DEVELOPING A WHOLE SYSTEM APPROACH TO URBAN FARMING IN AN AREA OF HIGH DEPRIVATION

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Abstract

The research presented was practice based and includes an analytical commentary and a portfolio of illustrations, photographs and diagrams. The thesis describes the exploration and testing of a whole system approach to urban food production and distribution through action research. This was implemented within an existing community characterised by high deprivation. The research drew on scientific, social, ecological, cultural and economic theories of local food production and distribution. It involved creative entrepreneurship to bring these theories into practice. The aims of the research were: 1. to design a whole system ecological approach to urban farming; 2. to establish a working model of such in an area of high social deprivation; 3. to create a centre for ecological research; and 4. to contribute to public awareness of health food and ecological systems in urban environments. The problem of ecological and social crises in relation to food production and distribution in a city context is established. Existing local alternatives to food production and distribution are critiqued. Systems thinking is used as a creative approach to overcome the challenges identified. A methodology of transdisciplinary action-research was used to experiment on the interconnectivity of an array of food production and distribution systems. A community interest company, Biospheric Foundation (CIC), was created in order to deliver the Biospheric Project. This has become an urban farm and research laboratory in inner city Salford. The analytical commentary documents the implementation of action research to tell the story of the Biospheric Project. A Portfolio of Works illustrates the implementation of the project. The various elements, systems and components have been used to create a closed system that is ecologically sustainable and adaptive. This created the first whole system approach to urban farming in an area of deprivation in Europe. An elegant design process and artistic aesthetic has been brought to the way in which the scientific systems connect to create a whole ecology, and thereby contribute new knowledge.

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1 Introduction

The research presented in this thesis was practice-based (Route 3) and is submitted in the form of an Analytical Commentary together with a DVD containing a portfolio of illustrations, photographs and diagrams. This portfolio does not represent an exhibition of work, but rather serves to further explain the research that was carried out.

This research grew out of previous experiences in Ethiopia and Nigeria, a documentary that was produced in the United States of America and time spent in Croatia living in a permaculture village. The documentary that was made in the USA in 2002 was called 'Angels in Poverty' and it addressed issues of homelessness and ecology. In Ethiopia and Nigeria in 2005 work was carried out with the World Agroforestry Research Trust. The work in Croatia involved living for 9 months during 2008 at Eko Sense, developing food systems inside and outside of dwellings (Portfolio of Works: 4 – 5). These real life experiences gave a core understanding of ecological systems across a range of food production models in both temperate and tropical environments. This knowledge, combined with understanding of the huge challenges within cities in relation to climate change, resilience, and adaptability, led the focus back to Manchester. Completing a Masters course in Architecture and Urbanism highlighted the challenges and opportunities of developing ecological systems within cities. It was a natural progression to then move on to a PhD based on action-led research[1].

[1] Lewin's (1951) conception of action-led research demands an integration of theoretical and applied research that translates research into problem-solving strategies through

This PhD thesis describes a programme of investigation that explored and tested a whole system approach to urban food production and distribution through action-led research. This was carried out at a local level within an existing community that was characterised by high deprivation. The research drew on scientific, social, ecological, cultural and economic theories of local food production and distribution. It also involved a form of creative entrepreneurship to bring these theories into practice, by delivering this programme within tight timescales and within funding restraints.

The original aims highlighted in the research proposal in 2010 were to conduct five experiments. These were intended to enhance understanding of the interconnectivity between food production and distribution models within a local community. These were to be: Forest Gardening; Permaculture; an Integrated Biospheric & technological Urban System; Vermiculture Technologies; and Mycelium Technologies. Over time, as the programme of investigation developed, these aims were refined as follows:

1. To design a whole system ecological approach to urban farming.
2. To establish a working model of such in an area of high social deprivation.
3. To create a centre for ecological research.
4. To contribute to public awareness of health food and ecological systems in urban environments.

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collaboration with researchers, community members and policy makers. This produces practical recommendations for resolving social problems.

The research did not intend to supply in-depth knowledge on each of the single systems, as these have already been well researched by leading experts. It did not intend to analyse the production volume or value of each particular system, but rather build upon this existing knowledge to assess how they interconnect, as a whole system ecology[2].

The Argument and Contextualisation establishes the problem of ecological and social crises and views this through an integrated prism of food production and distribution set in an urban community context. It critiques existing local alternatives to food production and distribution. This problematises the question of how we can continue to produce food at a time of growing urban populations. It outlines the wider context of social and ecological crises in relation to food production, distribution and access that forms the backdrop for this research. Systems thinking is used as a creative approach to address the gaps in knowledge identified in the Argument and Contextualisation and to enable these challenges to be overcome.

In the Systems chapter the different conceptual systems are explored in terms of food production and distribution. This is where the main arguments of the thesis are laid out. An overview is provided of three singular food production systems (Agroforestry, Mushroom production and Aquaponics), two food distribution platforms (a delivery

[2] Gregory Bateson saw ecology as the ‘pattern that connects’ (Bateson, 2000). Here the term is used as a metaphor to connect different networks and systems together to create a more complex whole. The concept of ecology sits across the individual systems, bringing together the social, economic and biological relationships between them.

service and a whole food store) and one waste system (vermiculture). This is followed by a discussion of the interconnections between systems in the Biospheric Whole.

The approach taken in this thesis grew out of the author's particular understanding of research methods, focusing on integrating a wide range of knowledge networks. Bringing together different actors such as researchers, practitioners, politicians, community groups and cultural organisations, enabled the holistic positioning of the programme of investigation. Rather than having a fixed idea of what was needed for the programme, the investigation emerged out of reflection on the needs and wants of these many stakeholders and collaborators. The role played by the author throughout the programme of investigation changed on a daily basis because of the need to engage with different sectors. Even within one day, this might entail working as a designer in the morning and working with stakeholders on funding applications in the afternoon. At the outset there was an expectation that the role would be that of PhD researcher throughout, and did not anticipate becoming landlord of a building, director of a company or ambassador for a clothing company. This indicates the degree to which the role emerged as part of the process of research.

This method of critically positioning the project comes as second nature to the author, enabling him to develop a transdisciplinary narrative that encompasses social, ecological, economic, cultural, climatic and biospheric realms. However, this does not mean that there were not moments of great doubt involved in the process. As a result of the diverse methodology, it would not have been possible to be an expert in all of the fields that were required to implement the project. That was neither the aim nor the approach taken. Even though each of the systems developed were not new, the whole system approach was. To implement this required a flair of adaptability in the author and enabled deep inspiration to come from the periods of doubt.

These transdisciplinary narratives enabled the author to incorporate a wide range of collaborators to develop unique research outputs. The different stakeholders and collaborators had different needs, wants and expectations and so it was necessary to develop different kinds of relationships with each of them in order to achieve the desired outcomes for all concerned. A list of the main collaborators has been included in Appendix 3.

The thesis is based on a methodology of transdisciplinary[3] action-led research that has used a site in Salford to test and experiment on the interconnectivity of an array of food production and distribution systems. It focused on a *practice* of geographically positioned action-led research. To deliver this programme it was important to create a community

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[3] As Nicolescu argues, 'as the prefix "trans" indicates, transdisciplinarity concerns that which is at once between the disciplines, across the different disciplines, and beyond all disciplines' (Nicolescu, 2008: 2). In using this approach it is not entirely possible to plan a methodology because transdisciplinarity emerges from the process of implementation. The whole becomes more than the sum of the parts, so the full understanding of the outcomes of this programme of investigation could not be predicted in the methodology. The new thinking about how the systems could be designed and connected and how to circulate the nutrients required to create a whole system approach to urban farming had to emerge from the creative process of implementation.

interest company, Biospheric Foundation (CIC). The Biospheric Foundation CIC legal status enabled the project to secure a variety of community, cultural and research funding streams to support the development of the programme. In collaboration with the Manchester International Festival, the Biospheric Foundation implemented its first project to address the first two aims of the programme of investigation: the Biospheric Project. In partnership with the Manchester International Festival the Biospheric Foundation secured funding from the People's Postcode Lottery for a public engagement programme for the Biospheric Project. The Biospheric Project has become a world-renowned *in-situ* urban farm and research laboratory in the heart of the Blackfriars neighbourhood in inner city Salford, a *place* for the experiments to be carried out in the *real world*. The methodology highlights the diverse expertise across technical, cultural, community, social and ecological actors needed to deliver the programme of investigation. Other projects have since been developed by the Biospheric Foundation, but these are beyond the scope of this thesis.

Significant funding was required to enable the research to be action-led and to implement the whole system approach. The methodology, therefore, needed to include conversations with funders and negotiating funding across social, ecological and commercial spheres. Without this, the programme of investigation would not have been implemented. The methodology section describes how the funding secured came from a number of sources that included cultural, technical and community partners as well as academic funding from MIRIAD at Manchester Metropolitan University, Queen's University Belfast, The University of Manchester and Durham University.

The thesis then documents the implementation of action-led research within the Biospheric Project and sets out the chronological order for each of the system components that were implemented as part of the research, to tell the story of the Biospheric Project. A Portfolio of Works that illustrates the implementation of the project accompanies this document. The various elements, systems and components have been used to create a closed system (as defined in the Argument and Contextualisation) that is ecologically sustainable and adaptive. This created the first whole system approach to urban farming in an area of deprivation in Europe.

This is followed by a discussion in the Conclusion, which sets out the major learning from the programme of investigation and includes a critical evaluation of how these were achieved. It clearly identifies the original knowledge developed in terms of creative system thinking as a design process within the context of urban food production and distribution in an existing urban community. The whole programme of investigation has brought an elegant design process and artistic aesthetic to the way in which the scientific systems connect to create a whole ecology.

The following artists and designers provided the inspiration for my work. Ross Lovegrove, also know as 'Captain Organic' is an internationally acclaimed industrial designer and the Director of Big Trees Corporation. He was born in Wales, and studied at Manchester Polytechnic. He creates functional design pieces that draw on art and ecology but are delivered through a design methodology. So for example, his Solar Tree, is inspired by the natural process of photosynthesis and creates a solar array that produces light at night time from an aesthetically pleasing sculptural form (Lovegrove, 2014). I have tried to mimic this in my own work by designing functional ecological systems with an artistic aesthetic. Michael Pawlyn is an architect who uses biomimicry in his designs. For example, in the Sahara Forest Project, the design of the seawater-cooled greenhouse was inspired by the Namibian fog-basking beetle that has evolved a way of harvesting its own fresh water in a desert (Pawlyn, 2011). In my own work it was the processes of up-cycling and connecting systems together to minimize waste that were inspired by the way these processes occur in nature. The preeminent ecological artists, Helen Mayer Harrison and Newton Harrison (Professors, University California Santa Cruz and Professors Emeriti, University of California San Diego) provided inspiration through their collaborative approach to practice and their ability to work with many disciplines. For example, their work the Serpentine Lattice involved working with biologists, ecologists, community planners and community groups in a way that inspired this project.

2 Argument and Contextualisation

'When everything is connected to everything else, for better or for worse, everything matters.' (Bruce Mau et al, 2004:129)

2.1 Introduction

There are multiple crises that are faced by humanity in the twenty-first century including global warming, poverty, biodiversity loss, and environmental damage. The scale of these crises is unprecedented and increasingly complex. It is fair to say that it is not possible to draw out the one major single problem that should be the main focus for us to solve. French philosopher Edgar Morin has coined the term 'polycrisis' to be able to conceptualise this (Morin, 1999). This captures the sense that we are witnessing not one single problem, but problems that are interconnected and overlap with each other (van Breda, 2007). This polycrisis is man-made, and so it is the responsibility of humanity to provide systemic solutions that can begin to deal with the major challenges of our times. Many of these crises and the responses to them can be seen through the context of food (Maxey, 2006), which is the focus of this programme of investigation. In particular, the focus will be on food production and distribution, which is becoming a major point of research on food security (Morgan and Sonnino, 2010).

This Argument and Contextualisation addresses the question of how can we continue to produce food in the context of an ecological crisis and growing urban populations. It will introduce the social and ecological crises in relation to food production, distribution and access, to provide a wider context for the programme of investigation. The Argument and Contextualisation then explores some existing grassroots alternative approaches to local food production and critiques them to highlight the existing gaps in knowledge that this research aims to address.

