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ZERO-ACREAGE FARMING DRIVING SUSTAINABLE URBAN DEVELOPMENT: A SPATIAL AND TECHNOLOGICAL COMPARISON OF URBAN AGRICULTURE FARMS

Jan Hugo,[1] Chrisna du Plessis[1] and Andy van den Dobbelsteen[2]

ABSTRACT

Zero-Acreage Farming (ZAF) recently developed as a novel land-use form and is aimed at addressing food security and sustainable urban development. While it is often lauded as a sustainable land-use form with potential to improve resource consumption and urban sustainability, little research into the spatial and technological requirements of this land-use form is available. This study undertakes a comparative analysis of ZAF and ground-based urban agriculture (UA) farms in diverse countries to differentiate their technical and spatial implementation parameters and uncover ZAF-specific characteristics and their implementation feasibility in rapidly developing cities. This qualitative study uses semi-structured interviews, triangulated with observational studies, to document ZAF and UA farms in South Africa, Belgium, the Netherlands and Singapore. The findings reveal UA as highly flexible, modular land-use forms while, contrastingly, the technological focus of ZAF farms often results in monofunctional and inflexible once implemented, isolated, and non-contextual solutions. While ZAF farms are appropriate to improve livelihoods and food security in dense urban contexts, the study highlights trends that must be addressed to promote the implementation of ZAF in poorer rapidly developing cities.

KEYWORDS

urban agriculture, urban agriculture technologies, zero-acreage farming, urban retrofitting, building-integrated agriculture.

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1. INTRODUCTION

Urban agriculture (UA) as a global phenomenon is implemented in multiple contexts, at various scales and spatial conditions, and within diverse communities. Its flexibility as land-use practice to adapt to multiple conditions is considered one of UA's main benefits (Lovell, 2010; Matos and Batista, 2013), making this a highly appropriate land-use form to implement in the rapidly growing and changing urban conditions often found in sub-Saharan cities (Chobokoane and Horn, 2015).

While diverse forms of UA have developed, UA can be broadly defined as the production and processing of plant and animal-based produce within the urban perimeter for food and non-food purposes (Lovell, 2010). It is also associated with multiple sustainable response strategies, ranging from national responses to crises such as the Cuban Special Period (Roset, 2001) and larger urban planning solutions as proposed by Ebenezer Howard (Howe et al., 2005), to small-scaled individual plots such as victory gardens (Howe et al., 2005). Recent developments of this land-use strategy address urban public space through Continuous Productive Urban Landscapes (Viljoen, 2005), contribute to urban green infrastructure networks (Matos and Batista, 2013), and improve climate change resilience of local communities (Lwasa et al., 2014; Padgham et al., 2015).

In addition to the systemic implementation of UA, multiple farm types have been recently developed that are closely integrated with the built environment. The integration of these productive spaces with the built environment has been identified by many as important steps to improve the resource circularity and efficiency of our cities. These land-use forms are defined as Zero-acreage farms (ZAF), which represents "all types of urban agriculture characterized by the non-use of farmland or open space" (Specht et al., 2014). While ZAF includes a variety of farming applications, Building-Integrated Agriculture (BIA) developed as a novel strategy that includes "high-performance hydroponic farming systems on and in buildings that use renewable, local sources of energy and water" (Caplow, 2009). Despommier (2010) further defined Vertical Agriculture (VA) as highly efficient growing systems on vertical planes or large-scale intensive stacked farming located within buildings, which improve food production safety, lower resource consumption, and increase efficiency through resource circularity.

ZAF has been implemented in cities across the globe (Thomaier et al., 2014; Davie, 2018). Yet, while UA is often lauded for its bottom-up, contextual and locally responsive solutions (Galt et al., 2014), few studies have considered the technological and spatial articulation of ZAF within diverse contexts. As a research objective this study undertakes a comparative analysis of the spatial and technical characteristics of ZAF and UA projects in diverse contexts to identify the spatial and technical attributes that differentiates ZAF farms from typical UA applications. From the findings, this study aims to contribute to our understanding of the implementation of ZAF projects in rapidly urbanizing regions by considering their material and technological qualities, and how these are adjusted to suit the local conditions.

The article is structured along four parts. It starts by discussing the potential of UA and ZAF to improve the sustainability of cities and identifies the specific sustainability attributes along which these farms are analysed. Secondly, the research method is discussed. The third section unpacks a taxonomy of farm types that define ZAF farms as novel land-use forms developing within the UA industry, and discusses specific spatial and technological characteristics uncovered from the UA and ZAF comparative analysis. Finally, specific trends documented in the ZAF industry are discussed.

2. LITERATURE REVIEW

2.1 Urban Agriculture and Zero-acreage Farming as drivers of sustainable cities

UA is considered as one of several sustainable strategies that can improve urban environments (Viljoen, 2005; Lovell, 2010), and has the potential for rapid and efficient deployment within existing cities. It can perform multiple roles, such as responding to local economic crises (Partalidou and Anthopoulou, 2017), improving social cohesion to remediate historic conflicts (Corcoran and Kettle, 2015), and promoting cultural identity (Kortright and Wakefield, 2011). Many advocate for UA's positive role in local place-making (Viljoen, 2005, Phillips, 2013), while others call for careful planning to achieve that (Napawan, 2015).

As a further sustainable attribute, UA is noted to facilitate local agency at the grassroot level. Lovell (2010) highlights bottom-up processes within the UA industry as uncoordinated grassroot efforts with cascading impacts on the larger system. Senes et al. (2016) identify the bottom-up quality of UA as critical to improving cities. However, many argue that top-down planning and policies are needed to leverage change by coordinating these activities (Lovell, 2010; Matos and Batista, 2013). Incorporating both processes when implementing UA is therefore important.

UA, specifically ZAF projects, can contribute to the sustainability of cities by improving resource efficiency (Nelkin and Caplow, 2008; Thomaier et al., 2014; Graamans et al., 2018), promoting circular resource consumption (Specht et al., 2014; Tillie et al., 2009), addressing urban heat island impacts and improving indoor thermal comfort (Castleton et al., 2010; Delor, 2011), as well as augmenting stormwater management and rainwater reuse (Astee and Kishnani, 2010; Lupia and Pulighe, 2015). Furthermore, on a larger urban scale, it contributes to local biodiversity (Bernholt et al., 2009), and integrates with green infrastructure networks (Dubbeling et al., 2009). Finally, many argue that UA contributes to the overall urban and climate resilience of cities (Lwasa et al., 2014; Padgham et al., 2015).

2.2 Spatial and technological qualities contributing to sustainable urbanism.

This widespread interest in UA resulted in significant technological development in the field. Building on arguments by Despommier (2010) and Caplow (2009), ZAF developed as a means to promote sustainable food networks, while improving the quality of the urban environment and its resource efficiency. Currently, there is a paucity of technological and spatial information on ZAF and UA, and few studies such as the work by Phillips (2013) and Jenkins (2018) address this. While industry information on industrial agriculture systems and technology exists, the translation of these systems into constrained urban spatial conditions lacks definition.

