Chapter 3: Research Design and Methods

In response to the need for more empirical research within urban agriculture (UA) and building-integrated agriculture (BIA) discourses, as identified in the preceding literature review, the study is premised in a pragmatism paradigm. The research design followed a concurrent mixed method approach to consider the potential of retrofitting unused spaces in the city of Tshwane using BIA as climate change adaptation (CCA) strategy to modulate the indoor thermal environment. The chapter is structured in four sections. It starts by discussing the research paradigm and overall approach to structuring the mixed method research design. The next section then expands on the research design and protocol for each of the three research objectives. The third section discusses the research ethics considerations of the study, before finally concluding the chapter.

1. Research paradigm and research design

This research project is premised on a pragmatism paradigm. This research paradigm originates from the work of Charles Peirce, William James and John Dewey around the turn of the 20th century (Saunders et al. 2016), and was developed by communities of practice arguing for research that has practical consequence (Denscombe 2008; Saunders et al. 2016). As paradigms and methods are underpinned by specific ontological assumptions (how reality is perceived), as well epistemological perceptions (what we deem as valid and legitimate knowledge) (Saunders et al. 2016), pragmatism responds to specific real world problems and aims to develop methods to inform practice.

Pragmatism is often associated with studies that set out to develop applied knowledge outcomes with specific practical results (Neuman 2014). The strength of this philosophy lies in its endeavour towards relevant, context-specific solutions (Saunders et al. 2016). In order to satisfy the ontological and epistemological requirements of this research paradigm, a variety of methods are employed to reflect reality as truthful as possible (Johnson & Onwuegbuzie 2004; Hofstee 2006; Denscombe 2008; Creswell & Clark 2011). Rather than emphasizing the differences between qualitative and quantitative research methods, this research paradigm sees these various methods as complementary (Creswell & Clark 2011). As a result, research within the pragmatism paradigm often follows mixed or hybrid methods (du Toit 2015). This allows this paradigm to be ontologically and epistemologically open and flexible (Creswell & Clark 2011).

In contrast to a reductionist approach, which is based on a positivism paradigm, ontologically ordered, and epistemologically driven towards quantifiable research outcomes (Saunders et al. 2016), this project rather followed a pragmatism paradigm. While this research paradigm presents less certainty to the researcher due to the open and complex nature, its focus on reflecting reality as accurately as possible is valued. More reductionist orientated research projects, such as the work by Graamans et al. (2018) and Delor (2011), present valuable data on the potential of urban agriculture. On the other hand, the more pragmatism orientated research such as the work of van Averbeke (2007), Jenkins (2018) and Campbell (2017) often present more nuanced outcomes that more closely resemble reality. Yet these studies reflecting reality have higher levels of uncertainty associated with their findings. As a result, this research paradigm also presents a series of weaknesses. Due to the use of mixed or hybrid methods, including quantitative and qualitative research methods, specific rigour in following diverse methods and using a selection of research instruments is needed (Creswell & Clark 2011). Yin (2006) further argues that mixed method research designs call for the integration of multiple methods and not merely employing them in a parallel or concurrent fashion. This requires that the researcher takes the time to integrate and use complementary methods to provide more depth and rigour to the analysis.

The concern regarding mixed method research design relates to the fact that the composition of these methods is often novel and presents little opportunity to follow a research tradition to both guide and assess the validity and rigour (Johnson & Onwuegbuzie 2004). In addition, these mixed method research designs allow for little basic research to be undertaken (Johnson & Onwuegbuzie 2004). While the lack of basic research is often a criticism of the urban agriculture discourse (Webb 2011), reductionist approaches premised on a positivist paradigm can potentially provide skewed results – possibly misinforming urban agriculture and food policies. As a result, pragmatism remains a more appropriate approach to developing research within the UA discourse.

2. Research design and protocol

The research undertaken in this project can be defined as both exploratory, due to the limited actual implementation of BIA in the Tshwane context, and evaluative in understanding its potential as CCA strategy to improve the indoor thermal environment. Exploratory research is generally considered as qualitative research that sets the premise for further quantitative research, while evaluative research normally monitors and measures the outcomes from a certain practice (du Toit 2015). This research project uses both approaches sequentially to understand the impact of BIA in Tshwane.

This research project, therefore, employed a mixed-method approach to consider the research question. As Creswell and Clark (2011) note, due to their complexity mixed method research projects must only be considered with substantial justification. A mixed method research design was used for the following reasons:

- Quantitative dominant research is needed within the UA discourse, yet the analysis must be cognisant of the context within which the industry is practised. This calls for context-specific research and employs multiple tactics to represent reality.
- To ensure the validity, or legitimation as argued by Onwuegbuzie and Johnson (2006), the study proposed using multiple phases and methods to inform the research design.
- These multiple phases included both qualitative and quantitative research methods.

The study undertook an emergent research process (Creswell & Clark 2011) that followed multiple parallel methods that were partially integrated with a quantitative dominant research focus (Leech & Onwuegbuzie 2009; Saunders et al. 2016). In the final phase, the parallel research design converged, informing the concluding phase, which is valuable if the researcher undertakes an exploratory study and is confronted with limited available qualitative and quantitative data (Creswell & Clark 2011). While there was little interaction between the various data collection and analysis phases, the research design allowed for emergence due to its partially sequential nature. It employed aspects of an exploratory sequential design that initiated the study with a hybrid of qualitative and qualitative research methods to inform the final quantitative analysis of the impacts of BIA (Creswell & Clark 2011).

In order to establish the quality of the research, the validity and reliability of the research procedure must be considered. Yet the criteria to ascertain the validity and reliability are often contrasting for both qualitative and quantitative research (Onwuegbuzie & Johnson 2006). In this study, validity and reliability were considered within each research phase and will be discussed in the subsequent sections.

In general, Creswell & Clark (2011) identify the need for both internal and external validity. Internal validity can be achieved if the researcher follows the appropriate collection, analysis and interpretation of the data (Creswell & Clark 2011; Onwuegbuzie & Johnson 2006). This ensures that the causality is correctly assigned in each research phase. External validity refers to the correct generalisation of the findings towards theory or larger population groups, again requiring that the final interpretations are correctly undertaken and not overestimated (Creswell & Clark 2011).

The integration and opportunity to triangulate the findings from the various methods provide opportunities to quickly and efficiently develop richer, comprehensive results (Johnson et al. 2007; Denscombe 2008). While this lends confidence in the research results, it also allows one to deal with the contradictions revealed in the results (Johnson et al. 2007). During the final interpretation stage the findings from the multiple research phases were integrated to support conclusions drawn from the study.