2.2 Food Poverty: A Social Crisis

Food banks have become one of the fastest growing charitable activities in the UK, with at least three new food banks opening each week (Church Action on Poverty, 2013). Oxfam and Church Action on Poverty estimate that over 500,000 people are now reliant on the use of food banks and receipt of food parcels, a figure substantially higher than the headline figure of 350,000 supplied by the Trussell Trust (Church Action on Poverty, 2013). Food banks across Britain report being inundated with requests for emergency meals during the school holidays. Parents whose children ordinarily receive free school lunches are among those who are struggling most, as they have to find an extra meal every day. The rise of food banks in the UK has brought food poverty sharply into public consciousness.

A range of experts, including David Taylor-Robinson – a population health scientist at the Medical Research Council, have warned that UK food poverty 'has all the signs of a public health emergency that could go unrecognised until it is too late to take preventive action' (Taylor-Robinson et al, 2013). This is not just a UK problem; food banks have been common in Canada since the 1980s, and have now become normalised. Graham Riches argues that they have become:

> Key institutions in the newly resurrected residual welfare state with governments relying on them as charitable partners providing feeding programmes of last resort. They permit the state to neglect its obligation to protect vulnerable and powerless people. They encourage the view that food poverty is not a critical public policy issue. They allow the corporate food industry to be viewed as responsible community partners (Riches, 2002: 654)

There is a real need to critique food banks within a wider context in order to be able to avoid their normalisation.

The rise of food banks has been connected to the coalition government's programme of welfare reforms (Lambie-Mumford and Dowler, 2014). However, the roots of malnutrition are deeper than welfare reforms. The issue of food poverty is in fact much deeper than a lack of food for people in crisis and is connected to poor nutrition for people with low income. As Julia Unwin of the Joseph Rowntree Foundation points out, 'poor nutrition is rightly described as the new malnutrition of our times' (Unwin, 2013). This phenomenon is connected to our industrialised global agricultural mode of production, which creates nutritionally deficient food, reduces biodiversity, and relies upon oil for each part of production, therefore creating an increasingly volatile market that contributes significantly towards climate change (Tilman et al, 2002). Food production and access is therefore an increasingly important area for research and public policy. The intersection of social and environmental crises necessitates a socially just solution within the planet's ecological limits, consistent with Professor Lang's call for better nutrition in a low carbon sustainable food economy (Lang, 2009).

The pressure on low income families, who have seen stagnation in terms of benefits or pay, is being made worse by the rise in living costs, of which food is a major element. Families in the lowest income houses spend a higher proportion of their income on food. It is estimated that the poorest 10% of households in the UK spent nearly a quarter (23.8%) of their gross income on food and non-alcoholic beverages in 2012 (Whitham, 2012). This means that low-income families are more vulnerable to increases in the price of food.

There have been increases in prices of food generally, and fruit and vegetables specifically, particularly since 2004 (Office of National Statistics, 2013). This is due in large part to increases in the costs of global production, which is connected to the fluctuations of peak oil prices (Trostle, 2010). Growing food is not expensive in itself, but the production of oil-heavy, pesticide-based global food is socially, economically and ecologically expensive. Developing new approaches to producing local food is a major public policy challenge of our time and a pressing issue of social justice.

Having peaked in 2006 and 2007, purchases of fruit and vegetables were ten per cent lower in 2011 than 2007 for all households. For households with the second lowest income, the reduction was twenty two per cent, and for households in the poorest ten percent it was fifteen per cent. Only those in the top fifth of incomes were estimated to be eating the recommended five servings a day (Office of National Statistics, 2013). As we can see from the rising costs of these items at the same time, there is a correlation between costs and consumption of healthy food, and a clear connection between low-income and poor nutrition.

The link between poor nutrition and ill health has long been established. As shown by the 2010 Marmot Review, Fair Society, Healthy Lives, general nutrition levels in the UK are poor, with people on low incomes even worse (Marmot et al, 2010). It is estimated that poor nutrition is a contributory factor in one third of all cancers (Department of Health, 1998); nearly 30% of deaths from coronary heart disease (Peterson and Rayner, 2003); and 30% of years of life lost due to disability or early death (World Health Organisation, 2002). Other negative results of a poor diet include a significantly increased risk of obesity and poor mental health (James et al, 1997).

Healthy food production and distribution is an area that can contribute towards solving social crises, but in order to be able to achieve this, there must also be considerations of the ecological crises that are created through the global food system.

2.3 The Global Food System: An Ecological Crisis

Industrial processes that are present in all aspects of the globalised food supply chain have become increasingly dominant in our society (Horrigan et al, 2002). The current model in which the vast majority of global food is produced is based on monoculture, is heavily dependent on the rapidly decreasing supply of oil, utilises pesticides that contribute towards less nutritious food, and employs global systems of transportation, packaging and refrigeration. While this may produce food that is 'cheaper' in the short-term and is an essential factor in currently being able to feed the world's population, ultimately it rests upon a mode of production that exceeds the earth's ecological limits and does not guarantee food security. Weis (2010: 315) identifies the 'deceptive efficiency' and 'instability' of cheap industrial food. As Monbiot (2009) points out, the dependence on oil, a resource which is depleting between two and three percent a year, will inevitably lead to further increases in price. As discussed above, this will impact particularly on people with low incomes. The ecological and social crises are thus inextricably linked.

2.3.1 The Dominant Agricultural Practice

It is important to note that the existing system is crucial in creating food for the world's population. Industrialisation has been the main means through which agricultural productivity has improved, and has resulted in food production rising faster than population growth in recent decades. However, existing models of 'industrial agriculture' are ultimately unsustainable (Woodhouse, 2010).

Farming in the 20th and 21st Century has accelerated the destruction of forest systems and woodlands to make space for agriculture. Techniques such as 'slash and burn' are still used to transform complex, vertical and fertile systems into horizontal monocultures (Thrupp, 2000). Mono-cultural farming entails the production of a single crop in mass fields. The consequent lack of a diverse range of plants and insects which support plants naturally, means that these single crops need to be managed by herbicides and pesticides and are almost always oil-heavy production systems. This reduces biodiversity and the reliance on pesticides has also been associated with increased cancer rates for both workers and consumers (Horrigan et al, 2002).

McDonough and Braungart (2002) argue that under the existing paradigm of manufacturing and development, diversity as an integral element of the natural world is typically treated as a hostile force and a threat to design goals. The industrialised model of agriculture creates more waste outputs, as it is not based upon a closed loop system that would re-utilise waste . This has a number of implications: it takes more energy to maintain; it is less resilient; it is less interconnected; it rests upon higher levels of maintenance; and it leads to higher greenhouse gas emissions (Crawford, 2010).

These poor land management techniques affect years of forest development and release a huge amount of accumulated and stored carbon back into the atmosphere. Once the forest is removed, the earth is ploughed. Ploughing, which turns the soil, releases carbon into the atmosphere, and over-exposes the living microorganisms and worms to the sun and to predators, leading to a depletion of important soil inhabitants. Hoksing (2009) argues that this process, over many years, kills the living organisms in the soil.

Metabolism is a biological systems approach of evaluating inputs and outputs (Newman, 1999). The main difference between the 'born' and the 'man-made' is the metabolism of its design. Human design (agriculture, cities and textiles) has had a significantly degrading effect on the living system by developing more open loop systems (see Glossary) that create more waste and are ultimately less efficient and more ecologically damaging. Intensively farmed land can be characterised as having an industrial metabolism. As Steel argues, the metabolism of this system works against the natural processes instead of in support of them (Steel, 2008).

The dominant model of food production rests upon simplistic approaches to complex problems. Monoculture has created an industrial food model that has spread pollutants into the air, water and soil. It has also decreased the diversity of species and cultural practices. Our dependency on crude oil has created a reliance on global food organisation to feed our communities. Climate change has been accelerated, soil erosion occurs, and the earth is experiencing increased deforestation and desertification. These are all related to price increases in food production and poor land management, showing the interconnected relationship between social and ecological systems.

2.4 Alternative Local Approaches

While the industrial model of food production may produce food that is cheaper in the short-term and is an essential factor in currently being able to feed the world's population, ultimately it rests upon a mode of production that exceeds the earth's ecological limits and creates social problems. However, alternative approaches to food production have emerged and are often conceptualised as a 'quality turn' by both producers and consumers in a shift away from the 'global agri-food complex' (Goodman, 2011). One way to develop a truly resilient, sustainable and adaptive food system is to shift from linear (open loop) systems, in which resource and capital investments move through the system to become waste, to a closed loop system where wastes can become inputs for new processes (Esty and Porter, 1998).

In order to achieve this, we need to adopt more radical local approaches that can contribute to solutions that are socially, ecologically and economically adaptive and that establish a platform for experimenting with innovative systems. Such systems have been developing across the world with the focus being on many different dimensions such as health, nutrition, social equity, food security, ecological conservation and economic development (Kremer and DeLiberty, 2011).

There are several benefits associated with local food production, including greater food democracy, reduced ecological damage, healthier food and the possibilities of ensuring that wealth is more efficiently circulated in the local economy (Maxey, 2006). Local self-reliance is based on the notion that local communities should be able to obtain at least their basic necessities, if not more of their goods, from within their own localities (Shuman, 1998). This idea encourages communities to use their limited resources in the most efficient and sustainable manner and challenges the globalised nature of industrialised food production. Local self-reliance can be applied at different scales, including household, neighbourhood, and the city (Grewal and Grewal, 2012).

Action at a local level can assume many different formats, and even the concept of localisation can be contested (Sonnino and Marsden, 2006). For instance, Hinrichs (2003) shows that the local food movement of Iowa in the United States is characterised by two quite different forms of localisation. 'Defensive localisation' imposes rigid boundaries around the spatial 'local' and stresses its homogeneity, while 'diversity-receptive localisation' embeds the local into a larger national or world community that is more relational and open to change.

For the purpose of this thesis local approaches will be taken to mean 'grassroots innovations': networks of organisations and community activists that generate locally-rooted solutions that can respond to the local context through experimenting with different innovations and alternatives, and which are consistent with the values and interests of communities. There are many examples of these innovations across the world, but here the focus is on three notable approaches that exist within the UK, before continuing to critique these models.

2.4.1 Transition Towns

Since its launch in Totnes 2005, the Transition Network has found considerable success and expansion. The movement has re-localisation and resilience at its core (Transition Towns, 2013). The concept is based upon the transition from an oil-based economy to renewable energy and all of their initiatives flow from this. The activities of this network include food growing groups, community-owned bakeries and breweries and community-based renewable energy production. The focus is on street-by-street transformation, building community relationships and transforming the local economy through local enterprise (Transition Towns, 2013). As Rob Hopkins, the co-founder of the transition movement, has stated, the aim is:

> Rebuilding local agriculture and food production; localising energy production; rethinking healthcare; rediscovering local building materials in the context of zero energy building; and rethinking how we manage waste. All build resilience and offer the potential of an extraordinary renaissance – economic, cultural and spiritual (Hopkins, 2008: 15).

2.4.2 Incredible Edible

Incredible Edible is a local alternative to food production and distribution that encourages people to grow food in their local areas, and is concerned with finding creative ways to use space to be able to do this within a particular local area and in a way that engages with the community (Clarke, 2010). It started in the Yorkshire town of Todmorden, and has seen food crops planted in different public locations throughout the locality. This allows people to be able to pick their own fresh fruit and vegetables, but it also has an awareness-raising role. Public space food plantings has become used as educational tools in what Incredible Edible call 'propaganda gardens' (Paul, 2011: online).

The Incredible Edible approach is based upon the following foundations:

- Creating opportunities for people to imagine and develop new projects;
- Finding land and space within the built environment to grow food, using buildings, and other tools and resources to rethink the approaches that are currently taken;
- Investing in local enterprises that support food production within the community;
- Providing the route to training in land skills and to environmentally conscious ways of distributing and buying food.

Incredible Edible has achieved significant popularity in spreading to places across the UK, and there is a strong emerging network (Paul, 2011: online).

2.4.3 Kindling Trust

The Kindling Trust is a not-for-profit social enterprise with charitable aims to establish a 'radical and pioneering social change centre and enterprise zone in the rural Northwest of England, to practice and demonstrate sustainable production, living and activism and to support others working towards an ecological and just society' (Kindling Trust, no date: online). This includes various different projects, such as Feeding Manchester and

Manchester Veg People. The former brings together sustainable food practitioners from across Greater Manchester to explore ways to create a more sustainable food system for the sub-region and provide strategic plans for action (Kindling Trust, no date). The latter is an emergent co-operative of local organic growers, restaurants and caterers who collaborate to provide fresh, seasonal food for Greater Manchester with the aim of making small-scale organic production more resilient (Manchester Veg People, no date).

