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Smart Urban Agriculture

– Exploring its Development in Sweden

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Future Food Reports 18 | 2022

Smart Urban Agriculture – Exploring its Development in Sweden
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Publication: Future Food Reports 18
Published year: 2022, Uppsala
Publisher: SLU, SLU Future Food
Editing and layout: Pernilla Johnsson, SLU Future Food
Cover photo: Istockphoto. Lettuce grown indoors under LED-light.
Photo: Istockphoto, p 4.
ISBN: 978-91-8046-795-7(print), 978-91-8046-796-4 (electronic)
DOI: https://doi.org/10.54612/a.7hllg1t7av

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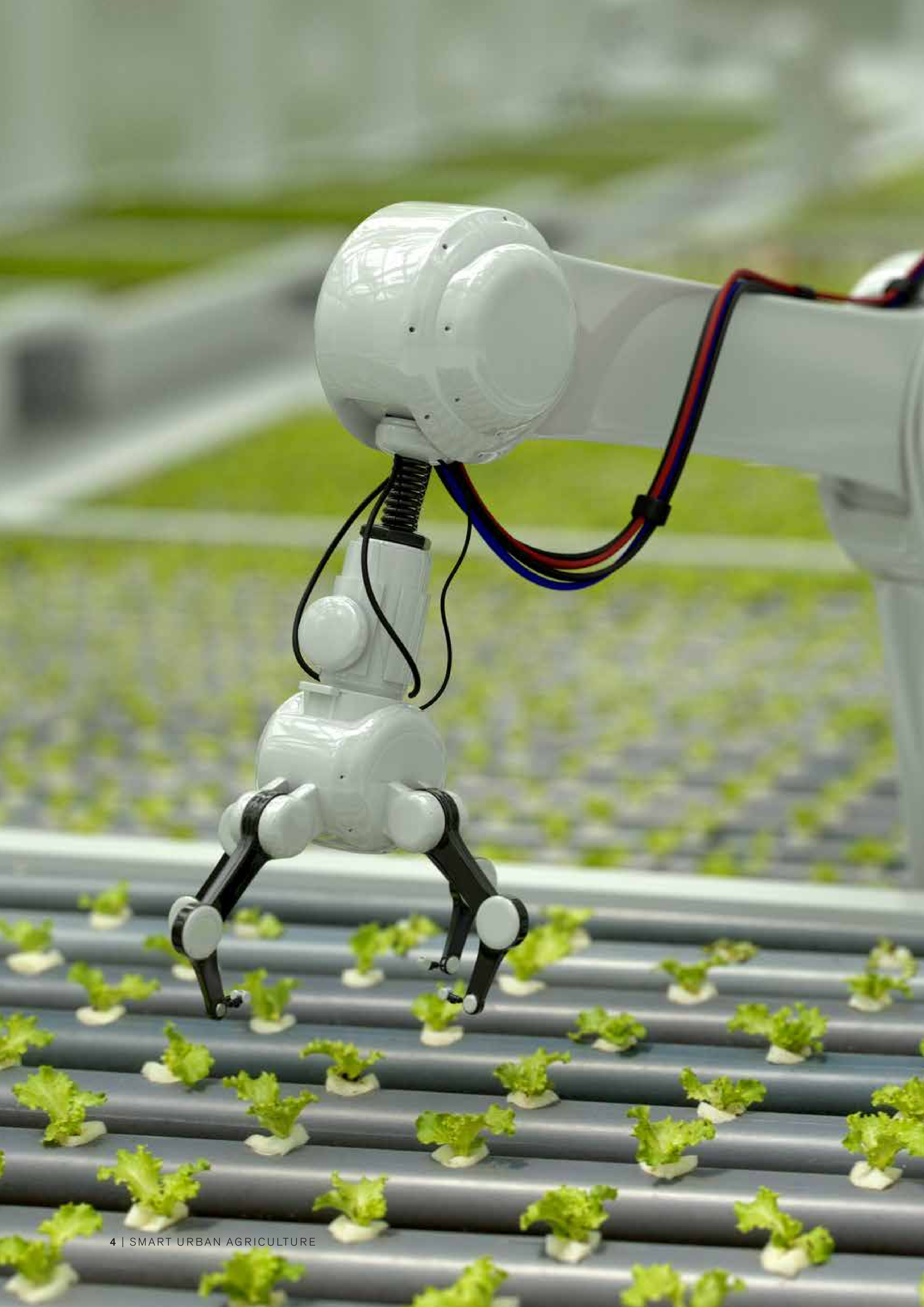

Summary

Smart urban agriculture initiatives where food is produced in closed, controlled and digitally augmented environments, such as vertical farms, plant factories and aquaponics systems can be found in cities across the globe. Such initiatives produce fresh food all year around using less chemicals and require fewer food miles. However, critiques of smart urban agriculture suggest it is a marginal activity that often produces food with low nutritional value and requires energy intensive artificial lighting. Technological advances in digitalisation and food production as well as social and economic developments may create opportunities for smart urban food systems to address these issues and become a more realistic food supply in cities. Using qualitative research methods, this report explores the development of smart urban agriculture in Sweden. Specifically, it identifies experimental and entrepreneurial initiatives and analyses these initiatives in relation to high level policy agendas such as food policy, smart city and digitalisation.