As previously argued the research design followed a mixed method approach. Three research objectives were identified as sub-questions to the overall research question. As noted in Figure 7 the findings from the various research objectives (phases) informed aspects of the other research objectives, ultimately leading to more comprehensive findings in the end.

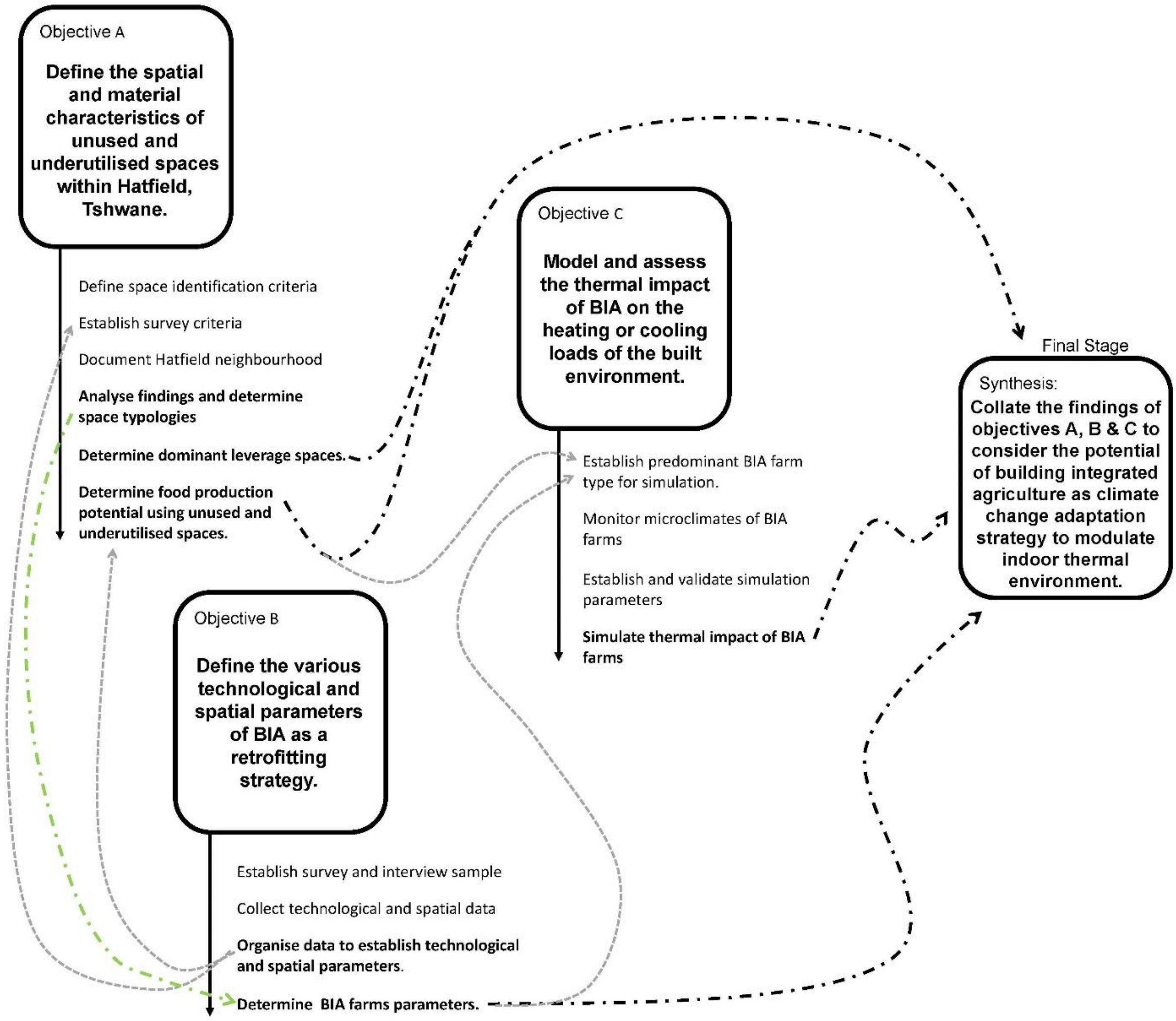

Figure 7: Visual description of the three research objectives and the final synthesis of the findings.

The research methods used to address the three research objectives are briefly discussed as follows:

a) **Research Objective A: Define the spatial and material characteristics of unused and underutilised spaces in Hatfield, Tshwane.**

Hatfield, a neighbourhood in Tshwane, was mapped and analysed to define the spatial and material characteristics of the unused and underutilised spaces located in the neighbourhood. The mapping considered both the neighbourhood itself and Hatfield campus of the University of Pretoria. Findings from this study allowed the researcher to define the CCA potential of the Hatfield neighbourhood in terms of its spatial and material characteristics, and importantly, also consider the potential to implement BIA as CCA response strategies in the neighbourhood.

b) **Research Objective B: Define the various technological and spatial parameters of BIA as a retrofitting strategy.**
A series of interviews with specialists in the UA industry and site visits to various UA and BIA projects were undertaken. The findings were used to develop a framework of the spatial and technical parameters when implementing BIA. Findings from this research objective enabled the researcher to define BIA as a distinct land-use form and informed the final research objective to correctly model BIA farms as implemented in the South African context. Furthermore, this research objective also allowed the researcher to consider the range of UA and BIA applications and their potential implementation in Hatfield (Research Objective A).

c) **Research Objective C: Model and assess the thermal impact of BIA on the heating or cooling loads of the built environment.**
A typical BIA farm type was modelled to evaluate its CCA potential to address the expected higher climate change-induced temperatures in the built environment. This phase allowed the researcher to assess the performance of the BIA farms and their effects on the thermal performance of the associated buildings under current and future climate change affected conditions.

As this study followed a mixed method research design, a final synthesis phase was included to allow for the integration of the findings from the three research objectives (Figure 7). This phase enabled the researcher to evaluate the potential of BIA to improve the climate resilience of South African cities. While the synthesis of the findings informs the final discussion regarding the potential of this land-use type as a CCA strategy to improve indoor thermal environments, the research findings were also considered on a more holistic basis to understand both the benefits and constraints of this land-use type.

2.1. Research design: Objective A - Mapping

The first objective set out to define the latent potential for retrofitting the unused spaces in a South African city. The mapping stage documented the unused and underutilised spaces in Hatfield, Tshwane, as a means to calculate the retrofitting potential and ultimate CCA capacity of the neighbourhood. In this study, the focus was specifically on the food production potential of the neighbourhood by considering the UA and BIA implementation requirements. Importantly, this research objective mapped a selection of contextually relevant risks to consider the leverage potential of UA and BIA retrofitting strategies and its integral impacts on other climate change risks within the context.