2.5 Critique of Existing Approaches

Initiatives such as Transition Towns, Incredible Edible and The Kindling Trust are an important part of the transformation that is required to become sustainable. We need a broad diversity of approaches to the question of how we can put healthy food on our table in the context of rising food prices, climate change and growing urban populations. However, these approaches can be critiqued on four main grounds:

- They do not recognise the centrality of the city in the 21^{st} century and the deprivation that often exists in urban areas;
- They lack potential for significant scale up;
- The models fail to consider and apply technological advances;
- These models are not based on an interconnected whole system approach to meeting future needs of food production.

This critique will be explained in more detail in the sections that follow.

2.5.1 Urban Deprivation

Cities are becoming increasingly important to human development. Brand (2009) explains that 1.3 million people a week, which is 70 million people a year, are moving into cities. Currently, 50% of the world's population lives in 2.5% of the landmass. He estimates that soon, 80% of the world's population will live in 3% of the landmass. Urbanisation is the dominant demographic trend and an essential element of land-transformation across the world (Grimm et al, 2000).

This migration to the urban landscape reveals a change in the way that communities and societies are organised, and provides both significant challenges and potential for positive change. Roberts et al (2011) argue that even in the distant past, population density and migration have been critical to the propagation of ideas. These factors have led to cultural and technological advances that over a given time have helped to support the growing populations. Cities are the prime drivers for future consumption and production. While they are the place in which unsustainable practices occur, they are also the 'operational units in which concrete actions can be envisaged, designed, (politically) facilitated and effectively rolled out' (Nevens et al, 2013). Additionally, Brand (2009) argues that the concentrations of populations and enterprises within urban environments bring significant efficiencies in terms of infrastructures. Paradoxically, they also produce the most waste and ecological destruction.

The urban transformation reflects the sheer ingenuity of humanity as cities are the most technologically complex systems that have been created. There are scholars who argue that cities have the potential to be the most green, sustainable, adapted and complex environments as well. For instance, Alberti (2005) asserts that earth ecosystems are becoming increasingly dependent on urban growth and therefore the city is the location where innovation needs to happen. There is a strong assertion that humanity has the ability to make development sustainable and to ensure that cities meet the demands of the present without compromising the ability of future generations to be able to meet their own needs (Brundtland, 1987).

There are, however, those who reject such notions. Hall and Pfeiffer (2000) argue that there are negative externalities that arise from pollution and contaminations within cities that contribute significantly to the threat of irreversible damage to the world's ecosystem. Here it is argued that city infrastructures are a good thing in relation to sustainability, because, as is seen in a healthy forest system, density and biodiversity is a way of developing bio-security. At the same time, a density of enterprise, people and ideas provides the most effective means of developing a rich soup of innovation. This potential is not currently being harnessed to its full extent. European food systems tend to develop horizontal systems, based on a system of monoculture, but cities are multi-dimensional urban infrastructures. As cities become denser we need to create more diverse ecological systems - we cannot simply rely on monoculture or horizontal systems.

This is a problem with the development of grass-roots initiatives, such as The Kindling Trust or Transition Towns as they are still based largely on monocultural practices, which can be spread across a wide area within (and outside of) the city. They also do not confront the problems created by social inequalities and deprivation within the city that affect local food infrastructures and access. They tend to be based within suburban contexts in which the immediate market seems more conducive, but in which need is arguably less. The concept of 'food deserts' has been developed to identify the problem of access to food, particularly foods that are essential to a healthy diet, for low-income households in deprived communities. This has become an increasingly important issue, but has not been addressed by initiatives for sustainable and healthy food production and distribution (Wrigley, 2002).

Incredible Edible does address many of these issues relating to social inequalities and it is a highly important part of developing green infrastructure in cities. However, the systems it develops are simple singular systems that do not have the necessary complexity to address the full spectrum of possibilities for producing food within cities. This simplicity has allowed the organisation to be very successful, so that they now run over a hundred projects in the United Kingdom and over seven hundred projects worldwide, but their systems are not connected to each other or to the broader systems of waste and recycling that need to be brought together to maximise efficiency and productivity.

There is a lack of local innovative experiments that are geographically situated within areas of urban deprivation, the very places they are needed most. There are clear challenges around situating an innovation within an area of deprivation – for instance, those living in deprived areas are less likely to volunteer than those living in more affluent areas (The Poverty Site, 2014). However, it is important not to assume that existing initiatives are grounded purely in voluntary participation. Connors and McDonald (2011) argue that Transition Towns operates with a top-down and rigid structure with a strong emphasis on the founder and a manifesto that appears prescriptive and inherently undemocratic.

To be able to address some of the major ecological and social challenges that confront us, it is important to recognise the centrality of the city in the 21st century and be able to provide solutions that harness this and move beyond monoculture practices, and do so in a way that also targets innovations in areas of deprivation where they are most needed. The existing models of grass roots innovation can often fail to do this. This programme of research has been positioned to be able to address some of these gaps, in creating a whole system approach in an area of urban deprivation, which draws upon technological and transdisciplinary approaches to reconsider food production and distribution.

2.5.2 Scaling-up

Mount argues that 'scaling up' is the next major challenge for the local food movement: in order to be able to deliver broader systemic impacts, local food systems must expand either through engaging with more or larger sections of consumers or food producers (Mount, 2012). By scaling up, there is potential for local food systems to be able to draw upon the efficiencies of the industrialised food system while at the same time maintaining the social and ecological concerns that drive them (Day-Farnsworth et al, 2010).

By supporting local innovation through piloting alternative approaches, learning can be shared across a wider number of platforms to ensure scale-up in a way that fits within a particular local context. However, if there is to be a true scaling up of the projects and innovations, then there must be some degree of commercialisation. As Lang (2009: 24) argues, new approaches need to be 'translated into the business model – how the food system works, its profit and loss account'.

Many of the existing local alternatives do not fully address this aspect of commercialisation. They are also often not situated within an urban environment, which means that there are arguably fewer market opportunities being generated. For instance, Transition Towns are not commercial entities. They are based on small groups that are trying to make themselves more efficient, but within the scale of cities this will not have sufficient impact. The Kindling Trust is more commercial in its approach. It remains relatively small-scale, however, and the systems that it uses to produce food are relatively simplistic, which will impact upon its potential to scale up.

2.5.3 Technological Advances

One of the major ways to achieve the necessary scaling up is through considering how best to harness technological advances. There has been an exponential growth in technologies, and these are creating new ways of looking at urban food production. Many existing grass roots initiatives fail to use any of these technologies and are based on traditional farming techniques. While these are important, it is also necessary to be able to explore emerging technologies to better understand the diverse systems that could be used to produce food in urban environments.

In order to explain this more fully, it is necessary to introduce the idea of the Biosphere. In 1875, the Swiss geographer Edward Suess coined the word Biosphere to mean all of the parts of the earth in which life is found (Lovelock, 2005). Living organisms are connected to the environment and seek opportunities to create life as part of a whole system made up of smaller ecosystems that are mutually supportive (Lovelock, 1983). The new discipline of Biospherology aims to learn more about biospheric processes and webs of relationships, in order to make systems such as food systems or cities, mimic the natural principles that are found in Gaia. Biospherology has radical potential to be able to answer the major ecological questions of our time by developing an integrated discipline that is connected to a range of different fields, including ecology, microbiology, engineering and social systems. This is a 'new integrating scientific discipline' that explores biotic cycles, which have varying levels of complexity and closure (Pechurkin and Somova, 2008: 691). Biospherics has the potential to develop a scientific basis for being able to create a harmonious relationship between humanity, technology and nature, which could re-imagine food production in the 21st century.

Biospherology brings together an array of academic disciplines and applied researchers in order to connect the needs of humanity, technology, and nature. There have been a number of significant action-led research projects that have been developed in the attempt to understand how we integrate biospheric and technological methodologies in order to better understand how to create resilient adaptive environments. Importantly, these programmes question how to evolve and stimulate such environments, aiming to construct sustainable life support systems (Allen and Nelson, 1999). One of the major areas of focus of this approach is how to use artificial ecological systems to develop technologies to solve pollution problems in our urban areas and to develop high yield sustainable agriculture. This approach is very different to those currently seen in the development of sustainable cities and through existing local alternatives.

It is the intertwining of the Bios and the Technos, the hardware and software, the Biosphere and Technosphere that is of interest in this programme of investigation. When these two networks truly connect there is significant potential for new ideas and innovation that could transform the city into a neo-biological era, in which the natural and built environments adapt (Kelly, 2010). It is a whole system approach that brings together technological and ecological design to create a deeper ecology and moves far beyond the reductionist approaches that are implemented through monoculture systems, even through local alternatives. This programme of investigation has drawn upon a range of different schools of thought and disciplines to develop technologies in order to deliver a system that is diverse, multi-layered and based upon a closed-loop system (explained below).

2.5.4 The Need for Closed Loop Systems

A system is a set of parts and things collaborating within an interconnecting network - a complex whole. Within human and natural contexts, there are many different systems on a variety of scales. Examples would be the human brain or heart, forests, coral reefs, a city and the Biosphere itself. The Biosphere is the global sum of many ecosystems, including many developed by humans as well as natural systems. Systems that sit within each other, like the brain or heart in a human body, are smaller systems within larger systems and can be called nested systems (see Glossary). Regarding food production there has been some research, but there is a failure to connect sophisticated systems and closed loop processes with the potential necessary at local scales within a city context (Picket et al, 2001).

Existing models that aim for a localisation of food production and distribution can often fail to ensure connectivity between systems. For instance, the Kindling Trust has a farm in a rural location, which distributes its produce in a suburban shop where there is particular demand. When the distribution system is separated from the production system there is no opportunity for the waste from one system to be fed back in to close the loop. This is just one example, but many of the existing initiatives fail to recognise the importance of having a closed loop system.

When a network of technologies is created, the relationship between the networks may eradicate the production of waste – for instance the waste from one technology becomes a nutrient that supports the connecting network. This idea of relationships between technologies potentially reduces carbon emissions as it becomes intrinsic to the functioning of the whole system and not an externality of one particular system or network. The principle of a closed loop system is, therefore, useful for food production and distribution. It means that the system is connected, which means it is more circular and efficient and based on more natural systems. This means that there is less waste in the system and therefore provides principles that can guide ideal food production when developing local alternatives to the industrialised agricultural model.

There have been several innovations in developing closed loop systems that can be drawn upon. The approach taken by action-led research programmes, such as Controlled Ecological Life Support System (CELSS) and Biosphere 2, are fundamentally investigating how to close loops between systems. They integrate natural design principles with human needs and ecological design. For local alternatives to be able to contribute towards systemic change, it is important to be able to consider the different ways in which this could be implemented within a city context, and in particular in areas of urban deprivation where the need is most acute.

2.6 Closed Ecological Systems

A life support system that approaches complete internal sustainability and which is biologically based is termed a closed ecological system. This means that it is essentially energetically open and materially closed, and recycles its major elements and nutrients. So, although energy may enter and leave the system, everything else remains within it by being recycled. Some examples of closed ecological systems are outlined below.

2.6.1 The Controlled Environmental Life Support System (CELSS)

Early laboratory experiments with biological regenerative systems were based on monocultures of unicellular organisms. They were not successful in that the systems used did not attain a stable, steady state and could not provide a significant portion of the human diet. They did, however, provide significant new knowledge that will be drawn upon throughout this programme of investigation in developing a whole system approach to urban farming (Olson et al, 1988).

NASA initiated the CELSS programme in 1978. There were three main aspects of this programme. At the Kennedy Space Center the 'Breadboard' provided a test bed for plant cultivation experiments in a closed ecological system. The Johnson Space Center focused on food processing and human diets in space, and the Ames Research Center was connected with basic research in system controls. These programmes included traditional agricultural crops, higher plants, as the core element in their bio-regenerative life support systems, although they were still, essentially, very simple systems because they included just a few species of plants and/or algae as their biological components. Systems such as these must be energetically open as entropy (see Glossary) is always increasing. So light needed for photosynthesis comes from outside of the system, and excess heat from the system needs to be removed to external heat sinks. Having said this, any energy that can be produced from within the system will reduce the need for energy to be supplied from external sources.

