Chapter 9: Synthesis of the findings

1. Introduction

This chapter synthesizes the findings from the three preceding research investigations, focusing specifically on the potential to retrofit existing unused spaces in multi-storey urban environments with building-integrated agriculture (BIA) as a climate change adaptation (CCA) strategy to modulate the indoor thermal environment. Due to the exploratory nature of the research problem, it was necessary to follow a mixed method research design that required a final synthesis of the research findings from the various research phases (Creswell & Clark 2011). To retain the pragmatism paradigm in the study, the research aimed to replicate reality as closely as possible. This resulted in research findings from the first two research objectives informing each other and the final research objective. This final chapter synthesizes the findings.

This chapter interrogates the CCA potential of this novel land-use type in general, but also specifically considers the CCA potential of a predominant local BIA farm type (passively controlled, non-integrated rooftop greenhouses). The interrelated approach to analysing the various findings is unpacked in Figure 105; it reflects the reciprocal relationship between the farms and the built environment. The material and spatial quality of the built environment informs the choice of farm types and their implementation; whilst the farms also affect the performance and spatial quality of the built environment. Furthermore, the study identified the three considerations being the spatial manifestation, the technological development and application, and the existing and adjusted microclimate. The farms and the built environment impact these three factors, but these three parameters also influence each other. Resultantly, by assessing these three factors one can consider the impact that BIA as a retrofitting strategy has on the built environment, and finally its CCA potential as land-use form in Hatfield.

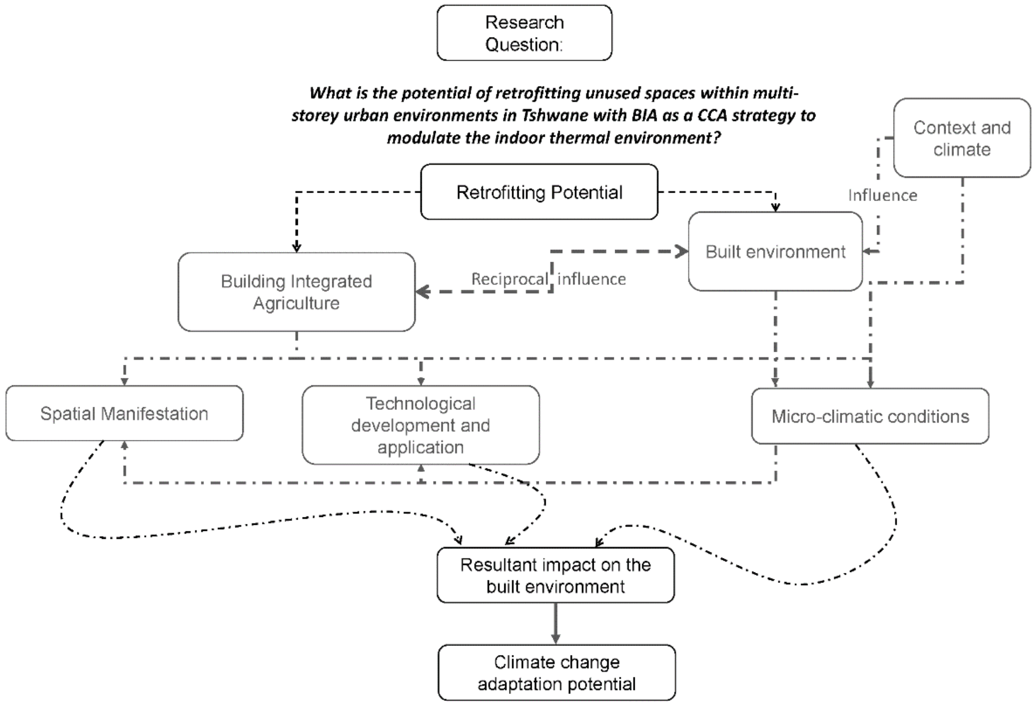

Figure 105: The synthesis of the research objectives towards understanding the CCA of BIA in Southern African urban contexts.