2.1.1. Study area and identification of neighbourhood

The Hatfield neighbourhood, Hatfield City Improvement District (CID) and Hatfield campus of the University of Pretoria (UP) were used as study areas in the research project. The neighbourhood was chosen due to its rapidly changing nature, being subject to significant developmental pressures, as well as the Hatfield CID and UP's initiative to actively play a role in the redevelopment of Hatfield as a world-class neighbourhood within which UP is located as an anchor institute (Hatfield CID 2016). This neighbourhood presents the typical Southern African poly-centric urban structure undergoing rapid urban densification (Chobokoane & Horn 2015). At the same time the neighbourhood is characterised by a series of anti-urban strategies (Trancik 1986), resulting in many "anti-spaces" that present opportunities for retrofitting (Trancik 1986).

Due to the changing nature of Hatfield and its rapid growth, the urban context comprises of a variety of unused and underutilised spaces that were analysed. These spaces are not assumed resultant of urban decay and degeneration, but directly attributable to poor design, urban planning and zoning regulation. Finally, the neighbourhood also plays a critical role as a regional transportation hub and is therefore subject to vehicular-orientated design practices noted as a typical anti-urban strategy by Trancik (1986). The context is discussed in more detail in Chapter 4.

2.1.2. Defining unused and underutilised spaces

The spatial condition that was mapped can be defined as unused and underutilised spaces within the particular neighbourhood. This required that the study considered spaces beyond vacant spaces, as was done in the work of Németh and Langhorst (2014) and Kim et al. (2018). Both studies considered vacant spaces that had been documented and defined by the local municipality in their studies. This study rather builds the argument by Bhaskaran (2018) to consider and include underperforming spaces or urban voids in the urban context.

Similar to the research noted in the work of Bhaskaran (2018), vacant spaces in South Africa are rarely open and unused, but rather appropriated for alternative uses. In addition we also find that South African city spaces followed similar Modernist urban planning principles, as identified by Trancik (1986), resulting in unsustainable sprawling cities (Dewar 2000; Chobokoane & Horn 2015). As a result, there are often unused and underutilised spaces available that are associated with active and functioning buildings, yet these spaces do not contribute to the spatial value of the urban environment.

2.1.3. Mapping phases

In order to identify and define the various unused and underutilised spaces in Hatfield a multi-phased process was undertaken. A ground level (site level) approach using a student cohort, as mapping assistants, was used to identify the various unused and underutilised spaces in the neighbourhood. This approach has proven to be an effective approach due to the undefined nature of these spaces. The mapping was undertaken in two phases. The first phase documented the unused and underutilised spaces in the neighbourhood, while the second phase verified the data through a second mapping round. The findings were finally verified and collated by the principal researcher. The final aggregated data are presented in Chapter 5.

Mapping phase 1

During this first phase, the student group that documented the spaces was introduced to the concept of unused and underutilised spaces. A series of preliminary spatial definitions were provided along which the mapping was undertaken. This first phase used a large group of students, twenty-one in total, and they were provided with explicit space typologies to document. After the initial collection period the spaces were defined and analysed.

Mapping phase 2

Reflecting on the outcomes from the first mapping phase, it was decided to allow for a second completely open-ended inductive mapping process. In the second phase, effort was made to limit any predefined spatial biases. As a result, during the second phase the students were not given any predefined definition of unused or underutilised spaces, but were rather requested to explore the concept and map it according to their own interpretations. While this group still documented specific spatial and material characteristics, the space types that they were required to document were open for interpretation. This enabled the main researcher to use the data from the second phase to verify the findings from the first mapping phase and define other spaces that were initially missed.

2.1.4. Protocol and research instruments for collecting data

As discussed in Chapter 2, the research builds on the argument voiced by Faling (2012) that proposes the densification and intensification of sprawling urban contexts. The research design builds on the work conducted by Patrick Geddes in the early twentieth century in Edinburgh (Lock 1977), that used a survey method to enable the rigorous documentation of the existing urban context. Using this method, Geddes developed the conservation surgery approach to working within historically sensitive neighbourhoods. This requires understanding the nature of the existing city before proposing any changes to it.

Trancik (1986) also considered the nature of lost or unused space, proposing the use of a figure-ground study to analyse the urban context. Once undertaken, Trancik (1986) used two theoretical approaches to address the existence of lost spaces in the urban context, these being the linkage and place approaches.These two approaches include identifying the spatial relationship between various spaces, while also recognizing and promoting the particular identity associated with these various spaces.

The research design used both studies to inform its research protocol, but in addition to documenting the urban morphology, in-situ mapping techniques and desktop analyses were also employed. As a result, using multiple research instruments to obtain, define and map data.

Each mapping phase (phases 1 and 2) used a sequential multi-method approach. It started with a desktop study of the research area, as well as the development of a parametric model of the built-up volume of the study region. This allowed for the initial identification of potential spaces of interest. Google Earth was used as source for the aerial photographs, and the parametric model was developed using Autodesk Revit as modelling program. The parametric modelling was developed using the building footprints from aerial photography. Heights were estimated and confirmed through ground-truthing. The building heights were calculated assigning a typical floor-to-ceiling height and multiplying the storeys to calculate the final height. A floor height of 3 m per storey was assumed.

Following the initial analyses of the site through a desktop study, an observational study of the context was carried out in the study area. This involved transect walks, as well as a visual and photographic assessment of specific spaces. The data and location of these spaces were captured using Epicollect5, an open-source online documentation tool developed by the Imperial College of London. Epicollect5 uses a survey approach to document, geo-locate and store data using personal cell phones. This was then uploaded onto a single online data repository from which the data was collected for analysis.

The spatial dimension of the data was interpreted using MapAble®, an online GIS programme. This was overlaid onto the existing figure ground and aerial photographic data to present the spatial relation and total coverage of the documented spaces. In addition to using the data through GIS mapping programmes, Microsoft Excel was used to undertake a descriptive statistical analysis of the data. The spatial and material parameters for the statistical analysis, as discussed in chapter 5, were developed in response to the expected climate change impacts for the Southern African interior.