The study's findings are discussed according to the spatial and technological characteristics uncovered during the inductive analysis process and promoted by many as sustainable urban development strategies. These include characteristics advocated by Ahern (2011) as resilient urban conditions such as multifunctional programming (intertwining functions that are spatially economical), modular technological articulation (distributed components of a system that grow and change over time) and adaptable solutions (adjustable solutions responding to changing contexts and needs). Viljoen (2005) promotes integrating UA with the city to transform it, and Ryan (2013) advocates implementing disruptive sustainable acupuncture interventions with cascading impacts. Finally, Campbell (2017) identifies human-centred technology as critical to develop long-term sustainable solutions.

These spatial and technological attributes were identified as co-benefits from UA and ZAF projects. UA projects were noted as suitable to implement in neglected spaces (Galt et al., 2014; Matos and Batista, 2013). Furthermore, as noted by Orsini et al. (2015) and Nelli (2020), these land-use forms also present diverse and flexible application capacities. A number of theorists postulate a high degree of modularity in terms of how these land-use forms occupy and grow in diverse spaces (Sanyé-mengual et al., 2015). In addition, Viljoen (2005) calls for the urban integration of UA projects, which many projects achieve through multifunctional programming (Nasr et al., 2017). Finally, UA and ZAF have advanced technologically, and both Campbell (2017) and Nelli (2020) highlight the importance of social innovation by adapting technologies and enabling diverse individuals and communities to implement these projects. Senes et al. (2016) furthermore identify UA as highly accessible land-use forms with extensive implementation capacity.

These technological and spatial attributes are discussed in terms of how they manifest in UA and ZAF projects in diverse contexts. The paper documents these variations in implementation and considers the resultant impact of contextual differences. Finally, the documented ZAF farm types are compared with the ground-based UA farms to differentiate novel ZAF farm typologies.

3. RESEARCH METHOD

Premised on a Pragmatism tradition that focuses on relevant and contextual results (Saunders et al., 2016), this study performed a qualitative empirical analysis of the technological and spatial characteristics of various UA and ZAF farms. Similar to research by Napawan (2015; 2016) and Thomaier et al. (2014), the study undertook several explorative interviews and observational analyses of existing farms in South Africa, the Netherlands, Belgium and Singapore to document the spatial and technological implementation of UA and ZAF farms in diverse contexts.

The research contexts were identified for their significant progress in the urban agriculture industry. The Netherlands was chosen due to its progress in the agricultural industry, and being the second largest agricultural produce exporter in the world (CBS, 2019; WUR, 2019). The Belgian examples were analysed due to a snowballing sampling process in which reference to Belgian projects was made by Dutch respondents. Singapore was included due to their significant strides in terms of sustainable development since the 1950s (UNDP, 2018), and their goal to achieve food resilience through strategic importing strategies and stockpiling, and promoting innovation within their local agriculture sector, specifically UA (MFA 2018). South Africa was included, as it represents a developing context where UA has been promoted as a sustainable development practice (Martin et al., 2000); furthermore, the recent National Climate Change Adaptation Strategy advocates for UA and alternative food networks as effective climate change adaptation measures (SA Government, 2019).

In terms of the human development index and gross domestic product (GPD), the four countries perform differently. Belgium, the Netherlands and Singapore perform very well on the global Human Development Index (17th, 10th and 9th respectively) and also have a GDP per capita above $ 43,000. South Africa is currently 113th on the Human Development Index and has a GDP per capita of $ 6,152 (UNDP, 2019; World Bank, 2019).

Finally, the farms are located within three different climatic conditions, enabling analysis of diverse technological and spatial responses within different climates. Belgium and the Netherlands both have temperate maritime climates with cool summers, the South African interior presents temperate climates with hot summers and dry winters, while Singapore is located in a hot tropical climate.

To consider the spatial and technological manifestation of these UA and ZAF farms, it was important to assess the land-use forms in their natural setting (Saunders et al., 2016), and align these observations with the findings from the interviews. As a result, the study included both qualitative explorative interviews and observational analyses of the farms. Due to resource constraints the study was limited to four countries.

The study used a non-probability sampling method to identify specific farms to analyse and interview particular individuals with experience and knowledge within the UA field (Saunders et al., 2016). The method allowed for snowball sampling based on referrals from the specialist interviews. The sampling group included urban farmers (n-17), UA and ZAF theoreticians (n-5), and specialists such as landscape architects, architects and engineers involved in the UA industry (n-10) (Table 4). The study also documented UA and ZAF farms (n-27), and additional information regarding these farms is discussed in Tables 5 and 6. The interviews were semi-structured to allow for the exploration of additional themes uncovered in the process (Saunders et al., 2016), and took on average 30 minutes to complete. The interviews covered several themes: i) site choice, spatial layout and planning; ii) the choice, implementation and management of the planting systems; iii) structural considerations and constraints; and iv) any problems or difficulties experienced during the implementation or management of the project in question.

Following the interviews, a semi-structured observational study was undertaken using photographic and video documentation. During this phase the researcher documented: i) the layout of the farm; ii) the types of planting systems; iii) the use of materials; iv) structures or methods used to ameliorate the microclimate; v) adjustments or additions to the existing buildings or infrastructure; and vi) movement and access control on the site. In addition to documenting spatial or technological aspects, this phase allowed the researcher to triangulate and verify unknown or misinterpreted aspects communicated during the interviews. The interview respondents often accompanied the researcher during the observational studies.

The study documented UA and ZAF projects in dense urban contexts to develop a benchmark from which the differentiating characteristics specific to ZAF projects can be identified. The collected visual material and transcribed interviews were analysed using a thematic analysis process following an inductive approach (Saunders et al., 2016). As both textual and visual data were interpreted, a manual approach was used to develop the thematic coding. The analysis process used the data from the interviews, textual transcriptions, visual observations, and photographic material to develop the coding and subsequent themes. A multi-phased approach was followed during which individual farms were analysed to generate the coding. Once established, these codes were assigned to the various projects. A concurrent process identified farm typologies, expanding on the farm type definitions developed by Goldstein et al. (2016). Finally, this enabled the researcher to analyse and organise the data according to the main coding themes which revealed specific spatial and technological characteristics associated to the specific farm types.

During the coding process, specific spatial and technological strategies and conditions were identified. While UA and ZAF farms are highly flexible land-use forms, trends were identified where specific spatial and technological strategies and conditions manifest in the various farm types. These findings were ultimately categorised according to the farm types identified in the study and used to differentiate and highlight particular ZAF trends. Finally, the findings are presented and contextualized with existing literature to generalize it within the UA discourse (Saunders et al., 2016).

In terms of delimitations to the study: i) the analysis excluded projects located in peri-urban conditions, and ii) while the study considered the spatial and technological definition of UA and ZAF, the observational analyses were qualitative and did not calculate or measure the quantities or efficiency of the food production on the various farms. While the study identified multiple spatial and technological trends (Tables 1 and 2), the findings and discussion sections were delimited to focus on selected themes related to development and implementation of UA and ZAF as sustainable land-use forms in cities as discussed in the literature review (Section 2.2).

4. FINDINGS—SPATIAL AND TECHNOLOGICAL CHARACTERISTICS OF UA AND ZAF FARMS

The study considered diverse UA farms and defined ZAF as novel farm types within the UA industry. These range from ground-based unconditioned farms, considered conventional UA, to indoor automated farms, identified as technologically sophisticated ZAF examples (see Tables 1 and 2). From the data a series of technological and spatial trends were identified and consequently the analysis divides the farms into eight types ranging from low-technological to highly sophisticated solutions.