The chapter is structured along two sections. It starts with a definition of climate change adaptation within this project. Subsequently, it discusses the potential of BIA as a land-use form in terms of its capacity to improve the local CCA capability.

2. Defining climate change adaptation within the context of the project

Retrofitting our current cities with CCA tactics can address the ingrained inefficiencies and risks posed to citizens in the built environment. Identifying the appropriate response strategy that contributes to the general CCA agenda of a city, in this case Tshwane, is therefore important. In order to understand the CCA potential of such a strategy the basic definition of CCA must be outlined.

The IPCC (2014c) defines climate change adaptation as "… (the) adjustment (of natural and human systems) to actual and expected climate and its effects… to moderate or avoid harm or exploit beneficial opportunities". While this gives clear guidance to CCA strategies that need to first and foremost limit the exposure and sensitivity of inhabitants to climate change-driven risks, this definition effectively addresses multiple spheres ranging from social, economic to environmental aspects. To affect change, the strategies must address all these multiple fields (Sharpe et al. 2016).

As a result, CCA strategies must be better integrated and embedded within the structure or their context to enable significant adaptation. O'Brien (2018) argues that in order to impel change, CCA strategies must address three spheres, the practical (or technological problems), political systems or structures, and personal values or beliefs. While this study focused on the technological sphere to understand the spatial, material requirements of BIA farms and its resultant impact on the built environment, by extension the building user, the CCA potential of BIA farms was considered in a more structured manner according to the following criteria:

- Fitness of the solution to the context.
  As the most important criterion, the appropriateness of the solution to the specific context must be considered; this includes several aspects such as the users, built environment characteristics, local natural resources and climate. Furthermore, Smith (2010) calls for proactive planning that understands the local risks, and is specifically cognisant of the long-term exposure to climate change-induced risks. Kithiia (2011) further argues for national policies to be adjusted to ensure local relevance. Finally, the appropriate solutions also require ongoing monitoring and assessment of the outcomes (Mukheibir & Ziervogel 2007). While Mukheibir and Ziervogel (2007) intend this to take place after implementation, technology is available to assist us with the upfront modelling to understand the potential resultant impact of a solution.

- Capacity to implement the solution.
  Adaptation strategies should not only focus on the potential scale of the hazards, but also consider the adaptive capacity of communities and individuals to limit their own sensitivity and exposure to these hazards (O'Brien & O'Keefe 2014). Adaptive capacity has numerous factors affecting it, including income distribution and availability of resources, access to knowledge, the immediate environment, existing infrastructure, and human capital (Carter et al. 2015). A study by Lwasa (2010) identifies that adaptive capacity is often present in many communities on a household level, but calls for local policies and macro structures to assist the agency of local communities. The identification and implementation of technologies are one of the factors affecting the local adaptive capacity. Campbell (2017), therefore, argues that technology must be accessible, intelligible, and adjustable at a grass-root level. This calls for a technological solution that responds to the complexity of place, user and function, and adapts as needed.

- Deep structural adjustments.

  O’Brien (2018) fittingly warns that climate change is often considered an adaptive problem requiring only slight changes to our current modes of practice. She continues calling for the identification of leverage points where significant change can be facilitated. While this calls for the identification of appropriate points of intervention, Pelling et al. (2015) argue that root causes and drivers of vulnerability must be adapted as well. Understanding the ingrained capacity to transform the existing, forms part of identifying points of intervention (Ziervogel et al. 2016). While many studies identify the social sphere as an important leverage point, this study argues for an in-depth understanding of the urban context itself to adjust and limit the vulnerabilities in our cities.

- Future orientated long-term solutions.

  All adaptation measures have significant costs associated with it, and O’Brien and O’Keefe (2014) argue that final gains in the form of lower morbidity and mortality must outweigh the initial inputs. By extension, this demands an understanding of the long-term impacts of these initiatives. This was adeptly done in a project by Gething and Puckett (2013) which documented and modelled several built projects to consider the expected climate change impacts on these projects. Their findings point towards significant benefits in preparing the current built environment once the long-term impacts are understood. As a result, developing the means and using these to understand long-term impacts are important when considering the potential of CCA strategies.