2.1.5. Data collection.

All the data was collected using a cohort of Honours students (4th year students). During the first phase (mapping phase 1) a group of twenty-one architecture, interior architecture and landscape architecture students were enlisted to document the neighbourhood. Their knowledge of spatial design in the built environment assisted with the documentation and identification of the unused and underutilised spaces. Employing diverse individuals allowed for vaguely defined spatial conditions to be defined and documented. The principal researcher verified the collected data. During the second phase (mapping phase 2), a similar mapping process was undertaken to verify the findings of the first mapping phase. During this phase a smaller student cohort was used. Unlike the first phase three students analysed the whole site based on their own interpretation of the unused and underutilised spaces. This research phase purposefully used an alternative method to interpret the study area and collect site-level data to complement the first round's data. The data from both phases were overlaid and collated to develop a more thorough spatial and material understanding of the unused and underutilised spaces in the study area.

2.1.6. Analysis of collected data

The collected spatial and material data were analysed in terms of their contributing factors to exposing citizens to a selection of critical climate change-driven impacts as well as the ingrained potential to enable certain climate change adaptation response opportunities. These risks and opportunities were identified during a literature review and covered thermal increases, water insecurity, food production, decentralised energy generation, and retrofitting capacity.

This mapping protocol was developed as a rapid and effective method to provide broad-ranging insight into the spatial and material quality of a neighbourhood. As a result, the findings do not present any detailed specifics of each of the identified sites. A descriptive statistical analysis of the data was undertaken that provide a quantitative interpretation of the mapping. The descriptive statistical analysis assigned basic values to each of the spatial and material aspects that were documented in these various spaces. This allowed the researcher to analyse the spatial and material quality of the various spaces based on criteria related to the identified risks or opportunities (Figure 8).

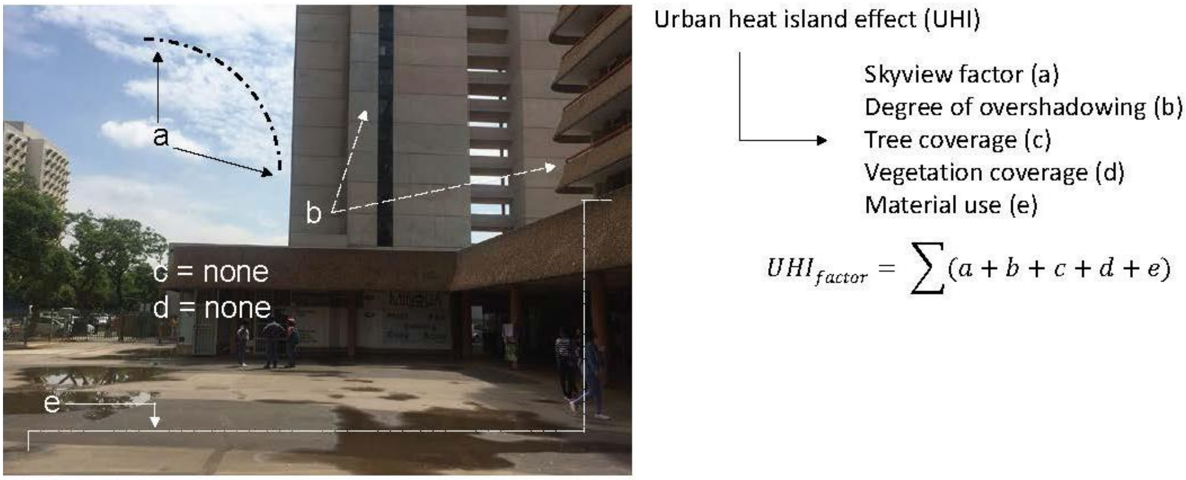

Figure 8: Example of a typical space that was documented and a representation of the reading and analysis of the space. The analysis considered its capacity to expose users to a climate change-related hazard, in this case being the local UHI effect.

Upon reflection, it must be noted that the composition of the various factors and how these influence the overall assessment of the risks or opportunities associated with these spaces (as noted in figure 8) will need further development in future studies. This is important, as the proportional impact of each factor can be defined more accurately. However, for the purposes of this study, this approach gave the spatial and material overview as needed.

To quantify the potential space impact (PSI) of these unused spaces, the mapping process calculated the availability of these spaces on a two-dimensional basis (excluding the facades). Although the spatial and material quality of these façades were not excluded from the analysis, the spatial (area) potential of these facades was excluded from the PSI calculations.

In terms of the food production potential, facades were excluded due to the limited application of vertical agriculture as façade treatment in the industry. In terms of decentralised energy generation, facades were also excluded as the latitudinal position of Tshwane results in vertically positioned photovoltaic panels being significantly less effective than in horizontal applications. As result the roof spaces were deemed more important than the façades.

2.1.7. Validity and reliability of the data collection and analysis

The internal validity was achieved by using recognised geospatial and parametric modelling programmes; furthermore, the sites were all confirmed through ground-truthing. The use of multiple participants that documented and read the city allowed for the collation of various interpretations. This was validated through a peer-reviewing process (Saunders et al., 2016) by employing a second mapping round using new research assistants.

The data analysis stages used Mapable ® to interpret the geo-spatial data, while the descriptive statistical analyses were carried out using Microsoft Excel. This allowed for quantitative analysis of the data to reveal both the spatial location and relation, as well as the proportioned manifestation of these space types. The use of photographs and transect walks enabled the triangulation of the results and further qualitative interpretations of the various spaces.

During the interpretation it was important not to assign a value judgment to various spaces, but rather develop a framework of unused and underutilised space types in the Hatfield neighbourhood. While the use of quantitative research instruments endeavoured to assure a high level of objectivity in the analysis, a certain level of subjectivity had to be accounted for due to the undefined nature of the spaces in question. This was countered by employing a second verification phase that used a new research group.

2.2. Research design: Objective B - Interviews and site visits

Due to the explorative nature of the research project, the study undertook a series of semi-structured interviews and site visits. This research phase clarified concepts, established snapshots of the UA and BIA industry at a point in time, and uncovered critical issues or concerns that are often overlooked. Using a similar approach to Thomaier et al. (2014) these explorative interviews aimed to extract the specific constraints and needs around the spatial and technological implementation of UA and BIA farms.

In addition to the interviews, an observational analysis of BIA and UA sites located in dense urban settings was undertaken. The observational studies, similar to studies of community gardens undertaken by Napawan (2015; 2016), validated and confirmed findings from the interviews and literature reviews, as well as revealed the spatial and technical aspects not discussed during the interviews.

2.2.1. Data collection

In order to generate a complete representation of the phenomenon and triangulation of the data, multiple tactics were used to collect the data as proposed by Groat & Wang (2013). This included interviews, photographic documentation and sketches of the various sites, and reflexive procedures subsequent to the interviews. As a result, the data collected were qualitative in nature. While meaning was generated during the interviews and site visits, cognisance of the natural setting within which the research was undertaken, and the subjective influence of the researcher was acknowledged (Groat & Wang 2013).

