technological area that can play a crucial role in securing the national food system.

Nonetheless, the government will need to subsidize hydroponic equipment and fertilizer in order to make the products of the current vertical farming projects competitive with imported products. Only vertical farms of a certain size and output can compete with imported products because latter are so heavily subsidized. This creates a vicious circle that can only be resolved if the government supports local production to the extent that it can compete on the import market and lowers the subsidies on imported foods at the same time.

8.3.1.4 Threats

- Almost complete dependence on imports and foreign markets
- Insufficient research and application of agricultural innovations
- High dependence on foreign experts, engineers, and workers
- Massive government subsidies for food, water, and utilities
- Expected population of 11.5 million in 2020
- Increasing, unsustainable water and food consumption
- Very limited and salinized water resources
- Heavy air pollution
- Increasing health problems and unhealthy lifestyle
- Little awareness of sustainability and resilience
- Exploding costs of living in Abu Dhabi and Dubai
- Regional instability in Gulf Cooperation Council states.

A secure food system depends to a large extent on regional stability. A collapse of regional order in the Gulf States could be dangerous and trigger a domino effect. The involvement in the Libyan civil war and the civil war in Yemen poses potential dangers because the UAE, along with Saudi Arabia, is militarily involved in this conflict, thus becoming a potential target for terrorist activities.[615] [616]

Agricultural projects conducted abroad on purchased or leased land can improve the UAE's food supply and reduce its dependence of foreign trading companies. However, they do not reduce its dependence on imports because other countries could easily ban the export of products in a crisis. Therefore, it is important to place these agricultural investments only in states with high political stability and no involvement in direct regional issues of the UAE.

Although the current government's policy tries to combine a sustainable infrastructure with renewable energy sources and green technologies, economic growth remains the dominant goal, even at the expense of sustainability and the environment. Despite all the measures taken so far to increase sustainability, the UAE continues to have one of the highest per capita ecological footprints in the world. Moreover, the UAE is one of the most polluted countries with 8.0 micrograms of pollutants per cubic meter of air, a fact that could seriously endanger the health of its population if this high degree of contamination continues.[617] [618] [619]

Although the Emirati government has made great efforts and continues working to remedy the shortage of local experts through its education system, the country remains totally dependent on foreign technology, science, and expertise. This affects all areas of public life and is also evident in all approaches to improving

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[615] Ardemagni, E. 2016: UAE's military priorities in Yemen: Counterterrorism and the South. https://www.ispionline.it/it/pubblicazione/uaes-military-priorities-yemen-counterterrorism-and-south-15573. Retrieved on 10.1.2019

[616] Acled. https://www.acleddata.com/2018/10/10/exporting-instability-the-uaes-role-in-yemen-and-the-horn-of-africa/. Retrieved on 10.1.2019

[617] Bertelsmann Stiftung. https://www.bti-project.org/en/reports/country-reports/detail/itc/ARE/. Retrieved on 10.1.2019

[618] MCO. https://mco.ae/uae-news/air-pollution-of-uae/. Retrieved on 10.1.2019

[619] Time. http://time.com/3933487/pollution-climate-change-world-bank-report-uae/. Retrieved on 10.1.2019

food security and consumer behavior. In this area the government must create stronger priorities for sustainability and resilience in the education system and promote the private sector as a driver of innovation.

The turn to innovative agricultural techniques such as hydroponics, aquaculture, and vertical farming may be the right solution if consistently pursued. For this reason, the UAE needs to invest more in researching key technologies tailored to its specific needs. Since all vertical farms require expensive, non-sustainable cooling systems, viable alternatives to power generation need to be developed. The application and development of such technologies are again associated with high costs and awareness of the problem, but initiatives to master these challenges are still lacking in the UAE.[620]

No problem is as grave or threatens the future of the UAE as much as the existing shortage of natural water sources. Nevertheless, thus far, nothing has changed in the wasteful behavior of the Emirati industry, the tourism industry, and the general population. The country uses its groundwater at a rate 20 times higher than its capacity to replenish its ground-water resources. According to several studies, the groundwater reservoir will be completely exhausted within the next few decades.[621] [622] [623] [624]

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[620] Chesters, C. (2016): Pure Harvest to Launch High-Tech Farm in UAE Following $1.1 mn Investment. Catering News Middle East, Dec. 2016, www.hotelnewsme.com/catering-news-me/pure-harvest-launch-high-tech-farm-uae-following-1-1mn-investment. Retrieved on 10.1.2019

[621] Shahin, S., Abdul Muhsen Salem, M. (2015): Food Security In The United Arab Emirates (UAE): The Great Competition between the Agricultural and Forestry Sector on Irrigation Resources. https://www.researchgate.net/publication/320192278_Food_Security_in_the_United_Arab_Emirates_UAE_The_Great_Competition_between_the_Agricultural_and_Forestry_Sector_on_Irrigation_Resources. Retrieved on 12.1.2019

[622] Zacharias, A. (2018): Special report: Abu Dhabi's dwindling water reserves charted in worrying Sorbonne research. 6. May 2018. In: https://www.thenational.ae/uae/environment/special-report-abu-dhabi-s-dwindling-water-reserves-charted-in-worrying-sorbonne-research-1.727757. Retrieved on 22.12.2018

[623] Shahin, S., Salem, M. (2015): The Challenges of Water Scarcity and the Future of Food Security in the United Arab Emirates (UAE). www.hrpub.org/download/20150201/NRC1-14203108.pdf. Retrieved on 14.2.2018

[624] Fanack Water (2017): Water Challenges in the UAE. https://water.fanack.com/uae/water-challenges/. Retrieved on 30.10.2018

One example is the capital, Abu Dhabi, which receives an average of 82 mm of rainfall per year, while the water evaporates at an annual rate of 2,000 to 3,000 mm. Water consumption increases at an annual rate of 9.5%, which means it has more than doubled during the last 10 years. At the same time desalination is expected to triple during the next 12 years, and desalination plants are expensive, contribute to global warming, and damage maritime biodiversity.[625] Since most of the 7,600 active wells are on private land, the groundwater is considered a private rather than a public good.

The water charges which the state demands are low and do not correspond to the real or environmental costs. In sum, sustainable water consumption is not practiced. Consciousness of sustainability is scarce among the population, and the government's efforts to initiate a paradigm shift and give water the same appreciation and importance for national resilience as fossil oil are not effective enough. Time is the deciding factor for radical actions to stop the unsustainable use of water, and the next decades will show whether there will be a secure food system in the UAE, as well.

8.3.1.5 State of Current Research

In his study Saif Al Qadi [626] examines the importance of leased or bought arable land in other countries for the food security in the United Arab Emirates and how such contractual relationships could be stabilized. He advocates linking oil supplies to food supplies, which means that oil and gas should preferably be supplied to countries that conclude contracts for food deliveries with the UAE. The same should also apply to countries where the UAE produce food on purchased or leased land.

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[625] Zacharias, A. (2018)
[626] Al Qaydi, S. (2014): Food Security in the United Arab Emirates; the Role of the State in Overseas Farm Crops Production. Asian Journal of Agricultural Extension, Economics & Sociology, 2014, 3(6): pp. 569-579

Despite adverse climatic conditions, lack of water and little fertile arable land, the UAE are determined to produce part of their own food themselves. In order to promote domestic agriculture, Abu Dhabi – which covers 85% of the total UAE – gives away the farmland to citizens free of charge and pays 50% of all the costs of food production. However, according to Al Quadi, many of these areas are not cultivated but are used for leisure activities, an abuse that has to be stopped.[627] In line with the government's current food security strategy, the author recommends the rapid introduction of new technologies such as hydroponics and aquaponics, which should preferably be used to cultivate plants that tolerate higher salinity in the water and desert climate.

Suzan Shahin and Mohammed Salem's[628] research results allow similar conclusions. According to their calculations, the groundwater reserves could be completely exhausted by 2030, if the current water consumption of around 1.489 million m3 per year persists and the population actually exceeds the 12 million mark by then. In order to prevent the collapse of local agriculture, the authors suggest the use of wastewater, which is so far used only for the forestry and landscaping sector.

However, since wastewater alone would not be sufficient for agriculture, it is necessary – as the authors Esposito, Tse, Soufani and Xiong argue[629] – to build additional vertical farms, that can produce with a minimum of fresh water and protect the dwindling groundwater reserves. These vertical farms could be complemented by 20- or 40-foot shipping containers that allow fresh vegetables to be grown near schools, food banks, restaurants or military bases. In order to

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[627] Al Quadi, S. (2016): The Status and Prospects for Agriculture in the United Arab Emirates (UAE) and their Potential to Contribute to Food Security. Journal of Basic & Applied Sciences, 2016, 12, pp. 155-163

[628] Sahin, S., Salem, M. (2015): The Challenges of Water Scarcity and the Future of Food Security in the United Arab Emirates (UAE). Natural Resources and Conservation 2015, 3(1): pp. 1-6

[629] Esposito, M., Tse, T., Soufani, K., Xiong, L. (2017): Feeding the Future of Agriculture with Vertical Farming. DOI: 10.17863/CAM.21014. Retrieved on 26.9.2019

promote acceptance of these modern technologies among the population, educational institutions and event campaigns should inform about the value and the advantages of such "non-field farming crops".[630]

Overall, not only the way of production has to change, but also the job description of the farmer, who has to perform the functions of a bio-scientist and systems engineer in these facilities. Esposito and colleagues are convinced that the best option for maintaining and strengthening local agriculture is a "revamping" of the future of agriculture. “Though vertical farms can never be expected to replace traditional farms, it is likely that they will have to complement each other if we are to meet the food demands of tomorrow. It is economically sensible, environmentally friendly, tech-savvy, and most importantly, health-sensitive. Vertical farming is not a fairytale. It is happening now.”[631]

Commercial urban agriculture can only be implemented outside the city centers in vertical farms because of the high land prices. These vertical farms can complement the local agriculture which needs – in the opinion of Asad Qureshi[632] – a pragmatic agroforestry concept. Since the high degree of salinity of 34% makes traditional agriculture impossible, planting Acacia (Acacia ampliceps) can create the conditions for the cultivation of special salt-tolerant grasses and at the same time counteract the increasing desertification. A large-scale adoption of such halophytes (salt tolerating plants) can significantly improve the quality of saline soils and transform them into productive agricultural areas.

8.3.1.6 Conclusion

The preceding SWOT analysis has clearly shown that the lack of arable land and water, desert climate, and insufficient agricultural research represent major

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630 ibid., p. 5
631 ibid., p. 6
632 Qureshi, A. (2017): Sustainable Use of Marginal Lands to Improve Food Security in The United Arab Emirates. DOI: http://dx.doi.org/10.18006/2017.5. Retrieved on 23.9.2019

weaknesses, but there are also impressive strengths and opportunities that provide the necessary foundation to balance these weaknesses and overcome challenges. Although the UAE is still considered food secure thanks to its successful trade and import policy, it is generally accepted that the UAE, which imports most of its food, will never become independent from food imports. In order to improve its food security, the UAE already relies on a strategic combination of subsidy, investment, and import policies complemented by research funding, the adoption of new technologies, and the fight against food waste.

On the basis of these components, the UAE needs to implement a holistic food strategy that unites all relevant private and public stakeholders via common approaches to reduce import dependency and create greater resilience. This will require increased investment in infrastructure improvements as well as in research and development related to innovative technologies of urban agriculture. “The core challenges facing the country have not been effectively resolved, only mitigated in the short term. Without research and development, the UAE’s food security strategies will lack real resilience and sustainability. The UAE’s efforts in developing a focused and overarching food security strategy have been inadequate.”[633]

In the short term, consistent campaigns, education and training programs, and strict rules could successfully limit the significant food waste and over-consumption of water. “Producing energy and water generate much pollution in the environment, which is generally based on the over-consumption of individuals and households mainly. That’s why, households’ share stands at 30 per cent in the ecological footprint in the emirate.”[634]The agricultural sector claims more than

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[633] Fischbach, T. (2018), p. 36

[634] Shaikha Al Hosani, Executive Director for the environment quality at the EAD (Environment Agency), cited in: Ahmed, A.: Abu Dhabi to recycle, re-use all waste water by 2020.

two-thirds of the total water consumption, and there is strong competition between farmers, forestry, and landscaping, especially in the construction of new condominiums.

Urban agriculture could be the solution for all these problems. It is highly productive and does not need fertile soil and very little water in a closed system. Dependence on imported products can be reduced and fresh food can be harvested in vertical farms as required, which in turn reduces food waste. There is ample need to use much more recycled, processed water instead of drinking water, with clear priorities to be established: Agriculture must take precedence over forestry and landscaping, new modern irrigation technologies with comprehensive monitoring and scheduling need to be introduced, the population has to be educated about the safe use of recycled domestic water[635] and an increasing proportion of necessary food should be produced in vertical farms.
The conversion of agriculture to closed systems must advance quickly and should not be exhausted in display projects. Also, small, private farmers must have a way to cope with the new technology and operate it reasonably profitably.[636] This implies simplified desalination techniques at the farm level to allow farmers to adopt hydroponic, soilless farming systems. Crucially, the future of Emirati food security will depend on advanced agrarian technologies, which the government fully realizes.

To this end, a close cooperation with Singapore has been decided, as this country already has significant experience in vertical farming, home farming, aquaponics and aquaculture facilities.[637] In this context the importance of research, education, and innovative technologies as the main stimuli of economic growth,

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https://gulfnews.com/uae/environment/abu-dhabi-to-recycle-re-use-all-waste-water-by-2020-1.2119892. Retrieved on 21.1.2019

[635] The World Bank: Annual freshwater withdrawals, total (billion cubic meters): data for United Arab Emirates, Washington, USA, 2013

[636] Murad, A., Al-Nuaimi, H., Al-Hammadi, M. (2007): Comprehensive assessment of water resources in the United Arab Emirates (UAE). Water Resources Management, 21, pp. 1449-1463

[637] Food Security Index. https://foodsecurityindex.eiu.com/. Retrieved on 21.1.2019

sustainability, and resilience cannot be emphasized enough.[638] [639] [640] In the case of the United Arab Emirates, it is of the utmost importance to access external know-how and international expertise in order to develop into a modern, competitive economy. This process has to be initiated and facilitated through "allocating more investments in education, science, technology, R&D activities, and infrastructure facilities which consequently will improve the country's business environment and increase its attractiveness to foreign investments."[641]

It follows that among other efforts, the UAE should seek further cooperation with experienced companies in order to apply solar-powered, reverse-osmosis desalination technologies for the safe production of drinking water. In addition, appropriate technologies have to be introduced to separate black water networks from gray water networks.

For the expansion of urban farming, scalable procedures have to be tested in open systems to include saltwater and gray water in the processes, and in closed systems that use very little water and rely primarily on cooling systems based on renewable energies. The UAE could import advanced technologies that capture and store rainwater through porous pavements and sophisticated sewer systems. This water could be returned to the empty groundwater wells or used for vertical farms.

In the UAE the agriculture of the future will always be urban farming, as the natural oases are depleted and only hydroponic, soilless methods and

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[638] Universität Bremen. https://www.va-bne.de/index.php/de/veranstaltungen/180-nachhaltige-entwicklung/die-bedeutung-von-innovationen-fuer-eine-nachhaltige-entwicklung/501-die-oekonomische-bedeutung-von-innovation. Retrieved on 24.10.2018

[639] Hackel, M. (2013): Diffusion neuer Technologien für eine nachhaltige Entwicklung. In: BiBB: Neue Technologien und nachhaltige Entwicklung. Juni 2013

[640] Decker, M. et al. (2012) (ed.): Der Systemblick auf Innovation. Technikfolgenabschätzung in der Technikgestaltung. Berlin 2012

[641] El Shaweesh, S. (2015): Transforming the United Arab Emirates into an innovation-based Economy: SWOT Analysis. http://www.worldresearchlibrary.org/up_proc/pdf/ 133-145216324036-40.pdf. Retrieved on 18.1.2019

aquaculture can guarantee a supply of locally produced food. This view has also been supported by Ashraf Omran, President of the Arabian Council for Water and Food Security, builder, operator and owner of numerous vertical farms and aquaponics. During his research stay in the United Arab Emirates, the author visited Dubai’s first vertical farm where he was given an extensive introduction to vertical farming technology and the opportunity for an interesting interview and exchange of ideas.

According to Omran, hydroponics is the optimal solution to the food, land, and water crisis, especially in Arab countries. There cannot be any efficient agriculture without questioning the water consumption and comparing water productivity per cubic meter with land productivity per square meter. High fertilizer and water prices, as well as the lack of fertile land, encourage Omran to pursue a soilless agricultural method. Since food can be grown on all kinds of material, even on sand, this technology reduces the pollution of groundwater and improves the quality of agricultural drainage water.

For Omran, water safety and food security are two sides of the same coin. Therefore, when developing a strategy for self-sufficiency, an accurate assessment of the available natural resources is needed. An effective food strategy must include all key components, such as the precipitation rate, water demand, population growth, and climate change.

Omran usually prefers closed hydroponics, where the water circulating under the roots of the plants contains the necessary elements for growth. In his farms, Omran grows mostly fodder, vegetables, herbs, corn, and fruits and practices aquaponics by using the excretions of fish as fertilizer for his plant nurseries. He has also installed several algae farms where he grows red, green, brown, and blue-green algae, as well as diatoms and dinoflagellates. The products are sold to high-class hotels and restaurants that prefer fresh produce to imported goods.

In the interview with Ashraf Omran, the benefits of producing food in enclosed greenhouses with the aquaponic method for a pragmatic food security strategy were made quite clear. As the Middle East and North Africa region is particularly vulnerable due to the scarcity of freshwater resources, regional conflicts, and rising temperatures, long-term strategic concepts are needed to strengthen their viability for the future. Here, the concept of vertical farming and the positive experiences with the vertical farm of Omran fulfill a key consulting function for the government of Dubai, which already plans another large vertical farming facility near the Al Maktoum International Airport. This $40 million USD facility will produce 2,500 kg of herbicide-free vegetables per day with a 99% lower water consumption than would be the case in conventional agriculture.[642] On an area of only three acres (130,000 square feet) it will produce the same amount as would be possible on 900 acres farmland.[643]

Similar to Saudi Arabia, Dubai has begun to take on a pioneering role in innovative agricultural technologies within the Gulf region.[644] At the same time awareness campaigns and educational programs have been launched in schools to provide Emirati citizens with knowledge of food production, as well as to empower and encourage them to become urban gardeners themselves.[645] These measures are essential for a sustainable food security strategy that relies not only on new technologies and large, centralized food production facilities, but also on bringing the issue of "nutrition" and especially of "healthy food" back into citizens' consciousness.