- Flexible solutions.

  Roaf et al. (2009) remind us that the ability to adapt to changing conditions has been a perpetual characteristic of societies throughout history. These often include flexibility and adaptability on multiple levels. As we enter an era of significant uncertainty, retaining the ability to modulate and adjust interventions is critical. De Souza et al. (2015), and O’Brien and O’Keefe (2014) call for emergent, flexible solutions that enable tight feedback loops to optimise their response measures. Retaining this quality in the built environment is essential.

The above-mentioned criteria were considered during the discussion on how well BIA farms, in particular the form currently implemented in Tshwane and Johannesburg, are suited as local CCA strategies.

3. The climate change adaptation potential of building-integrated agriculture

3.1. Fitness of solution to the local context

In terms of the fitness of the CCA solution to the local context, understanding the potential space available to be retrofitted in the Hatfield neighbourhood is critical. The study identified a series of five space types that constitute 11% of the neighbourhood. Of these spaces, accessible concrete roofs (open roof level spaces) and parking areas (open ground level spaces) were identified as the predominant spaces available for retrofitting. These constitute 7% of the total space covering, as well as 43% of the total number of unused and underutilised spaces identified in the study.

Furthermore, in terms of the risk assessment, the study found that 48% of these spaces share multiple characteristics that increase the local exposure to climate change-related hazards as well as host a series of opportunities for adaptation benefits should it be retrofitted. These hazards and opportunities include lowering heat exposure, limiting UHI, managing stormwater quantities, generating renewable energy and addressing local food insecurity. As 73% of these spaces are located on public property, adjusting these spaces present the opportunity for these public entities to contribute as a public good to the greater community.

In terms of the potential of these unused or underutilised spaces to accommodate BIA and urban agriculture (UA) projects, 42% of all the documented spaces have the appropriate site characteristics for these land-use types. This equates to 6% of the whole neighbourhood. Roof spaces make up 59% of these spaces and cover 3% of the whole neighbourhood.

Upon considering the spatial and technological requirements to implement BIA initiatives, the findings from research objective B identified this land-use type as highly flexible and often implemented in diverse spatial conditions. An inverse relationship between the microclimatic requirements and the technological sophistication of the growing systems was identified. As the technological sophistication increases, less spatial conditions need to be met. As a result, the industry has developed a number of innovative solutions that enable farmers to grow crops in most conditions and farmers use it effectively to identify diverse spatial opportunities for BIA projects.

Finally, in terms of research objective C, the assessment of current technologies that are being implemented in Johannesburg and Tshwane provided insight into how the rooftop greenhouses (RTGs) perform and their resultant impact on the built environment. These RTGs have no climate control measures and beyond the use of the building roofs these RTGs are not integrated with their associated buildings. Finally, these RTGs are specifically considered in the South African context. The findings from the fieldwork conclude that the greenhouse systems used in these farms do not provide farmers with the added control to improve the microclimate. Oftentimes, the RTGs have microclimatic zones forming within, limiting the ability of the farmers to optimise the greenhouse for specific crop types. Furthermore, while the resultant effect size of greenhouse structures to improve their interior microclimates are small, the largest influence was documented during the hottest period of the day. As a result, the greenhouses intensify already adverse conditions.

Based on these test cases, a number of simulations were run considering current and future impacts of retrofitting buildings with RTGs (See Chapter 8, Section 3.1-3.5). The simulations revealed that in terms of indoor temperatures, that highly insulated buildings (SANS 10400XA compliant) perform marginally better than retrofitting older poorly insulated buildings (built prior 2011) such as those found in the Hatfield neighbourhood. Notably, a retrofitted highly insulated building experiences up to 0.8 K drop in average temperatures; in contrast, the poorly insulated building simulation has marginally higher indoor temperatures. While the higher insulation benefits the indoor environment under current climatic conditions, the simulation of future climate change conditions (2100 simulation) revealed that the highly insulated building experiences the highest indoor temperature increases, up to 1.32 K, when completely retrofitted with RTGs.