2.6.2 Biospheric Systems

CELSS and other closed ecological systems contain essentially only one type of ecosystem – an agricultural one – for human life support. In this respect they differ from 'biospheric systems', which include a number of internal ecosystems. Biospheric systems are essentially materially closed, and energetically open, like a closed ecological life support system. However, their internal complexity provides additional buffering capacity for air and water regeneration, and increases the long-term prospects of a system resistant to catastrophic decline. It also enhances the 'live-ability' for its human inhabitants. These systems offer new opportunities for research into the complexity of ecological mechanisms operating in our Earth's biosphere. Morowitz et al (2005) argue that closure is a concept that is frequently used in the physical sciences, yet receives little attention in ecology, so there is plenty of scope for development here. Examples of biospheric systems include the Biosphere 2 project in Arizona, and the Japanese Closed Ecology Experimental Facilities (CEEF). Here the focus is on Biosphere 2.

Biosphere 2 was a £100 million project funded by Ed Bass, in which an artificial living system was created. Within it, there was ocean with coral reef, mangrove wetlands, tropical rainforest, savannah grassland, and fog desert in an area of 3.14 acres. The groundbreaking research ran for two years from 26th September 1991 to 26th September 1993. It was situated in Arizona, with eight people being sealed into the glass environment with over 3500 species. The people who lived in the system for the two years were called biospherains. They attempted to create the second closed system known to man, the first being the Biosphere itself. The Biosphere2 project was materially closed, while being energetically open like a closed ecological life support system. The internal complexity, however, provided additional buffering capacity for air and water regeneration (Kelly, 1994).

This man-made closed system was not just biological it was also highly technological. A super-computer monitored everything that the system would do, ensuring that the biology was safe: the technosphere supported the biosphere. This reveals the significant potential for connections between the built and natural environment that are not being explored sufficiently through the existing local alternatives of food production in the UK.

The importance of Biosphere2 project in relation to sustainable urban futures cannot be underestimated. This research opens a gateway to understanding the development and dynamics of ecological systems in a true controlled environment. This is not fully possible within the natural environment as it is nearly impossible to understand all the elements that may affect the processes in order to be able to determine and isolate particular causal factors.

The research also enables greater understanding of the connection between living and artificial life and how that can be monitored, captured, analysed, and visualised, in order to gain a deeper understanding of interconnectivity. Ultimately, it can provide very useful tools for developing urban food systems. The ecotechnics who designed this system and the biospherains, who lived in the closed system, learnt many things about closed loop systems. What was most interesting, however, were their insights into what is needed to create a biosphere, called the 'Principles of Biospherics' (Kelly, 1994).

The Principles of Biospherics include three major points of learning that can be drawn upon:

- Microorganisms do most of the work
- Soil can be viewed as an organism which is alive and breathes
- Diversity increases gradually

This is highly interesting because in action-led agroforestry research, it has been found that the development of complex woodland and forest systems have very similar rules. These points also highlight the difference of such systems from monoculture food systems. In the latter, diversity is reduced and the soil becomes a redundant system. Therefore it seems completely viable to think about these processes when developing urban food systems, either on land based systems or within buildings, as a means to confront the challenges created through the industrialised model of agriculture and provide true innovation.

There is significant scope to apply these principles within an urban food production context to create a platform for developing original knowledge about how integrated systems thinking can enhance the development of sustainable technologies. This can address the question of how to achieve more sustainable communities in a local context, in a way that is far from being achieved through existing practices in the UK.

2.7 Conclusion

We are currently living in a time of 'polycrisis' including issues of global warming, poverty, biodiversity loss, and ecological damage. In this Argument and Contextualisation two key aspects of this have been outlined: the social crisis of food poverty in an increasingly urbanised environment; and the ecological crisis that arises from industrialised food production processes. The global food system has been described and the impact that the dominant agricultural practice has in contributing to this crisis has been anaylsed.

An outline has been provided of three of the main alternatives that have developed in the UK in an attempt to produce food in more local ways. These grass-roots innovations have been critiqued in terms of not harnessing the potential from technological advances, not being based on interconnected systems, lacking in potential for significant scale up and failing to address the challenges of urban deprivation. This programme of investigation aims to explore ways in which these issues can be overcome by developing a whole system approach. These gaps in knowledge have been highlighted through action research involving the implementation and observation of closed loop systems within an urban context that also engages with deprived communities. Locating experimental innovations in food production as a means to create original knowledge to address this is important and contributes towards knowledge that can be applied to real life problems.

This thesis documents a series of action-led research activities, aiming to address this and challenge contemporary thought, addressing sustainable communities in a local context focused on urban food production and distribution. As outlined in the introduction, the aims were:

1. To design a whole system ecological approach to urban farming.
2. To establish a working model of such in an area of high social deprivation.
3. To create a centre for ecological research.

4. To contribute to public awareness of health food and ecological systems in urban environments.

3. Systems

3.1 Introduction

Following on from the Argument and Contextualisation, this chapter outlines the main arguments that underpin the thesis. The thesis is particularly concerned with the relationships between systems and the need to develop a wider transdisciplinary (see Glossary) approach. This chapter outlines understanding of the singular systems that are the components of the whole system approach: food production, food distribution and food waste. Understanding of these systems and the connections between them underpins the methodology for the project that is outlined in the next chapter. This approach draws upon different types of knowledge and brings them together through the creative design process, to apply them within an urban context in a community that experiences high levels of deprivation.

This chapter provides an overview and historical context for three singular food production systems, two food distribution platforms and one waste system. The systems examined are as follows:

- Food production – agroforestry, mushroom production and aquaponics
- Food distribution - a local food delivery system and a local whole food store
- Food waste - vermiculture.

The food production systems are stretched across different historical contexts, from ancient to contemporary systems. They utilise different scientific development and experimental methodologies, based on natural design principles and integrating technologies.

The particular systems are explored in detail and the benefits that they could bring are noted. Consideration is also given to how they could be tested within an urban context to assess particular strengths and weaknesses. The inputs and the outputs of the systems are explained, and there is a discussion of whether connectivity is possible between them. Finally, these production, distribution and waste systems are examined, not as six singular systems but as one whole interconnected life support system.

The programme of investigation implemented these production, distribution and waste systems to develop a series of interconnected systems and test these through implementation and applied research. This conceptualisation was directly influenced by the research into closed ecological life support and biospheric systems highlighted in the Argument and Contextualisation.

3.2 Agroforestry

3.2.1 Forests and humanity

Forests are living systems, with all living things within them working together as a whole to sustain and increase life. A forest is more than the sum of its parts: it is a community of nested systems all relying on each other to create more life for the whole. Forests have always been a place for people, providing food, water and shelter. Humanity has been transforming these landscapes both creatively and insensitively from the birth of humankind. We have supported forest systems to unlock the knowledge contained within them, and have mimicked their natural design principles in an effort to grow food more sustainably. One of these techniques is called agroforestry. A forest is an ecological system formed within its environment over time. Agroforestry is a system designed by human intellect, mimicking the structures, layers and forms seen in natural forest systems.

Agroforestry is different from other forms of agriculture because the system can store higher amounts of carbon in its biomass, and because it can generate higher levels of biodiversity (Schroth et al, 2011). An agroforestry system means that soil productivity is enhanced through biological nitrogen fixation, efficient capturing and cycling of nutrients (Nair, 2011) The interactive nature of forest systems, combining trees and shrubs with crops and/or livestock, means that they are intensely dense and diverse, supplying all the nutrients needed for the growth of the system without any external fertilisers.

3.2.2 Simplifying is Death

The density and diversity of an agroforestry system can be contrasted to a system of monoculture, in which one crop is grown in isolation over a large area. A monoculture system has only one output (food) whereas agroforestry has many outputs in addition to food – such as timber production, water purification, capturing carbon and promoting biodiversity. Monoculture systems often rely on the use of pesticides, because the pests that affect that particular crop are able to multiply across such a large area. In general, it is the case that the more complex a system is, the more sustainable it will be. Crawford (2010) demonstrates this in his comparison of arable land with a wild nature system. In summary a wild nature system: requires less energy; is more resilient; has higher diversity; has higher interconnectedness; has lower or zero greenhouse gas emissions; and requires little or no maintenance. In addition to this, Varah et al (2013) argue that monoculture systems use more water, and cause soil degradation. These are problems that are fundamental to many of the world's food production systems.

The combination of density, diversity and interconnectivity of agroforestry systems create the platform for true resilience. In contrast to the complexity found in almost all natural self-regulating systems, human design systems sometimes simplify, developing reductionist methods in an attempt to hit singular design goals that are often grounded in industrialized production. As Gunderson and Holling (2002) argue, ecosystem management often tends to focus on increasing the productivity of a particular narrowly defined product, which can ultimately make the system rigid and more vulnerable to disturbance. Biological diversity is needed to create self-regulating complex systems that are resilient. They define resilience as, 'the ability of a biological system and ecosystem or social system to withstand disturbance and still continue to function. The measure of resilience is the multitude of disturbance that can be experienced without persistent flipping into another state' (Gunderson & Holling, 2002: 17).

3.2.3 Multiplying is life

For a system to withstand disturbance it needs many components to regulate it, and complexity is central to this (Kelly, 1994: 469). An agroforestry system can contribute towards a more adaptive and resilient whole system through the diversity and complexity that it brings. The Intergovernmental Panel on Climate Change (IPCC) are investigating the potential of agroforestry in mitigating the atmospheric accumulation of greenhouse gases, as well as enabling farmers to adapt to climate change (Verchot et al, 2007). This shows the transformative potential of agroforestry systems across urban, rural and farmland contexts. The value of agroforestry systems derives from their closed loop nature, as well as their ability to provide protection against both ecological and socio-economic shocks (Tully & Lawrence, 2011).

The diversity and density of agroforestry systems produces a much richer system that encompasses a variety of life forms such as: microorganisms; fungi; worms; plants; birds; shrubs and trees. This diversity creates a density based on the interconnected web of life, in which different elements rely on each other to co-produce organic matter: living and dying, and so adding nutrients to the soil to create more biodiversity. Agroforestry systems are designed to mimic the forest strata, from the rhizosphere level to canopy level. They are highly efficient because as they mature, they maximize biodiversity, solar capacity, nutrients cycle, soil fertility and carbon store. Kelly describes this as a 'game of increasing returns' (Kelly, 1994: 469) as the system acts on the environment in a way that increases the density and complexity of the system itself. This feedback loop that heightens the density of clusters of living things is defined as the ‘panarchy framework’ by Gunderson and Holling (2002: 23).

An agroforestry system can be implemented within a city many times over as a result of its vertical complexity in contrast to a monoculture system which would take up larger space with fewer outputs. Agroforestry represents a viable, practical opportunity to develop systems for urban food production at a local level that can create and reproduce more sustainable approaches that can be used for the transition to more sustainable cities.

3.2.4 Diversity, Agroforestry and the Potential for Cities

Conventional community gardens within the urban context have been shown to have a number of benefits: increased community safety; reduction of crime in public spaces; improved access to food; increased physical activity; and improved mental health (Schmelzkopf, 1995; Krasny & Doyle, 2002; Wakefield et al, 2007). Agroforestry systems can deliver many more benefits as they create more than just food. They are resilient because of their diversity, and they can help cities to store carbon, increase biodiversity, improve soil fertility, and increase both water capacity and solar shade. Agroforestry can play a role in soil remediation in some areas that have been contaminated by previous industrial processes, which would then create more possibilities for ecological systems (Whitefield, 2004).

The reasons why agroforestry is potentially exciting within the urban context are as follows:

- The potential of creating a new ecological infrastructure to reduce carbon dioxide within the atmosphere;

- The way in which the vertical structures of agroforestry mirror the three-dimensional environment of cities;

- The potential to increase biodiversity within the city infrastructure;

- The remediation benefits to soil fertility, creating a platform to design contamination out over time.

Agroforestry systems enable the delivery of much more complex ecological systems within a land based urban context. This complexity is developed via layering of strata to creatively reproduce efficient ecologically sound adaptive systems. These systems enable a more comprehensive output, not seen in traditional urban growing systems like allotments, orchards, or raised beds. Developing agroforestry within an urban context can provide knowledge on how it can be applied in a more vertical structure that is consistent with the shift of the human population towards cities to create more sustainable communities.

3.2 Mushroom Production

3.2.1 Fungi

Fungi have evolved for 600 million years into a complex nested system within a forest, so that without fungi there would be no forest (Stamets 2011). Fungi include microorganisms such as yeasts and molds as well as the more familiar mushrooms. Trees and fungi live in symbiosis. Through the process of photosynthesis, trees give energy in the form of sugar/starch to fungi. Then, as a forest sheds it leaves or a tree decomposes on the ground, phosphorus is released into the soil. Fungi take up the phosphorus to repeat the cycle. Fungi act as peer-to-peer systems, cycling information and nutrients around an ecological niche (see Glossary) to supply trees and plants with nutrients. So trees supply energy as a trade off in order to access nutrients within the soil, connecting the system. Fungi are, therefore, fundamental for forest development.