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[642] The National. https://www.thenational.ae/uae/environment/emirates-to-build-dh147m-vertical-farming-factory-near-dubai-airport-to-produce-food-for-passengers-1.744383. Retrieved on 3.11.2018
[643] ibid.
[644] The National, 8 July 2018: Dubai government agrees on deal to start up to 12 vertical farms in the city. https://www.thenational.ae/uae/environment/dubai-government-agrees-on-deal-to-start-up-12-vertical-farms-in-the-city-1.748247. Retrieved on 4.1.2019
[645] Gulf News. https://gulfnews.com/going-out/society/uaes-long-term-food-security-strategy-under-study-1.2170588. Retrieved on 3.11.2018

8.3.2 The Masdar Vision

8.3.2.1 Goals

In recent years proposals for the construction of eco-cities have been developed in various countries and institutions, and Masdar is one of the most prominent. Masdar City was designed by the British architect Norman Foster and is currently being built outside Abu Dhabi in the United Arab Emirates. The Masdar Initiative started in 2006, and construction began in 2008 with an estimated budget of \$17,5 billion USD on an area of 6 square kilometers.

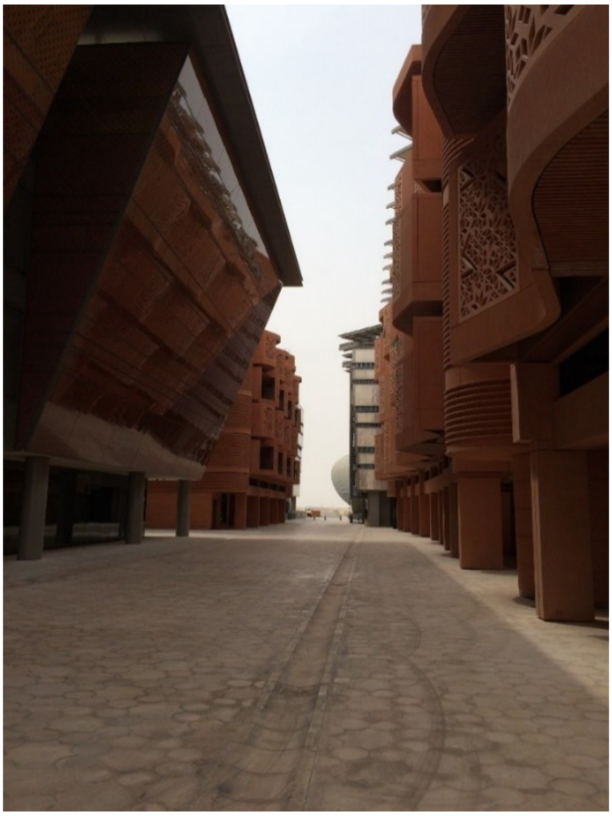

Image 9 – Masdar City – Shaded streets, author's study trip to Masdar in 2015

Masdar, which means “source” or “fountain,” will have a future population of about 40,000 people and become a place of work for 50,000 commuters.[646] Its ecological concept focuses on renewable energy production, reduced water consumption, recycling, advanced energy storage, and urban farming. As the first CO2-neutral city, Masdar should be a model project for successful, technology-based, global climate protection and, at the same time, a prestige project of the Emirati government.

The conception and construction of Masdar include some of the world’s largest corporations, such as General Electric and Mitsubishi, as well as major German companies such as Bosch, BASF, E.ON, Bayer, and Siemens.[647] As a unique project for sustainable urban development with little waste – 80% of the waste is recycled, and 20% is incinerated – this new eco-city is supposed to be almost CO2-neutral. The overall energy consumption is expected to be 45% below the internationally recognized standard of the American Society of Heating, Refrigeration, and Air Conditioning Engineers, and the water consumption should be reduced by 50%.

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[646] BASF Diplomatin für Nachhaltigkeit. Unsere Urbane Zukunft. https://www.basf.com/de/we-create-chemistry/creating-chemistry-magazine/resources-environment-and-climate/the-diplomat-of-sustainability.html. Retrieved on 1.10.2017

[647] Masdar: Masdar, City at glance. http://www.masdar.ae/en/masdar-city/detail/masdar-city-at-a-glance. Retrieved on 3.10.2017

Image 10 – Masdar City – Wind tower for cooling, author's study trip to Masdar in 2015

For this purpose, Masdar signed several contracts with different companies to build four pilot test desalination plants that operate through solar energy for reverse-osmosis desalination processes. To compare technological efficiency another contract was awarded to a French company for a forward osmosis plant. The successful operation of these plants could be the basis for urban agriculture projects and future installations that reduce the carbon footprint.[648] The entire energy supply of Masdar City was planned to be provided by photovoltaic panels on the roofs of the buildings and a 10 MW solar thermic plant which would feed excess energy into the Abu Dhabi electricity network. In addition, an innovative geothermal energy generation plant was planned that would pump water into the earth's crust in order to generate steam for energy generation.

[648] Todorova, V. (2014): Four companies chosen for desalination pilot schemes in Abu Dhabi. https://www.thenational.ae/uae/environment/four-companies-chosen-for-desalination-pilot-schemes-in-abu-dhabi-1.247297. Retrieved on 13.1.2019

Image 11 – Masdar City – Solar panels on the roofs, author's study trip to Masdar in 2015

Urban and peri-urban indoor-farming should ensure a high degree of self-sufficiency for the city and reduce the need for significant vegetable imports. In the ideal case, for a small town like Masdar, the vegetables required could be produced in vertical farms with surpluses delivered to neighboring Abu Dhabi. To this end, the "Father of vertical farming," Dickson Despommier, has already signed an agreement with the government of Abu Dhabi to build a four-story greenhouse in Masdar City as a first pilot project.[649]

In this country which has the highest water consumption in the world, Despommier accepted the challenge to prove that sustainability and development do not need to be mutually exclusive concepts. In several pilot projects around the world, Despommier's concept has already proved that it can be successful when the project planning not only involves agronomists, biologists, and

[649] Spektrum: Der Traum von den Stadttomaten. http://www.spektrum.de/news/der-traum-von-den-stadttomaten/1030383. Retrieved on 5.10.2017

engineers but also forward-thinking designers and architects.[650] [651] [652] [653] “You can control the temperature, you can control the humidity and you don’t need a lot of water, if you’re doing it hydroponically or aeroponically.”[654]

Additionally, an innovative government partnership has been announced between the UAE Office for Future Food Security and the Green Energy Institute of Masdar to cooperate for a better food security concept. Currently, it consists of two pilot projects, a vertical farming container and a smart home farm. With these initiatives, modern technologies and best practices will be tested in a controlled environment.[655] The smart home project will be a showcase of solutions for combining sustainable architecture with urban farming options. Local and international providers will present affordable, energy- and water-efficient technologies to the public.[656]

“This collaboration signifies an important step towards advancing innovations in agricultural production mechanisms and sustainable solutions to the challenges facing the agriculture industry in the UAE. It will also contribute to raising awareness about new, innovative solutions to enhance food availability and sustainable agriculture, and support emerging companies in the sector, boosting future food security in accordance with the UAE Vision 2021.” [657]

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[650] ArchDaily: In Tokyo, a Vertical Farm Inside and Out. http://www.archdaily.com/428868/in-tokyo-a-vertical-farm-inside-and-out. Retrieved on 5.10.2017

[651] Association for Vertical Farming: Reimagining the Vertical Farm. http://vertical-farming.net/wp-content/uploads/2015/03/CuelloBeijingMay2015D.pdf. Retrieved on 5.10.2017

[652] Esquire: 11 Vertical Farms to Transform Our Cities. http://www.esquire.com/news-politics/g545/vertical-farms/?slide=3. Retrieved on 5.10.2017

[653] Dezeen: Vertical Farms. http://www.dezeen.com/tag/vertical-farms/. Retrieved on 5.10.2017

[654] Reinisch, L. (2014): Farming in the Middle East 2050. http://static1.squarespace.com/static/5100ecebe4 b0b2093b3de5b6/t/51025693e4b091edd3f0e934/1 3591077 31457/brownbook_farmingME2050.pdf. Retrieved on 5.10.2017

[655] Webster, N. (2018): Forward-thinking plan served up to protect UAE's future food supply. The National, 30 July 2018. https://www.thenational.ae/uae/forward-thinking-plan-served-up-to-protect-uae-s-future-food-supply-1.755499. Retrieved on 14.1.2019

[656] Bridge, S. (2018): Masdar inks deal for vertical farming container pilot project. https://www.arabianbusiness.com/technology/401837-masdar-inks-deal-for-vertical-farming-container-pilot-project. Retrieved on 10.1.2019

[657] Almheiri, M., Minister of State for Future Food Security. https://masdar.ae/en/news-and-events/news /2018/11/21/08/38/masdar-partners- with-uae-office-for-food-security. Retrieved on 14.1.2019

8.3.2.2 Implementation

The first city district which is about 5% to 10% of the planned urban area, includes the university, several retail stores, a bank, a supermarket, and restaurants and is already built. In addition, the headquarters of the International Agency for Renewable Energies (IRENA) was established in Masdar in 2009. The completion of the whole Masdar project was originally planned for 2016, but the budget was decreased due to the economic crisis in 2008. As a result, the master plan had to be revised twice and the completion deadline was postponed several times, currently to 2030. Further, many ambitious projects had to be canceled, such as the carbon-neutral desalination plant and the goal to make Masdar independent of Abu Dhabi’s public grid.

The city itself is being erected on a 23-foot-high concrete base for maximal use of cooling winds and minimal need for air conditioning. Traditional Arab architecture characterizes the cityscape with narrow, shady streets and artificial giant palm trees with collapsible leaves, artificial lakes, green areas, and pedestrian walks. Wind towers made according to traditional models are positioned around three- and four-story buildings capturing the wind with their moving parts and moving it towards the streets for cooling.

For waste management in Masdar, two principles are to be implemented: waste prevention and consistent recycling. All the wastewater is recycled and used as gray water for the irrigation of green areas. Close cooperation with MIT, RWTH Aachen University and the German Aerospace Center has been established for research projects that cover environmental planning, sustainable traffic systems, water and sewage management, solar collectors, solar thermal power plants, and water treatment with electro-dialysis.[658] [659]

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[658] Scinexx. www.scinexx.de/dossier-detsil-507-8.html. Retrieved on 2.10.2017

[659] Lau, A. (2012): Masdar City: A model of urban environmental sustainability. http://web.stnford.edu/group/ journal/cgi-bin/wordpress/wpcontent/uploads/2012/09/Lau_SocSci_2012.pdf. Retrieved on 3.10.2017

Originally, no cars with internal combustion engines were to be allowed in Masdar; therefore, a driverless electric passenger transport system was developed. The public transport consists of a point-to-point personal rapid transit system (PRT) with traceable electric cabins for up to six persons.[660] [661] [662] However, the residents of Masdar – currently 350 students and approximately 2,000 people working there – do not want to give up using their own cars, so the planners had to integrate broad streets and underground garages into the new master plan.[663] The PRT now only circulates around the information center for demonstration purposes.

8.3.2.3 Evaluation

The founding idea was that Masdar would become the world’s most sustainable city. Buildings were erected according to the original master plan and were specially designed to be energy efficient and invite walking through the shaded streets. Houses with only five stories and solar panels on their roofs provide additional shade to the pedestrians. Here, the architecture has succeeded in successfully implementing a climate-friendly design.[664]

The extent to which the envisaged energy-saving potentials can actually be considered sustainable is questionable, as the numbers are always based on the average energy and water consumption in the UAE, which has the second-highest values worldwide.[665] In many other important areas, however, Masdar is

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[660] Arab Forum. http://arab-forum.de/de/2009/w-2009-02-abu-dhabi-masdar-city.php. Retrieved on 4.10.2017

[661] Advance Transit. http://www.advancedtransit.org/advanced-transit/applications/masdar-prt/. Retrieved on 4.10.2017

[662] PRT Consulting. http://www.prtconsulting.com/gallery11.html. Retrieved on 10.1.2019

[663] Schulz, B. (2017): Auf der Sonnenseite der Moderne. https://www.tagesspiegel.de/wirtschaft/immobilien/was-wurde-aus-der-zukunftsstadt-masdar-city-auf-der-sonnenseite-der-moderne/20658020.html. Retrieved on 15.1.2019

[664] CNCN. https://edition.cnn.com/style/article/conversation-masdar-city-lee/index.html. Retrieved on 15.1.2019

[665] Government UAE. https://government.ae/en/information-and-services/environment-and-energy/water-and-energy/energy. Retrieved on 20.1.2019

anything but sustainable, resilient, or energy efficient. From the beginning Masdar was meant to be an experimental laboratory for innovations in the field of renewable energies and other sustainability technologies. Building it in the United Arab Emirates, a desert state with no natural green spaces, forests, or rivers and the world's highest per capita ecological footprint, represents the true antithesis of sustainable development.[666]

Even if, so far, only a small percentage of the planned buildings and facilities have been constructed, the development has already used an immense amount of fossil energy without respecting the environmental impact. Its intensive water desalination alone has one of the highest carbon footprints in the world and the plan to operate it only with solar energy has failed.[667]

The entire Masdar concept is socially unsustainable because it has no roots in community activism and very little connection to the indigenous people. Urban farming and the whole idea of producing healthy nutrition has not yet arrived in the people's mind. In the United Arab Emirates, all planning processes are controlled by the government for its own purposes and have no connection to genuine initiatives from the local community. Thus, Masdar is developed and supported by the government and represents everything other than the result of an emerging community empowerment founded on basic needs and common environmental care objectives.

The city of Masdar, as an artificial construct, is controlled by the Abu Dhabi Future Energy Company (ADFEC), a development company that is 100% owned by the government of the Emirate of Abu Dhabi. Many experts have expressed their critique of an eco-city like Masdar because of the fact that it is socially exclusive,

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[666] Global Footprint Network: Advancing the Science of Sustainability. https://www.footprintnetwork.org/2015/11/18/united-arab-emirates/. Retrieved on 22.1.2019

[667] Masdar. Renewable Energy Water Desalination Programme. www.Masdar.ae. Retrieved on 22.1.2019

depends to a high degree of technological innovation and ignores the necessary social behavioral changes among the broad mass of consumers.[668 669]

If the projected “integrated eco-urbanism”[670] of the newly developed Masdar is truly implemented with all its objectives, this implies that, in practice, ecological security is only available to the rich upper class, whereas all other social groups will be excluded from progress and general consumption patterns will change in neither the social nor the economic realm.[671] Moreover, it is doubtful if local people would leave their luxurious villas in beach regions and move to Masdar city where they can walk in the shaded pedestrian precinct. In all probability, Masdar will be inhabited not by local people but for the most part by foreign students and so-called “expats” who voluntarily adapt to the desert climate and its limitations. Thus far, neither the local people nor the expats have shown much interest in urban agriculture.

Thus, in the case of Masdar, city planners do not try to solve specific environmental problems; rather, they aim to establish a showroom for possible technological solutions instead of striving for more comprehensive changes in society. The fact that cars are now allowed in Masdar and that wide streets and underground garages are being constructed shows that the vision of an eco-city clashes with reality. Neither the desire for such a settlement nor the awareness of the problem of sustainability and environmental protection exist among the population. According to the head of the energy company Transsolar, which developed the energy concept for the 600-hectare large Masdar, investors have finally given up sustainable goals because it is faster and cheaper to build in a

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[668] Weißmüller, L. (2018): Die erste CO2-neutrale Stadt der Welt. https://www.deutschlandfunk.de/zehn-jahre-masdar-city-die-erste-co2-neutrale-stadt-der-welt.691.de.html?dram:article_id=410385. Retrieved on 15.1.2019

[669] Crot, L. (2013): Planning for Sustainability in Non-democratic Polities: The Case of Masdar City. Urban Studies 50(13), Oct. 2013, pp. 2809-2825. https://www.jstor.org/stable/26145618?seq=1#page_scan_tab_contents. Retrieved on 16.1.2019

[670] Hodson, M., Marvin, S. (2010): Urbanism in the Anthropocene: Ecological Urbanism or Premium Ecological Enclaves? City 2010, 14, pp. 298-313

[671] ibid.

climate-damaging way than a climate-friendly one: “The new master plan of Masdar City is a catastrophe. It destroys the vision.”[672]

There have been a number of declarations of intent and contracts between Masdar institutions and international companies on urban farming and new agricultural technologies, but large-scale projects have not yet been implemented. Currently, a pilot project is underway on 1.5-acre plots where recycled shipping containers are used as greenhouses. In this closed environment, various crops are grown with only 40 liters of water per day. Advanced technologies enable the continuous monitoring of growth cycles, temperature, CO2 content, and fertilizer requirements. In the future, such mobile devices may be a viable solution for smaller communities to produce their own food, even in desert climates with low water consumption.[673] There is also a Masdar Institute Urban Farming Club, founded by Lina Yousef, who aims to educate her students on ways to improve the quality of soil: “New technologies are critically needed to improve the UAE’s level of local crop production and urban farming is one strategy that we can capitalize on to help meet this goal in a sustainable way.”[674]

The next decade will show how far the planned urban development initiatives in Masdar can be realized. However, as thus far only students have inhabited Masdar, urban agriculture there is only the nucleus and has to be brought to a higher level in the Emirati cities and gain the population’s acceptance. In this case the real value of a visionary eco-city like Masdar may be its function as a “useful

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[672] Schuler, M., quoted in: Weißmüller, L. (2018): Sand der Träume. https://www.sueddeutsche.de/kultur/mensch-und-umwelt-sand-der-traeume-1.3814391. Retrieved on 15.1.2019

[673] Webster, N. (2019): Masdar’s steel urban allotments could help solve food security crisis. https://www.thenational.ae/uae/masdar-city-s-steel-urban-allotments-could-help-solve-food-security-crisis-1.811838. Retrieved on 7.4.2020

[674] Yousef, L. cited in: https://www.ku.ac.ae/on-campus-urban-farm-to-promote-sustainable-agriculture/. Retrieved on 16.1.2019

utopia"[675] that stimulates sustainable development in existing neighborhoods as well as in countries with similar climatic conditions.