Although interviews as research technique are often seen as generating unreliable and invalid data that cannot be judged empirically, Qu & Dumey (2011) argue that, if carefully planned, prepared and using a pragmatist reflexive approach to qualitative interviews, this problem can be overcome. To ensure that the study retains objectivity, findings from this stage were first carefully examined before undertaking the final research phases. Furthermore, in order to retain reliability and validity the sampling and criteria of interview respondents and urban farms selection were carefully considered.

2.2.2. Selection of countries

The analysis considered UA and BIA farms in South Africa, Belgium, Netherlands and Singapore. While the study is based in South Africa, it included projects from these additional countries to generate a more complete representation of spatial and technological aspects of these types of projects in diverse contexts.

Several Dutch, Belgian and Singaporean projects were identified for their significant progress in the fields of agriculture, food production and urban agriculture. The Netherlands was specifically chosen due to its agricultural progress, resulting in a trade surplus balance exporting agricultural produce of 28.8 billion Euros, making it the second largest agricultural exporter in the world (CBS 2019; WUR 2019). The Belgium examples were included as the study allowed for a snowballing sampling process. Due to the close ties between Dutch and Belgium projects, the respondents often referred to Belgium projects that were included in the study. Singapore was included due to its significant strides in terms of sustainable development since the 1950s (UNDP 2018), and its goal to achieve food resilience through both strategic importing and stockpiling strategies, but also promoting innovation within its local agriculture sector, specifically UA (MFA 2018).

In terms of the human development index and gross domestic product, the four countries present varying achievements. Belgium, Netherlands and Singapore all perform very well on the global human development index (17, 10 and 9 respectively) and have GDP per capita of above $43,000. South Africa is currently 113th on the Human Development Index and has a GDP per capita of $6,150 (UNDP 2019; World Bank 2019). The intention of the study is not to rate the successes of the various countries, but to document the spatial and technological application of UA and BIA projects in countries where the industry has experienced significant development to provide a more complete understanding of UA and BIA as land-use practices.

2.2.3. Sample selection

The interviews intended to extrapolate specific technical and spatial data and not general sentiment. This required interviewing specific individuals with experience and knowledge in the urban agriculture field. In order to identify candidates for the interviews a non-probability sampling method was used (Saunders et al. 2016). The study also allowed for snowball sampling to occur through referrals from the specialists interviewed (Farthing 2016).

During the interview process a total of 31 specialists were interviewed. The specialists can be defined along the following:

a) Urban farmers (*n* - 17).
b) Academics and theorists working in the UA discourse (*n* - 5).
c) Nutrition specialist with involvement in UA (*n* - 1).
d) Engineer involved in UA projects (*n* - 1).
e) Landscape architects involved in UA projects (*n* - 2).
f) Agricultural specialist (*n* - 1).
g) Architects or designers involved in the technical development of UA (*n* - 2).
h) Product supplier of UA equipment (*n* - 2).

A total of 20 sites were visited; internet searches and snowball sampling were used to identify sites. Specific sites were visited that presented either the characteristics of BIA or UA farms. All these sites are closely related to the built environment and in dense urban settings. These included:

a) Tshwane, South Africa (*n* - 2).
b) Johannesburg, South Africa (*n* – 4).
c) Singapore (*n* - 2).
d) Amsterdam, Netherlands (*n* - 2).
e) Rotterdam, Netherlands (*n* - 4).
f) Den Haag, Netherlands (*n* - 1).
g) Venlo, Netherlands (*n* - 1).
h) Brussels, Belgium (*n* - 2).
i) Ghent, Belgium (*n* - 1).
j) Warregem, Belgium (*n* - 1).

2.2.4. Criteria for selection

Due to the non-probability purposive sampling, specialists and professionals were selected using the following criteria:

a) Professionally registered in his/her field, identified as an academic specialist in the field, or retaining extensive practical experience in the field.
b) Completed an UA project as part of the professional team, or written extensively on UA as research topic.
c) Experience in terms of food production and food safety, should limited experience in UA be evident.

d) Specialists can be contacted for an interview through personal meetings, via email, or telephonic conversations.
e) Specialists can be referred by 3rd party, through research and reviewing the specialist's experience, or by an interviewee.
f) Convenience sampling methods may be used if criteria A, B, E are met.

Urban agriculture sites were identified for analysis using the following criteria:

a) The site must present a specific relationship to buildings or the built environment by one of the following means:
   - Being physically linked to a building façade, interior or roof.
   - Using the urban grey infrastructure as resource.
   - Reusing and retrofitting existing urban spaces.
   - Implemented to specifically prevent the development of building developments.
   - Located in dense urban settings.
b) Sites had to be accessible.
c) These projects must be functioning UA projects – either mature or at inception phase.

2.2.5. Interview process

Due to the explorative nature of the research project, the interviews were purposefully semi-structured to extract undocumented data regarding the study field (See Appendix D for examples of the interview questions). Unstructured and semi-structured interviews are often cited as being the only means to obtain more in-depth data (Gill et al. 2008). Semi-structured interviews provide the opportunity to be guided by general themes during the interview, yet also drive down and elaborate on specific aspects or statements (Qu & Dumay 2011). This is a very popular research instrument as it allows for flexibility, accessibility, intelligibility and uncovers certain important hidden aspects, whilst remaining a convenient data gathering technique (Qu & Dumay 2011).

2.2.6. Documenting the UA and BIA farms

A quasi-structured observation approach was followed during the site visits. These observational analyses were effective in revealing the application of the phenomena, in this case BIA and UA, in their natural settings (Saunders et al., 2016). This research method allows for various research instruments to be used, such as graphic or photographic methods to provide a more complete depiction of reality (Groat & Wang 2013). The use of photography and videography also allowed for the documentation of certain detail that could have been overlooked during the analysis (Saunders et al., 2016). Finally, the use of technology to document the sites allowed for the variability and diversity of the projects to be documented and reliably compared at a later stage.

The observational analyses were always undertaken after the interview with the urban farmer was completed. This ensured that personal biases were limited during the observations and allowed triangulation of statements made during the interviews. During the site visits the following aspects were specifically considered:

a) The original building, landscape, or interior.
b) The spatial economy and functional use of space; this included cultivation, service, movement, and leisure spaces.
c) Access to public entrance and loading or delivery entrances.
d) Solar exposure.
e) Services points or spaces.
f) Predominant material choice and application thereof.
g) Type of system employed to cultivate food.
h) Planting beds - infrastructure,
   - structures,
   - joints,
   - and services (water or electricity or lighting) provision.
i) Visible changes made to accommodate the new functions - any joints and connections between existing and new systems.
j) Any visible damage to the existing structures or spaces due to the change in function.
k) Any visible adaptations to control the microclimate – screens, wind barriers, shading etc.
l) Any visible pest control.