Other studies have identified various farm types in the UA discourse. Napawan (2015) identifies several ground-based typologies ranging in scale, and Krikser et al. (2016) arrange them according to function and purpose. This study defined ZAF and UA farm types according to their technological and spatial characteristics and built on the taxonomy suggested by Goldstein et al. (2016), which identify four types of farms: ground-based unconditioned, ground-based conditioned, building-integrated unconditioned, and building-integrated conditioned. The taxonomy developed by Goldstein et al. (2016) was expanded by adding resource circularity (either in-situ or ex-situ), indoor agriculture, and automated indoor agriculture. The resulting eight farm types, as illustrated in Figure 1, include:

a. **Ground-based unconditioned:** Community or allotment farms that are farmed for personal use.
b. **Ground-based conditioned:** Community or commercial soil-based farms that use growing tunnels to enhance crop output.
c. **Integrated unconditioned:** Integrated with the built environment, and presenting aesthetic or cultural functions with less focus on produce output.
d. **Integrated conditioned:** Productive commercial farms that are integrated within the built environment. These often use hydroponic systems, greenhouses, and active systems to control the growing environment.
e. **Integrated conditioned in-situ circular resources:** Integrated with the built environment, these farms employ circular resource methods within the farm or building. These often represent integrated rooftop greenhouses (Sanyé-mengual et al. 2015) or aquaponics farms.
f. **Integrated conditioned ex-situ circular resources:** Building or urban system-integrated farms that optimise resource circularity within the greater neighbourhood.
g. **Indoor conditioned:** Artificially controlled indoor hydroponic commercial farms within optimised indoor environments (Graamans et al. 2018).

h. **Indoor conditioned automated:** Completely automated commercial farms that control the planting process, nutrient management, and indoor growing environment.

The technological and spatial trends documented in the study are organised in Tables 1 and 2 according to these eight farm types. Table 1 illustrates the various technological trends by analysing the resource and infrastructure inputs of the various farm types. Furthermore, it expands on the material use, growing space allocation, planting strategies and microclimatic amelioration strategies. Table 2 expands on the spatial trends documented throughout the analysis. It considers programming strategies, project location parameters, the layout protocol, and the spatial scale of these farms. Finally, it defines the space use characteristics, existing structural layout requirements, urban integration, and retrofitting potential (see Table 3 for definitions of selected farm type characteristics).

From the interviews and observational analyses several notable characteristics were documented. These were compared to reveal how these characteristics align with specific farm types (Tables 1 & 2; Figure 2). As argued in the literature review, these characteristics are often considered beneficial to the greater urban environment and were evident throughout the contexts and project types. From this analysis a selection of themes associated with sustainable urbanism was identified. These are distinctly spatial and technological, and relate to the manifestation of UA within cities. These characteristics include activating unused spaces, flexible space use, integration with the urban environment, multifunctional programming, adaptable technologies, and the modularity and flexibility of the technology.

4.1 Activating Unused Spaces

It was found that farmers often use in-depth knowledge of the urban context to appropriate spaces for food production, leading to both opportunistic responses to activate underutilised

FIGURE 1. Examples of the various farm typologies identified in the study.

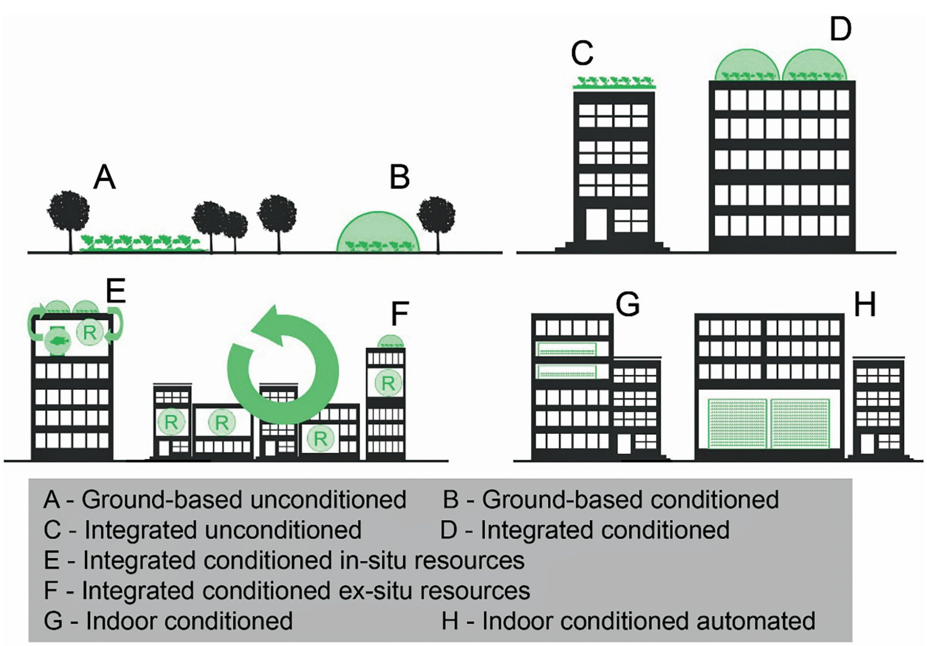


TABLE 1. Comparison of the technological trends and its relation to the farm types.

	Farm types	A	B	C	D	E	F	G	H
Resource inputs	Water	■	■	■	■	■	■	■	■
	Soil	■	■						
	Growing medium			■	■	■	■	■	■
	Electricity				■	■	■	■	■
	Nutrients				■	■	■	■	■
	Recirculated - thermal energy					■			
	Recirculated nutrients					■	■		■
	Internet connectivity								■
Infrastructure needs	Soil management	■	■	■					
	Water reticulation		■	■	■	■	■	■	■
	Electrical network				■	■	■	■	■
	Cold Storage		■			■			
	Growing tunnel		■		■	■	■	■	■
	Growing system				■	■	■	■	■
	Localised nutrient reticulation				■		■	■	■
	Integrated nutrient reticulation					■			
	Drainage system				■	■	■	■	■
	Air-conditioning							■	■
	Management software								■
Material Use	Appropriated or reuse	■	■	■					
	Natural material	■	■	■					
	Industrial				■	■	■	■	■
Growing Space	Soil-based	■	■	■					
	Growing bed - single layer				■	■			
	Growing bed - stacked				■		■	■	■
Planting Strategy	Organic planting	■	■	■					
	Optimised - natural nutrients					■	■		
	Optimised - artificial nutrients				■			■	■
Microclimate amelioration	Open - sunlight optimised	■	■	■	■	■			
	Adjusted thermal & sunlight optimised		■		■	■			
	Control and optimised						■	■	■

Parameters — *Parameter observed in farm type* ■

Farm type definitions:

A – Ground-based unconditioned
B – Ground-based conditioned
C – Integrated unconditioned
D – Integrated conditioned
E – Integrated conditioned in-situ circular resources
F – Integrated conditioned ex-situ circular resources
G – Indoor conditioned
H – Indoor conditioned automated

spaces, as well as utilising integrated networks to leverage the farms' economic feasibility. As a result, UA farmers present the capacity to improve the performance of the urban environment through in-situ transformation, as argued by a Singaporean ZAF farmer.

> "… It is basically just anti-land, by allowing us to come up here you have basically converted it into a productive piece of land where people can come to work and you can

TABLE 2. Comparison of the spatial trends and its relation to the farm types.