The local authorities already clearly understand the necessity of adopting a more sustainable approach to addressing the vital issues of food security, land management, and climate change. They are also aware that the application of new environmental technologies with regard to the usage of scarce resources such as farmland and fresh water can no longer be postponed. The UAE has neglected to optimize its consumption of resources for too long. According to Mohammed bin Obaid Al Mazrouei, Chairman of the Arab Authority for Agricultural Investment and Development,[676] vertical farming is the only future-oriented and viable agricultural technology for his country: "Given the limitations of the horizontal expansion, which requires massive financial investment, land reclamation and establishing the required infrastructure, we are focusing on vertical expansion."[677]

8.3.2.4 Conclusion

When the Abu Dhabi government announced the construction of the first fully sustainable, zero-emission city in 2006, this news met with a lively response in the media and academia. The praise for such an ambitious goal was great, and so was the skepticism regarding the feasibility of the announced objectives: zero emissions, 100% self-sufficient renewable energy, 100% waste recycling in a

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[675] Tubiana, L.: The Institute for Sustainable Development and International Relations (IDDRI). http://www.dw.com/de/masdar-city-%C3%B6kostadt-erwacht-zu-neuem-leben/a-16639495. Retrieved on 4.10.2017

[676] Arab Authority for Agricultural Investment and Development. https://www.aaaid.org/en/agricultural-investment. Retrieved on 16.1.2019

[677] bin Obaid Al Mazrouei. M. https://www.thenational.ae/uae/environment/the-future-of-farming-in-the-uae-is-vertical-1.79462. Retrieved on 5.10.2017

pleasantly air-conditioned, car-free, modern desert town and a sustainable food production with modern technologies. [678] [679] [680] [681] [682]

In recent years, however, only very sparse news and few scientific investigations of the development of Masdar City have been published. The reason for this was the global financial crisis of 2008, the multiple postponements of the completion date, and the fact that, by 2018, only about 5% of the original 6 km² green print had been completed.The greenhouse emissions of the city are reduced to 50% and not, as planned, to zero.[683] As the UAE uses its own rating system for sustainable buildings, it is not comparable to international standards. At present, around 2,000 people work as campus commuters, but only 300 students are real residents with free accommodation and tuition. The development of the autonomous transport system was abandoned after the construction of only two stops, and a bike-sharing station was set up, but there are no bicycle lanes outside the city. Urban farming exists only in small academic projects but has no support among the local population. Overall, the concept has lost so much appeal that Masdar City, according to Goldenberg, "could become world's first green ghost town."[684]

During the author's visit to Masdar he met only "expats", this means, professors, engineers and leading employees of foreign companies. The author talked to many local politicians and also to local scientists, but all the meetings took place

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[678] Scinexx. https://www.scinexx.de/dossierartikel/mehr-als-nur-eine-oekostadt/. Retrieved on 12.11.2018

[679] Heumann, P. (2008): Grüne öko-Stadt in der Wüste. https://www.spiegel.de/wirtschaft/grossprojekt-masdar-city-gruene-oeko-stadt-in-der-wueste-a-534205.html. Retrieved on 13.11.2018

[680] Bauer, W. (2009): Masdar City: Null-Emissions-Stadt in der Wüste. https://www.iao.fraunhofer.de/lang-de/presse-und-medien/245-masdar-city.html. Retrieved 4.12.2018

[681] Reiche, D. (2010): Renewable Energy policies in the Gulf Countries. A case study of the carbon-neutral "Masdar City" in Abu Dhabi. https://epub.wupperinst.org/frontdoor/deliver/index/docId /3463/file/3463_Reiche.pdf. Retrieved on 4.12.2018

[682] Prior, B. (2010): Masdar Update: The Green City in the Middle East Struggles with Dust and Departures Ship sinking; band instructed to keep playing. https://www.greentechmedia.com/articles/read/masdar-update#gs.bacgne. Retrieved on 14.2.2019

[683] Goldenberg, S. (2016): Masdar's zero-carbon dream could become world's first green ghost town. https://www.theguardian.com/environment/2016/feb/16/masdars-zero-carbon-dream- could-become-worlds-first-green-ghost-town. Retrieved on 13.5.2019

[684] ibid.

in Abu Dhabi city, because local people avoid going to Masdar which is missing any comfortable or luxury location.

A lifestyle dictated from above has little chance of long-term success, as the locals are not willing to accept a lifestyle without cars or in homes with narrow streets. Fossil oil is still heavily subsidized in the UAE, and so far, in the public consciousness, there are only tentative approaches to a real reduction of the very high ecological footprint; “this presents a major problem for Masdar City because it is offering an alternative way of life that locals are reluctant to embrace.”[685]

As far as urban agriculture is concerned, there are no Masdar residents – apart from a university study group – who perform horticultural activities indoors or outdoors. However, a smart home farming showcase called “bustani” (Arabic for “garden”) was developed to demonstrate the cultivation of food with the help of high-tech hydroponics in a hostile desert climate. The aim of this project is to identify solutions for improved food and water security and convince UAE residents to adopt a more self-sufficient way of life. [686] [687]

All the studies and critical reviews on Masdar City confirm the author’s findings that the original ideas were seen as visionary, even revolutionary and pioneering at the beginning. A decade later the essence of the ratings may be described as sobering for an idea that came too early for the people of the country. They lacked preparation and had little chance of success under such inappropriate circumstances.

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[685] ibid.

[686] Charlton, E. (2019): How Abu Dhabi found a way to grow vegetables in 40-degree heat. https://www.weforum.org/agenda/2019/01/abu-dhabi-masdar-farm-allotments-shipping-containers/. Retrieved on 13.5.2019

[687] Masdar. https://masdar.ae/en/news-and-events/news/2019/01/17/10/06/masdar-city-showcases-sustainable-smart-home-farming-solutions-for-increased-food. Retrieved on 14.05.2019

8.4 Case Study: UA in Singapore's Food Security Strategy

8.4.1 Environmental Issues

Singapore, officially named the Republic of Singapore, is a sovereign state and global city in Southeast Asia that consists of a main island and 62 small islands with a total land area of 719 km². As the world's only island city-state, Singapore successfully performs extensive land reclamation with soil from its own hills, the seabed, and neighboring countries and thus could increase its total size by 23% since its independence in 1965. With 7,807 living persons per km², it has the third-highest population density worldwide.

Due to its geostrategic location, Singapore has become an important hub for Southeast Asia and a center for finance, logistics, tourism, and business services.[688] [689] As a global financial center, Singapore is ranked fourth behind London, New York, and Hong Kong, and it is home to over 7,000 regional headquarters of multinational companies. Singapore's economy is stable and competitive, has very low inflation rates, and recorded a growth in real gross domestic product of 2.9% in 2018 over the previous year.[690] This success has been achieved despite serious environmental issues and constraints resulting from the country's particular geographical location and absolute resource shortage.

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[688] Changi Airport Group (2017): A Record 62.2 Million Passengers for Changi Airport in 2017, Press Release, 23 January 2018. http://www.changiairport.com/corporate/media-centre/newsroom.html#/pressreleases/a-record-62-dot-2-million-passengers-for-changi-airport-in-2017-2386732. Retrieved on 7.3.2019

[689] Bhaskaran, M. (2008): Getting Singapore in Shape: Economic Challenges and how to meet them. https://www.lowyinstitute.org/publications/getting-singapore-shape-economic-challenges-and-how-meet-them-0. Retrieved on 30.1.2019

[690] Statista. https://de.statista.com/statistik/daten/studie/321761/umfrage/wachstum-des-bruttoinlandsprodukts-bip-in-singapur/. Retrieved on 30.1.2019

As a very low-lying island state, Singapore is highly threatened by the rise of the sea level and coastal erosion because the majority of its commercial and industrial infrastructure is located near the coast and fewer than two meters above sea level. According to meteorological prognoses, the country is likely to face higher temperatures, more intense and frequent heavy rainfalls, very dry seasons, and higher sea levels in the future. According to the Center for Climate Research in Singapore,[691] in an extreme case, this could mean that the average daily temperatures could rise up to 4.6° Celsius, heavy rainstorms would occur, and the sea level could rise up to one meter.

According to the Population White Paper,[692] Singapore will have a population of between 6.5 and 6.9 million people by 2030, which will prompt a major challenge for Singapore's government to create additional agricultural land and develop land reserves and old industrial areas. Currently, only 0.9% of the total land area is available for traditional agriculture, and 10-year leases are often a hindrance to long-term planning and development.

Without natural rivers or lakes, Singapore heavily depends on a water agreement with Malaysia, which will expire in 2061, for its drinking water supply.[693] In order to become independent from water imports and achieve self-sufficiency, Singapore tries to secure its water supply through retention reservoirs, desalination plants, and the reclamation of sewer water (NEWater). However, if a drought that affects Singapore and parts of neighboring Malaysia lasts several months or longer, the production of NEWater[694] would not be sufficient.

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691 Data.gov.sg. https://data.gov.sg/dataset?organization=national-environment-agency&groups=environment. Retrieved on 23.01.2019

692 Npd.gov.sg: National Day Parade 2018. Population White Paper. www.npd.gov.sg./News: http://npdt.gov.sg./portals /0/news/population-white-paper-exec-summary_english.pdf. Retrieved on 8.12.2016

693 National Library Board Singapore: Singapore-Malaysia water agreements. http://eresources.nlb.gov.sg/infopedia/articles/SIP_1533_2009-06-23.html. Retrieved on 14.10.2017

694 NEWater, a pillar of Singapore's water sustainability strategy, is high-grade reclaimed water produced from treated used water. https://www.pub.gov.sg/watersupply/fournationaltaps/newater. Retrieved on 13.10.2017

Another serious problem are the steadily growing waste volumes. According to an assessment of the National Environment Agency (NEA), Singapore would need to build a new, 3,000-ton/day incineration plant every 5.7 years, plus a new, 350 hectares landfill such as Pulaau Semakau every 25 to 30 years to cope with the waste.[695] The rising amount of waste that is not yet sufficiently managed by an integrated solid waste management system for recycling represents a major environmental problem as well as a threat to food security. More landfilling is not a sustainable option for the island state because it will cause further soil contamination by waste, pesticides, and lead, and plants grown in such soil contain harmful chemical traces that pose considerable risks to human health.

Although Singapore is renowned as the cleanest city in the world, it frequently suffers from smoke and haze that result from forest fires in neighboring Indonesia. The National Environment Agency considers repeated “smoke crises” with pollution indexes of over 200 “very unhealthy” and a serious threat to urban life,[696] but Indonesian bushfires are not the only cause of Singapore’s heavy air pollution. As early as the 1990s, Singapore emitted the highest carbon dioxide amount per capita after the United States and Australia,[697] and over the last decade, industrial processes and construction sites have contributed to a worsening of indoor and outdoor air quality through the massive release of toxic emissions.

Although Singapore registers impressive rankings on competitiveness surveys[698] and in the 2018 INSEAD Global Innovation Index,[699] it is still behind in adopting

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[695] FactsandDetails: Environmental Issues in Singapore. http://factsanddetails.com/southeast-asia/Singapore/sub5_7a/entry-3795.html. Retrieved on 14.10.2017

[696] Shadbolt, P. (2013). http://edition.cnn.com/2013/06/19/world/asia/singapore-haze/index.html. Retrieved on 13.10.2017

[697] Factsanddetails. http://factsanddetails.com/ southeast-asia/Singapore/sub5_7a/entry-3795.html. Retrieved on 13.10.2017

[698] IMD. https://www.imd.org/wcc/world-competitiveness-center-rankings/world-competitiveness-ranking-2018/. Retrieved on 10.1.2019

[699] Cornell University, INSEAD, World Intellectual Property Organization (WIPO): Global Innovation Index 2018.Energizing the World with Innovation. Ithaca, Fontainebleau, Geneva 2018, p. xxxii

wind, solar, and hydropower technologies compared to other industrialized countries and their use of renewable power resources. “Here lies another dilemma. The country is already one of the most energy intensive in Asia to power its industries and fiercely air-conditioned malls and glass office towers – a paradox in a country at such risk from climate change.”[700]

8.4.2 Food Security Challenges

When Singapore gained its independence in the 1960s, there were still 20,000 farms managing 140 km² of arable land.[701] In the 80s and 90s, the government founded the so-called "agrotechnology parks" in the northwest of the island on approximately 15 km², where 200 farms, including 130 fish farms, 50 vegetable growers and three egg-producing farms (as of 2015), were created.[702]

The governmental agrotechnology program consists of three components: agrotechnology parks, agrotechnology science and research in molecular biology for agro-biological applications on a large scale, and intensive farming. All agricultural land outside these clusters is used for other economic purposes, and as early as 2013, less than one percent of the total 720 km² of national territory was available for food production.[703] [704] Singapore itself produces about 10% of the food it consumes, of which 12% are eggs, fish, and green vegetables.[705] The agricultural sector contributes less than 1% to the country’s GDP per capita and 0.119% of labor force in 2017.[706] Approximately 20% of leafy vegetables and

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[700] Fogarty, D. (2012): Singapore raises sea defenses against tide of climate. https://www.reuters.com/article/ us-climate-singapore/singapore-raises-sea-defenses-against-tide-of-climate-idUSTRE80Q05P20120127. Retrieved on 11.12.2016

[701] Nparks.gov.sg. https://www.nparks.gov.sg//media/cuge/ebook/citygreen/cg12/cg12_food_security_and_ community_bonding_ in_a_globalised_city-state.pdf. Retrieved on 1.2.2019

[702] Lim, J. (2015): Appetite for local produce growing. In: The Straits Times, 25 May 2015. http://www.straitstimes.com/singapore/ appetite-for-local-produce-growing. Retrieved on 16.1.2019

[703] The World Bank: Agricultural land (percent of land area), 2013, dataset. http:// data.worldbank.org/indicator/AG.LND.AGRI. ZS. Retrieved on 25.3.2018

[704] In comparison, 8 percent of land area is currently dedicated to parks and nature reserves.

[705] AVA: Annual Report 2016/17. https://www.ava.gov.sg/docs/default-source/publication/annual-report/ava-ar-2016-17. Retrieved on 21.11.2018

[706] World Bank. https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS. Retrieved on 12.1.2019

bean sprouts produced by local farmers are from hydroponic cultivation, and the remaining 80% are from soil cultivation.

Today, more than 90% of Singapore's food supply, including six key commodities, chicken, pork, fish, eggs, rice, and vegetables, have to be imported to meet demand. Malaysia and China are the two major suppliers of fruits and vegetables, while much of the key food comes from the U.S. and Australia. The authority responsible for this in Singapore is the Food and Veterinary Authority (AVA), whose primary strategy for creating a resilient food system is the diversification of exporting countries with appropriate redundancy concerning the providers of basic food products.[707]

Although a higher domestic production is the government's stated goal, especially because of difficult storage and transport possibilities for fruits and vegetables, Singapore is not likely to be independent of food imports due to its scarcity of land. This dependency on food imports from abroad poses a vulnerability that will increase in times of climate change and rising temperatures. Reduced agricultural yields as a result of storms, dry spells, and increasing losses in refrigerated transport are threats that cannot be avoided.

The same is true for eventual economic problems of its trading partners, a dramatic rise of fuel prices, or a major regional crisis with a blockage of transporting routes, which would have a devastating effect on Singapore's food security. Additionally, increasing urbanization and rural exodus, with fewer and fewer food producers and more and more urban consumers, have caused more competition for food that is not sufficiently available. A certain compensation may be the relatively high per capita income in Singapore, but in spite of this, if vital food imports from neighboring countries are dramatically reduced or entirely

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[707] AVA: Meeting Singapore's Food Supply. http://www.ava.gov.sg/exploreby-sections/food/singapore-food-supply/ meeting-singapores-food-supply. Retrieved on 4.10.2018

absent because of climate catastrophes or military conflicts, Singapore's food supply could be seriously jeopardized.[708]

8.4.3 Singapore's Climate Action Plan

8.4.3.1 Environmental Goals and Measures

To address the multiple environmental and geographic challenges, the government of Singapore launched a Climate Action Plan in 2016 to decrease greenhouse gas emissions and adapt to the consequences of climate change. All emergency, mitigation, and recovery programs are to be implemented and resilience capacities strengthened according to the guidelines established in this plan.[709]

A summary of Singapore's adaptation and mitigation strategy is contained in the current version of the Singapore Climate Action Plan "Take Action Today for a Sustainable Future,"[710] which essentially aligns with Singapore's commitment in the 2015 to the Paris Agreement[711] "to reduce our emissions intensity by 36% below 2005 levels by 2030, and to stabilize our greenhouse gas (GHG) emissions with the aim of peaking around the same time. … The industry sector is the largest emitter accounting for about 60% of our total emissions, followed by the buildings (17%) and transport (16%) sectors."[712]

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[708] Montesclaros, J., Liu, S., Teng, P. (2018): Scaling up Commercial Agriculture to meet Food Demand in Singapore: An Assessment of the Viability of Leafy Vegetable Production using Plant Factories with Artificial Lighting in A 2017 (First Tranche). NTS Report No. 7, February 2018

[709] National Climate Change Secretariat. https://www.nccs.gov.sg/resources/publications. Retrieved on 14.7.2017

[710] Strategygroup.gov.sg. https://www.strategygroup.gov.sg/media-centre/publications/climate-action-plan-take-action-today-for-a-sustainable-future. Retrieved on 15.10.2018

[711] UNFCCC. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. Retrieved on 14.7.2017

[712] ibid.

The measures initiated as part of the Climate Action Plan cover four key areas of public and private life: water supply, waste management, infrastructure, and the food system:

Secure Water Supply

In order to better confront drought scenarios in the future, a sophisticated drought resilience plan was conceived. It foresees that, as an ultima ratio for super-dry seasons, Singapore's ground water, whose volume is an estimated 700 billion liters, can be extracted and recharged during the monsoon seasons by the excess surface runoff that is usually discharged into the ocean.[713] Additionally, collected rainwater is channeled to 17 different reservoirs for storage, and used water is recycled to produce NEWater that can satisfy 20% of Singapore's water needs.[714]

Although the National Water Agency has developed a variable desalination plant to gap minor catchments and add to the drinking water supply, the output of recycled NEWater needs to be tripled to meet the demand in 2060 if the general water consumption is not drastically reduced.[715] However, this NEWater output cannot be achieved, and it is indispensable that the inhabitants of Singapore adopt a more sustainable way of life and reduce their per capita water consumption of 153 liters to a maximum of 140 liters by 2030.[716]

Waste Management

Waste has become a major problem in recent decades. Currently, all non-recyclable waste is incinerated in waste-to-energy plants, and ash and non-

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713 Ziegler, A.D. et al. (2014): Increasing Singapore's resilience to drought. In: Hydrological Processes, 28(15), 15 July 2014, pp. 4543–4548

714 Pub.gov.sg. https://www.pub.gov.sg/watersupply/fournationaltaps/newater. Retrieved on 6.1.2019

715 ibid.