This ancient system has been revolutionised for the contemporary world with an array of new academic and action-led research programmes being developed in the quest for sustainable urban futures. One of these new research programmes is mycorestoration (Staments, 2011). Mycorestoration has similar aims to agroforestry as a design system based on natural principles and processes, but the aim is not to produce food, but rather to clean up and support the growth of woodlands in an attempt to make the systems more efficient, diverse and ecologically sound. As Staments (2011: 55) argues, 'using mushroom mycelia as tools for ecological restoration is a new concept borrowed from the age-old methods of nature.'

3.2.2 Mushrooms

Mushrooms form naturally within forest systems. They have successfully created a niche in every biosphere and have been a source of food for humans since the time of hunter-gatherers. The twenty-first century will be no different. Some mushrooms are edible, like gourmet oyster mushrooms (Pleurotus Ostreatus), some are medical (Reish), and some have psychedelic properties (Liberty Cap). Other non-edible varieties can be deadly to humans (Chang, 2008). Pleurotus Ostreatus can be found in most hardwood forests in the world, and are said to be one of the easiest mushrooms to grow. They grow well in the UK as they thrive on elders, beech, birch and poplars. These tree species thrive in the UK in both urban and rural environments. Pleurotus Ostreatus is also a well-known decomposer, with the ability to decompose dead wood into organic matter and so return it to the soil.

Mushroom sales in the UK are increasing and the demand is likely to continue to increase. In 2011 mushrooms accounted for 8% of vegetable sales. The majority of these were closed button mushrooms (62%) while 10% were oyster mushrooms. There are a number of major suppliers of mushrooms in the world, notably Ireland, Poland and China, and many restaurants import large quantities of mushroom into the UK (Slawski, 2011). Furthermore, Sanchez (2004) argues that the improvement of mushroom technologies will lead to an increase in the productivity of mushroom cultures: computerised control; automated mushroom harvesting; preparation of compost; production of mushrooms in a non-composted substrate; and new methods of substrate sterilization and spawn preparation.

At present there are no local, community-led commercial mushroom production facilities within Greater Manchester, which is surprising as Manchester has a high demand for mushrooms across the food sector (Personal communication at Greater Manchester Sustainable Consumption and Production Group, 2015). This means that there is an opportunity to create commercial mushroom production systems in Greater Manchester, to further research into the expansion of mushroom development in an urban context, and to examine how this can support the reproduction of other nested systems.

3.3 Aquaponics

Aquaponics is a 2000-year old concept, linked to China. In its very basic form, an aquaponic system recycles fish waste, which is full of nutrients, and feeds it to the roots of plants like rainbow chard, spinach and celery. The plants use the nutrients as well as natural sunlight or artificial sunlight as their energy source to grow, thus producing food. The advantage of this is that it enables food to be grown anywhere in urban and rural situations. These systems also refrain from using pesticides and herbicides, and use less water. They aim to create sustainable technologies for food production. Aquaponics is consistent with the principles of sustainable agriculture (wastewater biofiltration by plants) and opens up the possibility of creating a more closed loop system through the production of organic vegetables (Blidariu and Grozea, 2011).

Literature on the commercial viability of aquaponics is limited. Goodman (2011) found that in temperate climates, sales of the tilapia fish and vegetables do not provide the necessary revenue to offset the costs when grown on a small scale and operated as a singular system. He did, however, note that it could bring community and economic development benefits. This issue was explored further through this programme of investigation to consider if the aquaponics system could form part of a whole system approach with the additional benefits that this would bring.

3.4 Food Distribution

Local food distribution platforms are a very important part of local production models, because the food that is produced needs to be distributed. Supermarkets are an important part of our food culture and their complex production and distribution systems are currently essential in feeding the populations of cities. However, supermarkets have a negative effect on ecological and economic systems both globally and locally (Lang et al, 2007). The dominance of the supermarkets in the whole supply chain has been researched by Frances and Garnsey (1996), and they suggest that there is not enough diversity within local production and distribution as a result of this dominance.

In the contemporary city, food production and distribution have been taken out of their local context into a global market. According to Joanna Blythman (2004), in the 1970s only 10% of the money spent in the UK on groceries went to supermarkets, while now the figure is 80%. Industrial processes that are present in all aspects of the globalised food supply chain have become increasingly dominant in our society. This contributes to both food poverty and ecological damage as highlighted in the Argument and

Contextualisation. In order to increase access to local food, communities need diverse models of food distribution to accompany local production systems.

The answer is not a binary choice between supermarkets and local food initiatives, but rather collaboration between them all. Local production and distribution hubs developed by communities for communities would be able to augment the supermarket. If these local production and distribution systems developed a more sustainable business model, as was noted by Lang (2009), then it might be possible to see a reduction in supermarket dominance because the demand for their service may decrease. Supermarkets have very complex and technical distribution models enabling them to feed the UK constantly without fail. In order for local food production to work in urban environments a considerable amount of attention has to be devoted to distribution.

Debates around local food distribution systems have become more prominent as climate change has become a more mainstream concern and the carbon footprints of goods and products have come under scrutiny (Edwards-Jones et al, 2008). Doron (2005) calculates that if food in the UK was produced and consumed locally, then the level of $C0_2$ emissions would be reduced by 22%, which is twice the amount that the UK has committed to reduce under the Kyoto Protocol. However, Coley et al (2009) have argued for the need to look more closely at local food distribution. They studied the carbon emissions from the operation of a vegetable box system compared to those from a supply system in which the customer travels to a local farm shop. They found that if a customer drives a round-trip distance of more than 6.7 km to buy organic vegetables, then the total carbon emissions are likely to be greater than if the vegetables are delivered to their doorstep from a vegetable box supplier.

Within the UK there are many examples of local food distribution initiatives, such as local food delivery services, whole food stores and farmers markets. Whole foods are unprocessed and unrefined foods. The majority of whole foods are imported into the UK, because foods such as lentils, beans and chickpeas cannot be grown efficiently in the UK, but are an important part of the healthy diet. Both wholefood stores and food delivery services can supply a wide range of organic whole foods and fruit and vegetables to make them accessible in local communities.

One example of a food delivery services is Abel and Cole (Abel and Cole, 2015). Their key selling point is that they work directly with farmers, butchers and bakers. Abel and Cole are one of the best in the field, but they are marketed very much towards the middle class and their prices are expensive, so many people would not be able to afford their produce even if they wanted to. Furthermore, Abel and Cole market themselves as locally oriented, but they are a national business, so the money spent on the service will not stay within the local community.

In addition to the consideration of carbon emissions, Morgan et al (2006) have highlighted the environmental and social benefits of local food systems. Research by Bodor et al

(2008) in America has found that if fresh vegetables are available within 100 metres of a residence, then vegetable intake is increased. This is backed up by the findings of Wrigley et al (2003) in Leeds. An essential aspect of providing access to local healthy food is to create comprehensive distribution models in imaginative and enterprising ways that are rooted within a particular community.

The need for local distribution hubs has given funding bodies inspiration to develop innovative ways to address these problems. For example, the Plunkett Foundation and Esmée Fairbairn Foundation are developing a new initiative called 'Our Urban Shop'. They are aiming to build on the success of rural community-owned co-operatives: there are 324 of these across the UK, with a 96% survival rate. Our Urban Shop acts as an information point, providing key resources needed to develop community-owned co-operatives. They also highlight successful stories to share good practice: Hisbe in Brighton; Natural Food Store in Headingley; Real Food Store in Exeter; and Stirchley Stores in Birmingham (OUS 2014). This is a much needed initiative, as the majority of high demand for food comes from within the urban context, and as cities expand this will become even more pertinent and the market will increase.

3.5 Vermiculture

Vermiculture is the cultivation of earthworms. Earthworms have been a part of the biosphere for millions of years. Worms are an integral part to forest systems. Earthworms consume leaf matter from the soil top and burrow into deeper soil horizons, excreting organic matter (wormcast) and so creating richer soils. Charles Darwin referred to them as 'nature's ploughs' because of this mixing of soil and organic matter (Darwin 1881).

There is a lack of functional, living soil in cities and this leads to damage of water circulation and reduction of biodiversity (Siebielec, 2012). Furthermore, Hall & Pfeiffer (2000) argue that in urban environments, it is essential to reduce the input of materials and to reduce waste through recycling to ensure more efficient use of resources. As earthworms are partially responsible for the breakdown and recycling of dead organic matter (Butt, 2006), the potential for vermicomposting in urban environments is evident.

Vermicomposting uses earthworms, bacteria and fungi to break down organic material. It produces vermicompost, which Aira et al (2008) have shown to have a high water-holding capacity and to contain many nutrients in forms that are readily taken up by plants. Research on vermicomposting in the United Kingdom has developed over the past 20 years but remains relatively small scale compared with other countries, such as Spain and the United States (Butt and Williams, 2011). The majority of existing research at present uses worms as a waste system facility. There is significant potential for vermiculture to be more widely used as a means of maintaining ecological balance and using resources more effectively (Li et al, 2010). Earthworms are a connector between other hubs, networks, platforms and systems. Earthworms also have great economic value, costing around £18 for 1500 worms, and are used by everyday consumers across a wide spectrum from fish bait to composting.

Although earthworms have been highlighted as a possible threat to the biosphere, in relation to the output of greenhouse gasses (Majeed et al, 2013), this has not been comprehensively proven (Chen et al, 2014). Earthworms have played an important part in the development of the biosphere, successfully occupying the majority of terrestrial ecosystems. Earthworm processes and outputs enhance plant growth, soil fertility, and water retention and reduce soil compaction (Aira et al, 2008). Vermiculture is a growing area of research with significant potential to act as an interconnector between different ecological systems, with the aim of creating a whole system approach to sustainable technologies within an urban context.

3.6 The Biospheric Whole

The research in the Argument and Contextualisation highlighted that the biosphere is the system where all life resides: the creative connection between all ecosystems - from microorganism to complex forest systems - it is the sum of every living thing. The biosphere is an interconnected system, integrating all living matter into one complex life support system. The complex diversity and density of living matter within the biosphere creates a resilient and adaptive model for sustainability. This is an energetically open and materially closed, self-regulating system that generates all life, nutrients, water and shelter for all living matter. The various systems connect with each other to create efficiencies, cycling nutrients across the whole system to reduce waste, water and energy use. For instance, the brown and green waste from the food distribution system is utilised through the vermiculture system, which in return supplies a range of nutrients across the agroforestry and aquaponic systems.

The programme of investigation that is described in this thesis sat within a very different context to the closed loop systems outlined in the Argument and Contextualisation in regards to its social, ecological, economic, cultural, and geographical context. The methodology and vision was similar, however: to create a whole system approach in an attempt to develop sustainable technologies for food production and distribution. The major difference was that this programme of investigation was real. It was not isolated in a glass dome or in a university lab, but in a real community, with real every day challenges. The urban context itself was the living laboratory.

The programme of investigation aimed to interconnect the systems detailed in this chapter into one whole system (Research Aim 1): agroforestry; mushroom production; aquaponics; a local whole food store and food delivery service; and vermiculture. In this whole system, the inputs and outputs of each system were used to feed the other systems, creating an integrated whole. The aim was to do this by nesting these diverse systems into an existing community. This was an attempt to create an energetically open and materially closed, self-regulating urban life support system that was integrated into the needs and wants of the Blackfriars community. The reason for creating a complex system of different nested systems was that, as Capra suggests (1996), the more complex a system is, the more self-regulation becomes stable.

A particular interest was to create a platform of density and diversity within the community, by integrating environmental, social, and business factors as one whole system ecology through a process of creative design. In environmental terms, the aim was to circulate nutrients around the built environment, the community infrastructure and Irwell House using a diverse set of ecological and social systems. This was to increase food production and distribution, increase biodiversity and reduce waste by closing the loops in the whole system and enhancing interconnectivity. This was to be done without any use of inorganic pesticides or negative effects on the biosphere or community. In social terms the aim was to develop an array of ecological systems that would act as a life support system for the community. This was to provide a platform for education and meaningful engagement, and for the production and distribution of healthy organic whole foods, fruit and vegetables. It would, therefore, challenge contemporary food culture in a local urban context. In business terms, the aim was to develop an array of integrated social ecological life support systems that generated beneficial local enterprise. The aim was for these to become financially viable over time by maximising the asset within the community.