	Farm Types	A	B	C	D	E	F	G	H
Programming	Mono-functional		■		■		■	■	■
	Multifunctional	■	■	■	■	■	■		
Location parameters	Access points	■	■	■	■	■	■	■	■
	Microclimate concern	■	■	■	■	■			
	Location of resources						■		■
	Flexible location						■	■	■
Layout procedure	Organic layout	■	■	■	■			■	
	Professional input needed		■	■	■	■	■		
	Predetermined - no flexibility							■	■
Spatial scale	Anthropomorphic	■	■	■	■	■	■	■	
	Produce optimised				■	■	■	■	■
Space layout integrated to structural needs	Structural integration			■	■	■	■	■	
	Pre-manufactured structure - no integration needed		■				■		■
	No structures installed.	■	■						
Space use tactics	Large range of property sizes	■	■	■	■	■	■	■	
	Modular flexible implementation	■	■	■	■	■	■	■	■
Urban integration	Integrate with public space	■							
	Integrated with patrons only	■	■	■	■	■		■	
	Isolated visual access					■		■	
	Isolated no access				■		■	■	■
Retrofitting capacity	Retrofit infrastructure	■	■				■		
	Reuse empty / unused sites	■	■			■	■		■
	Retrofit buildings			■	■	■		■	
Parameters		*Parameter observed on farm type*						■	

Farm type definitions:

A – Ground-based unconditioned | *B – Ground-based conditioned* | *C – Integrated unconditioned*
D – Integrated conditioned | *E – Integrated conditioned in-situ circular resources* | *F – Integrated conditioned ex-situ circular resources*
G – Indoor conditioned | *H – Indoor conditioned automated*

actually provide food for people around here … in the future, farms that we are building will be 10 times as big …" (Respondent 1, 13/01/2018)

A similar response to implementing the farms in existing unused and underutilised spaces were documented in Belgium and South Africa (Figure 3). In these cases, empty unused buildings and open spaces are used to accommodate ZAF projects.

In all these cases the ability of farmers to use local knowledge to identify project opportunities is critical. As confirmed by Matos and Batista (2013) and Krikser et al. (2016), these processes of spatial appropriation contribute to the universal bottom-up characteristic associated with UA. The documented projects often responded to specific local needs and spatial opportunities, and align local contextual solutions to solve resource provisioning and space use concerns by activating latent spaces within the city.

FIGURE 2. Images of typical overall implementation and detailed growing systems of the various farm types.

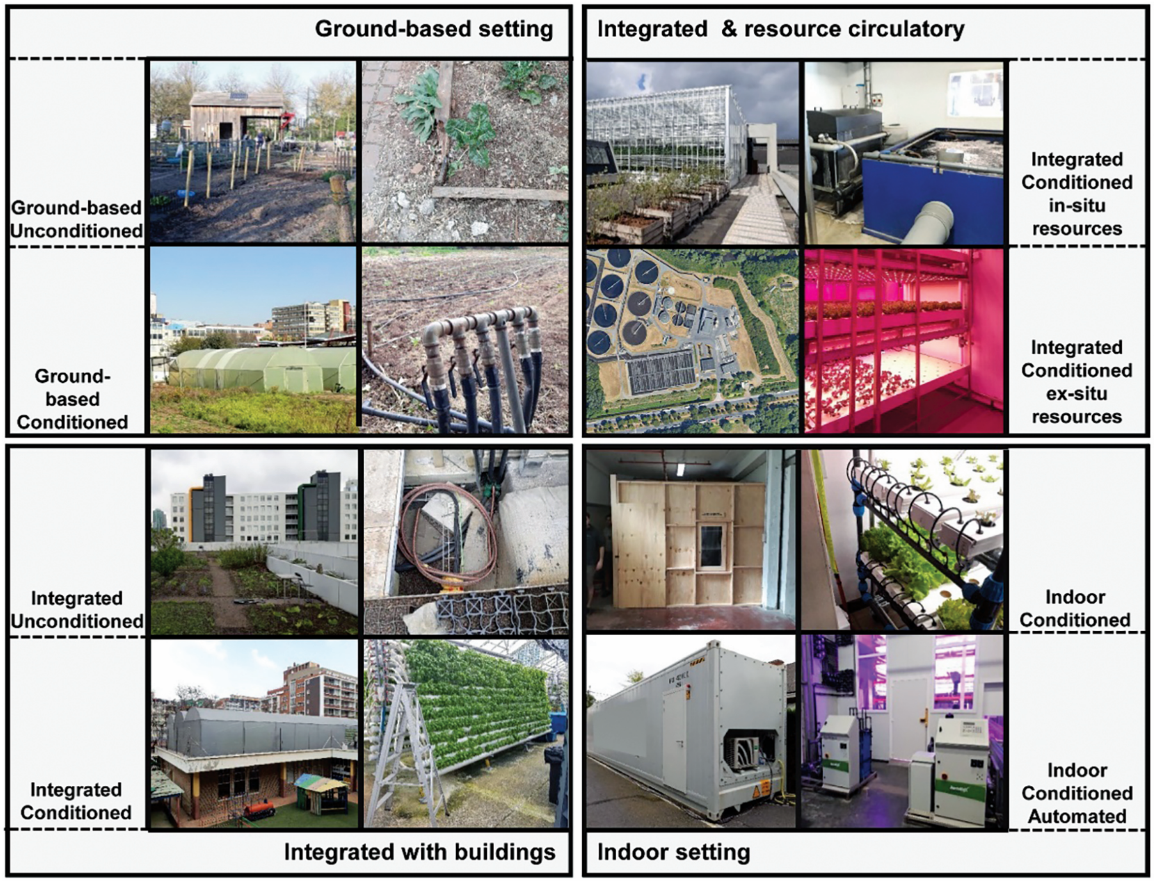


FIGURE 3. Example of a farm implemented in an unused or underutilised space. A farm implemented along a stormwater channel.

4.2 Flexible Spatial and Location Parameters

The study documented diverse UA and ZAF farm types varying in scale and context. This revealed location and spatial parameters that are flexible and adaptable. The analysis of the Singaporean farms uncovered a variety of spatial conditions, and the farm sizes (ranging from 1240 to 3220 m^2) and growing conditions differed significantly. These ranged from outdoor soil-based (ground-based unconditioned) to highly controlled indoor growing systems (indoor conditioned) (Figure 4).

The commercial Dutch and Belgian urban farms (ZAF and UA farms) often employ technologies that improve the microclimate to broaden the spatial conditions within which the farms function. This resulted in production-orientated farms using artificial lighting to improve the existing lighting conditions, and in many cases functioning completely in integrated indoor environments. These farms ranged from outdoor farms located on dormant land parcels (2960 m^2) to growing chambers positioned in storage cupboards (4 m^2) (Figure 5).

In the South African conditions, limited technological microclimatic amelioration strategies are being employed. In these projects the optimum microclimate is important to ensure their success, yet growing tunnels are often used to extend their growing season (Figure 5). While an optimum microclimate is critical in all these farms, their implementation scales still differed significantly (255 m^2 to 6200 m^2). While their diverse implementation scales ensure high spatial flexibility, the limited utilization of active indoor environment amelioration systems result in less site choice flexibility.

The spatial and implementation flexibility of ZAF and UA farms are closely related to the sophistication of technological inputs. The analysis revealed an inverse relation between the spatial flexibility and microclimatic needs, and the levels of technological inputs. The more complex and developed the technological inputs, the broader and less critical the spatial and microclimatic needs.