716 FactsandDetails: Environmental Issues in Singapore. http://factsanddetails.com/southeast-asia/Singapore/sub5_7a/entry-3795.html. Retrieved on 14.10.2017

incinerable waste are still disposed of on Semakau Island. Food waste, which accounts for approximately 10% of total waste, is also burned for the most part, as only 16% of it is further processed.[717] Because the 40% increase in food waste over the last 10 years has been a growing problem for the recycling industry, Singapore's authorities have started to engage in a food waste recycling program that feeds food waste into a bacteria-filled processor of a food recycling plant, which converts it into biogas energy and compost.

When the conversion facility is fully operational, it could become Southeast Asia's largest bio-mechanization and renewable energy plant, with a recycling capacity of 800 tons of food waste per day.[718] Thus, although it once ranked among the nations with the lowest environmental sustainability index after countries like Iran, Vietnam, Malawi, and Senegal, Singapore is now rated as one of the most environmentally sustainable countries in the world (rank 14).[719]

Green Infrastructure

Singapore's government is convinced that a green infrastructure is not only one of the most effective tools to mitigate the impact of flooding and destructive heat waves, but also an effective solution to increase the city's resilience by creating a comprehensive, biodiverse urban environment for people and wildlife.[720] According to the Climate Action Plan, the complete outlook of the city will be retrofitted by designing an allover green infrastructure with extensive green networks, green bridges for traffic-free routes, green roofs, walls, facades and wildlife corridors for greater biodiversity in the urban ecosystem.

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[717] Nea.gov.sg. https://www.nea.gov.sg/our-services/waste-management/3r-programmes-and-resources/food-waste-management. Retrieved on 8.2.2019

[718] Reuters: Trash and burn: Singapore's waste problem. https://www.reuters.com/article/us-waste-singapore/trash-and-burn-singapores-waste-problem-idUSSP9046620080522. Retrieved on 14.10.2017

[719] Yale Environmental Performance Index: Report 2016. https://issuu.com/2016yaleepi/docs/epi2016_final. Retrieved on 14.10.2017

[720] Mewr.gov.sg: Public Sector Sustainability Plan 2017-2020. https://www.mewr.gov.sg/docs/default-source/default-document-library/grab-our-research/Public_Sector_Sustainability_Plan_2017-2020.pdf. Retrieved on 6.2.2019

All new and old buildings will be constructed or refurbished to meet the criteria of the Green Building Master Plan. Since the greening of buildings is considered an efficient way to reduce a city's carbon footprint, the Building and Construction Authority (BCA) has developed a plan for 80% of Singapore buildings to achieve these standards by 2030.[721]

Image 12 – Singapore – "Green" hotel, author's study trip to Singapore in 2017

As part of the Biophilic Cities[722] network founded in 2013, which now includes 15 cities worldwide, Singapore introduced a strict landscape replacement policy, which requires that the city "replace, at least one-to-one, what is lost at the ground level with nature in the vertical realm,"[723] for example with vertical gardens.[724] [725]

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[721] Bca.gov.sg. https://www.bca.gov.sg/greenmark/others/3rd_green_building_masterplan.pdf. Retrieved on 8.2.2019

[722] Biophiliccities: What is a Biophilic City? www.biophiliccities.org. Retrieved on 1.11.2017

[723] Council for European Studies. https://www.europenowjournal.org/2017/06/05/the-vision-and-practice-of-biophilic-cities/. Retrieved on 7.7.2018

[724] Urban Redevelopment Authority Singapore (2009). https://www.ura.gov.sg/uol/circulars/2009/apr/dc09-09. Retrieved on 15.10.2017

[725] Urban Redevelopment Authority Singapore (2014). https://www.ura.gov.sg/uol/circulars/2014/jun/dc14-12. Retrieved on 15.10.2017

Following E.O. Wilson's sociobiological concept,[726] [727] [728] further characteristic features of a biophilic city that have been integrated into Singapore's holistic approach are sky gardens and green atria, green walls and courtyards, urban trees, edible landscapes, urban forests, ecological parks, sustainable green buildings, and routes for pedestrians and cyclists.

In a compressed, compact city like Singapore, a green public realm with large trees and urban woodland is considered indispensable for people's social contacts, a healthier micro-climate, and an attractive atmosphere. For this purpose, 9% of the whole land area has been reserved for nature reserves and parks, and 90% of all houses should be built within a 10-minute walk of a park. To show that cities are natural systems themselves and therefore should not be detached and disconnected from the ecosystems, Singapore changed its motto from "Singapore, a garden city" to "Singapore, city in a garden."[729]

In order to have more free space for pedestrians and cyclists, more roads are planned to be built underground, and all above-ground streets should receive permeable paving to avoid flooding and facilitate the collection of rainwater by a modified drainage system. Other measures of the Climate Action Plan include automatic public transport and limitations on car traffic to make room for green corridors, lower the air pollution, and reduce dependence on fossil resources. In order to reach these goals, the Singaporean government encourages its citizens to enrich biodiversity in the urban environment and enhance horticultural competencies by establishing "world-class gardens" and urban food production.[730]

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[726] Wilson, E.O. (1984): Biophilia. Cambridge 1984
[727] Beatley, T. (2016): Handbook of Biophilic City Planning and Design. Washington, D.C. 2016
[728] Europe Now Journal: The Vision and Practice of Biophilic Cities. http://www.europenowjournal.org/2017/06/05/the-vision-and-practice-of-biophilic-cities/. Retrieved on 15.10.2017
[729] Convention on Biological Diversity: Singapore – A City in a Garden. https://www.cbd.int/doc/meetings/city/subws-2014-01/other/subws-2014-01-presentation-singapore-en.pdf. Retrieved on 15.10.2017
[730] ibid.

8.4.3.2 Food Security Strategy

In October 2013, the responsible national organization, the Agri-Food and Veterinary Authority (AVA), introduced a “Food Security Roadmap” for a resilient supply of safe food based on supporting and enabling strategies.[731] The government has conceptualized and already partly implemented a path to greater self-reliance and safety following the recommendations in the UN Report “The transformative potential of the right to food” by Olivier de Schutter: “As the competition increases between putting land to urban or to industrial use in the urban and peri-urban perimeter, and as increased food supplies create unprecedented logistical challenges for food distribution and transport systems, it is vital that cities assess their food dependencies, identify weaknesses and potential pressure points, and, where possible, develop a variety of channels through which they can produce their food. Urban and peri-urban agriculture, as well as the development of short food chains connecting cities to their local food shed, will therefore play an increasingly important role.”[732]

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[731] Agri-Food and Veterinary Authority of Singapore: Food security roadmap. www.ava.gov.sg/files/avavision /issues3-4_2013/food-security-roadmap.html. Retrieved on 5.2.2017
[732] SRFood.org. https://www.srfood.org/en/documents. Retrieved on 5.2.2017

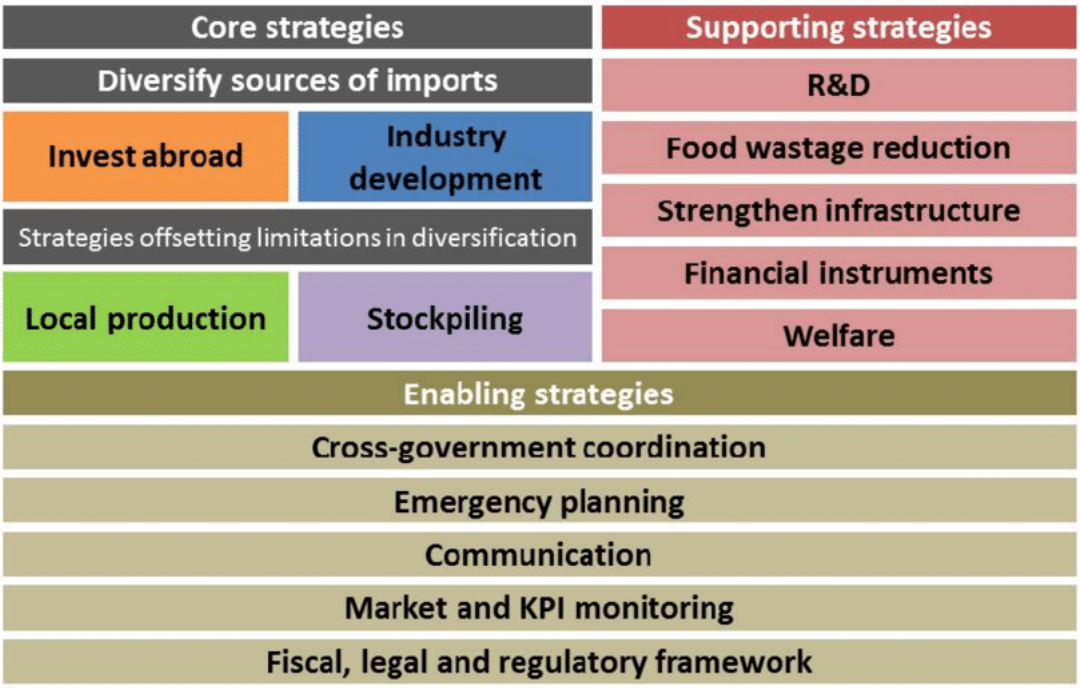

Figure 18 – Food Security Roadmap of Singapore, Agri-Food and Veterinary Authority of Singapore

Land management in Singapore faces significant challenges. In addition to land for local agriculture, it must also provide space for housing, manufacturing and services, and important infrastructures such as ports and airports, while the resource land is limited and can hardly be increased. For this reason, it is not a realistic goal to produce all the necessary food in the country itself. Rather, the cost of land and imports must be balanced so that the import of foods that last longer and remain fresh when chilled is an acceptable solution.

Import Policy and Laws

Although Singapore imports 90% of its food, it ranks first in the Food Security Index 2018 ahead of Ireland, the United Kingdom, and the United States. The reasons for this are its open market structure, excellent trade relations with strong partners, and its importance for the food retail market.[733] Source diversification is Singapore's success strategy; currently, it imports food from 180 countries, a fact that creates the advantage of great flexibility.

If one key provider is affected, alternative sources can quickly fill the emerging gap. Low agricultural tariffs facilitate food imports and help make Singapore an important market for food processing and re-exporting. As the most developed food retail market in Southeast Asia, Singapore re-exports about 20% to 25% of its imported food.[734] [735]

In early 2019, an important measure to improve the quality assurance and reliability of its foreign imports was decided in the parliament; it required mitigating strategies from the exporting states in the event of supply disruptions: "In the event of a sudden and sharp food disruption, there are plans to ensure that food remains available for Singaporeans… These plans have been worked out closely with the industry, to ensure the promptness of sourcing, logistics arrangements, and distribution."[736]

In addition to imports, stockpiling is another important element in Singapore's food security strategy. At the moment, the country holds a two-month stockpile in government warehouses, an amount that would certainly be insufficient in times of crisis and could at best help stabilize prices during short-term shortages. Thus, Singapore is currently exploring the possibilities of a common regional stockpiling of all ASEAN states, similar to the ASEAN Plus Three Emergency Rice Reserve

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[733] The 2018 Global Food Security Index provides a worldwide perspective on which countries are most and least vulnerable to food insecurity and how resource risks increase vulnerability. Germany is ranked 11th. https://foodsecurityindex.eiu.com/Index. Retrieved on 10.2.2019

[734] Foodexport: https://www.foodexport.org/get-started/country-market-profiles/southeast-asia/singapore-country-profile. Retrieved on 9.2.2019

[735] Clc.gov.sg: A Case Study of Singapore's Smart Governance of Food. Center for Livable Cities Singapore, 2015. www.clc.gov.sg/documents/books/smart_food_ governance_paper-sg_case_study_final_sept%2028_3.pdf. Retrieved on 11.2.2019

[736] Ministry of National Development (MND) spokesman. https://www.gov.sg/news/content/singapore-food-security. Retrieved on 9.2.2019

(APTERR), which has existed since 2012.[737] APTERR consists of the ASEAN Member States,[738] the People's Republic of China, Japan, and the Republic of Korea, and it cooperates with the aim of helping each other in emergencies caused by natural disasters and other humanitarian purposes.

At present, the organization has rice stocks of a total of 787,000 tons, consisting of 87,000 tons from the ASEAN member countries and 700,000 tons from the Plus Three countries. Another option under consideration for Singapore's food security is virtual stockpiling, where an agreed quantity of key commodities is reserved within the producing country and can be called upon in times of need.[739] This import strategy is supplemented by contract farming with other countries, especially Indonesia, Poland, Denmark, and China. Here, Singapore has more control regarding supply and quality, as well as in the agriculturally joint ventures with Brunei (fish farms) and China (vertical vegetable production).[740]

Local Food Production

An increased local food production is the third element in the "Three National Food Baskets" (TNFBs), which is meant to strengthen national food security and function as a buffer for a more resilient food supply.[741] Today, traditional agriculture takes place mostly in six 1,465-hectares agrotechnological parks. In order to achieve the best use of the field soil and increased productivity, AVA has

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[737] APTERR. https://www.apterr.org/. Retrieved on 9.2.2019

[738] ASEAN member states: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam

[739] AVA. https://www.ava.gov.sg/files/avavision/issues3-4_2013/food-security-roadmap.html. Retrieved on 9.2.2019

[740] Poh Koon, K.: Speech by Minister of State Koh Poh Koon for the Ministry of National Development at the Committee of Supply Debate, 7 March 2017. https://www.gov.sg/microsites/budget2017/press-room/news/content/speechby-mos-dr-koh-poh-koon-for-mnd-at-the-committee-of-supply-debate. Retrieved on 11.2.2019

[741] ibid.

established training programs, especially for older farmers.[742] [743] Additionally, a newly established agricultural fund assists farmers with bank loans for new farming systems and post-harvest processes, as well as for aquaculture and poultry waste treatment systems.[744] [745]

In March 2017, AVA launched the “Farm Transformation Map” to help farms “grow more with less and translate research into commercially viable farming solutions.”[746] Adopting a new “account management” approach, AVA assigned each farm an account manager to provide assistance in the areas of finance, business development, and technological innovations.[747] The Food Security Roadmap focuses its investments on three key staple foods: leafy vegetables, hen-shell eggs, and fish. These three key foods should buffer the food supply in difficult times and thus boost the resilience of the food system. In this context, the government has set specific production goals for the next five years and opened fixed-price tenders for plots to be used for aquaponics and fish farming.[748]

At present, only 12% of the total vegetables are produced locally, while 92,000 tons per year are consumed. This is a potentially lucrative market for the new hydroponic, vertical farming technology, which is used more often and fits perfectly into the Skyrise Greenery Incentive Scheme (SGIS), which the National

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[742] Teng, P., Escaler, M. (2010): The Case for Urban Food Security: A Singapore Perspective. NTS Perspectives Is., 4, 31 Dec. 2010

[743] Center for Livable Cities Singapore (2015): A Case Study of Singapore’s Smart Governance of Food. www.clc.gov.sg/documents/books/smart_food_ governance_papersg_case_study_final_sept%2028_3.pdf. Retrieved on 11.2.2019

[744] Teng, P., Escaler, M. (2010): The Case for Urban Food Security: A Singapore Perspective. NTS Perspectives Is., 4, 31 Dec. 2010. Retrieved on 8.2.2019

[745] Center for Livable Cities Singapore (2015): A Case Study of Singapore’s Smart Governance of Food. www.clc.gov.sg/documents/books/smart_food_ governance_paper-sg_case_study_final_ sept%2028_3.pdf. Retrieved on 11.2.2019

[746] Mnd.gov.sg. https://www.mnd.gov.sg/mndlink/2017/jul-aug/pdf/future-of-farming.pdf. Retrieved on 11.2.2019

[747] AVA: AVA Annual Report 2016/17. https://www.ava.gov.sg/docs/default-source/publication/annual-report/ava-ar-2016-17. Retrieved on 15.11.2017

[748] AVA. https://www.ava.gov.sg/files/annualreport/AR2017-18/#p=10. Retrieved on 22.2.2019

Parks started in 2009.[749] [750] With this initiative, more than 185 existing buildings have already received up to 50% off the installation costs to retrofit them with green roofs, edible gardens, or green walls.[751] “The role of green infrastructure in addressing the challenges of the 21st century cannot be underestimated. It is a natural, service providing infrastructure that is often more cost effective, more resilient and more capable of meeting social, environmental and economic objectives than ‘gray’ infrastructure.”[752] [753]

An illustrative example of this innovative, multi-layer approach is the newly built Khoo Tech Puat Hospital (KTPH) (see 12.2.2 Further Image Material), which acknowledges that greener living environments not only relieve stress and improve people’s mood, but also possess an important healing power.[754] [755] [756] hospital building has green roofs with fruit trees and an interior green courtyard with a waterfall for recreational purposes: “Right from the start, KTPH was conceptualized as a ‘hospital in a garden, and a garden in a hospital’. When we built KTPH, we ensured that for every square meter of land we took, we added three square meters of greenery. Despite our compact size, we achieved this by having vertical gardens which also complement the building’s facade and sleek lines.”[757]

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749 Nparks.gov.sg. https://www.nparks.gov.sg/skyrisegreenery/incentive-scheme. Retrieved on 24.2.2019
750 Wai Wing, D. (2011): Beyond Skyrise Gardens. The Potential of Urban Roof-Top Farming in Singapore. http://global.ctbuh.org/resources/papers/download/882-beyond-skyrise-gardens-the-potential-of-urban-roof-top-farming-in-singapore.pdf. Retrieved on 26.2.2019
751 ibid.
752 Landscape Institute (2013): Position Statement. Infrastructure: An integrated approach to land use. https://www.landscapeinstitute.org/wp-content/uploads/2016/03/Green-Infrastructure_an-integrated-approach-to-land-use.pdf. Retrieved on 13.10.2018
753 ARUP: Cities alive. https://www.arup.com/publications/research/section/cities-alive-rethinking-green-infrastructure. Retrieved on 13.10.2018
754 Bellows, A., Brown, K., Smit, J. (2008): Health Benefits of Urban Agriculture. https://www.researchgate.net/publication/238742667_Health_Benefits_of_Urban_Agriculture. Retrieved on 23.9.2019
755 Söderback, I., Söderström, M., Schälander, E. (2009): Horticultural therapy: the ‘healing garden’ and gardening in rehabilitation measures at Danderyd hospital rehabilitation clinic, Sweden. https://www.tandfonline.com/doi/abs/10.1080/13638490410001711416. Retrieved on 5.2.2019
756 Hardman, I. (2020): The Natural Health Service: What the Great Outdoors Can Do for Your Mind. London 2020
757 Teng Lit, L. (2018). Chief Executive Officer of Alexandra Health Singapore. http://www.greenroofs.com/projects/khoo-teck-puat-hospital-ktph/. Retrieved on 13.2.2019

In fact, converting green roofs into rooftop gardens has proved to be a pragmatic and successful approach of "scaling-up" urban agriculture. The findings of several studies show that Singapore's public housing estates are suitable for rooftop farming, and if such structures were implemented nationwide, an increase of 700% in domestic vegetable production could be achieved.[758] [759] [760] Since more than 80% of Singapore's population lives in public Housing and Development Board (HDB) apartments, the available roof space provides ideal conditions for the implementation of building-integrated urban farming. An additional advantage of these estates is their management infrastructure, which is necessary for the operation, waste collection, and transport that are the precondition of running the farms effectively.[761]

Some roofs, such as the Scape shopping mall in Singapore, are also suited for high-end commercial roof-top farming, like the vegetable and fish farm of the company ComCrop, which produces 10 times more than conventional farms in the same space.[762] By applying vertical farming techniques with a closed-loop irrigation system, ComCrop breeds tilapia fish to fertilize the water for its Italian basil, peppermint, spearmint, tomatoes, and leafy greens, which are sold to local restaurants.