3.7 Conclusion

This chapter has highlighted singular systems that have been well researched and documented. For the first time in the contemporary world, a diverse set of experts were to be brought together to integrate the systems discussed here into a complete network. This would create a whole system approach to urban farming while geographically positioning the action led research in an existing community. The systems were chosen to be complementary and to form the components of the whole system approach that would be established. This involved a shift of thinking. Within a singular mind frame the systems are seen as ‘objects’, while here they were seen as ‘relationships’ across the different networks. The ‘ecology’, as Gregory Bateson points out, is ‘the pattern which connects’ (Bateson, 2000).

This approach enhanced understanding of the scope of innovation in environmental, social and business terms. This entailed thinking not only about the technical challenges and opportunities, but also about wrapping the project around the needs and wants of the community. It was clear that just developing an urban farm with a shop would not be enough to engage the community. A comprehensive public engagement programme would be needed to bridge the gap between the vision, and the needs and wants of the community.

4 Methodology

4.1 Introduction

Having established that there was a need for alternative food production and distribution systems within an urban community context, it was important to identify appropriate techniques that could implement and evaluate the necessary structures to address the aims outlined in the introduction. Specific objectives were identified for each of the four aims as follows:

1. Aim: To design a whole system ecological approach to urban farming.

   Objectives:

   a. To build on existing knowledge of ecological systems by attending courses and visiting research organisations.
   b. To work in association with established experts with the skills needed to create single systems.
   c. To creatively design a set of systems that could be linked together to create a whole system to include: agroforestry; mushroom production; aquaponics; vermiculture and food distribution.

2. Aim: To establish a working model of such in an area of high social deprivation.

   Objectives:

   a. To form a Community Interest Company through which to deliver the whole system approach to urban farming.
   b. To raise funds through liaison with academic, social and cultural partners to finance the programme.

c. To acquire a building with adjacent land within an urban area of high social deprivation.
d. To commission experts with the skills necessary to implement the project.
e. To build a team of staff and volunteers to implement the project.

3. Aim - To create a centre for ecological research.

Objectives:

a. To use the implementation of the project as transdisciplinary action-led research to further understanding of whole system ecological approaches to urban farming.
b. To learn from the implementation of the project and suggest possible future developments for approaches to urban farming.

4. Aim: To contribute to public awareness of health food and ecological systems in urban environments.

Objectives:

a. To work with local community groups at all stages of the design and implementation of the programme.
b. To use the centre for ecological research as a platform for community engagement through courses, open days and informal conversations.
c. To carry out a schools engagement programme to enhance involvement of children from deprived social settings.
d. To use the food distribution models as a platform for engaging the local community.

The focus, then, was on a creative design *practice* of action-led geographically located research.

The practice of action research took the project out of the traditional realm of research within the university and geographically positioned it where it was needed. The manifestation of this action was the creation of the Biospheric Project in the heart of the Blackfriars neighbourhood in inner city Salford. The project became an in-situ laboratory: a place to develop a series of interconnected systems where experiments could be carried out in the real world to investigate and evidence new knowledge.

In the sections that follow the methodology that was adopted will be outlined.

4.2 Designing a whole system ecological approach to urban farming

4.2.1 Building on existing knowledge

Initially the focus was on extending knowledge by attending courses, and conducting investigational trips and interviews with ecological practitioners and specialists. There was a paucity of information linking the various technologies together, so it was important to have knowledge of the different approaches that could then be connected and applied to an urban community context.

4.2.1.1 Courses Attended

Courses were attended on Basic Agroforestry and Advanced Agroforestry as well as an Agroforestry Design Workshop. The Basic Agroforestry course developed understanding of the basic principles of natural forests and agroforestry systems. It helped in the adoption of a holistic design approach for developing land-based systems. The Advanced Agroforestry course was a seminar for those already underway with their own forest gardens. Unlike the first course, participants were encouraged to talk about their own gardens and discuss their successes and failures. It provided a useful way of discussing problems and also for learning new ideas.

An Agroforestry Design Workshop was set up with Martin Crawford, who is the leading expert on agroforestry in the UK, with the aim of gaining a deeper understanding of the complexity and layering of natural design principles and methods. Martin Crawford agreed to support the design of the urban agroforestry system to be implemented in the Blackfriars Community as part of the Biospheric Project. Crawford's agroforestry systems are very complex and have developed over a 25-year period. They are far too complex for the majority of people to understand, so it was important to develop a system that would be more understandable to the general public, while still using all the layers found in a temperate climate agroforestry system. This was an important observation, because it was necessary to convey a complex system in a simple way, and this was a design challenge. It would be necessary to create a more linear system, which the community, schools, and other users could understand, without jeopardizing the integrity of the agroforestry design method. This was not about simplifying a complex system - it was about designing a complex system that was more understandable than the systems that I had witnessed at the Agroforestry Research Trust. The methods that were chosen to design the Biospheric Project system were the biological trench and alley cropping (see Glossary).

4.2.1.2 Investigational Visits

Visits were made to Humungus Fungus in Wales and Farm:shop in London to gain further insights. Humungus Fungus works exclusively with Raymond Blanc at Le Manoir aux Quat'Saisons to develop low-input systems for the production of organic mushrooms. The project is also working to develop mushroom-based treatments to counter the effects of pathogenic fungi that can destroy trees (Humungus Fungus, no date). The aim of this trip was to gain a deeper understanding of the challenges and opportunities of growing organic mushrooms, and to understand the present-day market of mushroom adoption and the needs of restaurants that want gourmet organic mushrooms.

Farm:shop in Hackney describes itself as the world's first urban farming hub. Food is grown using aquaponics in a converted derelict shop. It operates as a workspace, a cafe and an events venue (Farm:shop, no date). The Farm:shop directors were approached and a visit to the site arranged to gain an understanding of the challenges of developing aquaponic systems within a building. This investigational trip gave great insight into the design specifications and implementation needs for such a system.

4.2.2 Working with established experts

A number of experts were consulted to enhance knowledge further. Jim Frederickson is a Senior Research Fellow at the Open University. Although he was not in a position to become a partner on the project, he directed me to the leading earthworm and vermiculture researchers in the UK: Steve Ross and Kevin Butt.

The late Steve Ross was the Director of the Worm Research Centre, which was initially set up to provide objective information about the use of worms for the benefit of the environment, investigating their scientific and technical performance. Steve Ross was approached to gain understanding of the build and design techniques needed to develop a vermiculture system, as Steve had extensive knowledge of this and had a number of live vermiculture beds at the Worm Research Centre.

Kevin Butt completed his PhD in the Biosystems Research Group at the Open University, and is now Reader in Ecology at the University of Central Lancashire. His research focuses on soil ecology with earthworms acting as a focal group. He has researched the use of earthworms in soil remediation and now sees earthworms as 'ecosystem service providers' in various soil types (University of Central Lancashire, no date). Butt was approached in order to gain an understanding of the vermiculture research being developed in the UK from a community perspective and for an insight into how earthworms are being used in relation to closed systems. It was also useful to connect to the other vermiculture researchers in the Northwest of England.

4.2.3 Creative Design of linked systems

This new knowledge acquired on courses, investigational visits and interviews with ecological practitioners and specialists did have benefits. It enabled the observation of action-led research delivered by practitioners on singular systems. It provided an overview of the design and implementation of ecological systems across a wide spectrum of disciplines. It also provided first-hand knowledge of how to develop the systems that were to be explored through the programme of investigation.

However, many of these experts are bound to their particular disciplines and it is evident that they do not look across a number of systems and how they might interact with each other. While these experts might not recognise this as a problem, it does mean that they are remaining in their own discipline, whereas the biosphere is where all systems connect with each other to create a more sustainable, adaptive and whole ecological system. In transdisciplinary research it is necessary to connect beyond disciplines (and indeed beyond the university). It was important, therefore, to access the deep thinking of experts, but also to consider how those thoughts connect to the wider social and ecological dimensions of this research. This was applied by drawing on existing expertise in singular systems and experimenting on how to connect them together to form the components of a whole system approach to urban farming.

The main aim of the research was to investigate how the singular systems identified in the previous chapter could be integrated and connected with each other to create one whole ecological system within the Biospheric Project. Furthermore, it was important to understand how each of these scientific and experimental methods could transfer knowledge outside of the Biospheric Project to the wider community. This was conceptualised within the following themes: environmental impact, social impact and business impact. These three aspects and their intersection are the constituent elements that have been the focus of the programme of investigation. In order to deliver a system thinking approach to urban farming in an area of high deprivation, a dense environment of systems that interconnect was designed.

1. An agroforestry system was developed as a method to understand the advantages and disadvantages of complex self-regulating three-dimensional food producing systems in an urban context.

2. A mushroom production system was developed to test for the best sustainable substrate on which to grow mushrooms in an urban environment.

3. An aquaponic system was developed in order to understand the technical challenges and the advantages and disadvantages of closing the loop across architectural and natural infrastructure.

4. A food distribution system was developed as a method to understand the advantages and disadvantages of closing the loop by developing a fruit and vegetable delivery box service and a whole food store.

5. A vermiculture system was developed to enhance understanding of the advantages and disadvantages of closing the loop using earthworm culture to utilise green and brown waste.

These systems were designed to allow investigation of the interconnectivity between the ecological systems, especially the interconnectivity between the ecological systems and a commercial venture in the form of the food distribution system. They were designed to enhance biodiversity and fertility across the Biospheric Project and the community as a whole through the agroforestry and vermiculture sytems. They were also designed to enhance understanding of the circulation of nutrients around a multilevel building to produce food through the aquaponic system.

4.3 Establishing an urban farm in an area of high social deprivation

This section outlines the elements that needed to be put in place for this design to become a reality.

4.3.1 Forming a Community Interest Company

To deliver this programme it was important to create a community interest company, Biospheric Foundation (CIC). The CIC legal status enabled the project to secure a variety of community, cultural and research funding streams to support the development of the Biospheric Project, which was the first project delivered by the Biospheric Foundation.

4.3.2 Raising Funds

Food can act as the social fabric for our communities, supporting the development and greater understanding of the cultural aspects of our food. Developing a relationship with a prominent cultural partner enabled the programme of investigation to inspire the minds of the whole city, rather than being confined to design and research silos. Manchester International Festival takes place biennially in Manchester having been launched in 2007. The Festival is led by artists, and commissions new works in the performing arts, visual arts and popular culture (Manchester International Festival, no date). The Biospheric Foundation gained the support of Manchester International Festival and was nominated as a main commission for the festival in 2013. This led to the project receiving considerable local, region and international press attention as well as substantial capital investment to support the 'Biospheric Project' within the Biospheric Foundation.

Significant funding was required to enable the research to be action-led and to implement the whole system approach. The methodology, therefore, needed to include conversations with funders and negotiating funding across social, ecological and commercial spheres. Without this, the programme of investigation could not have been implemented. The funding secured came from a number of sources that included cultural, technical and community partners as well as academic funding from MIRIAD at Manchester Metropolitan University, Queen’s University Belfast, The University of Manchester and Durham University. The details of this funding can be seen in Appendix 1.

4.3.3 Aquiring the assets

To deliver the programme of investigation, various assets needed to be secured in order to implement the action-led research. These assets were:

- A three-story warehouse situated within a deprived area that could be used for the development of ecological systems.
- A piece of land to start to develop land-based ecological systems.
- A shop unit to develop a distribution model.

The detail of how these assets were obtained is described in the following chapter.

4.3.4 Commissioning Experts

It was evident from the aims and objectives of the project, and through the courses that had been attended, that the implementation would require a tremendous amount of technical knowledge across a range a disciplines. The design teams needed to be comfortable working across the disciplines of architecture, engineering, and ecology. BDP Architects in Manchester were commissioned because of their world-renowned multidisciplinary approach to design. Their multidisciplinary workforce would complement the transdisciplinary approach. They were commissioned to develope the structural engineering package for Irwell House to enable the aquaponic system to be designed on the second floor. Siemens in Manchester were commissioned to provide a labour team and capital for the monitoring system to regulate the aquaponic system. Architects from Queen's University, Belfast were commissioned because of their interest in initiating action led research into the design and implementation of aquaponics systems within existing disused urban buildings. They were commissioned to design and implement the aquaponic system at Irwell House. Rock Architecture supported the planning application to the City of Salford needed for the change of use of Irwell House. They were also appointed to a project management role due to the high number of different contractors that needed to be on site throughout 2012 and 2013 to transform the building.

4.3.5 Building a Team of Staff

A team of staff was needed because of the complexity of the programme of investigation and to support delivery of the many facets of the Biospheric Project for the Manchester International Festival 2013 and beyond. This consisted of a Personal Assistant, a Project Manager, a Shop Manager, two Volunteer Co-ordinators, a team of twenty-five core volunteers and numerous other ad hoc volunteers. There was also a wider team of sub-contractors.