FIGURE 4. Diverse growing technologies used in a single farm in Singapore.

FIGURE 5. Range of farm types implemented in diverse spaces—ranging from unused open plots (left—unused bowling field), integrated with buildings (centre—unused parking area), to storage cupboards in buildings (right).

4.3 Multifunctional Programming

Napawan (2015) identifies the importance of multifunctional programming as principal spatial driver within community gardens in San Francisco, USA. Similarly, Wiskerke (2001, in Van der Ploeg and Roep, 2003) argues that the differentiating factor of UA farms is the multifunctional processes they undertake, not their location in the city.

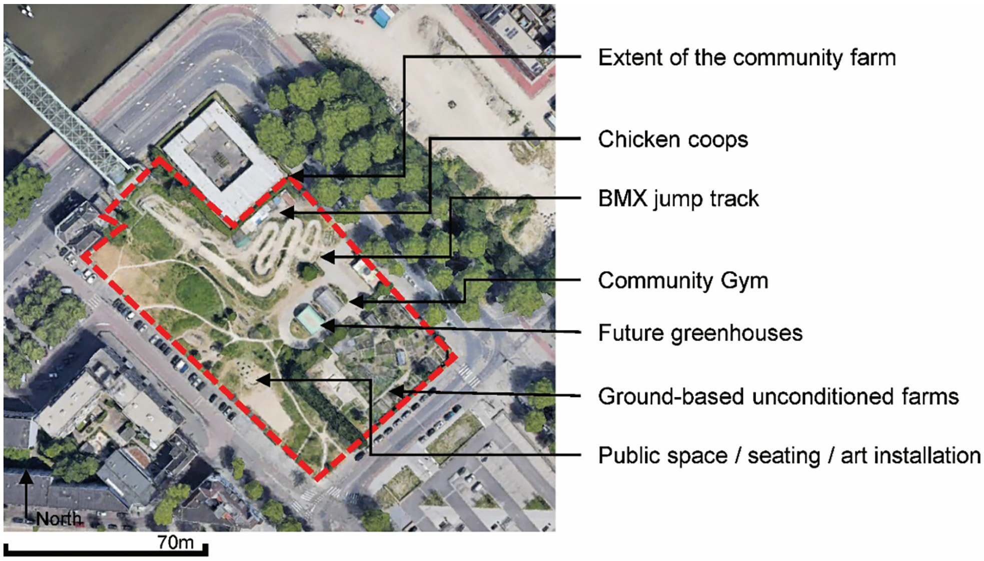
Similarly, the study found ZAF and UA farms that incorporate diverse multifunctioning programming, which include leisure spaces, events spaces, product manufacturing, and educational, social, and therapy programs, provide a stable social and economic basis for these projects.

Dutch and Singaporean farmers emphasized the importance of multifunctional programming. These farms focus on producing and serving food in on-site restaurants, promoting alternative leisure and education opportunities, experimenting with produce and growing technologies, and functioning as event spaces. A Dutch farmer argued that including a restaurant in a ZAF project generated additional revenue and effectively made it financially sustainable.

> "… this moment the sharing between our hospitality revenue and our sales revenue is 50-50, of course then it becomes a little bit harder to track, because we sell a lot of produce to the outside but we also transform a lot of produce on the inside …" (Respondent 12, 23/04/2018)

The same farmer stated that the restaurant and social space facilitated in connecting the immediate community with the ZAF project and local production processes. While these multifunctional spaces often manifest as spaces of consumption, projects promoting additional social and cultural functions were also documented. These include other leisure activities such as community gyms, BMX tracks, and space for social engagements (Figure 6). The Belgian examples reflect more varied responses to multifunctional programming. The study found projects intent on integrating multiple programs within the projects, while other farms actively discouraged such approaches. As the farms become more technologically focused and production orientated, a shift towards monofunctional farms is noted. In these cases, the lack of multifunctional

FIGURE 6. Multifunctional planning of a community garden implementing a range of additional functions that benefit the local community (Image adapted from Google Maps).



integration was not discussed, but the benefits to the food industry and improving food safety when automating and isolating the farms were emphasized.

In the South African context, a few UA farms (including some ZAF examples) implement multiple or additional functions. Limited multi-functional programming was documented, revealing that the bulk of the South African farms focus on production output.

While two South African farms, in this case ZAF farms, are associated with other programs on their respective sites, these farms are still production orientated, as reflected in their spatial layouts. As a result, they contribute little to the other programs beyond food production. One such ZAF farmer elaborated on multifunctional programming within his farm:

FIGURE 7. Farm type solely focused on food production.

> "… Yeah, when I started I [would] bring people around … There's too much administration, it's a mess. You know, I'm having tourists coming here … going through your business modelling … sending e-mails … it's not part of my business modelling … As much as I'd love to fit them in what I'm doing, but … I'm good, I'm not being arrogant or being cocky, but that's not why I came here …" (Respondent 9, 12/04/2018)

In conclusion, while many UA and ZAF farmers identify the importance of multifunctional programming of urban farms, the research revealed varied application thereof. Many farmers solely focus on production (Figure 7), while the farmers who implement multifunctional strategies all noted its importance to ensure their financial survival.

4.4 Urban Integration

Viljoen (2005) called for integrating UA and BIA farms within the urban environment to transform public spaces and improve the local food networks. While this spatial opportunity is important, in practice the integration of UA with the public realm is often limited (Napawan, 2016). In this study, the documented ZAF and UA farms also presented varying degrees of accessibility and urban integration.

The South African and Belgian farms revealed a dichotomous relationship with the city. While many farmers noted the importance of urban integration and the benefits from being located within the city, these farms are often located in isolated spatial conditions—on top of roofs, hidden in containers, or in isolated supermarket storerooms (Figures 3 & 7). Furthermore, there were limited attempts to include the public in these farms. The lack of urban integration results from two principal reasons being i) increased food safety through isolation, and ii) limiting their risk to theft or damage of goods and equipment, ultimately ensuring the availability and quality of produce to secure the farmers' income.

A selection of Dutch and Singaporean farms considered their projects as part of large urban regeneration initiatives and focused on re-programming existing derelict buildings to improve the local neighbourhood. In these cases, the ZAF projects were used as catalytic projects within buildings; alternatively, UA projects played active regenerative roles within the neighbourhoods. While the success of these projects documented in the study must still be determined, positive regenerative outcomes were noted in cities such as San Francisco and Detroit (Galt et al., 2014; Hashim, 2015).

While the spatial location and layout of conventional UA farms using soil-based organic farming practices can facilitate successful urban integration, these farms often embody varied levels of integration with the city. In some cases, the farms form part of larger public spaces (Figure 6), in other cases the farms function as extensions of restaurants, implying that only their patrons are welcome. Often farms have small gates to demarcate their extent, providing limited access control.

In conclusion, the farms presented varying degrees of urban integration. The farms that employed multifunctional programming reflected higher levels of urban integration, with multifunctional programming allowing users to interact with the farming processes.

4.5 Adaptable Technology

Implementing technologies and adapting them for local use were important technological strategies employed in many farms, specifically in the South African and Singaporean examples. This can be assumed as critical strategies allowing farmers to develop context-specific solutions and ensure the resilience of the project.