Of course, this level of urban food production can only be a first step to making Singapore more resilient against food supply disruptions. Therefore, the company intends on scaling up the farm by 10 times at another location, where 23 tons of

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[758] AVA. https://www.ava.gov.sg/files/avavision/issue1_2018/farming-in-unusual-spaces.html. Retrieved on 12.2.2019
[759] Seneviratne, K. (2012). https://ourworld.unu.edu/en/farming-in-the-sky-in-singapore. Retrieved on 12.2.2019
[760] Yhinhui Astee, L., Kishnani, N. (2010): Building Integrated Agriculture: Utilizing Rooftops for Sustainable Food Crop Cultivation in Singapore. Journal of Green Building: Spring 2010, 5(2), pp. 105-113. https://doi.org/10.3992/jgb.5.2.105. Retrieved on 13.2.2019
[761] ibid.
[762] ComCrop. www.comcrop.com. Retrieved on 12.2.2019

food per month will be produced:[763] “Our goal is that when a time of need comes, the rooftop farm can convert into something important.”[764]

Perhaps the most important key technology for increasing the resilience of the food system is vertical farming, which combines maximum yields with minimal water and land consumption, above all in indoor facilities. Its scalability and adaptability allow its use to meet the requirements of almost any crop. As the new focus of the national economic strategy has shifted to emphasize Singaporean innovation and small-to-medium enterprises, the number of vertical farms increased from only one in 2012 to seven as of August 2016.[765] Examples of successful enterprises are the frequently cited Skygreens,[766] the largest aeroponic farm worldwide, with an extremely successful vertical growing system, and the Panasonic vertical farm,[767] which was founded in 2014 and has since quadrupled its acreage.[768]

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763 Pao, M. (2014): Urban Farms Build Resilience Within Singapore's Fragile Food System. https://www.npr.org/sections/thesalt/2014/08/20/341623536/urban-farms-build-resilience-in-singapore-s-food-system?t=1543766497134. Retrieved on 13.2.2019

764 Lim, A., Co-founder of ComCrop. ibid.

765 Bryna, S. (2016): Vertical farms on the rise in land scarce Singapore. The Straits Times, 10 July 2016. http://www.straitstimes.com/lifestyle/vertical-farms-on-the-rise-in-land-scarce-singapore. Retrieved on 3.11.2017

766 Skygreens: https://www.skygreens.com/. Retrieved on 13.2.2019

767 Garfield, L. (2017): Panasonic's first indoor farm can grow over 80 tons of greens per year - take a look inside. https://www.businessinsider.de/panasonic-indoor-farm-photos-2017-2?r=US&IR=T. Retrieved on 13.2.2019

768 Businesswire: Panasonic Contributes to Singapore's Self-Sufficiency Level of Vegetables with First Indoor Vegetable Farm. https://www.businesswire.com/news/home/20140731006714/en/Panasonic-Contributes-Singapores-Self-Sufficiency-Level-Vegetables-Indoor. Retrieved on 13.2.2019

Image 13 – Singapore – Vertical farm, author's study trip to Singapore in 2017

In the future, when urban and peri-urban opportunities are exhausted, vertical farms could also be established on ships or on off-shore landfill areas such as Pulau Semakau.[769] Architects from the Barcelona-based design firm JAPA have developed the concept of a so-called "Floating Responsive Agriculture" (FRA). These innovative farms consist of huge, L-shaped floating constructions with many levels for agricultural production; they are designed for the optimal use of sunlight and can provide sufficient fresh food for the population at all times. "The loop shape enables the vertical structure to receive more sunlight without having significant shadows… We believe these types of initiatives can be applied closer to the existing and new emerging urban centers in order to help mitigate the future food issue… This can transform a city's nearby territories into more stimulating environments, capable of self-producing quality food in order to avoid massive imports from abroad."[770]

[769] ZeroWasteSG: Semakau landfill. http://www.zerowastesg.com/2015/07/12/semakau-landfill-expanded-to-meet-singapores-waste-disposal-needs/. Retrieved on 16.10.2017
[770] Ponce, J. (2014): https://www.sciencealert.com/floating-vertical-farm-systems-offer-food-solutions-to-the-densest-countries-on-earth. Retrieved on 15.10.2017

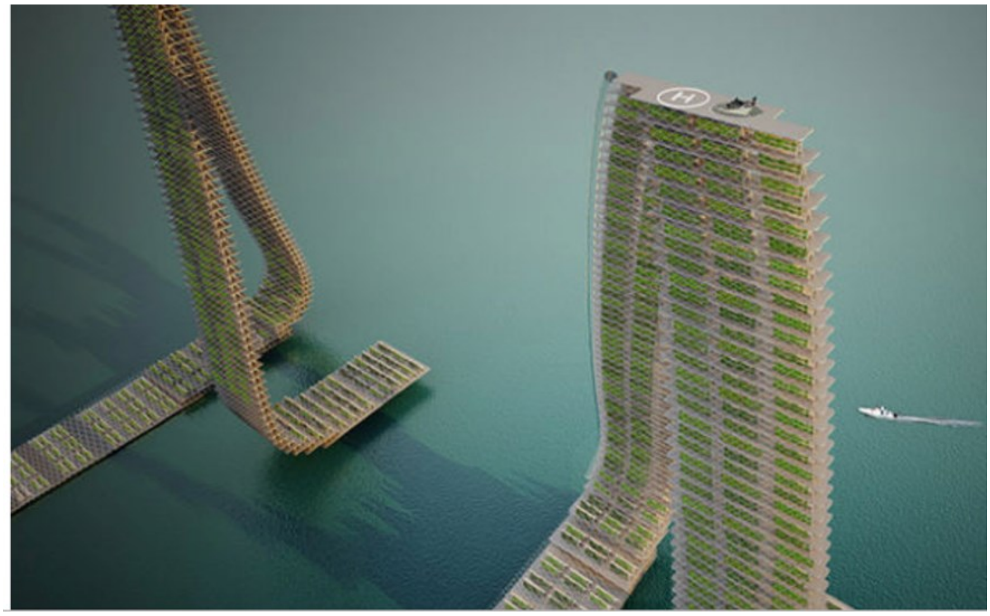

Image 14 – Floating vertical farms, https://www.sciencealert.com/floating-vertical-farm-systems-offer-food-solutions-to-the-densist-countries-on-earth

With vertical farming and hydroponic technology, Singapore has viable solutions to address the problem of its high dependence on food imports. Consumer interest in locally grown food has grown steadily, and numerous individuals, families, and micro-enterprises have begun to grow their own vegetables, herbs, and fruits in their residential spaces.[771] In addition, the number of registered community gardens has increased and this new trend is supported by the government through Community in Bloom (CIB), a gardening program initiated by the National Parks Board. Today, CIB has 1,400 community gardens with over 36,000 gardening enthusiasts actively engaged in growing edibles and herbs.[772] Additionally, the National Parks Board has also provided 1,000 allotment garden plots in 10 parks island-wide for urban hobby gardeners who wish to have their

[771] Lim, J. (2015): Appetite for local produce growing. In: The Straits Times, 25 May 2015. http://www.straitstimes.com/singapore/ appetite-for-local-produce-growing. Retrieved on 16.1.2019
[772] Nparks.gov.sg. https://www.nparks.gov.sg/gardening/community-in-bloom-initiative. Retrieved on 14.2.2019

own space to cultivate.[773] In this context, Singapore's declared goal to further encourage this ground-up interest in food growing has several objectives, which together improve the national resilience: "There are many value propositions for urban farming in Singapore that go beyond local food production. It fosters closer interaction, and community bonding, and provides a great platform for partnership between people, public, and private sectors."[774]

8.4.4 Evaluation

The highest priority for human survival is the satisfaction of basic needs through the provision of food, water, sanitation, shelter, and energy. Protection and continuity of personal savings, education, and functioning healthcare services are additional, but subordinated priorities, as are social cohesion and trust in the urban authority.

Singapore's adaptation and mitigation planning for environmental and food security challenges are complex and strategically well conceptualized. Its proactive mitigation strategy and urban growth are based on complete vulnerability assessments that specify risk areas. This planning combines redundant components, such as the diversification of food imports, with consistent efforts to make the city-state as robust and crisis-proof as possible. Moreover, based on materials and design, Singapore's urban planning and architecture tries to adapt to the requirements of an increased mitigation and adaptation in order to cope with climatic effects and other possible hazards. It attaches great importance to social groups and communities, both for the development of common policy objectives, such as technological progress, economic stability, and national resilience, as well as for the creation of a sustainable work and leisure environment.

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[773] Nparks.gov.sg. https://www.nparks.gov.sg/gardening/allotment-gardens. Retrieved on 14.2.2019

[774] Wee Meng, W., Secretariat of the Ministry of National Development (MND)'s Taskforce for Urban Farming (TURF). https://www.nparks.gov.sg/-/media/cuge/ebook/citygreen/cg12/cg12_food_security_ and_ community_bonding_in_a_globalised_city-state.pdf. Retrieved on 14.2.2019

8.4.4.1 Green Infrastructure

An example of this is the government's stated goals to be achieved by 2030. A highly significant increase of the sky-rise greenery area by 178% from 72 hectares in 2015 to 200 hectares by 2030 should make a decisive contribution to improving the urban climate, air quality, and opportunities for urban agriculture.[775] [776] Green areas, such as parks and the length of the park connectors, are to be increased by 32% and 165%, respectively. The enrichment of Singapore's urban biodiversity and extensive greening are part of the national vision of a "City in the Garden." The creation of tree-lined streets, over 300 parks, and a network of park connectors help lower the temperatures in the city center. The supply of natural ecosystems (including evergreen rainforests, mangroves, freshwater rivers, freshwater swamp forest, coral reefs, and mud flats) should continue to be preserved in order to ensure a positive development of biodiversity.

By augmenting the amount of vegetation in the city, humidity levels become regulated, hot temperatures are lowered, and dirt and carbon dioxide emissions are captured. Urban agriculture on steep slopes or other areas not suitable for settlement is used to prevent mudslides and help reach the government's goal of reducing flood-prone areas by 28% by 2030.[777] This goal can be achieved with Singapore's source-pathway receptor approach, which also includes platform levels, porous pavements, green areas, and roof gardens for flood mitigation.

The continuous development of a green infrastructure has already shown considerable success. The annual average of PM 2.5 and PM 10 was reduced by 50% by 2018 compared to the previous years. By 2030, the values of PM 2.5 and PM 10 are to be reduced by 50% and 45%, respectively, and the ozone levels

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[775] Mewr.gov.sg. https://www.mewr.gov.sg/ssb. Retrieved on 30.5.2019
[776] Mewr.gov.sg: Our Home, Our Environment, Our Future. https://issuu.com/silosobeachresort/docs/ssb2015. Retrieved on 15.5.2019
[777] ibid.

by 33%.[778] Singapore's goal is to reduce its emissions by 36% from 2005 levels by 2030 and stabilize them with the aim of peaking around 2030.[779]

Singapore aims to reach these goals primarily through the intensive greening of the city and the surrounding areas, since complete independence from fossil resources is hardly possible and therefore unlikely.[780] The reason for this is the special geographic location of the island state, which has no land available for the large-scale use of solar and wind energy. However, there have been some innovative approaches and initial projects to install solar systems on the water in the recent past.[781] [782] [783]

8.4.4.2 Urban Agriculture and Food Strategy

In 2005, the government of Singapore started its CIB (Community in Bloom) program with just one experimental garden; it has since developed into a true gardening movement with over 1,400 community gardens. There, participants from societal groups meet to garden together and share their experiences.[784] In addition to the CIB movement, there are other community-based initiatives, such as the Ground-up Initiative,[785] which currently conducts two urban agriculture projects and workshops on the use of garbage enzymes.

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[778] Climatewatchdata. https://www.climatewatchdata.org/ndcs/country/SGP/. Retrieved on 25.5.2019
[779] ibid.
[780] UNFCCC: Article 4.10 (UNFCCC) of the Convention refers to Parties, especially developing country Parties, with economies that are vulnerable to the adverse effects of the implementation of climate change response measures." https://unfccc.int/resource/docs/tp/tp0200.pdf. Retrieved on 23.5.2019
[781] Gnana, K. (2018): At the heart of floating solar: Singapore - Floating solar special report. https://issuu.com/kanagagnana/docs/16_seris_fpv__case_studies. Retrieved on 24.5.2019
[782] Tan, S. (2018): Singapore's largest offshore floating solar panel system to be built along Straits of Johor. https://www.straitstimes.com/business/singapores-largest-offshore-floating-solar-panel-system-to-be-built-along-straits-of-johor. Retrieved on 23.5.2019
[783] International Bank for Reconstruction and Development, The World Bank (2018): Where Sun Meets Water. Floating Solar Market Report. http://documents.worldbank.org/curated/en/579941540407455831/pdf/131291-WP-REVISED-P161277-PUBLIC.pdf. Retrieved on 23.5.2019
[784] Mewr.gov.sg. https://www.mewr.gov.sg/ssb/our-targets/community-stewardship/community-in-bloom-gardens. Retrieved on 23.5.2019
[785] Ground-up Initiative. https://groundupinitiative.org/. Retrieved on 26.5.2019

Sustainable Urban Farms[786] (SURF) is another program for sustainable community gardens, and Balik Kampung is a weekly urban farming event especially for social networking. In order to make these and other, future projects workable and networked, the government plans to increase the number of active green volunteers by 233% to 5,000 and the number of CIB gardens from 995 to 2,000.[787] The government's efforts to conserve and expand community gardens are not primarily aimed at producing food in the city, but rather at creating strong communities in the citizenry for close social cohesion. Here, common gardening is the means for a successful community stewardship, which is important for national resilience.

The government's aim is to increase the local production by 30% for eggs, 15% for vegetables, and 10% for fish[788] by establishing six agrotechnology parks in Singapore that occupy 1,500 hectares. These parks are divided into two- to 30-hectare parcels of land that are leased to farming companies for 20 years.[789] Singapore is aware that it can never achieve complete food self-sufficiency because this is structurally not possible. Therefore, it concentrates instead on strengthening its food resilience by continuously enhancing local production through the utilization of modern farming technologies for higher productivity.[790] Singapore already practices highly effective land management and has compensated the loss of thousands of hectares to urbanization by significant intensification of agricultural production on the remaining land. As a backup resource in case of import restrictions or a blockade of international transport routes, vertical farms and rooftop facilities are the only source of supply for the population besides traditional agriculture.

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786 ISSUU. https://issuu.com/finte/docs/urban_agriculture_for_singapore. Retrieved on 26.5.2019
787 ibid.
788 AVA (2015): Singapore's food supply: the food we eat. http://www.ava.gov.sg/explore-by-sections/food/singapore-food-supply/thefood-we-eat. Retrieved on 24.5.2019
789 Agri-Food and Veterinary Authority of Singapore: Farming in Singapore. http://www.ava.gov.sg/explore-by-sections/farms/land-farms/farming-in-singapore. Retrieved on 16.10.2017
790 Fischbach, T. (2018): Strengthening Resilience: advancing Food Security in the UAE. https://www.mbrsg.ae/getattachment/859ddec7-f5ed-48dd-99dd-4e1b8f326112/Advancing-food-security-in-the-UAE. Retrieved on 19.12.2018

Vertical and rooftop farms can also become profitable businesses, and thus they constitute elements of an economic sustainability strategy. The premise is that they concentrate on production areas where they have a comparative advantage, such as the production of fresh and delicate foodstuffs, food that relies on intensive land use, and multifunctional products. Such redundant supply structures are essential for urban food security and resilience, and as high-quality urban spaces (including community gardens), they "can provide a boost to local economies by giving a place for people to meet and socialize, using entertainment services in the local area instead of traveling out of town. This encourages local enterprise and in turn bolsters the financial security of the local area."[791]

Global ranking	Country	2012	2013	2014	2015	2016	2017	2018	7-year change
1st	Singapore	83.2	0.0	1.1	0.1	1.0	-0.4	0.9	+2.7
2nd	Ireland	82.6	-0.5	0.6	1.2	3.2	-0.4	-1.2	+2.9
=3rd	United Kingdom	79.1	0.3	0.5	0.8	3.6	0.1	0.6	+5.9
=3rd	United States	85.6	-0.4	0.3	-0.9	0.9	-0.6	0.1	-0.6
5th	Netherlands	83.4	-0.3	0.5	-0.1	0.5	-0.9	1.6	+1.3
6th	Australia	82.1	-0.6	-0.4	1.9	0.8	-0.3	0.2	+1.6
7th	Switzerland	82.6	-0.9	1.1	0.3	0.8	-1.0	0.6	+0.9
8th	Finland	80.2	-0.1	-0.8	-0.7	1.8	0.9	2.0	+3.1
9th	Canada	82.8	-1.2	0.4	0.7	0.5	-0.7	0.7	+0.4
10th	France	83.9	-0.5	-1.3	0.4	0.9	-0.9	0.4	-1.0
11th	Germany	81.5	-0.2	0.8	0.5	1.0	-0.8	-0.1	+1.2

Figure 19 – Global Food Security Index, The Economist. Intelligence Unit: Global Food Security Index https://foodsecurityindex.eiu.com/Index

[791] ARUP: Cities alive. www.arup.com/cities_alive/rethinking_green_infrastructure. Retrieved on 13.10.2017

8.4.5 State of Current Research

In her study of resource-integrated agriculture in Singapore, Seignette[792] has confirmed that the Singapore government has a "high political willingness to develop sustainably and adopt new innovation,"[793] especially regarding the role of vertical farming in its long-term strategy for higher independence from food and water imports. Scaling-up vertical, controlled, and resource-saving urban agriculture ideally complements its import policy for food and limits its vulnerability to import fluctuations.