4.4 Creating a centre for ecological research

4.4.1 Transdiciplinary action-led research

Lewin's (1951) conception of action-led research demands an integration of theoretical and applied research that translates research into problem-solving strategies through collaboration with researchers, community members and policy makers. This produces practical recommendations for resolving social problems.

In order to put this concept of action research into practice it was important to bring together disparate methods and techniques from a range of different cultures, scientific areas and disciplines in order to create a coherent framework. Transdisciplinary research is suited to the challenges identified in the Argument and Contextualisation, as it is not restricted to single problems, but studies multiple problems and the interconnections and relationships between them. The notion of transdisciplinary research is a response to the concept of polycrisis. There is not one single problem, but rather overlapping and interconnected crises, that necessitate an integrated approach that brings together knowledge from different academic fields. In order to face the challenges that the world faces, Wickson et al (2006) argue that there is an increasing need for research that considers the interaction and complex relations between environmental and social systems, and that engages communities in participatory research.

As Williams (2010) argues, in the field of sustainable urbanism there are many different actors involved: built and natural environment specialists; social scientists; engineers; cultural professionals and those involved at a community level. Furthermore, most problems in sustainable urban development are not structured within the confines of traditional disciplinary boundaries (Nolmark and Ab, 2007). Transdisciplinary research has the explicit aim of solving problems that are complex and multidimensional, and that involve connections between human and natural systems (Wickson et al, 2006). Therefore it was important that this thesis was based upon the principles of transdisciplinary action-led research with the aim of creating original knowledge that could contribute to practical solutions.

There is broad agreement in the literature that there can be no single prescribed methodology for transdisciplinary research, as the methods need to be able to respond to and reflect the problem and context under investigation (Wickson et al, 2006). The different methods that I have described in this chapter bring together expert knowledge of singular systems – such as vermiculture and soil analysis - that I have drawn upon in order to connect the different components together into an ecological whole system.

4.4.2 Applied Action Research

Williams (2010) argues that there is a need for a much more robust evidence base around the intersections of both social and technical knowledge. This would enhance understanding, on the one hand of how social contexts and processes can enable the development and use of sustainable technologies, and on the other, how technologies can inform social and community development. Experiments are needed to bridge the gap between social and environmental systems. It is rare for 'community' and 'science' to collaborate with the expressed intention of creating meaningful sustainable urban communities. Experiments can advance the understanding of urban sustainability from a bio-analogous (see Glossary) perspective and can serve to deepen both the theoretical and practical knowledge of ecological processes.

The Biospheric Project was created as a research laboratory to test a whole system approach to urban farming in an area of deprivation. A dense ecology of systems were designed that interconnected and applied existing knowledge from single systems to a whole system approach. To be able to investigate the full potential across a variety of food systems in a dense urban community, it was necessary to establish a centre to provide a situated platform of research. This enabled a series of experiments, research, development and enterprise to be conducted on different food production and distribution systems. It also allowed the utilisation of skills from within the community, such as the knowledge of gardening, whilst empowering local people through the transfer of knowledge.

4.5 Raising public awareness

A substantial public engagement programme was developed via the collaboration between the Biospheric Foundation, the Manchester International Festival and the People's Postcode Lottery.

4.5.1 Working with local groups

The first step in raising public awareness of health food and ecological systems was to liaise with existing local community groups. Councillor Paul Dennett played a crucial role in establishing this aspect of the research because he was aware of the city strategy for sustainability development as well as being knowledgeable about the local community. He was Chair of the Vertical Villages Tenants and Residents Association that represented the interests of the people living in the local tower blocks and was also able to establish contact with other community associations and organisations in the area of Blackfriars (See Appendix 2 for a list of community organisations who were liaised with).

4.5.2 Community engagement platform

A further aspect of community engagement came from the establishment of the Biospheric Project at Irwell House in the heart of the Blackfriars community. This meant that the activities there were very visible to local residents and passers-by. Local people could see the developments there and this stimulated interest in the Foundation. This was facilitated by Open Days and workshops, and there was also a ripple effect created through the engagement with local volunteers who would then spread knowledge to their family and friends.

4.5.3 School engagement programme

The aim of engaging with the most socially deprived groups within the local community was difficult to achieve through the other activities outlined in this section. A programme of engagement with local schools was designed to ensure that children from these groups were included. Children from nine schools in the Manchester area visited the project. 45%

of the children in these schools were eligible for free school meals, which is an important indicator for poverty and low income. Children and their families in these communities are likely to have much poorer diets than those in other areas and are therefore most likely to benefit from being educated about healthy foods, and how to access, grow and prepare these on limited budgets.

4.5.4 Engagement through the food distribution model

Both the food delivery system and the whole food store contributed further to community engagement. These were an effective way of being able to engage with the local residents and encourage healthy eating, to inspire people to cook for themselves and try new ingredients. This was enhanced by the development of Community Recipe Cards with ideas produced by local residents and distributed via the delivery scheme and whole food store.

4.6 Conclusion

Attending courses and carrying out investigational visits enhanced the knowledge that came from previous experience. It was also important to develop in-depth conversations with experts in architecture, engineering, and ecology and to engage with community and funding bodies. Initial design time with these experts highlighted the practical challenges that would be involved in implementing the ecological systems within the assets. Negotiation with the different technical teams was necessary to understand the volume of in-kind support possible and to create a programme timeline. It became apparent that bringing together all the technical partners would take a considerable degree of organisation due to the time constraints and the volume of technical challenges. Through the transdisciplinary approach it was possible to connect knowledge between and across disciplines and so to move beyond all disciplines. As Nicolescu argues, ‘as the prefix “trans” indicates, transdisciplinarity concerns that which is at once between the disciplines, across the different disciplines, and beyond all disciplines’. (Nicolescu, 2008: 2). In using this approach it is not entirely possible to plan a methodology because transdisciplinarity emerges from the process of implementation. The whole becomes more than the sum of the parts, so the full understanding of the outcomes of this programme of investigation could not be predicted in the methodology. The new thinking about how the systems could be designed and connected and how to circulate the nutrients required to create a whole system approach to urban farming had to emerge from the creative process of implementation.

5 Implementation Story

‘Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand.’ (Albert Einstein)

5.1 Introduction

This chapter will set out the chronological development of each component that was implemented as part of the research. It will tell the story of the Biospheric Project, which has been used as a site of action research to contribute knowledge on the density of systems and a whole system approach to urban farming. This should be viewed in conjunction with the Portfolio of Works. It begins with the acquisition of Irwell House and the retrofit of this building. It then goes on to discuss the implementation of each of the systems in turn: The Whole Box; 78 Steps; the Forest Garden; Vermiculture; Mushroom Production; and the Aquaponics system. The outcomes and potential outputs of each of these systems is assessed in terms of their environmental, social and business impacts.

5.2 Irwell House and the local area

Irwell House is a 100-year-old warehouse on the banks of the River Irwell located in the heart of Blackfriars community in Salford (Portfolio of Works: 7 – 10). During the Industrial Revolution this was a highly industrialised area, but many of the mills, including Irwell House, became vacant and fell into disrepair as industry declined. More recently Irwell

House had been used as a print works, but decline of this industry led to it being sold. Urban Splash bought the building in 2000 with a view to develop the site into residential buildings, but the financial crisis of 2008 brought an end to this plan. This presented the opportunity to rent the top two floors, which had the three main components that were required for the action-led research: a building that could be retro-fitted to meet the aims and objectives; a disused piece of land outside (not secured until later); a situation in the heart of a deprived community. Signing the lease for Irwell House for fourteen months involved substantial risk, including investing capital and taking on the building that needed a minimum of £100, 000 worth of retrofitting works.

Within the first three months of obtaining the lease at Irwell House, a lot of time was spent walking around the community of Blackfriars, getting to understand the area geographically and the local infrastructure in relation to community centres, shops and amenities. This gave a sense of the place and the diverse demographic in Blackfriars, which is an area with poor health, with limited access to fresh fruit and vegetables, as well as having high levels of multiple deprivation.

The housing stock in Blackfriars is highly diverse with buildings of different ages and types: high-rises; terraced housing; semi-detached dwellings; and new student accommodation. This means that there is a range of different family structures within the community: students; young professionals; families; and single occupiers within the high-rises (Office for National Statistics, 2011).

Salford City as a whole has 60% green space, an important factor that separates Salford from most cities in the UK. Blackfriars similarly has a lot of green space. Blackfriars also sits on the edge of the River Irwell. Salford's Neighbourhood Renewal Strategy (Salford Partnership, 2002) highlighted that, 'in Broughton and Blackfriars there is great potential for developing the canal and riverside sites and attracting private investment along the River Irwell.' Unfortunately, the green space and river in Blackfriars is poorly managed and designed and has very rarely been used for any form of community engagement. Also, much of the green space in Blackfriars is highly contaminated, due to its industrial past. While this could present a major problem, it can also provide an opportunity and the fact that the land is contaminated should not be hidden but used as an opportunity to review and develop actions that can clear contamination up, which is an element that emerged through this research project. The problem of contamination did in fact mean that the Forest Garden could not produce food for human consumption. This issue is discussed further in the final chapter.

The first person who was contacted from the local community was Councillor Paul Dennett, chair of the Vertical Villages Tenants and Residents Association. This group is an independent voluntary body that represents the interests and needs of the local community living in the tower blocks in the Blackfriars and Greengate areas of Salford. Councillor Dennett was involved both in city wide politics and the local community and was therefore a great initial contact to help to understand the city strategy for sustainability development and community development, and to build connections with other people in the local community. Councillor Dennett was fully supportive of the ideas and vision behind the proposed research. He established connections with all the right places, communities, people and organisations to open up discussion about the potential development in Blackfriars.

As noted by Williams (2010), transdisciplinary research with a range of partners can mean different people working to different definitions and concepts. Therefore it was important to be able to develop a conversation with the local community in order to engender a shared understanding. This would enable a dialogue, to bring together into one vision their local knowledge in combination with the prior knowledge of ecological and community development that was brought to the project by the author. This would demonstrate to the community the proactive and serious intention to work with Blackfriars and Salford to reconsider how to build resilient, adaptive and ecologically sound communities.

The community organisations that were approached were: Vertical Villages; Bridgewater Residents Association; Broughton Trust; The Angel Centre; East Salford Community Committee; and St Sebastian's Community Centre. These groups were asked for advice or for the opportunity to present the initial ideas to them. It was important to gain respect from the communities and this was achieved by demonstrating a good understanding of sustainability and community engagement, and a willingness to listen and communicate.

These initial engagement conversations were about listening to the community and shaping the project to best reflect their needs and wishes rather than telling them what needed to be done. This allowed the programme of investigation to be aligned with their needs, not the other way round, and was a very important part of the negotiation with the local community.

In response to this engagement, the Biospheric Foundation started to envision transforming the disused, former print works (Irwell House) into a new urban farm laboratory, reframing urban agriculture by reconnecting complex, three-dimensional urban ecologies to local communities, researchers and the general public. The details of this process are presented in the Portfolio of Works (Portfolio of Works: 11 – 18).

5.3 Food Distribution

This section describes the development stages of the food distribution system. To understand the need for a local food distribution service the Biospheric Foundation mapped the local area to gain a holistic understanding of the food available. The mapping highlighted the following retailers in the area:

- Takeaways and fast food including pizza, kebabs, burgers, and fish and chips;
- Newsagents including sweets, crisps, chocolate and soft drinks;
- Convenience stores including snacks, food and alcohol;
- Cafes and sandwich shops including sandwiches, burgers, chips and cake;

- Pubs and bars including snacks, pub food and alcohol;
- Supermarkets including a wider choice of food; and
- Restaurants including a wider variety of food.

The results of the mapping were overwhelming with 67 places to buy unhealthy food (Portfolio of Works: 26). The mapping also highlighted a lack of access to a diverse range of organic food. The high levels of obesity and poor health in the Blackfriars area highlights some of the risks associated with the deprivation index for the area (Salford Partnership, 2007: 40). What is clear from the mapping is that people in the area do not have the access or choice to buy healthy food in the heart of the community. This makes it increasingly difficult to engage in a healthier lifestyle, which is consistent with the literature on so-called 'food deserts' (Wrigley, 2002). It is evident even if people and the community wanted to eat more healthily that the local food infrastructure is not there to encourage healthy eating. One of the aims of this programme of investigation was to explore how local food distribution systems could encourage the community to eat healthier food.