2.2.7. Analysis: thematic coding of data

The interviews and observational analysis were interpreted following an inductive approach, although the study as a whole can be considered as deductive. Saunders et al. (2016) argue that in practice one is usually confronted with both approaches being present in research projects.

The analysis of the data followed an inductive thematic analysis process that enabled the development of themes (Saunders et al. 2016). The analysis started with initial themes and codes developed from the research question. While these initial themes were used to initiate the thematic analysis structure, in-vivo codes were developed as the analyses progressed, which required re-categorisation and re-coding as more themes or data emerged (Saunders et al. 2016).

The coding process followed a manual procedure. During the first phase each interview and site visit were considered on an individual basis. Using the in-vivo coding, the individual interviews and photographic analysis identified the various themes revealed during the data collection. During the second phase, the themes developed from the first round of analysis were used to structure the discussion. The themes were grouped by identifying cross-cutting themes that correlate between the various countries and farms (Henning et al. 2004). This allowed for the systematic categorisation of the data and ultimately comparing its application in the different farm types.

While considering the similarities and contrasting themes within these frameworks, the study ultimately generalised the data on a higher conceptual level to contribute to the discourse (Saunders et al. 2016). As a final stage, the BIA examples and related findings were extracted from the analysis in order to both develop an overall understanding of this land-use form and its application.

2.3. Research design: Objective C - Performance modelling

The final phase of the research project used a simulated research design that was verified with experimental research. This research design is often used in architectural research as a means to test certain theories or assumptions in the built environment (Groat & Wang 2013). This allows one to evaluate existing phenomena whilst developing simulation models for further analysis.

Many studies have used this research design as a means to document and analyse phenomena in the built environment (Holm 1985; Haberman et al. 2014; Orsini et al. 2014; Taleghani et al. 2014; Kleerekoper et al. 2017). These studies often also developed solutions based on the findings from the simulations (Kleerekoper et al. 2017).

Representing reality and allowing the researcher to test various scenarios in a real world setting is one of the major advantages of simulation research. If the researcher follows a rigorous research method, using a quantitative approach to analyse the data, a high level of certainty and validity of the data is ensured (Saunders et al. 2016). Yet the accuracy and completeness of the simulation can only be ensured if reality is correctly depicted during the research process (Groat & Wang 2013). The mixed-method research designs used Research Objectives A and B to ensure that the simulation model is both relevant and valid for the context of analysis. Integrating simulation methods with real-world examples allows for the calibration, adjustment, and verification of the research model and setting (Kleerekoper et al.

2015). From the simulated representation of reality, a more positivist paradigm can be followed arguing that the research outcomes will be measurable and quantifiable (Groat & Wang 2013).

2.3.1. Research focus

During this final research phase the thermal cooling or heating impact of BIA was measured to consider its potential as a CCA strategy that responds to the temperature increases forecasted for the South African interior (Davis et al. 2017; IPCC 2018a). The simulated experiment considered changes experienced in the building interior due to adjustments to the thermal resistance of the building envelope (Castleton et al. 2010), changes to the envelope's albedo factors and exposure to irradiance (Taleghani et al. 2014; Kleerekoper et al. 2017), and the impact of rooftop greenhouses (RTGs) in terms of changes in evapotranspiration and thermal energy stored within the greenhouse volume (Graamans et al. 2018).

2.3.2. Overall research protocol

The research protocol followed a modelling and validation method developed by Taleghani et al. (2014) and Skelhorn et al. (2016). It documented the micro-climate of five BIA farms. After interpreting the field data from the farms, ENVI-MET and IESve simulation models were developed, calibrated, and verified by the data collected from the fieldwork. From these models a set of parameters of a typical RTG was developed. This allowed the findings from it to be generalised and applied to the Hatfield study area that was analysed in objective A. From these models the place specific data, regarding the impact of BIA farms on the built environments, were developed

2.3.3. Experimental research: Farms documented during the fieldwork.

The fieldwork experiment was undertaken on five farms. These farms were located in Tshwane (n-1) and Johannesburg (n-4). As further discussed in Chapter 4, Johannesburg and Tshwane are similar in terms of climatic conditions (specific climate files were still used for each respective site to accommodate any climatic differences that exist), urban spatial structure and general built environment attributes. The four farms located in Johannesburg were developed by the same company, *Wouldn't it be Cool (WIBC)*. The fifth farm was developed by an independent farmer and uses a different farming technique and RTG structure.

The farms are located at:

a) Brooklyn Design Square, Brooklyn, Tshwane
b) The Hoofd Mansions, Jeppestown, Johannesburg
c) Stanop Building, Jeppes Town, Johannesburg
d) The Newgate Mall, Newtown, Johannesburg

e) The Minerals Council Building, Marshal Town, Johannesburg.

All these farms are functioning urban farms and managed as commercial entities. In all cases these farms are positioned on roof spaces and are subject to high amounts of insolation. All five farms can be defined as passively controlled, non-integrated rooftop greenhouses (a form of BIA farms). The four farms in Johannesburg use an NFT system as growing technology, while the farm in Tshwane uses a vertical soil-based system with drip irrigation.

2.3.4. Simulation and verification of the computer models

After the completion of the fieldwork and analysis of the findings, simulation models were developed representing one farm documented in Johannesburg. The farm on the Stanop Building was chosen as the most exposed rooftop greenhouse, with limited overshadowing and wind protection from other structures. The Stanop Building farm represents therefore the project with the least external impacts and variables.

The simulation set out to establish the correct model parameters to enable a correlation between the simulated data and data collected during the fieldwork. The parameters developed from the verified model informed the final simulation models that considered the performance of a typical RTG located on an office building in Hatfield, Tshwane. An office building typology was chosen as it represents one of the predominant multi-storey building types in Hatfield, and have highly homogenous construction, layout and use patterns that allowed for accurate assumptions to be made during the simulations.

2.3.5. Research instruments - Measuring equipment

In all five sites the following variables were documented and analysed:

a) Ambient temperature.
b) Relative humidity.
c) Globe temperatures.
d) Air movement.