According to Tortajada et al.[794] the use of new agricultural cultivation methods, such as hydroponics and vertical farming has increased local vegetable production by 30% within 10 years. However, this can only be considered a first step towards an increased urban resilience because there is an urgent need for further reductions in food waste and increased investment in innovative food science and urban agriculture expansion on the East coast of Singapore or in sky-rise buildings.

Ichioka[795] has come to the same conclusion in his remarks on the special challenges that the small city-state faces: "Advanced technology is tasked with addressing the global challenge of climate change and the local challenge of land scarcity in part by decoupling farming from the very elements that used to define it: the vagaries of weather (for example, through enclosed, temperature-controlled environments) and the need for traditional soils (for example, through the use of hydroponic and aeroponic systems)."[796]

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[792] Seignette, E. (2016): Vertical, controlled and Resource-Integrated Urban Agriculture. Driving and Scaling-up a Potential Transition in the Contexts of Linköping and Singapore. Utrecht University 2016
[793] ibid.
[794] Tortajada, C., Kumar, T., Paramasilvam, S. (2015): Singapore's Impressive Food Security. https://thediplomat.com/2015/09/singapores-impressive-food-security/. Retrieved on 23.5.2019
[795] Ichioka, S. (2017): Food Security and Community Bonding in a Globalized City-State: The Case for Urban Farming in Singapore. https://www.nparks.gov.sg/-/media/cuge/ebook/citygreen/cg12/cg12_food_security_and_community_bonding_in_a_globalised_city-state.pdf. Retrieved on 23.5.2019
[796] ibid., p. 36

In this context, Fischbach[797] has confirmed for the Singapore government a highly successful support strategy by creating an attractive "pro-enterprise tax and financial environment" for investors in research and development of agricultural technologies that improve food resilience and security. In this argument, “these policies have helped Singapore maximize what little agricultural potential it has, and provide sufficient supply of the three designated staple foods. Indeed, Singapore has pioneered hydroponic and aeroponic technologies which have proven to be commercially successful while maximizing limited water and land resources.”[798]

As early as 2005, Wilson[799] highlighted the usability of rooftop farming in a study performed by the Ngee Ann Polytechnicum. The roofs of one-tenth of the total built-up urban area in four suburbs of northern Singapore would be eligible for the cultivation of about 39,000 tons of fresh vegetables using hydroponics on 212 hectares. Extrapolating from this calculation, for all of Singapore, about 1,000 acres would be available for rooftop farming.

An investigation by Asteee and Kishnani[800] found similar results, which proved that domestic vegetable production could be increased by 700%, thereby satisfying about 35% of the total demand, solely with the use of state-owned residential buildings. At the same time, the carbon footprint would be reduced by 9,052 tons a year by decreasing food imports.

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797 Fischbach, T. (2018)
798 ibid.
799 Wilson, G. (2005): The next profit frontier for green roof companies? Food from the Roof? https://www.greenroofs.com/projects/raffles-city-shopping-centre/. Retrieved on 26.5.2019
800 Yhinhui Astee, L., Kishnani, N. (2010): Building Integrated Agriculture: Utilizing Rooftops for Sustainable Food Crop Cultivation in Singapore. Journal of Green Building: Spring 2010, 5(2), pp. 105-113. https://doi.org/10.3992/jgb.5.2.105. Retrieved on 13.2.2019

Tortajada et al.[801] who explored how Singapore managed to achieve its first place on the food security index. They cited as one of the main reasons the diversification of Singapore's import sources, which provides for each food domestic vegetable production, could be increased by 700%, thereby satisfying about 35% of the total demand solely with the use of state-owned residential buildings item a separate contract with at least three different suppliers in different countries (Fig. 13). Furthermore, the establishment of the Sino-Singapore Food Zone in Jilin improves the resilience against supply disruptions as well as agricultural investments and contract farming in stable, secure countries such as the USA, Brazil, and Australia.

According to Tortajada et al., food security is not synonymous with food-self-sufficiency because few countries can produce all of their food themselves. An increased local production is achieved by supporting farmers with the Food Fund which has already benefited more than 40% of local farms. Urban agriculture does not have to focus solely on gardens, vertical farms, and roof-top farms because highly sophisticated greenhouses can also be built on specially adapted ships along the coast. In this regard it is a favorable condition that the inhabitants of Singapore are generally very open to new food concepts and sustainable products.

Although Singapore occupies a high place in competitiveness surveys (it also ranks third in the 2018 World Economic Forum [WEF] Global Competitiveness Index, second in the 2018 WEF Ease of Doing Business rankings, and fifth in the 2018 INSEAD Global Innovation Index),[802] there is also some justified criticism of its innovation strategy. The limited nature of Singapore's economy complicates necessary scaling-up processes because there are too few emerging, local

[801] Tortajada, C. et al. (2015): Singapore's Impressive Food Security. https://www.linkedin.com/pulse/singapores-impressive-food-security-cecilia-tortajada/. Retrieved on 23.5.2019

[802] Cornell University, INSEAD, World Intellectual Property Organization (WIPO): Global Innovation Index 2018. Energizing the World with Innovation. Ithaca, Fontainebleau, Geneva 2018. p. xxxii

companies, and the economic emphasis is currently on governmental and multinational companies: “Singapore’s economy has become unbalanced, with disproportionate roles for government-linked and multinational companies and a dearth of non-GLC Singaporean enterprises with regional or global reach.”[803]

A study by the IMF[804] shows that risk aversion is also a key obstacle to Singapore's ability to develop and adopt innovations. In order to overcome this hindrance, the government needs to support local companies with research and development, for example by linking these firms with Singapore universities and international research institutes. [805] Thus, urban agriculture is not only essential for an improved food security, but it also has the potential to become an important growth industry: “Urban food cluster members will need to focus on capturing specific food product segments which are presently being imported, rather than the same ones that are presently being produced by local producers. This will lead to a complementary relationship that allows for a net increase in domestic food production, contributing positively to the economy as well as to Singapore’s food security.”[806]

8.4.6 Conclusion

The review of all available sources and documents has shown that all basic needs, such as the provision of food, water, shelter, and energy, are guaranteed for the entire population in Singapore. The same applies to all central concerns of personal life, which must be protected or regulated by the state. The current state programs to safeguard water and food supplies, to develop green infrastructure and to mitigate climate and geographic threats, reveal many

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[803] Bhaskaran, M. (2008)
[804] International Monetary Fund: Singapore, Selected Issues Paper, IMF Country Report No 17/241, July 2017. https://www.imf.org/en/Publications/CR/Issues/2017/07/28/Singapore-Selected-Issues-45148. Retrieved on 5.2.2019
[805] Montesclaros, J., Teng, P. (2018): Ensuring a successful Singapore Urban Food Cluster. https://www.rsis.edu.sg/wp-content/uploads/2018/02/NTS-Insight-_-Ensuring-A-Successful-Singapore-Urban-Food-Cluster-_-February-2018.pdf. Retrieved on 23.5.2019
[806] ibid.

characteristic features of a resilient city, such as reflectiveness, resourcefulness, robustness, redundancy, flexibility, inclusiveness, and integration. [807]

8.4.6.1 Achievements

Singapore's government has set lease periods in the new agronomic parks for 20 years instead of the usual 10 years. This will make it easier for farmers to borrow money needed to transition to new agricultural techniques such as aquaculture and hydroponics. The drinking water policy and the comprehensive structural measures for mitigating floods have so far proved to be effective prevention measures. In waste management, state-of-the-art recycling plants help reduce the growing waste problem. A new food waste recycling plant now produces fertilizer, and, in 2020, another plant will be able to produce fuel from plastic waste.[808]

Examples of a successful integration of urban architecture in major projects like the Khoo Tech Puat Hospital and Changi General Hospital, demonstrate that urban agriculture can be perfectly implemented in new, complex buildings. Together with urban gardens and numerous parks, they create a green infrastructure that can improve the urban micro-climate and promote biodiversity.

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[807] Rockefeller Foundation. https://www.100resilientcities.org/. Retrieved on 10.8.2017
[808] Lim, V. (2019). https://www.channelnewsasia.com/news/singapore/singapore-to-open-recycling-plant-capable-of-producing-fuel-from-11492596. Retrieved on 5.6.2019

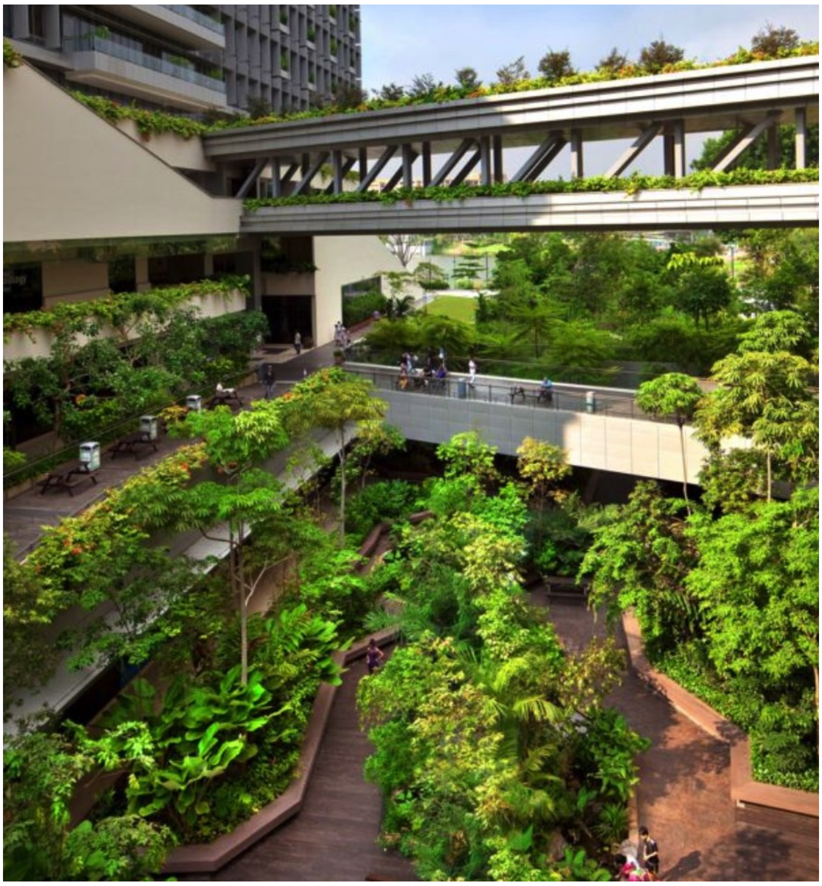

Image 15 – Khoo Teck Puat Hospital, http://www.greenroofs.com/projects/khoo-teck-puat-hospital-ktph/

The government has properly recognized the important social and health significance of community gardens, giving them a high profile within their community stewardship. Common green spaces and urban community gardens foster social cohesion and offer an ideal platform for communication and friendships, which are the soft, authentic human factors of resilience. Without them, survival in times of crisis, conflicts, and natural hazards is not possible.

8.4.6.2 Continuing Challenges and Limits

Singapore's geographical limitations and the resulting challenges and threats are essentially unchangeable. However, the government continuously works on improvements that can mitigate the effects of climate change (flood, droughts, and air pollution) and improve sustainability and resilience. Even in a food-secure state, unforeseen threats to food security can arise as a result of regional or global crises and conflicts.

Singapore's water policy, which has been highly successful so far, is threatened by population growth and possible long dry spells, and it should be supported more than it has previously through a changed, more sustainable lifestyle and a more economical use of water.

At present and in the near future the consumption of fossil resources cannot be eliminated within Singapore. Thus, with only low-level alternative energy sources, the high dependence on oil and natural gas represents Singapore's most significant vulnerability.

8.4.6.3 The Role of Urban Agriculture

All the authors of the previous discussion agree that partnerships, financing, technology, research, and development are key elements of Singapore's government strategy to improve sustainability and resilience. In this context modern urban farms are a key technology for sustainable land management in Singapore, reducing the vulnerability and dependence on food imports and thus strengthening survivability in a crisis. With Asia's population expected to grow to 3.3 billion by 2050, urban agriculture must play a key role in securing regional food security.[809] Professor Teng of the National Institute for Education formulated this challenge accurately: “The question is not should we do urban farming, but how much urban farming should we do?”[810]

There is no doubt that both the urban government and the citizens show great interest in urban vegetable farming and aquaponics. Currently, there are around

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[809] Teng, P. (2016), cited in: Edb.gov.sg: Putting Food on the Table. https://www.edb.gov.sg/en/news-and-resources/insights/innovation/putting-food-on-the-table.html. Retrieved on 24.4.2019

[810] ibid.

12 rooftop farms in Singapore, located on commercial buildings and factories that mostly produce lettuce, kale, mizuna, and microgreens. However, the only customers are hotels and restaurants which can afford these high-value vegetables. To promote the further development of vertical farms, the government must liberalize strict regulations and adapt to the new technologies.[811] The expandable potential for local food production is significant, and so far, it has only been used in a few, highly successful approaches.

[811] Senior Minister of State for Trade and Industry Koh Poh Koon in: https://www.straitstimes.com/singapore/berry-fresh-prospects-for-vertical-farming. Retrieved on 12.4.2019

9.0 RÉSUMÉ

In the introductory part of this study, factors that constitute the background and conditions for the implementation of urban agriculture have been shortly outlined. In summary these were:

- the growing world population which demands more living space, fossil and renewable resources and food
- the global climate change which increases the likelihood of extreme weather conditions and events with potentially increased vulnerability, especially in cities
- the continuous urbanization and development of megacities in which the population is exposed to the negative effects of climate change
- the increasing deterioration of ecosystem services, largely due to industrial agriculture.

In the following chapters the various forms and types of agricultural techniques as used in modern UA have been extensively evaluated with regard to their sustainability and resilience-promoting quality. According to the preferred triangulation method, the multiple benefits of urban agriculture have been extensively documented and compared with the research results of leading experts from different projects in various countries. The advantages of UA are evident in the ecological, social, and economic realms. Hydroponics, aquaponics and vertical farms represent very environmentally friendly, highly efficient cultivation methods. Especially closed vertical farms that produce controlled, healthy and unencumbered food in a small area have the potential of becoming a promising business model.

The main results from the online survey with 120 participants showed, that

- UA is a welcome addition to the urban landscape among all ages, urbanites, and people living in the periphery of cities or rural areas

- there is a definite need for more green spaces and tree plantations for leisure and climate regulation
- there are certain understandable concerns about small animal breeding in inner city areas, but there is sufficient space in the urban periphery for these projects
- the cultivation of one’s own vegetables, flowers, and herbs is back in vogue, and this is not just a short-term trend, but a real need
- in rural areas, the older generation is characterized by the fact that it generally has a larger supply of food and has higher food sovereignty through its own food crops
- younger people in the city often lack the gardening know-how and, above all, the necessary conditions, such as a private balcony or garden
- regardless of age, education, and place of residence, important actions to improve urban resilience receive undivided support

In the near future, conventional intensive agriculture cannot be replaced due to the increasing food requirements. But within a more sustainable and resilient food system, urban agriculture can be a synergistic solution that – as shown in the online survey in Germany and the case study about Singapore – is accepted by society. The goals of a sustainable and resilient urban food system should be:

- Improving the health of the urban population
- Reducing the negative impact of food production on the environment
- Supporting local food producers in the context of a green circular economy
- Maintaining essential knowledge and the development of ecological technologies.

Urban sustainability and resilience require effective adaptation and mitigation measures that should be characterized by:

- the use of environmentally friendly agricultural methods

- the promotion of a sustainable food system
- the design of local programs for sustainable development (Agenda 21 and Agenda 2030) based on technical and "nature-based" solutions
- the support of local UA initiatives to strengthen urban food security and complement green infrastructures.

A more developed and widespread urban agriculture could support Germany's mitigation and adaptation strategy in the following areas:

- in the reduction of air pollution, since the planned 40% reduction has not yet been achieved in regard to the central goals of the National Biodiversity Strategy
- in compensating and limiting the increasing soil sealing due to continuous conversion for settlements and traffic areas
- as an important addition to a sustainable urban food system whose characteristic properties reinforce urban sustainability efforts
- in improving the urban climate, reduce UHI, neutralize particulate matter, etc. and thus contributing to an urban mitigation strategy.

Germany, like any other country, must face the challenge of producing enough healthy food for a growing, urbanized population without further harming its ecosystems. Urban Agriculture fits perfectly into the sustainability strategy of the Federal Government which aims to promote local initiatives for sustainable and ecological development and to improve the resilience of cities as part of the Agenda 21 and Agenda 2030.

The empirical research in this study has shown that the urban gardening movement is not a short-lived trend but an expression of a new awareness of sustainability and individual resilience, healthy nutrition, and organic food culture. It meets a high level of acceptance among the population. This goes hand in hand with changes in consumption and purchasing behaviors since more consumers prefer local, sustainably produced food. People increasingly acknowledge the sustainable potential of urban agriculture for supplying food while reducing the ecological footprint by using ecological agriculture and shorter transport routes.

The semi-structured interviews with experts and urban gardeners indicated, that

- UA is a social glue that brings people together and promotes social participation
- participants highly appreciate the projects, as do the inhabitants of the districts
- urban gardening offers experiences that seemed to be lost or forgotten in daily urban routines
- aspects of organic food production, fresh air, and the acquisition of horticultural knowledge inspires the people and stimulates their engagement
- founding initiatives originate from private persons, school and university projects, gardening activists.

For a successful integration of urban agriculture into an urban mitigation and adaptation strategy, state land and urban planning programs have to be meaningfully harmonized with private, corporate and public initiatives to improve the ecological and social urban environment. Efficient measures could be:

- the use of all available fallow land with urban agriculture, even if only temporarily
- the promotion and establishment of more peri-urban herb gardens and self-harvest gardens
- the greening of facades and the provision of suitable urban flat roofs for food production
- the establishment of a food council in every major city
- more educational offers, school and community projects to ensure the participation of broad sections of the population.