The importance of adapting technology to the local conditions were emphasized during the interviews with South African UA specialists. This form of locally appropriated technology can be defined as situated technology (Campbell, 2017), giving control to the local farmer to use, adapt and maintain the farm and agriculture system.

> "… Technology is both physical, the hardware aspects of things but it's also a software, it's a way of being able to use something or how you use something and sometimes it's a bit of both that go together …" (Respondent 24, 14/05/2018)

This study defines the adaptation of technology as either the adjustment of certain technologies to suit specific functions or conditions, or the integration of existing technologies with alternative elements to optimise their function. In many cases these *alternative elements* are used to perform completely new functions contrary to the original design intention. This highlights the importance of using appropriate technology that ensure both the technological transfer and the adaptation thereof. Different levels of technological adaptation were documented at the various farms.

In many South African cases, farmers use locally produced equipment supplemented with self-made components to create self-built systems (Figure 8). In all these examples the farmers endeavour through experimentation and reuse of products to develop their own solutions. This often results in combining flexible materials with specialist products to develop contextually appropriate solutions.

While cost saving often drive the development of adaptable equipment, farmers also experiment with the growing systems and conditions to optimise the produce yield. Farming techniques and technologies ranging from completely self-built to hybrids of adapted technologies were noted. This confirms that simple adjustable technological solutions are appropriate and feasible for both ZAF and UA land-uses.

FIGURE 8. Adapting existing technologies or objects for alternative use.

Similarly, the Singaporean examples revealed a high level of technology adaptation and self-built technologies. Several products normally associated with alternative functions were used. These included the use of scaffolding structures to construct shading structures, found objects as stands, and shading material as growing mediums. Solutions ranged from specialist products such as self-contained, automated growing chambers, to self-made growing systems. These farms all use diverse adapted growing systems to suit the local conditions and optimise the produce yield.

The Dutch farmers did not discuss the adaptation of technology. One can assume that in more technologically developed farms, specialists are employed to develop the system, yet the visual assessment documented various forms of adapted technologies in ZAF and UA projects. The site visits revealed the adaptation of technologies and the use of alternative building elements to perform new functions such as using hydroponic growth bed frames as service ducts, revealing hands-on testing and implementation approaches to developing farms.

In conventional UA, particularly community gardens, this form of adaptation through alternative use of materials is more prevalent in the Netherlands. In these examples the farming infrastructure is often self-made, with reused components and building materials. Similar to the South African examples, self-made infrastructure often incorporates specialized products to achieve desired outcomes.

The Belgian ZAF examples that were analysed can be considered more technologically sophisticated. During the interviews with the farmers and product suppliers, the adaptation of technologies to suit the specific conditions was less evident. Many farmers opted to use specialist equipment that are purpose-built for specific uses (Figure 9). We see therefore less on-site adjustments and changes to respond to specific needs. This does not necessarily result in inefficient systems as these are already optimised.

While the adaptation of technology is less prevalent in developed countries, this practice still takes place. A notable trend was the reduction of technology adaption as the technological complexity increases. This prompts concerns around the flexibility and local appropriation of technologies as the UA industry develops.

FIGURE 9. Examples of specialist growing systems used in ZAF farms.

4.6 Modular Solutions with Continued Flexibility

The implementation of agricultural technologies in diverse conditions reveals high levels of modularity and flexibility. The modular quality of these farming technologies is important as it allows various scales of farms to develop and grow, or in some cases shrink, over time.

These modular and flexible technological characteristics were documented throughout. The soil-based UA farms, often community gardens, presented high levels of flexibility and signs of changes over time. The ZAF examples using more sophisticated technological solutions to limit weight bearing and optimise produce output, revealed high flexibility at the project inception, yet less once implemented. One of the South African farmers noted that their growing system requires changes to optimise the produce output, but this proved impractical and difficult to undertake. In a second example, one of the South African ZAF farmers had to implement a completely new greenhouse structure and growing system due to unfavourable microclimate conditions. Ad-hoc, organic planning and development of the farms were documented in South African, Dutch and Singaporean contexts due to the flexible and modular quality of the technology, yet to enable this the technology must allow for flexibility and growth over time.

The study concludes that more advanced technological solutions result in highly flexible site choices. Concurrently, the inverse was revealed: in changing conditions, low-technological solutions present high adaptability, while sophisticated technology solutions are often inflexible once implemented.

5. THE SPATIAL AND TECHNOLOGICAL TRENDS DOCUMENTED IN ZAF EXAMPLES

The study reveals diverse spatial and technological characteristics in the implementation of the various UA and ZAF farms. As a result, specific parameters are not defined. Yet, categorising the technological and spatial resolutions and their relation to the farm types reveals several trends (Tables 1 & 2). As the farms move towards more sophisticated ZAF types, trends such as produce optimisation, loss of urban integration, levels of inflexibility, limited functional diversity, and concerns regarding technological adaption and agency were noted.

5.1 Trend—Produce Optimisation and Technology Optimisation

In projects using advanced technology, there is movement towards *Integrated conditioned* (often implemented as rooftop hydroponics) and *Indoor conditioned* farm types, a clear shift towards production intensity and optimisation was noted. This results in the optimisation of the growing environment and increasing the resource efficiency through monoculture farming, with the farmers often choosing a single technological solution to optimise produce outputs and isolate growing areas to increase control and food safety. In all these cases, technological optimisation was documented as principal spatial and technological drivers. Consequently, farmers neglect other spatial considerations and co-benefits to the immediate community (Figures 3 & 7).

5.2 Trend—Isolation from Surrounding Context

While all the farmers acknowledge their larger role within the urban environment, the analysis revealed increasingly isolated farming conditions as these farms integrate with architecture and become more technologically sophisticated.

The urban farms often revealed limited integration with the urban public realm, with *ground-based unconditioned* farm types (typically community gardens) exhibiting the highest level of integration with the public realm. Most of the ZAF farms that integrate with public space restrict access to patrons, and as the farms become more technologically developed, higher levels of isolation are employed to optimise growing conditions. In the case of *Indoor conditioned* and *Indoor conditioned automated* ZAF types, complete isolation was documented to optimise growing conditions, ensure food safety and secure the environment from unwanted damage and theft (Figure 10).

5.3 Trend—Inflexible Technology after Implementation

While some projects managed to continually experiment and evolve after their initial implementation, there are cases where integration with the structure and resource flows on site limit further adjustments. As the technological sophistication of the planting systems increase, the ability of the farmer to adapt the growing conditions to sudden changes became limited.

As a result, increasing the technological sophistication of the planting systems intensifies the farm's vulnerability to external disruptions and long-term changes. As the projects shift towards automated ZAF solutions, their ability to adjust to sudden major impacts such as loss of electricity, water and communication must be considered. This is especially relevant in rapidly developing urban contexts.

5.4 Trend—Lack of Multifunctional Programming

While many farmers advocated for and incorporated multifunctional programming to ensure financial sustainability, the study revealed less integration with alternative programs as the farm types become more technologically sophisticated. This trend can be linked to the focus on produce optimisation to increase revenue. Furthermore, as the farm typology moves towards automated farming processes, isolating the growth chambers to optimise and control the lighting, thermal and air quality is critical. All this results in reduced multifunctional programming, limiting the interaction between producers and consumers.

FIGURE 10. Example of a farm isolating itself from the immediate environment to ensure the security of its produce and equipment.