The following instruments were used to document the variables:

a) SSN-22 USB temperature / humidity logger.
b) An ET-951W hygrometer was used to verify data at each test site.
c) A WS400 Mini pocket anemometer was used to measure the air velocity within each greenhouse.
d) An HP200 Wi-Fi wireless weather station was used to document the local weather on the building during the data collection period.

e) An AZ87786 Portable heat index monitor and data logger with 75 mm black ball was used to measure the wetbulb globe temperatures and globe temperatures.

The SSN-22 USB temperature/humidity logger functions between 0-100% relative humidity, -35 - 80°C and is IP66 compliant. It also has an accuracy tolerance of ±3% relative humidity and ±0.3°C temperature measurements. The ET-951W hygrometer has an accuracy tolerance of ±2% relative humidity, and was used to validate the SSN-22 measurements. The HP200 Wi-Fi wireless weather station functions between -30 to +65°C, 0-99% relative humidity, and wind speeds of up to 50 m/s in outdoor conditions. The WS400 mini pocket anemometer functions in wind conditions of up to 30 m/s. The AZ87786 monitor and data logger functions between temperatures of 0-50°C (accuracy ±0.6°C), globe temperatures of 0-80°C (accuracy ±1.5°C), and in relative humidity conditions of 0-100% (accuracy ±3%). As all the instruments were new and calibrated by the product suppliers, the researcher compared the instrument output over a 48-hour period to check for data errors. None were found and any data variations between the instruments proved negligible.

On each farm measuring equipment was located in the following positions to measure the thermal impacts:

A. On the north-western perimeter, inside the rooftop greenhouse.
B. On the south-eastern perimeter, inside the rooftop greenhouse.
C. An open, uncovered part of the building.
D. The weather station was located on an open unclosed section of the roof.

Figure 9: Typical location and installation of the sensors used to monitor the rooftop farms.

The sensors were specifically located both inside the rooftop greenhouse and outside on the roof itself. This allowed the researcher to compare the immediate microclimate with any changes experienced within the rooftop greenhouse (Figures 9 and 10). The researcher took care that the weather station and the sensors were not overshadowed due to their position on the uncovered part of the building. Furthermore, the interior stations were positioned on both the north-western and south-eastern perimeters, this allowed the researcher to monitor what was assumed to be the coolest (south) and hottest positions (north) in the greenhouses. To not interfere with the general farming processes these sensors were positioned in the corners of the rooftop greenhouses.

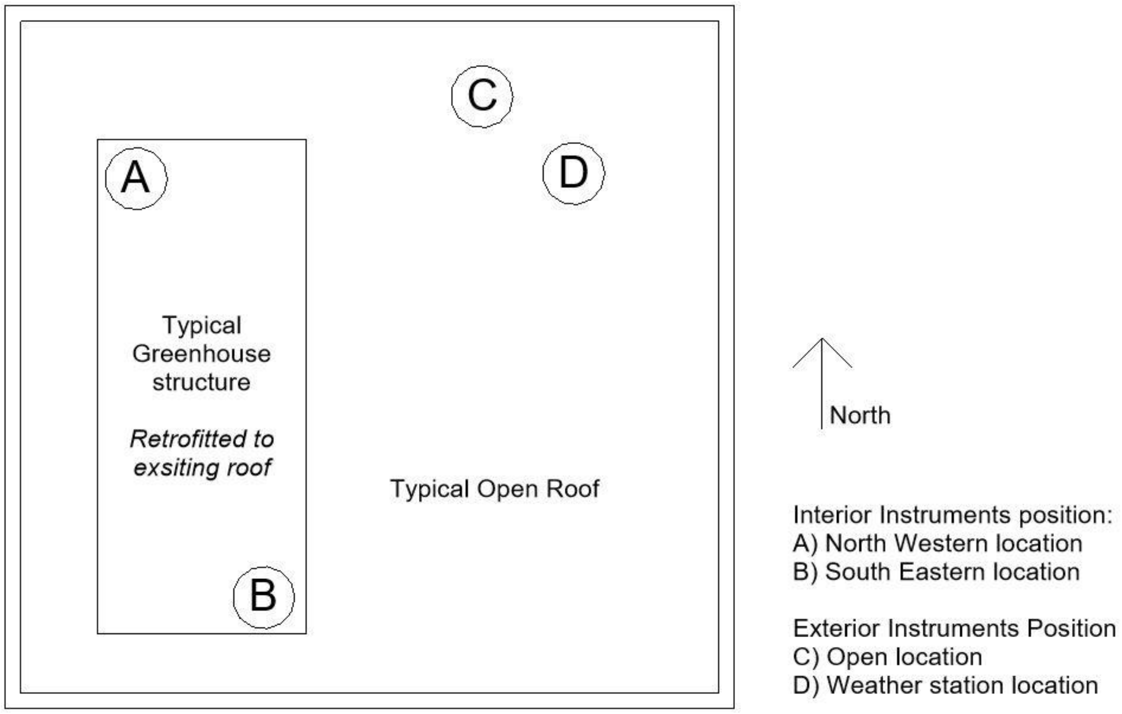

Figure 10: Layout and measurement locations of a typical rooftop greenhouse documented during the study.

2.3.6. .Research instruments - Simulating the data

Several simulation programmes exist, the choice of software used in this study was verified through a literature review of existing projects that undertook simulation research designs. The review identified ENVI-MET and Integrated Environmental Solutions (IESve) as appropriate simulation programmes for the research objective.

ENVI-MET was developed to simulate the surface-plant-air interaction; it considers the urban environment on a three-dimensional basis (ENVIMET 2018). It has been used in a series of studies that considered the impact of vegetation, wind and solar radiation fluxes due to material use in the urban environment (Porritt et al. 2012; Perini & Magliocco 2014; Taleghani et al. 2014a; Skelhorn et al. 2016).

IESve is a reliable performance assessment program used extensively internationally and nationally. It uses the basic EnergyPlus building energy simulation engine and allows for local weather files to be integrated into the performance modelling assessment. IESve has been validated by ASHRAE 140 & 90.1 as well as CIBSE TM33 and the ISO 7730 calculation method (IES 2018). The program has also been Agrèment approved in South Africa for Regulation 10400XA3 of Part XA: building performance modelling (IES 2018).

In order to use the software, context-specific weather information is needed, various open-source weather data is available on the Energyplus website. Weather data generated for Johannesburg was used in the Johannesburg-specific simulations. With the assistance of the CSIR using Meteonorm, weather data for the Pretoria simulation was developed and used in the models. The weather file is typically extrapolated from hourly data of the nearest weather station. In this case it is the Proefplaas weather station located 3.5 km from the simulated site (Conradie 2019; Herrera et al. 2017). The weather files also simulated the 2100 performance of the buildings under climate change conditions. These weather files were generated based on the IPPC A2, business-as-usual, scenario developed in the Emissions Scenario report (IPCC 2000; Meteotest 2018).