10.0 CONCLUSION

10.1 Seed Scale and Emergence Theory and Variants

With the aim of filling an existing research gap, this study made a contribution to the emergence theory and presented pragmatic solutions for the implementation and further development of UA. The use of qualitative and quantitative methods made it possible to show and analyze the close interaction of urban agriculture with central ecological problem areas from a comprehensive perspective. Extensive literature research, interviews, online surveys, SWOT analyzes, on-site visits and case studies on urban agriculture in Germany, Singapore and the UAE including the Seed Scale and Emergence approach represent a multi-dimensional research framework that provides new insights and conclusions about mitigation and adaptation strategies.

It has been shown that urban agriculture:

- can take on diverse manifestations
- can have its origin in spontaneous, private or organized citizens' initiatives, entrepreneurial projects and also in government programs
- can promote, as an important part of a green infrastructure and nature-based measures, urban resilience and sustainability
- can adapt to any city structure and represent, together with peri-urban agriculture, a useful addition to the urban food system
- requires, as an urban planning component, the participation of the citizens from the beginning of the concept development
- has great inherent potential for research and development regarding building-integrated forms and new technologies.

The online survey with lay persons proved that ideal conditions for further Seed Scale and Emergence processes exist in Germany. The vast majority of respondents welcome very much urban gardens, planting of facades and roofs and the establishment of gardens in schools and hospitals, and therefore an expansion of urban agriculture in these various areas would meet broad support from the population. Also, an urban strategy that would build agro-parks including vertical farms in the periphery would be very well accepted by the population.

A mitigation and adaptation strategy that integrates urban agriculture as an important component in urban planning for the use of fallow land and roofs is advocated by the majority of the population because of its ecological and resilience promoting advantages. Moreover, the urban non-commercial gardening movement arises from a genuine need for self-determined ecological food production, greater independence and food security. The high ecological advantages of vertical farms have not yet fully reached German society, but the results of the survey in this study indicate that this new type of agriculture within a more regionally oriented urban food system would find wide acceptance.

So far, the present study is the only one that has chosen the theoretical Seed Scale and Emergence approach to explain conclusively the development, popularity and spread of urban agriculture. Interviews with hobby gardeners and commercial vertical farming operators, with official institutions in Munich as well as the two case studies carried out on Singapore and Masdar prove the explanatory potential of the Seed Scale and Emergence theory and the value of the result triangulation.

Be it the great success of the urban community gardens in German cities, the peri-urban herb gardens, the failed Agropolis project, the Masdar model or the success story of urban agriculture in Singapore, the systemic character of UA can always be explicated by the Seed Scale and Emergence Theory. It emphasizes the collaboration among like-minded citizens which creates a movement from below and is not imposed from above. It also describes how individual garden projects as well as the application of innovative agricultural practices develop, that are based on the initiative of entrepreneurs, scientists and creative hobby gardeners – without significant investment, experts or any support from the government.

The interviews with initiators of German urban garden projects showed that – in line with the Seed-Scale and Emergence explanatory model – personal energy and the self-reliant recognition of human needs form the nucleus for community empowerment which creates a successful movement without hierarchical structures. For all the urban gardens visited, the formation of solidarity communities with the aim of acquiring land and capital led to the successful production of organic food in their immediate vicinity and to networking with similar interest groups. Successful Seed Scale and Emergence processes could be shown in the development of the visited urban gardens in Ulm, Heidelberg and Cologne which are exemplary for numerous similar projects in Germany.

The Seed-Scale and Emergence approach was also suitable for checking various urban planning and food security concepts like the Agropolis concept in Munich and the Fraunhofer InFarming concept which is continuously developed and can be adapted to many new and old buildings. Since the Agropolis project did not actively involve the citizens of the new residential area in the planning, development and preparation phase and did not inform the general public, the project failed. This was also one of the reasons why the Masdar project became a failure. As a pure government program, it did not generate the necessary enthusiasm and commitment within the neighborhoods which were not integrated in the planning process.

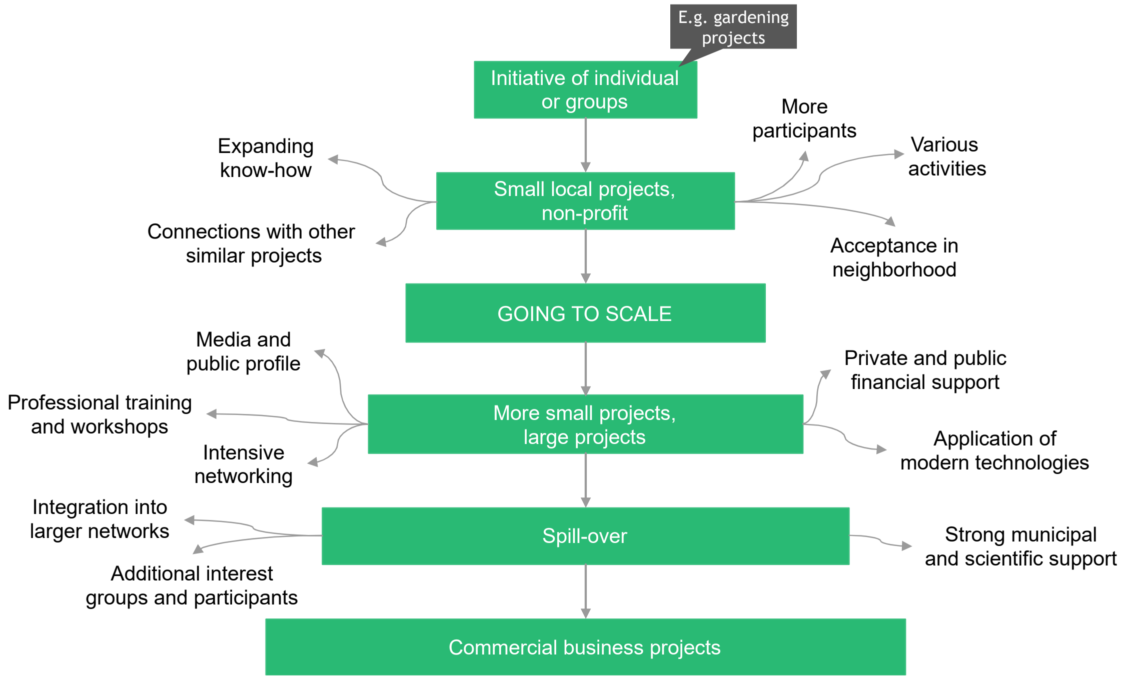

Image 16 – Seed Scale and Emergence Theory and Variants – Germany, author of study

The case study of the Emirati Food Security Strategy clearly showed that an awareness of sustainability, environmental protection and resilience issues is not yet sufficiently anchored in society. The most important prerequisite for a successful sustainable government policy is a real understanding of sustainability in the population. This cannot be replaced by newly created cities or exclusive showcase projects since the pursuit of sustainability and resilience must be anchored and lived down to the smallest units, the families.

However, although the need for a change to a more sustainable lifestyle with resource efficiency and waste avoidance is not yet internalized in the public consciousness, commercial urban agriculture is developing strongly in the UAE. Urban agriculture in closed vertical farms and in a highly profitable form through government-sponsored and private entrepreneurial initiatives is expected to prevail sooner and faster in the UAE than in Germany. The reason for this is the high availability of capital, the urgency due to the dwindling water resources and the determination of the government to take all measures necessary to relieve the critical situation. Beginning with the first vertical farm in Dubai, a spill-over and up-scaling process has been set in motion, leading to the establishment of more and more vertical farms. In accordance with the premises of Seed Scale and Emergence, the commercial success and personal commitment of the first entrepreneur has led to numerous imitators and even gained entry into the official food security strategy.

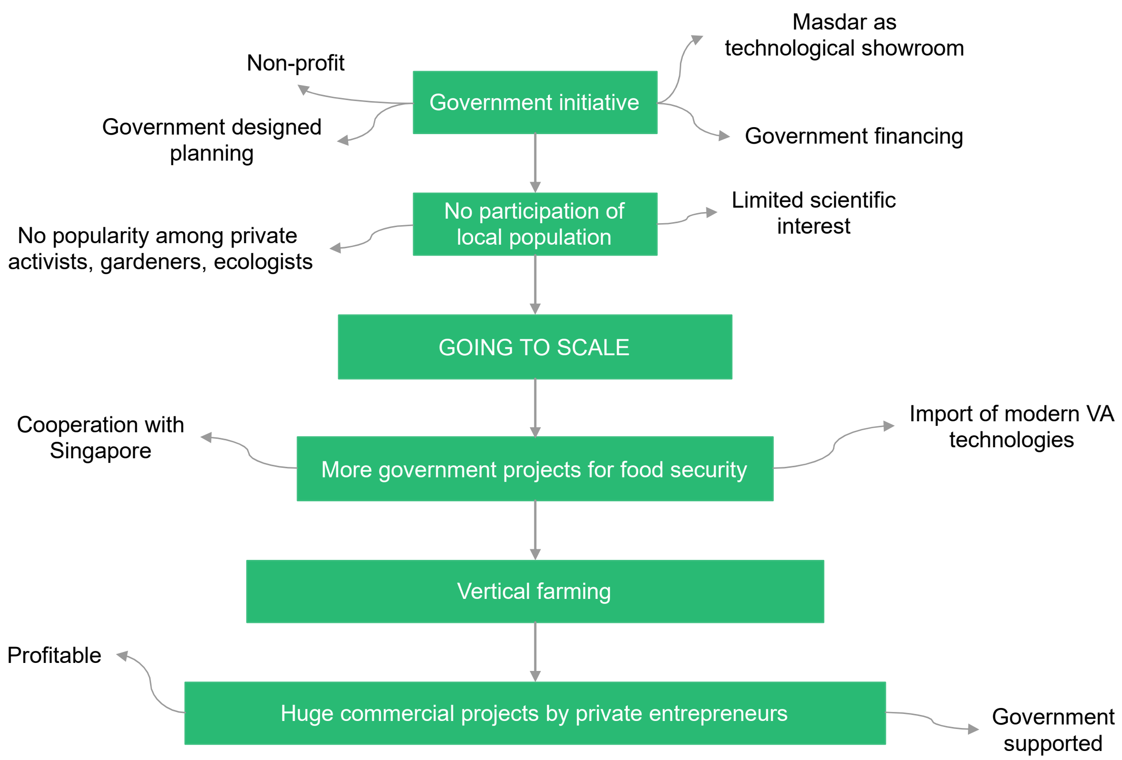

Image 17 – Seed Scale and Emergence Theory and Variants – UAE, author of study

So, while the garden projects in Germany can be traced back to the initiative of individuals or groups who are primarily motivated to beautify their immediate surroundings, to improve the environment and the urban climate and to practice gardening with other activists, an emergence and reorientation exclusively in the economic and political area with a rapid up-scaling development is taking place in the UAE.

The results of the Singapore case study indicate another variant of the Seed Scale and Emergence process. The ambitious Climate Action Plan of the Singaporean government has developed into a successful adaptation and mitigation strategy to counter its most pressing problems like food security, waste management, emission reduction and water recycling. It also showed how modern agricultural technologies – especially vertical farm and roof-top farms – can significantly increase the local production of food. The commercial variant of urban gardening takes place in closed vertical farms which are characterized by the latest technologies and high profitability.

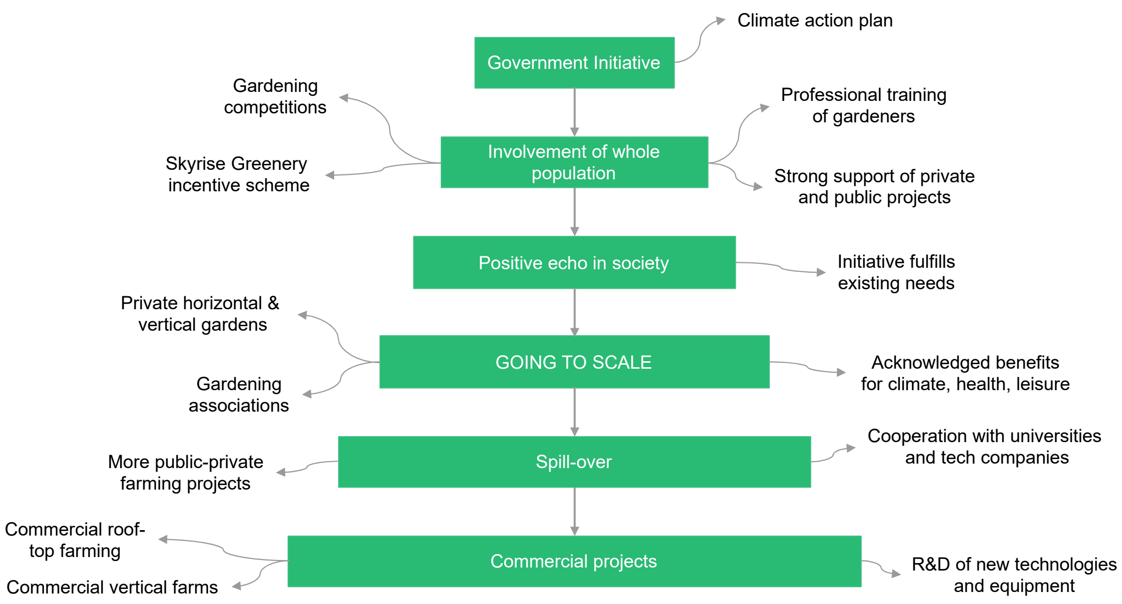

Image 18 – Seed Scale and Emergence Theory and Variants – Singapore, author of study

Contrary to the urban gardening movement in Germany and the vertical farming business movement in the UAE, a government program for the establishment of a green infrastructure with urban gardening and farming has generated a lasting positive response and acceptance in the population. The integration of urban gardens not only in architectural showcase projects such as hospitals, hotels and shopping centers but within the entire green infrastructure has transformed

Singapore from a garden city to a city in a garden. Here, the original government initiative succeeded in generating a huge acceptance and enthusiasm among the population so that urban gardening has been transformed into a real popular movement with its own dynamic. Parallel to traditional house and roof gardens which already produce a large part of the urban vegetables today, ultra-modern vertical farms with advanced agricultural technologies enable Singapore to export important know-how to its neighboring countries.

10.2 Transferability of the Singapore Strategy

The Singapore case study lists a number of measures that have been successfully implemented in accordance with the Climate Action Plan and which can also serve as suggestions and recommendations for the German mitigation and adaptation strategy. They make it clear that the state has many options to improve urban sustainability and resilience based on an active involvement of the population. This includes the greening of roofs, walls, the establishment of horizontal and vertical gardens for schools, hospitals, senior residences, companies and apartment buildings.

With its limited space, Singapore is a good example of the combination of vertical and horizontal green infrastructure. In Germany, the Fraunhofer InFarming concept would be ideal for following the example of Singapore and setting up a building-integrated green infrastructure on both levels.

Singapore only uses permeable street paving for its new roads to prevent flooding and to replenish the groundwater. This measure can also be recommended in Germany, at least for cities in areas at risk. It would counteract the ongoing soil sealing in German metropolitan regions and help to preserve the water supplies.

Vertical farms and innovative agricultural technologies such as the water-saving closed loop irrigation system are strongly promoted in Singapore, partly through half-private half-state enterprises. Such facilities offer skilled jobs and are profitable. Singapore's vertical farming expertise, equipment and technology are now exported to numerous other countries. A stronger engagement of German tech-companies in this field could become an important export good and stimulate the development of vertical farms which is only just beginning. Innovative companies willing to take risks (for example in Berlin and Hamburg) first have to prove their profitability in the face of competition by cheap and subsidized products from traditional farmers.

Similar to Singapore, Germany could set up an own “Skyrise Greenery Scheme,” where the state financially supports the retrofitting of buildings with green roofs, edible gardens or green facades. Converting green roofs into rooftop gardens would be a pragmatic approach of scaling-up urban agriculture.

10.3 A More Sustainable and Resilient Urban Food System

In this study modern agricultural techniques were examined for their sustainability and their value for a more resilient urban food system. The results indicate that hydroponics, aquaponics and especially vertical farms that use these technologies do not put a strain on the ecosystem and can even improve it in many areas. Thus, they can – together with the traditional gardens – play an important role in modern urban planning which needs to be directed towards adaptation and mitigation of climatic and other crisis-like threats.

The adoption of such a new paradigm for a more resilient and more sustainable food system presents urban and rural spatial designers with the challenge of combining local, regional and global food production in their planning in such a way that the advantages of shorter transport and distribution routes can be used more effectively for local food producers. This primarily includes the use of fallow land, peri-urban agriculture and, in particular, the management of suitable roofs that do not replace supra-regional supply but can complement it in an ecologically sensible way. Food produced in the city can best be brought to the consumer in local markets. Here, too, the administrations of large and small cities must create the necessary conditions.

Concerning the possibilities of a sustainable and resilient urban architecture in Germany, many research areas still have not been fully explored. Sufficient quantified data collections with regard to the climate-mitigating benefits of the various types of building-integrated urban farming are still lacking. Innovative research projects like the Fraunhofer InFarming House could help examine the possibilities to integrate urban agriculture into existing and new buildings in order to better investigate the microclimatic effects of greening and urban agriculture at the city level. Additional InFarming houses like the one in Duisburg and the water farm in Berlin would give researchers more possibilities to investigate and validate the effects of urban agriculture on the immediate environment. They would also provide an important platform for research projects in the areas of material development, recycling methods and the architectural and structural integration of UA.

Specific research projects should also examine what kinds of products are best suited for urban agriculture in defined areas and how new value chains could be created. Stronger incentives for more investments in resilience-enhancing measures at the local level should support vertical farm start-ups for which appropriate quality and certification processes are needed. As the role of vertical farms becomes more important in the future, the possibilities of up-scaling need to be further explored in order to determine economic and commercial feasibility and profitability. Therefore, economic full-life cycle analyzes have to be performed in various pilot projects to determine the prerequisites for a competitive business model.

The educational potential of urban garden projects and related events and activities for different population groups should be the subject of further research. Urban community gardens, school gardens, allotment gardens and various other garden projects are very well suited to communicate nutritional knowledge and sustainable issues to all social classes so that a long-term change in dietary behavior can be achieved. The same applies to vertical farms that offer guided tours and training programs to the public. In this way, prejudices and uncertainties regarding the products of vertical farms can be effectively reduced. Municipalities could set up a platform – ideally in conjunction with the food councils – on which committed citizens can discuss their ideas for urban gardens and also in general for greening their immediate living environment.