5.5 Trend—Agency and Technology Adaptation

Finally, the adaptation of the planting technology is increasingly difficult as the projects become technologically sophisticated. Within the context of developing countries, Campbell (2017) noted that new technologies must achieve the following:

a. include elements of the existing local technologies;
b. allow the farmers to test, transform and adjust it over time;
c. retain affordability to implement, adjust and maintain it.

During the analysis of the ZAF farms, many specialists indicated they only develop but do not manage the farms themselves. In addition, many companies provide turnkey solutions which control the complete farming process. This highlights concerns regarding the long-term sustainability and ability to implement these projects in poorer developing communities. The separation of the project development, implementation and management impedes technology and knowledge transfer, limiting the agency within these communities to adjust solutions over time.

6. THE IMPACTS OF THESE IDENTIFIED SPATIAL AND MATERIAL TRENDS

As one considers the implementation of the various UA and ZAF farms within the study regions, many of these examples followed bottom-up processes to develop alternative food sources and address urban sustainability. The fact that these farms are implemented in diverse left-over spaces, points towards developing this land-use option as networks of small-scale urban acupuncture projects. Furthermore, the many low-technology examples (*ground-based unconditioned* to *integrated conditioned* farms) revealed high levels of technological adaptation and adjustment to local conditions (See Tables 1 and 2). This provides opportunities to build agency and improve the adaptive capacity of local communities.

These farm types are critical to implement in rapidly urbanizing cities that are confronted with multiple social, ecological and economic problems, as well as developmental pressures. The modularity and flexibility of the technologies allow for the rapid deployment and adjustment of these land-use functions as the local conditions change.

In contrast, this analysis reveals concerning trends emerging within the ZAF industry. Implementing technological solutions that limit farmers' ability to adjust and adapt to local conditions, reveal long-term sustainability concerns regarding these projects' technological suitability. The study notes that adjusting this technology to specific, and often rapidly changing conditions, is important to ensure the success of these farms. As the bulk of global urbanization will take place in the developing world (United Nations, 2019), often following informal uncontrolled processes (Chobokoane and Horn, 2015), developing technologies that can function within uncertain and rapidly changing conditions are critical. Whether the implementation of these technologies in new informal urban contexts is feasible begs careful consideration.

While UA and ZAF projects are often considered as environmentally and socially sustainable initiatives, the spatial and technological analysis highlights the influence that architects and spatial designers have when promoting these land-use forms as part of sustainable projects. Decisions that result in specific spatial and technological solutions ultimately translate into spatial and technological outcomes that either promote sustainable outcomes or inhibit the sustainability capability of the end user.

7. CONCLUSION

This paper intended to shed light on the spatial and technological implementation of UA and ZAF farms as assumed sustainable land-use forms within urban contexts. It documented the spatial and technological characteristics of both UA and ZAF within South Africa, Belgium, the Netherlands and Singapore in order to differentiate the ZAF-specific trends developing in the industry.

The findings revealed different levels of flexibility and modularity throughout the industry. These types range from low-technological solutions that are highly flexible and evolve during implementation and management, to technologically sophisticated projects that are flexible in their microclimatic and spatial requirements, yet rigid and inflexible once implemented.

The sophisticated ZAF farms revealed certain trends, oftentimes resulting in mono-functional, isolated, inflexible applications that are ignorant of the farmers' needs, and increasingly focused on production optimisation. The resultant inflexible ZAF solutions, which require stable resource inputs, point towards vulnerable applications with limited capacities to adapt to informal, rapidly urbanizing, developing contexts.

It is important to highlight the need for diverse forms of farm types and their contextually relevant application. If the intention is to use left-over and under-utilized urban spaces to create economic opportunity and reduce the food transportation miles of high-value commercial crops, technologically sophisticated isolated projects make sense in urban conditions which can provide a stable infrastructure to support these very vulnerable systems. On the other hand, if the intention is to use UA in poorer or developing contexts as a catalyst for urban regeneration and community building, or providing local food security through traditional crops or crops with a high nutritional value, simpler, more robust and multifunctional approaches are more appropriate.

As the livelihood and wellbeing of future urbanites are critical in rapidly growing cities in developing contexts, the study highlighted the importance of understanding the implications of promoting ZAF within these cities, hopefully prompting the industry to develop locally responsive, adaptable technology that follows bottom-up capacity building processes. It furthermore identified the technological and spatial implications of this new land-use form, thus providing guidance to architects and spatial designers when choosing ZAF as socially and environmentally sustainable land-use forms.

While the study contributes to the UA discourse and its application in the built environment by analysing the spatial and technological definition of UA and ZAF farms, it has certain limitations. The study did not consider aspects such as the management and implementation of UA and ZAF projects, social integration of the two forms, limiting the risk during the retrofitting of farms to existing spaces or buildings, the economic sustainability of these farms, and the larger impacts on the local communities. These aspects present opportunities for future consideration, especially in how they manifest in both developed and developing contexts. Furthermore, more longitudinal research is needed to consider the robustness and appropriateness of these ZAF farm technologies within developed and developing contexts. Understanding these range of factors will ultimately further our understanding of contextually appropriate technologies and their application in these diverse contexts.

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ADDENDA:

TABLE 3. Schedule of terms used to define selected characteristics of the various farm types.

Terminology	Description
Growing medium	Organic or inorganic matter that holds the plants. Diverse types used, some hold limited moisture and nutrients.
Nutrients	Mineral and organic matter used as nutrients to stimulate plant growth.
Recirculated—thermal energy	Waste thermal energy captured locally and reused in the growing space.
Recirculated—nutrients	Waste matter converted through aerobic or in-aerobic process into nutrients that are used for growing produce
Soil management	The strategic management and cultivation of the soil to ensure optimum produce output
Cold Storage	Thermally controlled storage, lowering pathogenic growth and biological degradation of the food produce.
Growing Tunnel	Enclosed growing space that allows for insolation but limited airflow and thermal losses.
Growing system	Artificial technical growing system within which the produce grows.
Growing bed	Artificial system of trays or spaces within which produce are grown.
Organic planting	Use of organic planting, growing and harvesting strategies that excludes the use of genetically modified produce, artificial pesticide, herbicides or nutrients.
Microclimate concerns	Considering the microclimatic parameters of the site and produce requirements.
Organic layout	The unplanned development of the farm layout, allowing it to change and growth over time.
Anthropomorphic	The scale and spatial layout adjusted to the human body.
Produce-optimised	The scale and spatial layout only consider the optimisation of the production output.

TABLE 4. Details of interview respondents.