Our findings show that smart urban agriculture broadly consists of technology-oriented entrepreneurial start-ups and experimental initiatives that includes, but are not limited to production, community and technology oriented initiatives. Production oriented initiatives are mainly organised to produce herbs and leafy greens; community oriented initiatives are mainly prioritising social benefits; and technology oriented initiatives develop and supply digital solutions and services for smart farming. These initiatives are interesting because of their claims about superior sustainability performance compared with conventional food production. Specifically these sustainability claims include resource efficient production in contained farming environments that are chemical free and can be located close to the market. Given the sustainability debate inherent with food production and consumption, smart (urban) agriculture has gained commercial traction and momentum, e.g. financial investments. The product output is, however, limited to a small variety of financial high margin crops that are sold at premium prices on the market. When examining smart urban agriculture in relation to high level strategic agendas, our findings show that urban agriculture is recognised for its environmental and social benefits (e.g. to mitigate flooding as well as offer space for recreation), but not as a realistic food supply. Here, food policies have a conventional view in that food is produced in rural areas and consumed in urban areas. The developments of smart urban agriculture challenge this conventional view. However, food production-consumption systems are excluded from high level policy agendas on smart cities and digitalisation. These insights suggest that there are established institutional arrangements (e.g. in food policy and urban planning) that may constrain development and uptake of smart urban agriculture and its possibility to bring significant sustainability benefits.

Introduction

This report investigates smart agriculture in urban environments. As a starting point we identify urban agriculture as food produced in urban locales where the term urban means human settings that are related to cities. Smart urban agriculture typically refers to food produced indoors in contained and digitally augmented environments such as vertical farms, plant factories and aquaponic systems (c.f. Despommier, 2010; Kozai, 2013; Butturini and Marcelis, 2020; Kozai and Niu, 2019). In such systems, plants are grown in narrow beds that are stacked in layers, and with the roots covered in a nutrient-rich mist. These systems use artificial light (usually LED light), climate controls and add nutrients to plants in closed environments that are monitored by sensors. Smart urban farms can be found in urban locales across the globe. They are typically driven by commercial interests, which differs from traditional images of urban agriculture, which highlight social or environmental motives, e.g. urban health.

Smart urban agriculture is, however, contested. On the one hand, it is viewed by its proponents as a promising way to produce fresh food all year around, using fewer chemicals and reducing food miles. Critical voices, on the other hand, state that it is a marginal activity that requires energy intensive artificial lighting and produces food with low nutritional value (Albright & de Villiers, 2008; Langendahl et al., 2017; Bergstrand et al., 2020). Technological advances in digitalisation and agriculture as well as social and economic developments may however, create opportunities for smart urban agriculture to become a realistic food supply. This report therefore investigates the development of smart urban agriculture initiatives in Sweden and identifies several apposite avenues for further research.

The findings presented in this report has particular relevance for actors interested in cross-disciplinary research and collaborations on smart urban agriculture as well as actors in public and private organisations interested in supporting development of urban food systems. The analytical approach in this study draws on socio-spatial notions of innovation (micro, meso and macro) which are used in subsequent sections of the report to analyse smart urban agriculture initiatives at multiple scales. Methods for data collection and analysis include a combination of literature review, document analysis as well as collection of primary data from key informants via semi-structured interviews, participant observations and workshops. Finally, we report findings from analysis on smart urban agriculture in relation to macro- meso, and micro-level insights and present a research agenda.

Analytical approach and method

Innovations are needed to create more sustainable production practices that satisfy food demands while mitigating sustainability challenges such as climate change, resource depletion and biodiversity losses (Mylan et al., 2019). While much research on innovation in the agri-food industry has focused on innovations in primary production to resolve sustainability issues, we know very little about initiatives in urban environments that may change practices of food production and consumption (Markard, 2017). Cities are likely to play a key role in transforming agri-food industry practices given that 80 percent of all food is expected to be consumed in cities by 2050 (EMF, 2019). Here, innovations may include new production practices (e.g. vertical farming), new distribution practices (e.g. food services) and new user practise (e.g. consumer habits) that have the potential to assist in sustainability transitions. Since innovations require both social change and change in technology, they are socio-technical and can be purposively planed and develop within socio-technical experimental initiatives (Markard et al., 2012).

Socio-technical experiments are not experiments that take place in controlled environments to find a hard objective truth about material reality. They are experiments, in which society itself is the laboratory (e.g. urban living labs; research and development projects) within which a variety of real world actors are involved in the introduction of alternative technologies and practices. Research on socio-technical experiments in urban environments is well-established with particular reference to energy and transport (Markard, 2017; Bulkeley et al, 2018). Here, Information and Communications Technologies (ICT) are deployed in such experiments to create so called smart energy and mobility systems. However, research on the adoption of ICT in socio-technical experiments related to smart agri-food systems is underdeveloped. This study will address this gap in knowledge by undertaking a pilot study to examine the development and uptake of smart urban agriculture in Sweden.

In this study, smart urban agriculture is conceptualised as an innovation in food production involving digital technology to produce food in contained environments. However, beyond this techno-centric definition, development and uptake of smart urban agriculture involves socio-technical processes because the social and technical is difficult to disentangle. Indeed, there are different analytical approaches to analyse innovation conceptualised as socio-technical process (cf. Köhler et al., 2019 for a review). One approach that is established in research on transitions follows the Multi-Level-Perspective (MLP) and associated strategic niche management (Geels, 2004; Schot and Geels, 2008). The MLP is a three-level nested hierarchy comprising 1) an exogenous landscape, which includes slow variables such as political ideologies; 2) a regime comprising various mainstream socio-technical configurations situated at the meso-level; and 3) technological niche environments in which new and more radical innovations develop.