On the other hand, the simulations revealed that once strategies to actively cool the indoor environment are employed, the performance of the highly insulated building changes. In this case, the higher temperatures in the RTG translated into an overall building energy consumption increase of 3.4% (current weather conditions) to 3.8% (2100 simulation). This results from a 9.6% (current weather conditions) to 14% (2100 simulation) increase in cooling and heating loads on the top floor. While these impacts are findings from the SANS 10400 XA compliant models, the highest single adverse impact was documented for the poorly insulated building simulation (SANS 10400XA non-compliant) during which the cooling load on the top floor increased with 17.6% under the current weather conditions and by 11.9% under A2 climate change affected conditions. Notably, the proportional adverse impact of the RTG is worse under current climatic conditions, although in absolute terms the cooling load increase due to the RTG’s impact under A2 climate change conditions is significantly worse (a 69% increase was documented).

In terms of their final performance, RTGs have adverse impacts on the built environment when they are:

i. not contextually appropriate in terms of their design,
ii. neglect to employ active systems to manage their indoor environment,

iii. not fully integrated within the built environment in terms of resource circulation strategies.

These RTG’s increase the exposure of the indoor environment to outdoor heat gains due to overheating in the greenhouses and further intensifies under future climate change conditions. While the study did not simulate heatwave conditions, the findings support the concern that the retrofitting strategy will further increase inhabitant’s exposure to the hot conditions during heatwave events.

In conclusion, it must be noted that this passively controlled non-integrated RTGs as BIA farm type, does not present a successful CCA strategy for South African conditions. Due to the increase in heat exposure to the indoor environment, this strategy adds to the local risk profile. Furthermore, the future long-term impacts are worse as it exacerbates the expected hotter climate conditions. During discussions with the farmers it was noted that the lack of microclimatic control does not give them any advantage within the food industry. Accordingly, this solution affects the building and its users, increases the air-conditioning energy consumption adversely, affecting the local UHI, and finally provides little advantage for the farmers themselves.

3.2. Capacity to implement adaptation strategies and flexibility to adjust these to change

In terms of the local capacity to implement this solution, the local space availability and technological requirements were considered. In terms of the available unused and underutilised spaces in the Hatfield neighbourhood, it is important to note that three space types were identified for potential food cultivation. These include open roof level spaces, open ground level spaces, and ground level spaces attached or in close relation with vertical building façades. The material and spatial analysis of BIA farm types concluded that RTGs are the predominant type of BIA farms which use NFT hydroponic systems (integrated conditioned farms). This was also confirmed in a study by Goldstein et al. (2016).

The analysis revealed in terms of area coverage, 30% of the unused and underutilised spaces are rooftop spaces that can be used for agricultural cultivation (Chapter 5, section 6.2), 60% of these roof spaces are accessible to the public, while the remaining 40% are more difficult to access. Both types of roof spaces are feasible for retrofitting, as the analysis of existing farms documented many instances where farms are located in isolated spaces with limited access.

These roof spaces make up a total of 70,900 m^2 and 75% of the spaces range from 500 m^2 to more than 2000 m^2. This range of available spaces correlates with farm sizes that were documented during the observational study, confirming that the neighbourhood has a number of spaces available that can be retrofitted. The existence of these spatial opportunities can count towards a certain level of adaptive capacity in the neighbourhood.

The spatial and technological documentation of existing farms identified several technologies that will enable the use of these spaces. However, as noted in Chapter 6 (Section 3), as a typical farm type shifts towards BIA farm typologies, so do the technological requirements. This often results in increased difficulty for the farmers to adjust the technologies as needed, as well as limiting access to the technologies due to costs. This was noted from analysing the RTGs in Tshwane and Johannesburg (Chapter 7, section 3), which highlighted the inability of the farmers to optimise their growing conditions. This emphasises the fact that technology can either improve the in-use adaptive capacity or inhibit it. On the other hand, the technological development steadily moves towards modular solutions that allow for easy implementation and growth should the farm be successful. This reveals both development opportunities and, unfortunately, the barriers to access the technology. Furthermore, the findings also emphasise the importance of addressing the flexibility of technological solutions.