Respondent Number	Place	Date	Role/Occupation	Description
1	Singapore	15.01.2018	**Farmer**	**ZAF farmer**
2	Singapore	16.01.2018	**Farmer**	**ZAF farmer**
3	Sydney, Australia	21.03.2018	**Specialist**	**Researcher**
4	Cape Town, South Africa	04.04.2018	**Product Developer**	**Vertical farming technology**
5	Pretoria, South Africa	05.04.2018	**Specialist**	**Project developer**
6	Pretoria, South Africa	11.04.2018	**Specialist**	**Researcher**
7	Pretoria, South Africa	11.04.2018	**Farmer**	**Aquaponics / ZAF farmer**
8	Johannesburg, South Africa	12.04.2018	**Specialist**	**Researcher**
9	Johannesburg, South Africa	12.04.2018	**Farmer**	**ZAF farmer**
10	Amsterdam, Netherlands	18.04.2018	**Specialist/Farmer**	**Researcher / UA farmer**
11	Wageningen, Netherlands	19.04.2018	**Specialist**	**Researcher**
12	Den Haag, Netherlands	23.04.2018	**Farmer**	**ZAF farmer**
13	Amsterdam, Netherlands	24.04.2018	**Farmer/Developer**	**ZAF Farmer**
14	Amsterdam, Netherlands	24.04.2018	**Farmer**	**ZAF Farmer**
15	Venlo, Netherlands	25.04.2018	**Farmer**	**Researcher**
16	Brussels, Belgium	26.04.2018	**Farmer**	**BIA farmer**
17	Brussels, Belgium	26.04.2018	**Farmer**	**ZAF Farmer**
18	Brussels, Belgium	26.04.2018	**Farmer**	**ZAF Farmer**
19	Ghent, Belgium	27.04.2018	**Farmer**	**Researcher / BIA Farmer**
20	Ghent, Belgium	27.04.2018	**Farmer**	**Researcher / BIA Farmer**
21	Waregem, Belgium	27.04.2018	**Product Developer/ Farmer**	**BIA farming technology**
22	Johannesburg, South Africa	08.05.2018	**Farmer**	**UA farmer**
23	Pretoria, South Africa	11.05.2018	**Farmer**	**UA farmer**
24	Johannesburg, South Africa	14.05.2018	**Specialist**	**Researcher**
25	Pretoria, South Africa	15.05.2018	**Specialist**	**Researcher**
26	England	17.05.2018	**Specialist**	**Researcher**
27	Netherlands	26.05.2018	**Specialist**	**Project developer / Professional**
28	Germany	26.05.2018	**Specialist**	**Project developer / Professional**
29	Netherlands	12.06.2018	**Specialist**	**Project developer / Professional**

TABLE 5. Details of the farms visited during the study.

Nm	Country	Date visited	Farm type	Location & Urban Context	Size (m2)
1	Singapore	12.01.2018	ZAF, BIA, BG-UA	Outside city centre & Medium density mixed use	3,220
2	Singapore	13.01.2018	ZAF	City centre & High-density mixed use	1,240
3	South Africa	11.04.2018	ZAF	Outside city centre & Low density residential	680
4	South Africa	12.04.2018	ZAF	City centre & High-density office and commercial	255
5	Netherlands	18.04.2018	BG-UA	Outside city centre & Medium density residential	2,960
6	Netherlands	19.04.2018	BG-UA	Outside city centre & Industrial	14,400
7	Netherlands	20.04.2018	BG-UA	Outside city centre & Medium density residential	9,400
8	Netherlands	23.04.2018	ZAF	Outside city centre & High-density mixed use	3,280
9	Netherlands	24.04.2018	ZAF	City centre & High-density mixed use	4
10	Netherlands	25.04.2018	ZAF	City centre & High-density office and commercial	1,470
11	Netherlands	25.04.2018	ZAF	Outside city centre & Low density mixed use	50
12	Belgium	26.04.2018	ZAF	Outside city centre & Medium density mixed use	9
13	Belgium	26.04.2018	BIA, ZAF	City centre & High-density mixed use	6,270
14	Belgium	27.04.2018	ZAF	Town centre & Low density mixed use	15
15	Belgium	27.04.2018	BIA	Outside city centre & Medium density mixed use	50
16	Netherlands	29.04.2018	BG-UA	City centre & High-density office and commercial	530
17	South Africa	08.05.2018	BG-UA	Outside city centre & Low density mixed use	6,200
18	South Africa	11.05.2018	BG-UA	Outside city centre & Low density residential	640
19	South Africa	20.08.2018	ZAF	City centre & High-density residential	320
20	South Africa	20.08.2018	BG-UA	City centre & High-density mixed use	7670
21	South Africa	18.04.2019	ZAF	City centre & High-density Office and commercial	380
22	South Africa	21.05.2019	ZAF	Outside city centre & Medium density office and commercial	540
23	South Africa	05.06.2019	ZAF	Outside city centre & High-density residential	340
24	South Africa	03.06.2019	ZAF	Outside city centre & Medium density	540
25	South Africa	10.06.2019	ZAF	City centre & High-density commercial	270
26	South Africa	16.07.2019	ZAF	City centre & High-density office and commercial	690
27	South Africa	16.07.2019	ZAF	City centre & High-density office and commercial	255

Abbreviations: Nm—Farm number; GB UA—Ground-based urban agriculture; BIA—Building Integrated Agriculture; ZAF—Zero acreage Farming

TABLE 6. Details of the farms visited during the study (Continued).

Nm	Function	Produce	Employment	Users
1	Comm	Leafy greens—Rocket, Basil, Lettuce, Pak choi, Lavender, Mint, Porcelain, local indigenous produce, Mushrooms, Black soldier flies	Formal employment	Employees, Restaurant Patrons, Tourists
2	Comm	Leafy greens—Rocket, Basil, lettuce, Pak chiy, Lavender, Mint, Porcelain, local indigenous produce	Formal employment	Employees, Restaurant Patrons,Tourists
3	Comm	Leafy greens; Herbs; Fish	Formal employment	Employees
4	Comm	Basil ; Coriander	Self-employed	Employees
5	Co-gar	Diverse Vegetables	Volunteer	Volunteers, Local community
6	Co-gar/ Comm	Diverse Vegetables; Poultry	Volunteer / Formal employment	Volunteers, Restaurant Patrons
7	Co-gar	Diverse Vegetables	Volunteer	Local Community
8	Comm l	Leafy Greens; Tomatoes; Fish	Formal Employment	Employees
9	E&R	Leafy greens	Volunteer	Volunteers only
10	Comm	Diverse Vegetables	Formal Employment	Employees, Restaurant patrons
11	E&R	Leafy Greens	Research project	Researchers
12	Comm	—	Self-employed	Employees
13	Comm	Leafy Greens; Tomatoes; Fish	Formal Employment	Employees, Restaurant patrons
14	Comm / E&R	Leafy Greens; Experimental proof of concept crops	Formal Employment	Researchers, Employees
15	E&R	—	Research Project	Researchers
16	Co-gar	Diverse vegetables	Volunteers	Local Community, Volunteers
17	Comm	Diverse Vegetables	Self-employed, casual labourer	Employees
18	Comm	Diverse Vegetables	Self-employed	Employees
19	Comm	Leafy Greens—Spinach and basil	Self-employed	Employees
20	Edu	Diverse Vegetables	Volunteer & Educational	Employees, Students
21	Comm	Leafy Greens	Self-employed	Employees
22	Comm	Diverse Vegetables; Pak choi, Basil, Lettuce, Spinach, Rosemary, Tomatoes, Mint,	Self-employed & Formal employment	Employees, Customers
23	Comm	Leafy greens—Spinach	Self-employed	Employees
24	Comm	Leafy greens—Basil, Coriander	Self-employed	Employees
25	Comm	Leafy Greens—Lettuce	Self-employed	Employees
26	Comm	Leafy Greens—Lettuce	Self-employed	Employees
27	Comm	Leafy Greens—Basil, Lettuce, Lemon balm	Self-employed	Employees

Abbreviations: Nm—Farm number; Co-Gar—Community garden; Comm—Commercial; E&R—Experimental and Research; Edu—Educational