Innovations in socio-technical transitions are characterised by interactions between niche and regime, where systemic change is achieved either through the incorporation of innovations into the regime, reconfiguration of the regime or substitution by a new regime (Geels et al., 2016). The MLP is useful for investigating developments of technological niches and how they compete with technologies embedded in a regime. However, since smart urban agriculture, by implication relates to multiple regimes (e.g. food, urban and digitalisation) the MLP was not used in this study. Rather, we have focussed on experimental projects and analysed these against temporal and spatial scales, rather than levels of structuration (Raven et al., 2012). Here, temporal scales refer to developments over time. Spatial scales include both territorial units such as local, regional and national, as well as conceptual spaces such as food sector, policy, information- and communication technology (ICT), urban planning and so on. This notion of spatial scale was deployed in this project for analytical purposes to zoom in and collect data on specific smart urban agricultural initiatives developing on the so called micro-level. It also enabled us to zoom out to investigate developments of smart urban agriculture in relation to high level agendas developed in specific social domains, which we here treat as the macro-level scale. In terms of temporal scales, we did not investigate developments over time, but our study can rather be viewed as a snapshot of smart urban agriculture in Sweden during spring 2020.

Analytical framework

The analytical framework for this study consists of three analytical levels: macro, meso and micro. Here, the macro-level scale refers to conceptual spaces such as policy-, technology-, urban planning-, and market developments in relation to smart urban agriculture. Specifically, we investigate developments in policy (e.g. national and regional food policy), technology (e.g. advances in horticulture, digitalisation and architecture), urban planning and markets in relation to smart urban agriculture. In our micro-level analysis, we zoom in on entrepreneurial (e.g. business models) and experimental initiatives (e.g. testbeds) in which aspects of smart urban agriculture develop. Specifically, we explore what types of entrepreneurial and experimental initiatives that are developing on the ground including their visions and key challenges for further development and scale up of smart urban farming. Our initial framework for this study focused on the micro and macro scales of analysis. Following preliminary analysis, a third category was identified as being necessary, the meso-level. Here, the meso-level refers to a space in-between macro and micro and involves trans-local networks. The analytical framework is depicted in Table 1 in terms of themes and categories.

Methods for data collection and analysis

This section presents methods deployed in this project to explore smart urban agriculture in Sweden. As a starting point we completed a brief systematic review of scientific and grey literature that was complemented with purposive sampling technique[1] to identify key themes in research on smart urban agriculture. Google Scholar was selected as a search engine since it covers multiple research areas. Keywords identified relevant for the search were: smart, urban, agriculture, controlled environment farming and vertical farming. Synonyms were included among the keywords when deemed necessary. The search was limited to peer-reviewed English language articles but without limits in terms of publishing date or research area. A narrative analysis of the literature was applied to provide a structured synthesis. Document analysis of grey literature such as policy and

1 Purposive sampling is a way of finding literature by using a key document on the subject as a starting point.

Table 1: Analytical framework and categories

Analytical scales	Analytical categories
Macro	Conceptual spaces such as food sector, technology, policy and urban planning at national level
Meso	Intermediary organisations that forms trans-local networks or platforms
Micro	Entrepreneurial and experimental initiatives in Sweden

industry reports were carried out on smart urban food production. Following our literature review we proceeded with qualitative methods to collect data on smart urban agriculture. Methods for data collection included semi-structured interviews with key informants, web- and document analysis and workshops.

Semi-structured interviews with key informants

Seven semi-structured interviews were conducted with key informants. Key informants were identified via purposive sampling methods, and included actors involved in developing or operating smart urban agriculture initiatives. Following a purposive sampling strategy, informants were selected based on their on-going engagement in smart urban food production in Sweden. Selection criteria included either individuals involved in an operating business beyond planning phase based in Sweden, individuals involved in an active network of actors or a governmental body with documented activity in supporting smart urban food production initiatives locally or regionally. A total of 7 interviews were conducted over the telephone. The interviews were structured around the themes of strategy, market, networks, material conditions and policy environment. Each interview took between 45-60 minutes. All interviews were transcribed.

Workshop process

Three on-line workshops on the topic of smart urban food production were organised in spring 2020. The first workshop focused on societal developments in relation to smart urban food production. The second workshop focused on experimental and entrepreneurial initiatives in Sweden in terms of visions and expectations of such initiatives as well as the challenges they face. The third workshop was dedicated to discussing what type of research is needed if smart urban food production is to develop as part of future food systems.

Workshop participants were recruited from the organisers' professional networks, through organisations from which interviewees were drawn and through the SLU Future Food newsletter. Prior to the first and second workshops, participants were given a summary of the literature review and some findings from the interviews, coupled with three thematic questions to inspire discussion in the workshops. Each workshop lasted 90 minutes and was attended by 20-30 participants. A list of participant organisations is presented in Appendix 1, and includes organisations representing academia, business, governmental agencies, civil society organisations and sector networks.

Method for data analysis

The data were analysed using a funnel approach to facilitate analysis (Hammersley & Atkinson, 1995). The funnel approach refers to exploratory research that becomes more focused as research proceeds. Thus, data about smart urban agriculture was collected while simultaneously reviewing literature. This iterative process of interplay between data collected and literature reviewed enabled the analytical template of the micro, meso and macro levels to emerge. The micro, meso, macro analytical framework helped to transform rich data into meaningful interpretations by capturing the levels of actors and dynamics at play and thereby obtain a better understanding of current state of smart urban food production in Sweden and its possibilities to develop. This section reports findings from research on smart urban agriculture in Sweden. First, it presents an analysis of smart urban agriculture initiatives at the micro-level with particular focus on experimental and entrepreneurial projects. Second, we examine smart urban agriculture in relation to macro-level developments notably food policy, urban planning and digitalisation. In the third section, we identify the emergence of intermediary organisations operating at a meso level in between the micro-level initiatives and the high level agendas, i.e. the macro-level, in relevant societal domains.