To model the evapotranspiration impact of the vegetation in the rooftop greenhouse the FAO Penman-Monteith method (FAO-PM method) was used. The Penman-Montieth evapotranspiration model was originally developed by Monteith (1965) and adjusted for easier application for the FAO by Allen et al. (1998). While a study by Graamans et al. (2017) developed the evapotranspiration energy balance model for closed greenhouse energy models, in this case plant factories, the data collection revealed that the rooftop greenhouses located in Tshwane and Johannesburg function more as open systems. It was, therefore, decided to use the FAO-PM method to define the latent thermal impact of evapotranspiration. This method has been used in several other studies (Pereira et al. 2002; Stockle et al. 2003; Steduto et al. 2009).

A basic latent thermal impact coefficient was defined using the FAO-PM model. This was adjusted for the local conditions based on the local climate conditions, the site's longitudinal position, and the adjusted reference crop characteristics (including adjusted surface and aerodynamic resistances). The latent thermal impact coefficient was adjusted to the typical produce capacity and accommodating annual climatic and daily solar fluctuations by scheduling its impact in the IESve software.

2.3.7. Data collection and time frame

The experiments were undertaken during the summer and winter seasons and the data were collected over a consecutive five-day period. This was conducted from 28 May - 22 July (2019) and 24 October (2019) – 27 January (2020). Due to the limited availability of data-collection equipment, the fieldwork was undertaken consecutively, rather than simultaneously, at the five different sites. As a result, the analysis procedure was adjusted to analyse each site individually before collating the overall findings.

The measuring instruments were fixed to purpose-made laminated timber stands in order to minimise interference during the measurement periods. Temperature and humidity loggers were positioned at both 500 mm and a minimum of 2100 mm above the finished floor level. The higher position of the measuring equipment had to be adjusted according to the specific spatial conditions inside the rooftop greenhouses. The wetbulb globe thermometer was located at 500 mm above the finished floor level. While wetbulb globe thermometers are typically placed between 1100 mm – 1800 mm when measuring globe temperatures to calculate mean radiant temperature (Thorsson et al. 2007; Liang & Huang 2011; Taleghani et al. 2014), this study specifically considers the impact of UA integrated within the built environment. Based on the findings from a study by Liang et al. (2014), the impact of vegetation on the mean radiant temperature can be most accurately measured within a 1 m range from the surface. As a result, the temperature and humidity loggers, as well as the globe thermometers, were positioned within 500 mm of the surface slab being adjacent to the height of the lowest planting tray to collect an accurate reading.

While no disruptions were experienced during the winter-data collection period, some disruptions were experienced during the summer period. One of the farms documented during the experiment, De Hoofd Mansions, burned down due to an electrical malfunction. No summer measurements were therefore collected at that specific farm. Furthermore, due to a series of extreme rain events experienced in November/December 2019 the summer data collection period was extended to January 2020.

2.3.8. Analysis of data

The data analysis used an Analysis of Variance (ANOVA) method to consider the variations between the data collection points at the sites; a similar approach was used by Cheung and Jim (2018). The analysis considered each of the five sites individually and compared the relative humidity, ambient and globe temperatures inside the greenhouses with the measurements taken on the open roofs themselves.

Following the data collection and analysis from the various sites, simulations reflecting one of these sites were developed in ENVI-MET and IESve. The data output from these models was verified with the findings from the fieldwork, using root-mean-square deviation and correlation (Pearson's R) analyses (Caldwell 2010). Once the validity of the models was assigned the final analysis of the Hatfield neighbourhood was undertaken. The Hatfield analysis used basic descriptive analysis methods to consider the findings.

The final simulation data was analysed by comparing the results from two primary baseline models. These models presented SANS 10400XA compliant and existing poorly insulated models, and each baseline model was simulated with and without a retrofitted rooftop greenhouse. Through comparative analyses the two baseline models were used to consider the impacts of retrofitting the buildings with rooftop greenhouses. Importantly these simulations were tested under both current climatic conditions and future climate change affected (2100 A2 scenarios) conditions (IPCC 2000). In each case the comparisons were made accordingly.

3. Ethics

Ethical approval were obtained for the research project. The spatial analysis undertaken for Objective A only considered the spatial and material characteristics of the Hatfield neighbourhood. The research focused on spaces in the public realm and refrained from documenting any spatial conditions that detracted from the building owners' privacy. Furthermore, the study did not share any location data in the form of GPS coordinates or addresses and only considered the space in its collective aggregated format.

During the semi-structured interviews (Objective B), all the interviewees completed a consent form stipulating the nature of the study and the use of the data. The interviewees were contacted via email and telephone prior to each interview to ensure that it was undertaken on a voluntary basis. Care was taken to ensure that the respondents retained anonymity. In cases where respondents worked in larger companies, the opportunity was given to first obtain permission from their management structures to undertake the interview prior to meeting the respondents. Finally, the data is being safely stored for the next five years in a secure environment.

The fieldwork for Objective C communicated with each farmer using email and telephonic communication methods. Each farmer gave consent for the research to be undertaken and all the data collected on each farm were shared the respective farmers.

4. Conclusion

This research design set out to consider the potential of BIA to retrofit the unused and underutilised spaces in Hatfield, Tshwane as a CCA strategy to modulate the indoor thermal environment during higher temperature conditions. This research question was divided into three sub-questions. The first sub-question (sub-question A) considered the implementation potential of BIA applications by mapping and analysing the spatial and material characteristics of the unused and underutilised spaces located in Hatfield. The second research objective (sub-question B), was undertaken concurrently and documented the spatial and technological considerations of BIA as retrofitting strategy. It used interviews and observational research methods to collect the data. The spatial and technological manifestation of both UA and BIA farms were documented in multiple countries to give a more accurate overview of these land-use forms. The final research objective (sub-question C) considered the performance of BIA farm types in Tshwane and Johannesburg. During the third research phase the cooling and heating load impact of BIA, specifically passively controlled non-integrated rooftop greenhouses, on the built environment was assessed using simulation and experimentation research processes.

Finally, the CCA potential of the BIA farms to limit indoor thermal fluctuations in Tshwane was considered by collating and interpreting the findings from the preceding three research phases. In order to address the project's pragmatism ideals, the study considered this phenomenon from multiple perspectives and hopes to convey a more grounded and holistic understanding of this land-use form.