As a result, the adaptive capacity of BIA as a land-use form can be retained, as is often noted in the UA discourse (Dubbeling & De Zeeuw 2011; FAO 2012), as the available space already allows for it. Nevertheless, to improve the adaptive capacity of this land-use form, access to the technology must be ensured as it requires increased upfront costs, which can exclude a number of individuals. Furthermore, as argued by Campbell (2017), ensuring that farmers can adjust the technology to suit the specific context and use is critical. This calls for designing and developing contextually appropriate technology that improves the adaptive capacity.

3.3. Future orientated solutions

The study simulated the current and future impacts of a typical BIA farm type (in this case a series of locally developed RTGs). As noted in section 3.1, the CCA strategy performs poorly in both current and future conditions. Considering the increased exposure of South African cities to higher thermal conditions, the application of this technology on empty roof spaces can be considered a mal-adaptation. Unfortunately, the current condition of these existing roof spaces in the built environment further increases the inhabitants' exposure to these adverse climate change impacts. This points to both a concern and opportunity for future solutions; pivotal in this quandary is the application of technological systems.

The findings from the AGY farm, located in Tshwane (Chapter 7), reveal a slight difference in its performance that can be attributed to the different greenhouse technology implemented on this farm. This calls for improved design, more simulations, and long term monitoring of technological systems to ensure beneficial impacts on the greater built environment.

3.4. Deep structural change

The analyses undertaken in Chapters 7 and 8 support the notion that BIA can have deep structural impacts on the greater built environment, and by extension on the building occupants. Unfortunately, the specific technological solution, and its application within the context of the study, results in negative systemic impacts. So, as not to repeat what has been stated before, Chapter 5 identified several spaces in the Hatfield neighbourhood that can be retrofitted to address a series of climate change-driven risks. Adjusting the technology and developing appropriate smart solutions to benefit both the farmer and the building user have the potential to bring about the deep structural change as argued by Pelling et al. (2015). This can affect change both on a technological level, by improving the efficiency of the built environment, and on a social level, by providing alternative work opportunities and increasing the availability of locally produced food.

Finally, the spatial and material analysis of UA and BIA farms (Chapter 6) documented a range of farms that contribute to the quality of the local public space to varying degrees. The study also identified trends in the BIA industry, where farms are increasingly isolated to limit public access. The mapping of the unused and underutilised spaces identified several spaces that can contribute to the public space quality of Hatfield. This requires a change in programming and setting out of BIA farms by exploring the inclusion of multifunctional programming and spatial adjustments of these farms to accommodate both production and social functions. This can contribute to building local social ties and local support networks that can in turn improve the local social CCA capacity (Battersby & Marshak 2013; Ziervogel et al. 2016).

4. Conclusion

This chapter synthesizes the findings from the previous research objectives to gain a deeper understanding of the CCA potential of BIA when retrofitted to buildings in the Tshwane context. The synthesis concluded that the potential to function as a CCA tactic is embedded in the BIA land-use form, but the resultant application of this strategy eliminates any potential benefits. Unfortunately, the use of passively controlled, non-integrated RTGs, as documented in this study, provides little benefit to the farmers, neither to the associated buildings, nor the greater context.

It also emphasises that use of technology has extensive impacts. In this case it affects the local CCA capability in terms of the local adaptive capacity, flexibility to adjust to changing conditions, ability to bring about deep-seated long-term changes, and unlocking co-benefits to the greater context. The resultant performance of the technological solution highlights the impact if solutions that work in different contexts, are implemented under alternative microclimatic conditions without the required adjustments to the application.

To address this concern, the technological application and solutions must be developed and tested for contextual application. This requires contextually appropriate bioclimatic design solutions that are integrated with the built environment and greater context on multiple levels, take cognisance of changing user needs and ability to adjust it, and focus on limiting the engrained local exposure to climate change-induced hazards. If effectively undertaken this can potentially provide the CCA co-benefits as advocated by many authors in the UA discourse.