Results

Micro-level: Smart Urban Agriculture Initiatives

This section analyses selected[2] smart urban agricultural initiatives in Sweden. An overview of such initiatives is presented in Appendix 2 and includes information on location and value proposition. Findings from analysis of micro-level initiatives on smart urban agriculture is depicted subsequently.

Developments of smart urban agriculture are technology-oriented entrepreneurial start-ups and experimental initiatives

The empirical investigation of micro-level developments of smart urban agriculture in Sweden shows that it is dominated by experimental initiatives and entrepreneurial start-ups located across different urban and peri-urban areas. Experimental initiatives include projects that have received public and private funding to develop and test technological solutions (e.g. digital software, hardware, and modular growing entities) for indoor farming. Entrepreneurial start-ups are commercial initiatives that have established a more or less viable business on producing food in urban locales and or supplying technology or services to such initiatives. Here, we identify three broad categories of smart urban agriculture; these are:

- Production oriented urban farms that produce and sell food, e.g. herbs and veges. Examples includes Grönska, Urban Oasis and Johannas Stadsodlingar

- Community oriented initiatives that emphasises social benefits urban food can provide local communities. Examples include Odlande Stadsbasarer, Refarm Linné

- Technology oriented initiatives that are focus on developing and offering technological solutions and associated services (e.g. modular growing entities, digital platforms and software) that can be used for farming in contained environments. Examples Alovivum, Sensefarm and Swegreen.

The combination of high start-up costs (e.g. for equipment needed to produce food in indoor environments) with relatively low returns on investments, represent financial challenges for these initiatives. Many smart urban agricultural initiatives are positioned as technology-oriented projects, rather than (only) food producers, to attract funding. Workshop participants pointed to an interest in Swedish governmental research and innovation funding agencies to fund experimental initiatives, whereas entrepreneurial initiatives experience difficulties in obtaining financial support after initial pilot phases. From a financial perspective, the food industry produce low value commodities, which generates low return on investment. Therefore, many smart urban agriculture initiative focus on experimental activities in collaboration with technology firms to develop technological solutions and know-how instead of food production.

2 The initiatives illustrated in Appendix 2 shows an overview of smart urban agriculture initiatives, but it must be noted that this is not a complete list of such initiatives developing in Sweden.

Smart urban agriculture is founded on claims about superior environmental performance compared to conventional food production

Smart urban agriculture is founded on the notion that it offers superior environmental performance when compared to conventional food production which typically occur in rural settings. Specifically, it is claimed to be more environmentally sustainable than traditional agriculture because it requires fewer resources in production such as land and chemical inputs such as pesticides, herbicides and fungicides. Its proximity to markets where food is consumed reduces food miles, holds potential to reduce environmental impacts. Here, environmental performance of smart urban agriculture is well documented at the individual project level, and environmental performance is often based on comparisons with conventional agriculture in rural settings or food imports. This insight suggest that smart farming is based on the idea that technological interventions is applied in response to sustainability challenges with the purpose to enhance environmental performance of farming practices. However, sustainability effects beyond resource efficiency such as the impact of smart urban agriculture on urban environments is not well documented. Indeed, urban spaces are subject to competing interests, such as housing development, access to resources (e.g. labour), and infrastructures (e.g. energy, water, waste). Here, research participants in this project saw an opportunity for smart urban agriculture to develop especially in peri-urban locales. Related to environmental performance are claims that smart urban agriculture is more resilient because food is produced in controlled environments which are not sensitive to disruptive weather patterns and diminishing soil qualities.

Smart urban agriculture appears to be limited to a small variety of high margin crops that are sold at premium prices

Many of the Swedish initiatives investigated (see Appendix 2), operate vertical and hydroponic farming systems to produce leafy veges and herbs that are sold to local markets or to retailers. The overview of commercial initiatives identifies that the majority of them are focused on producing so called financially high margin crops. This finding accords with international studies (e.g. Yamori et al., 2014) in that the most common produce in smart urban agricultural are lettuce and spinach. While smart urban agriculture does not (yet) have the capacity to produce bulky food items, developments in agricultural practices (e.g. horticulture) coupled with developments in technology may open up opportunities for more varieties. Also, and importantly, the appetite for local produce is expected to increase the demand for urban or peri-urban food production (ref). However, developments of new food varieties in technologically augmented environments should be treated with caution and can be assigned more or less favourable names (c.f. Benke & Tomkins, 2017) such as 'Frankenfoods' and Clean-Green-Gourmet (CGG). Further, critical challenges that may constrain the development and uptake of smart urban agriculture include: 1) consumers tend to have a low level of acceptance for food produced in innovative forms of agriculture that connote intensive or high-tech (Benke & Tomkins, 2017; Bustamante, 2018); 2) consumers prefer food that is produced in conventional and traditional forms of agriculture (Al-Chalabi 2015; Benis & Ferrao, 2018; Sanyé-Mengual et al., 2016; Specht et al., 2016). Consumers may consider food produced indoors not to be natural and doubt the nutritive value and taste of veges grown hydroponically, notably because these products are grown without natural light and soil (Fang, 2016; Yano et al., 2016).

To overcome such market barriers, more knowledge about the nutritional value and taste of products as well as food safety and environmental sustainability is needed. In practice, marketing activities, such as package design, display, tastings, and seminars, may play an important role to assist in the diffusion and establishment of smart urban agriculture (Yano et al., 2016). In the next section, we zoom out to examine smart urban agriculture in relation to such macro-level spaces.