It should be emphasized that society is called upon to acknowledge not only the role of urban agriculture as an integral part of urban landscapes, but also the genuine relationship between people and land, and the importance of immanent values of human existence and nutrition. These social values are needed, especially for the younger generations, who have largely lost contact with natural ecosystems and their vital food sources. The solution must be a realistic conceptualization for the present status of the ecological hierarchy by taking into account that there are few intact ecosystems left in the world. Urban agriculture is not the panacea for all problems of the current food system, but it is a step in the right direction to combine nutritional awareness, sustainability and resilience efforts with environmentally friendly food production.

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12.0 APPENDIX

12.1 Survey Questions

12.1.1 Personal Questions

1) Which gender are you?
- Female
- Male

2) How old are you?
- Younger than 20 years
- 20 to 29 years
- 30 to 39 years
- 40 to 49 years
- 50 to 59 years
- 60 to 69 years
- 70 to 79 years
- 80 years or older

3) What education do you have?
- Secondary school
- High school
- Completed apprenticeship, Abitur
- University diploma
- Other

4) What do you do for a living?
- Pupil
- Apprentice
- Student

- Employee
- Civil servant
- Self-employed
- Unemployed / looking for work
- Other

5) What is your approximate monthly net income?
- I do not have my own income
- Under 1000 €
- 1000 € to 2000 €
- 2000 € to 3000 €
- 3000 € to 4000 €
- 4000 € to 5000 €
- More than 5000 €
- I do not want to answer that

6) In what environment do you live?
- Suburb
- City
- Countryside

7) How do you rate yourself as a consumer?
- Very environmentally conscious and critical
- Rather environmentally conscious
- Less environmentally conscious
- Sustainability is not an issue for me

8) How do you assess your gardening skills?
- Very good
- Good
- Poor

- Very poor

9) Do you grow your own vegetables, fruits or herbs?
- Yes
- No

10) If yes, where?
- Window ledge
- Balcony
- Terrace
- Garden
- Roof garden
- Allotments
- Community garden

11) Why do you grow your own vegetables (fruits, herbs)?
- Because I love gardening activities
- To save money
- The self-produced food is healthier and safer than the purchased one
- Gardening is effective stress management and attractive leisure activity
- Gardening is important for the environment
- Home-grown vegetables taste better
- It provides greater independence from the food system
- Other

12.1.2 Consumer Behavior

12) Where do you buy fruits, vegetables and herbs?
- Hypermarket
- Farm shop, or directly from the producer
- Local supermarket
- Specialty shops (e.g., health food shop)
- Weekly or daily farmer’s market
- Other

13) Would you rather buy regional and local products, if you have the opportunity?
- Always
- Most of the time
- Rarely
- Never

14) Why would you rather buy local products?
- Products are easy on the environment
- Products are fresher
- Product quality is safer
- Strengthening the local economy
- Transparency regarding manufacturer and place of production
- Other

15) Would you buy products produced on a Vertical Farm, even if they do not carry a conventional organic label?
- Yes
- No

16) If not, why?
- Is not a natural cultivation

- Competition for conventional agriculture
- Food should not be grown in the city
- Products are (probably) more expensive
- Wasting energy for air conditioning and lighting
- Use of artificial fertilizer instead of bio fertilizer
- Other

12.1.3 Urban Agriculture: Acceptance and Preferences

17) What forms of urban agriculture are you aware of?
- Balcony, - and terrace cultivation
- Roof gardens
- Community gardens
- Greenhouses
- Home gardens
- Garden plots
- Herb gardens
- Allotments
- Self-harvest projects
- Vertical Farming
- Other

18) What social benefits do you see in a community garden?
- Meet new people
- Leisure activities for families
- Joint gardening
- Image of the district is improved
- Integration of migrants
- Interesting events (cooking, eating, seminars, botany, beekeeping, etc.)
- Beautification of the neighborhood
- Other

19) What ecological advantages do you see in a community garden?

- Biological diversity
- Preservation of plant/seed varieties
- Organic cultivation
- Creation of a natural environment for pollinating insects (such as bees, bumblebees, butterflies)
- Improvement of air quality
- Other

20) What health benefits do you see in a community garden?
  - Various health benefits (exercise in the fresh air, leisure activity, healthy eating, stress reduction)
  - Raised beds are particularly suitable for old or handicapped hobby gardeners
  - Possibility of recreational activities in nature
  - Improvement of the quality of life, food and nutrition even for low-income earners
  - Other

21) What forms of urban agriculture would you accept in your neighborhood? (Rate from "With pleasure", "Gladly", "Less preferred" to "Not acceptable")
  - Agro-parks (commercial cultivation in urban peripheries)
  - Roof gardens for house residents
  - Fish farming and aquaponics (use of fish excrements for the fertilization of plants)
  - Gardens for hospitals and retirement homes
  - Intercultural gardens
  - Mobile gardens on brownfields
  - Public community gardens - everyone can join
  - School gardens
  - Vertical cultivation in empty buildings

22) Do you feel sufficiently informed about the possibilities of urban gardening in your immediate vicinity?
- Yes
- No

23) For what reasons would you personally participate in a community garden?
- Attractive community events (cooking, eating, garden parties)
- Enjoyment of own vegetable production
- Health-promoting hobby
- Ideal leisure activity
- Doing something in community is more fun
- No private garden available
- Children are allowed to join gardening
- Learning from other hobby gardeners
- Other

12.1.4 Sustainability and Resilience

24) What do you understand by sustainability?
- All measures of environmental protection
- Conservation of biodiversity
- Promotion of local social and economic projects
- Raw material recycling and waste prevention
- Economical use of fossil resources
- Environmentally friendly technologies
- Responsible, proactive planning social policy
- Use of renewable energies
- Foresighted, nature and environmentally friendly planning in politics and business
- Other

25) Do you feel sufficiently informed about possible threats to cities due to climate change?
- Very well informed
- Reasonably well informed (through school, profession or other experiences)
- Only little knowledge available
- No knowledge available

26) How should the resilience (resistance) of a city help against the effects of climate change?
- In severe disorders, the normal state returns after a relatively short time
- The citizens do not lose confidence in the crisis management of their city
- The vital supply of food, water and medicines is preserved
- Quick repair and spare parts are available for the affected infrastructure (e.g. roads, telecommunications, power)
- In case of disaster all public help systems (medicine, administration, police, fire brigade) are available
- Material damage does not jeopardize the survival of the urban community
- Other

27) What measures should be taken to improve urban resilience?
- Alternatives to supplying the population with water and food in times of crisis and conflict
- Effective civil protection in the event of floods, storms, earthquakes, big fires, forest fires
- Security measures and replacement strategies in case of power outages
- Preventive measures against flooding, fire, earthquakes, etc.
- Preventive measures against water shortages and food shortages
- Other

28) How important are the following measures for green urban infrastructure to effectively counteract the effects of climate change? (Rate from "Very important", "Important", "Less important" to "Not important at all")
- Tree planting to improve the city air and capture CO2 emissions
- Greening of the streets with shady trees
- Roof gardens
- Reduction of soil sealing so that the water in the cities can quickly seep away
- Community gardens on brownfields for flowers or vegetable production
- Use of polder areas for the overflow of rivers and streams for urban agriculture
- Parks for climate improvement and local recreation (without having to use a car)
- Porous road surfaces to avoid flooding
- Creation of as many green spaces as possible, in order to replenish the groundwater continuously during rainfall

29) In your opinion, what dangers can arise for the current urban food system? (Rate from "Most likely", "Likely", "Less likely" to "Unlikely")
- Lack of imports endangers the entire supply of the population
- Failure of the Internet would make cashless shopping impossible
- Rising commodity prices or commodity crisis would lead to high price increases
- Disruptions of the transport routes would jeopardize replenishment for the supermarkets
- Power outages could make selling in stores impossible
- Supply shortages endanger social peace and can lead to unrests

30) How could Urban Agriculture help adapt to climate change?
- Promoting biodiversity and preserving plant/seed varieties
- Promoting health through gardening and healthy eating
- Low water consumption

- Greater independence in food supply
- Indoor farms allow continuous harvests regardless of the weather
- Food for birds, bees and other insects
- Recycling of organic waste and composting
- Conservation of resources
- Absorption of CO2 emissions
- Urban gardens increase the quality of life and living
- Urban garden projects strengthen social cohesion in the neighborhood
- Improvement of the urban climate
- No long transport routes and expensive cooling
- Passing important gardening knowledge on to the next generation
- Extra income and self-care for families and low-income earners
- Other

31) Should cities and towns allow unused land and brownfield land to be used for urban gardens until another use is made?
- Yes
- No

32) For how many days do you have food supplies in the house in the event that the supply of food in the supermarkets is omitted?
- < 3 days
- 3 days
- 1 week
- 2 weeks
- 3 weeks
- 1 month
- No answer

33) How should cities and towns promote Urban Agriculture (UA)?
- Greening flat roofs of urban buildings wherever possible

- Creation of gardens for kindergartens, schools, retirement homes, hospitals
- To provide land (brownfields)
- Integration of UA in urban planning
- Providing project funding for intercultural and educational garden projects
- Allow or support street markets for urban agriculture products
- Other

12.2 Documentation of Online Survey on LimeSurvey Platform

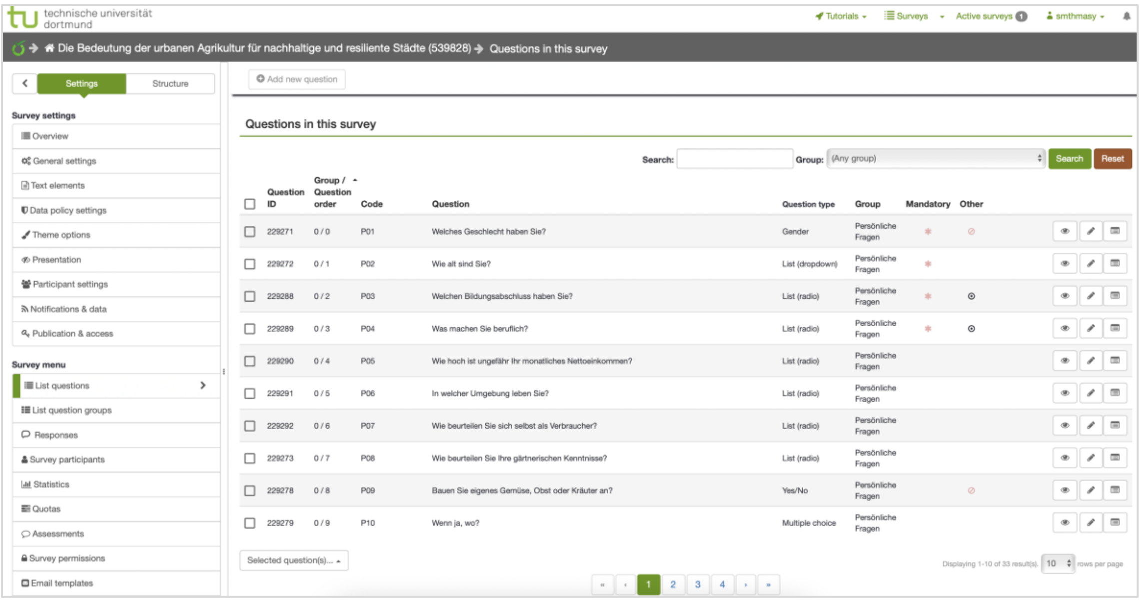

Image 19 – Setup of questions on LimeSurvey Platform, author's survey in 2019

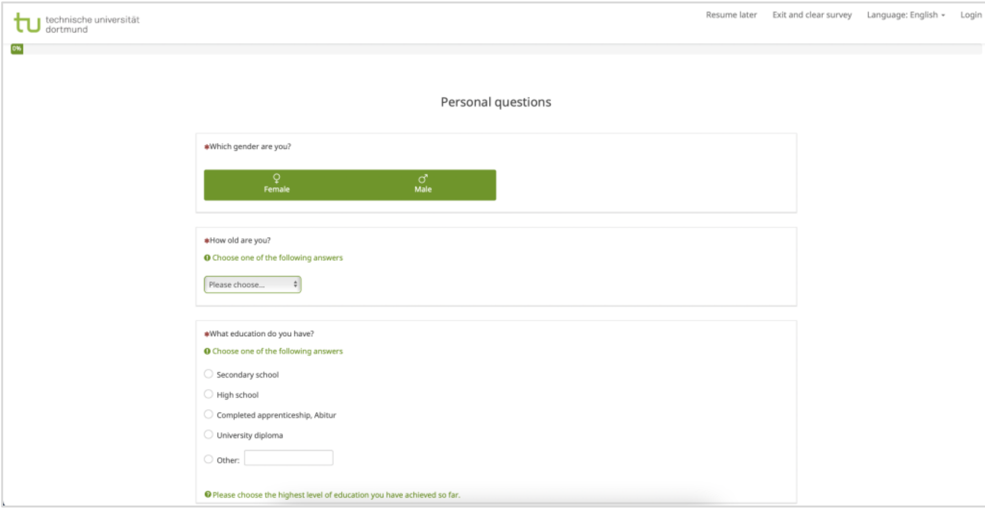

Image 20 – Example of questions types on LimeSurvey Platform – dropdown and radio button questions, author's survey in 2019

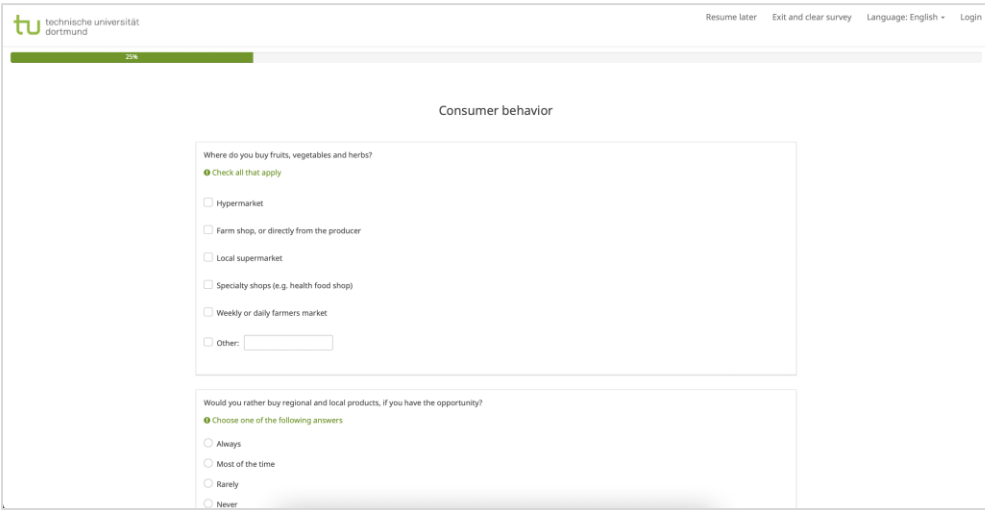

Image 21 – Example of questions types on LimeSurvey Platform – multiple choice questions, author's survey in 2019

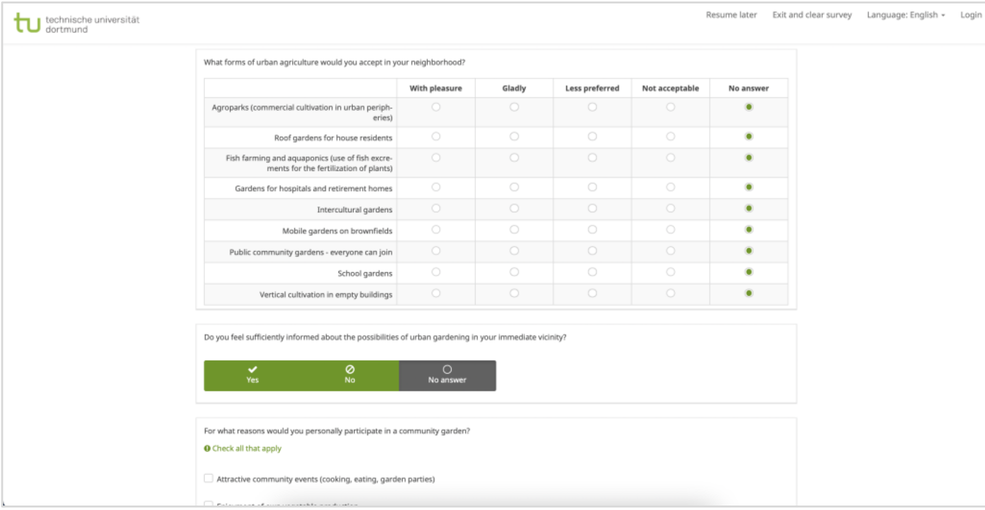

Image 22 – Example of questions types on LimeSurvey Platform – Likert scale and yes/no questions, author's survey in 2019

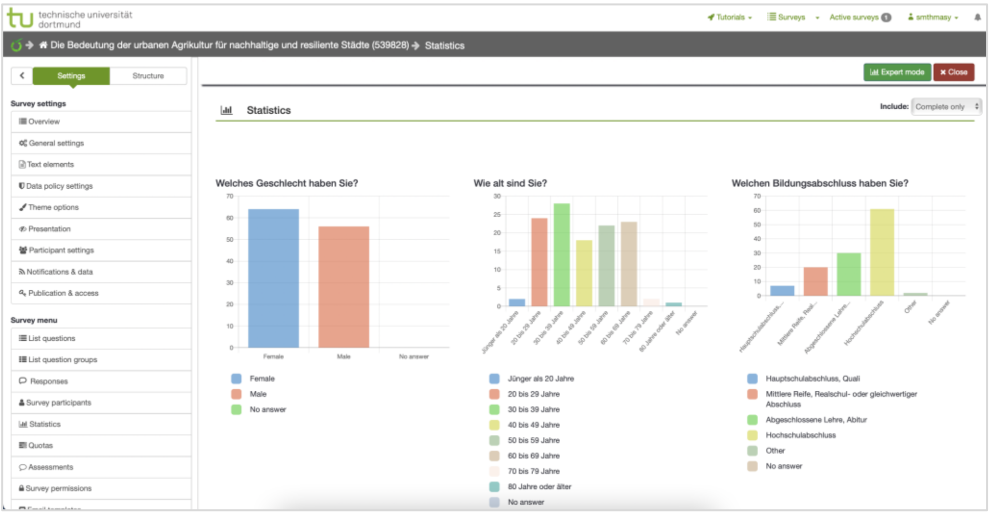

Image 23 – Online interim analysis on LimeSurvey Platform, author's survey in 2019