Smart urban agriculture from a macro-level perspective

The empirical investigation of smart urban agriculture initiatives from a micro-level perspective

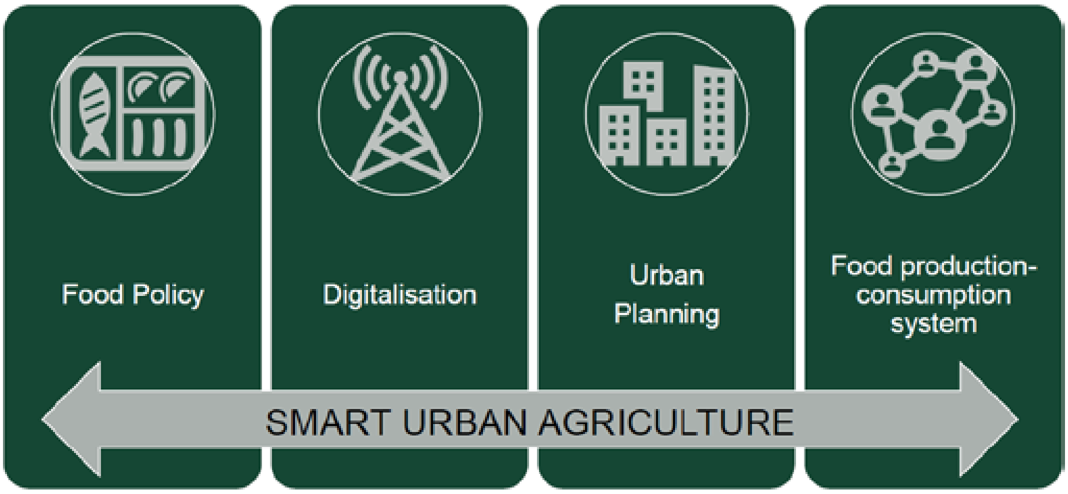

Figure 1: Smart urban agriculture develops in relation to multiple conceptual spaces

shows that it is a complex, multiple and diverse phenomenon. From a food industry perspective, it can be viewed as an advancement in production practices (e.g. agriculture, horticulture and aquaculture) by developing new production methods and product varieties adjusted to contained farming environments. From a technology perspective, it involves information and communication technologies (ICT) that offer possibilities for digitally augmented farming methods in contained environments, e.g. hydroponics, aeroponics and aquaponics. The opportunity here is often framed around using ICTs to create good growing conditions, enhance growing rates and productivity as well as to manage plant profiles and taste. Since food is produced in contained environments, it can be designed as modular entities that can be shaped and scaled (e.g. up or down) depending on the area of application, e.g. container, basement or tower blocks. Thus, smart urban agriculture can be seen to develop in relation to multiple and related developments such as food production and associated polices as well as technology development, urban planning and market, see Figure 1.

In this section we zoom out and present findings on smart urban agriculture in relation to developments in related societal domain, e.g. food policy, digitalisation, urban planning and food system. Here, we suggest that smart urban agriculture is an emerging innovation that is becoming embedded in these societal domains. In this way we identify and reveal dynamics associated with smart urban agriculture at a more systemic level with reference to competing interests and implications for future development trajectories.

Urban agriculture is recognised for its environmental and social benefits, but not as a realistic food supply

Urban agriculture is a well-documented phenomenon in terms of academic research, food policy development as well as regional and urban planning (cf. Goodman & Minner, 2019). Research on urban agriculture identifies multiple rationalities underpinning such developments, i.e. that urban agriculture develops for different reasons across time and place contexts. Specifically, urban agriculture is well established in the Global South to ensure livelihoods and food security (c.f. Poulsen et al., 2015). Similarly, in low-income neighbourhoods in for example the United States, such practices have emerged to overcome so called food deserts and improve access to healthy food (e.g. veges) in urban places that lack access to supermarkets (Kaufman & Bailkey, 2000; Gordon et al., 2011; Reynolds & Cohen, 2016). In high-income regions (e.g. Copenhagen) urban farming provides environmental benefits such as creating habitat for pollinators, reducing heat-island effects and redirecting waste water (Goddard et al., 2010). Urban agriculture is also recognised for its social benefits as it can help in creating links between farmers and consumers as well as nature and people in urban environments, such as allotments, which in turn contribute to health and wellbeing (Ulrich, 2016). Thus, urban agriculture is recognised in urban planning practices for its environmental and social benefits. On the contrary, commercially oriented urban agriculture has not been properly investigated in relation to urban planning or vice versa.

Food policies position food production in rural areas and food consumption in urban areas

Unsurprisingly, food policies are primarily focused on rural settings. Taking the Swedish national food strategy as an example, the established view is that food is produced in areas experienced as rural and consumed in areas experienced as urban. The urban environment is not recognised as a location for food production. Although not necessarily recognised as a realistic food supply to feed many people, our findings show that urban agriculture is important in city planning due to its associated environmental and social values.

Urban food production-consumption systems are excluded from smart city and digitalisation agendas

Smart development agendas are well established in many sectors, e.g. agriculture, city, energy and transport. For example, the digital transformation of the food system is increasingly prominent in food production in rural areas, and concepts such as precision farming and smart farming are moving up on the political agenda (e.g. Skånes livsmedelsstrategi 2030 – Smart mat). Similarly, the smart city agenda seeks to embed advances in ICT into infrastructure of urban environments with the aim to use digital technology to augment city planning and city life (e.g.smartcitysweden.com). The combination 'urban' and 'agriculture' is however not mentioned in these policy agendas.

This insight suggests that the smart urban food movement is a marginalised development that has a somewhat different trajectory compared to other more established smart agendas (May, 2019). Here, we do not argue that smart urban agriculture should be included in these agendas. Rather, we identify that the idea of urban food production-consumption systems are not subsumed into established development trajectories.

This analysis of smart urban agriculture from a macro-level perspective suggests that it is a marginal endeavour that falls outside mainstream developments in food policy, urban planning, and digitalisation/smart city. Here we recognise that urban food production-consumption does not fit with established food system or urban planning arrangements. Food production and consumption are dominated by the established views on how and where food is produced and consumed. In the next section we identify the emergence of intermediary organisations that are constructing links between policy agendas and smart urban agricultural initiatives.

Meso-level: Intermediary organisations

At the meso level we identify intermediary organisations such as social networks and platforms, which are supporting and promoting smart urban agriculture (Goodman et al., 2012; May, 2019). Examples of international networks include Milan Urban Food Policy Pact (a global network) and Sustainable Food Cities Network (SFCN) in the UK. National ones include Matlust; The Swedish Surplus Energy Collaboration (SSEC), Krinova, and Greenhouse living. Specifically, SSEC[3] facilitates the development and uptake of urban food production, which is identified here as a new industrial segment in which food (e.g. fish and veges) is produced in urban and industrial settings.

3 SSEC is a research and development programme led by Swedish University of Agricultural Sciences, with a focus on the development of industrial symbiosis and sustainable food production. SSEC is organised as a membership platform where public (e.g. municipalities) and private (e.g. food, energy and consultancy) organisations can participate by paying an annual fee to gain membership

This and other social network (or platform) consists of a coalition of actors representing different societal domains such as municipalities, academia, consultants, and firms in food and energy industries as well governmental agencies, such as Business Sweden.

The emergence of social networks and platforms are of particular interest for the development and potential uptake of smart urban agriculture when considering their capacity to mobilise concepts (e.g. production technology and business models) and translate their promises to relevant national and regional development agendas such as urban policy or the national food strategy. These network-based organisations may therefore play an important role in mobilising resources (including knowledge), facilitating the development of testbeds and entrepreneurial initiatives and enabling knowledge transfer between initiatives. Here, testbeds can function as "transition labs" where new practices are experimented with and develop (Sengers et al., 2019). Such testbeds are fundamental for creating learning processes to modify and adjust technological solutions (including horticultural practices, digital technology and architecture) and to prepare them for further uptake and diffusion.

Knowledge synthesis and research agenda

Our empirical investigation provide insights on smart urban agriculture at three inter related scales; these are the macro, meso and micro levels (see Figure 2). At the micro level, we identify multiple and diverse experimental or entrepreneurial initiatives on smart urban agriculture. At the macro level, our findings suggests that the notion of smart urban agriculture is not well established in high level policy agendas, notably food policy and urban planning. At the meso-level, we identify social networks and platforms that may play an important role in mobilizing and link emerging ideas and concepts of smart urban agriculture with high level policy agendas and associated practices, e.g. urban planning.

Specifically, our findings show that smart urban agriculture at the micro level consists of technology oriented entrepreneurial start-ups and experimental initiatives that range from production, community and technology oriented initiatives. The commercial value proposition of many of these initiatives consists of claims about superior environmental performance compared with conventional food production. Smart urban agriculture appears, however, to be limited to a

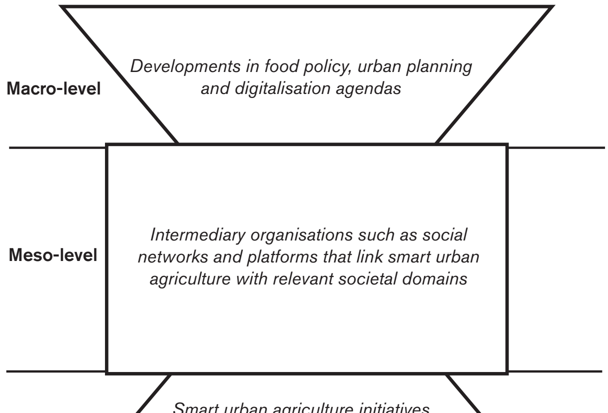

Figure 2: Smart urban agriculture in Sweden analysed at multiple scales

small variety of high margin crops that are sold at premium prices.

Examining smart urban agriculture in relation to macro level developments our findings shows that urban agriculture is recognised for its environmental and social benefits but not as a realistic way to supply food for many. Here, food policies appear to embody the view that food is produced in rural areas and consumed in urban areas. Similarly, food production-consumption systems seem to be excluded from smart city agendas. These insights suggests that there are established institutional arrangements (e.g. food policy and urban planning) which may constrain development and uptake of smart urban agriculture. Here, we identify the emergence of intermediary organisations that form trans-local networks such as SSEC, working at the meso level to overcome such obstacles. These organizations are composed of actor coalitions with varying capacity to promote and shape the development and uptake of smart urban agriculture.

Research agenda

In this section, we propose a series of topics for future research that have emerged from this investigation.

- How are digital technologies in urban agriculture adapted, adopted and up scaled? What actors and organisations are driving the adoption and adaptation of digital technologies in urban agriculture; what are its implications for users and associated institutional arrangements?

- What are the sustainability implications of smart urban agriculture in terms of social, environmental and economic outcomes on urban places, people and markets?

- Smart agriculture is developing in rural, peri-urban and urban environments – what are the similarities and differences between smart agriculture areas?

- How does smart (urban) farming inflect the image and governance of food and farming? Here, we observe the emergence of new farming skills, knowledge and agricultural practices such as digitally mediated farming, which stands in contrast to hands-on farming, where technological solutions replace 'natural elements' (e.g. soil and sun) and the emergence of new farmer identities, e.g. joystick farmers, cyborg farmers.

- How do intermediary actors and organisations such as national, regional and local food initiatives, reshape smart urban agriculture?

Specifically, we call for more cross-disciplinary research collaborations to further investigate the above and other related research avenues.

Acknowledgments

We thank SLU Future Food for financing this project. We also thank all of you who have participated in this project via interviews and workshops. Finally, we thank Professor Matthew Cook at the Open University for analytical support.

References

Albright, L.D., de Villiers, D.S. (2008). Energy Investments and CO2 Emissions for Fresh Produce Imported into New York State Compared to the Same Crops Grown Locally. [online]. URL. (Accessed 10 August 2018). https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/SustainableUrbanAgriculture.pdf.

Al-Chalabi, M. (2015). Vertical farming: Skyscraper sustainability?. Sustainable Cities and Society 18: 74-77

Benis, K. & Ferrão, P. (2018). Commercial farming within the urban built environment – Taking stock of an evolving field in northern countries, Global Food Security, Vol. 17, pp. 30-37, https://doi.org/10.1016/j.gfs.2018.03.005

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

Bergstrand K-J., et al., (2020). Opinion: växtfabriker driver på utveckling av ny odlingsteknik. Ny Teknik, 2020-04-22. https://www.nyteknik.se/opinion/vaxtfabriker-driver-pa-utvecklingen-av-ny-odlingsteknik-6994048

Bulkeley et al., 2018. Urban living laboratories: Conducting the experimental city? European Urban and Regional Studies, pp- 1-19

Bustamante, M.J. (2018). AgTech and the City: The Case of Vertical Farming and Shaping a Market for Urban-Produced Food. In Managing Digital Transformation, (Eds.) P. Andersson, S. Movin, M. Mähring, R. Teigland, & K. Wennberg, Stockholm: Stockholm School of Economics Institute for Research (SIR)

Butturini, M. & Marcelis, L.F.M. (2020). Vertical farming in Europe: Present status and outlook, In Plant Factory (Second Edition), Eds. Kozai T., Niu, G. & Takagaki, M. pp. 77-91. Academic Press. London. https://doi.org/10.1016/B978-0-12-816691-8.00004-2.

Despommier, D. (2010). The Vertical Farm: Feeding the World in the 21st Century. Thomas Dunne Books/St. Martin's Press

Ellen Macarthur Foundation (EMF), 2019. Cities and Circular Economy for Food. ECM, available online: https://www.ellenmacarthurfoundation.org/assets/downloads/Cities-and-Circular-Economy-for-Food_280119.pdf

Fang W. (2016) Business Models for Plant Factory With Artificial Lighting (PFAL) in Taiwan. In: Kozai T., Fujiwara K., Runkle E. (eds) LED Lighting for Urban Agriculture. Springer, Singapore

Geels, F.W. 2004. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. Research Policy, vol. 33, pp. 897-920

Shot and Geels, 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda and policy. Technology Analysis & Strategic Management; Vol. 20, No. 5, September 2008, 537–554

Geels, F.W., Kern, Florian, Fuchs, Gerhard, et al., (2016). The enactment of sociotechnical transition pathways: a reformulated typology and a comparative multi-level analysis of the german and UK low-carbon electricity transitions (1990–2014). Res. Policy 45 (4), 896–913.

Goodman, D,, DuPuis, E.M. & Goodman, M.K. (2012). Alternative Food Networks: Knowledge, Place and Politics. London and New York: Routledge

Goodman, W., & Minner,, J. (2019). Will the urban agricultural revolution be vertical and soilless? A case study of controlled environment agriculture in New York City. Land Use Policy, vol. 83; pp. 160-173

Goddard, M.A., Dougill, A.J.& Benton, T.G., (2010). Scaling up from gardens: biodiversity conservation in urban environments. Trends Ecol. Evol, vol. 25 (2), 90–98. DOI: https://doi.org/10.1016/j.tree.2009.07.016

Gordon, C., Purciel-Hill, M., Ghai, N.R., Kaufman, L., Graham, R. & Van Wye, G. (2011). Measuring food deserts in New York City's low-income neighborhoods. Health Place, vol. 17 (2), 696–700

Hammersley, M. and Atkinson, P. (1995) . Ethnography: Principles in Practice, 2nd Ed. London: Routledge.

Kaufman, J. & Bailkey, M. (2000). Farming Inside Cities: Entrepreneurial Urban Agriculture in the United States. Lincoln Institute for Land Use Policy

Kozai, T. & Niu. G. (2019). Role of Plant Factory with Artificial Lighting (PFAL) in Urban Areas. In In Plant Factory (Second Edition), Eds Kozai, T., Niu, G, & Takagaki M, Academic Press.London. pp. 7-33.

Kozai T. (2016). Why LED Lighting for Urban Agriculture?. In: Kozai T., Fujiwara K., Runkle E. (eds) LED Lighting for Urban Agriculture. Springer: Singapore

Kozai, T. (2013). Resource use efficiency of closed plant production system with artificial light: Concept, estimation and application to plant factory. Proceedings of the Japan Academy, Series B, 2013, vol. 89; 10, p. 447-461

Köhler, J., Geels, F.W. and Kern, F. et al., 2019. An agenda for sustainability transitions research: State of the art and future directions. Environmental Innovation and Societal Transitions, 31, 1-32.

Langendahl, P.A., Cook, M. & Mark-Herbert, C. (2017) Exploring agriculture in smart urban development: a realistic food supply or middle class indulgence? Presented at CFP – 7th Nordic Geographers Meeting, Stockholm 18-21 June 2017

May, D. 2019. 'Smart food city': Conceptual relations between smart city planning, urban food systems and innovation theory.

Markard, J., 2017. Sustainability transitions: guidance and reflections. Keynote Talk for the Newcomers Session at the 8th International Conference on Sustainability Transitions.

Markard, J., Raven, R. P. J. M., and Truffer, B. 2012. Sustainability transitions: an emerging field of research and its prospects. Research Policy, vol. 41, pp. 955-967

Mylan, J., Morris, C., Beech, E., and Geels, F.W. 2019. Rage against the regime: Niche-regime interactions in the societal embedding of plant-based milk. Environmental Innovation and Societal Transition, vol. 21, pp. 233-247.

Poulsen, M. N., McNab, P., R., Clayton, M. L, and Neff, R.A. 2015. A systematic review of urban agriculture and food security impacts in low-income countries. Food Policy, vol: 55, PP: 131-156

Raven, R., Schot, J., and Berkhour, F. 2012. Space and Scale in Socio-Technical Transitions. Environmental Innovation and Social Sciences, vol. 4, pp. 63-78

Reynolds, K. & Cohen, N. (2016). Beyond the Kale: Urban Agriculture and Social Justice Activism in New York City. The University of Georgia Press, Athens

Sanyé-Mengual, E., Anguelovski, I., Oliver-Solà, J., Montero, I.J. & Rieradevall J. (2016), Resolving differing stakeholder perceptions of urban rooftop farming in Mediterranean cities: promoting food production as a driver for innovative forms of urban agriculture. Agric. Hum. Val., vol. 33 pp. 101-120. https://doi.org/10.1007/s10460-015-9594-y

Sengers, F., Wieczorek, A. J.& Raven, R. (2019). Experimenting for sustainability transitions: A systematic literature review, Technological Forecasting & Social Change, vol.145, pp. 153-164

Specht, K. Weith, T. Swoboda, K. & Siebert, R. (2016). Socially accep urban agriculture businesses. Agron. Sustain. Dev., vol. 36 , pp. 1-14. https://doi.org/10.1007/s13593-016-0355-0

Ulrich, R. (2006). Evidence-based healthcare architecture. Lancet, vol. 368(12), pp. 38–39

Yano Y., Nakamura T. & Maruyama A. (2016). Consumer Perception and Understanding of Veges Produced at Plant Factories with Artificial Lighting. In: Kozai T., Fujiwara K., Runkle E. (eds) LED Lighting for Urban Agriculture. Springer, Singapore

Yamori, W., Zhang, G., Takagaki, M. & Maruo, T. (2014). Feasibility Study of Rice Growth in Plant Factories. J Rice Res, vol. 2: 119. DOI: http://dx.doi.org/10.4172/jrr.1000119

Appendix 1: Workshop participants

Akademiska hus
Allovium
ALMI Uppsala
Business Sweden
Clean Production Center
CoSolutions with You AB
Ecoloop
Föreningen för den gulliga folkrörelsen (DGF)
Green Innovation Park
Greenhouse Living
Grönovation
Helsinborgshem
Högskolan Kristianstad
Innovation Skåne
IVL
KTH
Mälardalens högskola
Odlande stadsbasarer
Ramboll
Region Skåne
Region Uppsala
RISE
SECC
18 researchers at SLU
SLU Future Food
SLU Holding
Student
STUNS
Sweden Foodtech
Swegreen
Svenska samernas riksförbund – SSR

Appendix 2: Smart urban agriculture initiatives in Sweden

Smart urban agriculture initiatives	Description
Alovivum	Located in Helsingborg and Malmö, develops digital platform for farming in industrial and residential buildings
Bonbio	Located in Helsingborg, produces leafy greens and herbs in vertical hydroponic systems for retail; develops solutions for circular food production
FutuFarm	Located in Halmstad, develops technology for vertical and hydroponic systems
Grönovation/ Optima planta	Located in Uppsala, produces leafy vegetables to restaurants and resellers. Medicinal plants and extracts for nutritional and personal hygiene for the Chinese market
Grönska Stadsodling	Located in the Stockholm region, produces leafy greens, herbs and cabbage in indoor farming systems and develop supply vertical farming technology, such as the GrowOff
Johannas stadsodlingar AB	Located in Vallentuna, Stockholm. Produces leafy vegetables and fish in aquaponic system to local market via Reko-rings
Kretsloppsbolaget	Located in Stockholm, develops and supplies aquaponics systems
Odlande Stadsbasarer	Located in Stockholm, Helsingborg and Landskrona, produces leafy greens in underground growing system and positioned as local community initiatives
Peckas Solutions	Located in Härnösand, produces tomatoes and rainbow trout in aquaponic system; products are sold to retailers
Refarm Linné	Located in Växjö, education and capacity building for aquaponic systems
Sensefarm	Located in Lund, develops digital platform for farming and park management
Swegreen	Agtech firm located in Stockholm. Develop and supplies smart farming services such as in store farming.
Urban Oasis	Located in Stockholm, produces leafy greens in indoor growing systems

SLU Future Food
SLU Future Food är en plattform som stimulerar och utvecklar tvärdisciplinär forskning och samverkan för ekonomiskt, ekologiskt och socialt hållbara livsmedelssystem.

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