5.3.1 The Whole Box

The Whole Box was the first enterprise developed by the Biospheric Foundation and was launched on 26th January 2012 with a personal initial investment of £600. The mission statement of The Whole Box was to provide fresh and beautiful local food for communities in Salford and central Manchester, not just to households who have higher levels of disposable income but also to deprived communities who often have little choice when it comes to healthy eating. The Whole Box provided whole, organic and fresh food in a box at an affordable price. Customers were able to order a number of different boxes of locally produced fruit and vegetables each week that they were able to collect from Irwell House or have delivered to their homes (Portfolio of Works: 27 – 29). Customers also had the chance to purchase Fair Trade whole foods such as lentils and chickpeas and baked goods from our house baker. From Thursday to Sunday Irwell House also operated as a shop for people to come and taste and buy our products.

The social purpose of the business was to provide affordable and high quality food to support healthy lifestyles across our target communities whilst creating employment and volunteering opportunities. Steve Coles was recruited from the local community on a part time basis as manager of the scheme. In addition Ryan Parker worked as a volunteer to support the manager. All produce was sold at only a 100% markup price in order to keep the cost affordable for local people. This meant that not only was the food made accessible, it was also cheaper than the equivalent produce in supermarkets. Details of the branding, marketing and positioning campaign can be seen in the Portfolio of Works (Portfolio of Works: 20 – 25). All profits were re-invested in either supporting the Whole Box or other community projects run by the Biospheric Foundation such as food education campaigns. The food distribution system was also essential to the development of other systems and the whole system approach to urban farming, as it was essential that there was demand for the supply of food that would be created through the food production systems.

To promote the Whole Box further, leaflets were delivered in the local area highlighting the new enterprise. It was important to listen consistently to customers, because if the Whole Box became unreliable or did not suit their needs, then they would choose to buy in different places. Running the Whole Box for 14 months and developing a core customer base, interesting feedback was received. This feedback was gathered in an informal way as food was delivered to customers on the doorstep. Customers were happy with the Thursday and Friday deliveries but would like deliveries on other days. They also wanted an increase in the variety of food that was available: not just fruit and vegetables but also whole foods like lentils, mung beans and chickpeas. They also suggested local breads, local dairy products and organic meats. It was evident that these requests would need to be responded to in a creative way that was consistent with the wider business model. The Biospheric Foundation team came together to consider the feedback from customers in order to devise and develop new approaches.

The Whole Box could not deliver a wider variety of food or deliver on days other than Thursday and Friday, because there was neither the availability of staff nor the capital required to be able to buy more products. It became apparent that a whole food store would need to be developed, which would be able to satisfy the existing customer base, and also provide the platform to develop a wider geographical clientele. A new shop would allow a larger product range and customers would be able to access that range every day of the week. This shows the need for the development of a food distribution system to be a flexible and customer-focused enterprise that responds to commercial, social and environmental needs.

5.3.2 The Whole Foods Store - 78 Steps

This section highlights the development stages of initiating and opening the first whole foods store in Salford. The Whole Box boxes were delivered on foot only to very local customers as shown on the map in the Portfolio of Works (Portfolio of Works: 27). This was a strategy to keep the highly local approach. In order to have a wider reaching customer base a 'food hub' was created in the community where customers could come seven days a week and where a larger range of food could be provided (although the Whole Box offer was kept up). Developing this within Irwell House was considered, as there was a huge amount of space, but the store had to be visually stimulating and easy to access – and delivering this within Irwell house would have been expensive.

Research by Bodor et al (2008) in America, found that greater fresh vegetable availability within 100 metres of a residence was a positive predictor of vegetable intake. This showed the importance of small neighbourhood food stores and their fresh produce availability in affecting fruit and vegetable intake. There were vacant shop units at the bottom of New Bank Tower, which was a residential tower block adjacent to Irwell House, just 78 steps away. One of the shop units that were available was owned by Salford City Council and managed by Salix Homes. As Salix Homes had been a supporter of the project, free rent was negotiated on the shop unit for one-year. The shop was called 78 Steps to highlight the local nature of this enterprise and its connection to the wider Biospheric Foundation (Portfolio of Works: 31 – 32).

Lang (2009) has suggested that it is important that the commercial aspects of food innovation are reflected upon. It was important to draw in a wider customer base from outside of Blackfriars to ensure a higher chance of commercial viability, ensuring the service was available for local people while being able to develop from a stronger business strategy It was important to have a design that reflected a sense of quality, so Peter Masters, the Manchester-based and well renowned interior designer, was approached to support the project by developing the interior design of the shop. He was given a simple brief to develop a rustic but contemporary feel for the shop, which would integrate the old materials found in Irwell House (Portfolio of Works: 33 – 35).

Developing a new supply chain for organic produce was needed for the whole food store. Suma Whole Foods were approached: the UK's largest workers cooperative and wholesalers of organic, vegan, vegetarian and specialist foods. Suma had a number of accounts in the North West so they were an ideal supplier of the whole foods for the shop. A contract was negotiated with them to supply the health food store for one-year. A contract was also negotiated with Organic North to supply locally grown organic fruit and vegetables for a year (Portfolio of Works: 36).

A comprehensive business plan was developed with the business support team and an accountant. This highlighted several potential growth areas including: the University (sales of Whole Box food to campus students); schools (sales of Whole Box food to school canteens and caterers); local residents (sales of Whole Box and food produced at the Biospheric Project); businesses in Blackfriars (sales of Whole Box and food produced at the Biospheric Project).

The store opened its doors for the first time on Saturday 5th July 2013, which signaled a landmark enterprise in the community (Portfolio of Works: 37). 78 Steps enabled local residents to access a more diverse range of food than had typically been available from the Whole Box delivery service. The support for the store was overwhelming from local residents who were keen to have access to local, healthy and dietary specific foods (Portfolio of Works: 38).

5.4 The Forest Garden

Once the lease on Irwell House had been negotiated and signed, the land next to the building had to be secured. The land was owned by Salford City Council and was managed by Urban Vision. Urban Vision delivers an extensive range of development and regeneration services aimed at providing safe, accommodating and future-driven neighbourhoods (Urban Vision, 2012). They were approached with the plan to use the land as a way of regenerating the area, connecting to community participation and as a means of developing ecological systems. The land was to be an important asset as one of the systems for the project, but more importantly, as a great engagement tool for the local community. It would enable them to see what was being done and for them to participate in the project, building on the research that suggests that community gardens can have a positive impact upon local social capital (Krasny & Doyle, 2002).

Irwell House is a large uninviting building and it was unlikely that many people would come and knock on the door to find out what was happening there. The land and the plans to develop it were visual and immediate: it represented an important opportunity to be able to create conversation with local people about what was being done in the building, and to discuss the benefits that the Biospheric Foundation could bring in partnership with the community. After lengthy negotiations, a ten-year lease was obtained from Urban Vision on 22 August 2011.

The aim was to develop a dense and diverse agroforestry system in the heart of the Blackfriars community. This would create a platform to educate and to develop new skills within the local community by being able to practically and visually demonstrate the different ways that food production systems could be established (Portfolio of Works: 40). As this would be the first agroforestry system developed in Salford, it would be a great asset to open up the discussion and to support the community and the wider city to become more sustainable. Biodiversity is an important part of inner city green spaces, but although it is referenced in various planning documents and local policies, often it is not adequately resourced - especially in the current economic climate. The Biospheric Foundation aims to address this and the Blackfriars Forest Garden is a living experiment in increasing and sustaining biodiversity, while being a part of a wider system of food production and distribution systems within an urban community context.

5.4.1 Site Investigation

The land occupies an area of 0.28 acres adjacent to Irwell House. When the land was taken on, it was young and unmanaged woodland that had been used as a dumping point. It was full of rubbish including washing machines, microwaves and car engines as well as items that were extremely unhygienic for the local population, such as used needles and condoms. In this condition, it was evident that the land was far from a community resource. It was something of a 'non-space' that was not valued, and which allowed it to become a place in which crime and anti-social behavior occurred. It became used as a central point for drug dealing and prostitution and the land adjacent to the area had the highest crime index in Salford (Salford Partnership 2007). This provided an opportunity to show how ecologically reclaimed land could become a socially valuable resource for the local community, from which transformation could also be connected to the wider urban food production system that was being delivered (Portfolio of Works: 41).

Following negotiations with Salford Council and Urban Vision, it was agreed that the Biospheric Foundation would take control of the land. Within the first 14 months of signing the lease there were a number of important activities that had to take place in order to be able to gain full understanding of the land and its properties.

5.4.1.1 Botany Report

On the 28th June 2011 a botanical and habitat survey was conducted, the method used was a field observation/botanical and habitat walk around. The surveyor was Cameron S Crook. The botanical report highlighted that this was young woodland, which had not been managed and therefore had begun to establish its own layers, for example groundcovers, shrubs, and canopy trees. In the original canopy structure (trees) the main species found were, beech, birch, poplars, and willow (Portfolio of Works: 43). It was evident from the topology of the site it would be very difficult to keep the trees in their present location. The trees were very large compared to the site size, because the site had been left and trees had grown. The canopies of the trees were so large that they were reducing the solar capture for the lower layers. The canopy cover could be reduced by shredding the tree canopy or by removing the trees completely. As noted in the Systems chapter, however, mushrooms have developed a symbiosis with hardwood trees. This made a third option possible: to use the trees as a substrate to develop a fungi community using oyster mushrooms, as a way of decomposing the tree timber back into the soil. The trees were cut down, but were recycled to increase the fertility (nitrates) of the land, while retaining the calorific value and specifying a new use of the land for food production, based on Permaculture techniques.

The original understory and groundcover structure included grasses, shrubs, tall herbs, ferns, nettles and short perennials. This revealed that the land was naturally regenerated woodland that was in an early stage, and suggested that with good design, the land could be developed into a more complex agro-forestry system.

5.4.1.2 Soil Samples

It was important to be able to understand the soil properties of the land in order to be able to gain insight to the present health of the particular system ecology that we would be able to develop in relation to the agroforestry system. With the support of Manchester Metropolitan University, soil samples were taken from the woodland site and analysed in the School of Science and the Environment to establish the baseline condition of the soil. Tests were made on 22 varied samples for pH, water content, soil conductivity and organic matter.

5.4.2 Site Development

After the initial investigation of the site it was decided to rethink the whole design and not to work with the initial site ecology, but rather to restructure and re-design the plans that had initially been made. As with the development of the food distribution system, flexibility was required in order to respond to the context in which the programme of investigation took place. The Biospheric Project was an onsite laboratory within an urban community context, and so the conditions for experimentation were different than within controlled conditions, but from this new knowledge was created (see the discussion of action-led research in the Argument and Contextualisation).

It was evident from the botanic survey and the structure of the trees that it would be not possible to create a forest garden that would thrive without removing the trees. The tree canopy layer is highly important, and so if this is poorly designed, it can affect all other layers. Therefore it was decided that the trees would be removed; but that the biomass would be reused on the land with a view to developing a flow of organic matter to improve the soil system and thus the integrity of the whole design. This ensured that all the materials available were utilised to turn waste into nutrients.

5.4.2.1 Suppression

Suppression (see Glossary) is a well-known technique within Permaculture, agroforestry and organic farming, also known as mulching (see Glossary). The technique can be used in different ways to support healthy soil. Two of the beneficial effects as identified by Crawford (2010) are: reducing or eliminating weed competition with young trees allowing them to grow up to twice as fast in their early years; helping to slow the loss of soil moisture during summer and so maintaining better soil conditions for tree roots. Mulching can be done with a variety of different materials such as cardboard, woodchips, straw or grass cuttings, depending on what is available within a particular locality. Both cardboard and woodchip were sourced from Salford City Council at no cost. It is important to begin mulching and suppression as early as possible, to kill off the existing grass and weeds before planting trees. This process can take between four and twelve months. It was decided to use a technique called sheet mulching (see Glossary) because this had been found very effective for the Agroforestry Research Trust (Crawford, 2010). Sheet Mulching on the land started in January 2012, giving an eight month period of suppression before the first layers of the forest garden were implemented – namely, fruit trees and shrubs in autumn (Portfolio of Works: 44).

5.4.2.2 Tree Removal

There were 52 trees within the original land. The removal of the trees turned out to be a very sensitive topic within the local community, although this had not been anticipated. It was interesting that even though the land was clearly not being taken care of, there was a real concern within the community about taking the trees out. This mainly came from the residents who overlooked the land from the high-rise buildings, as it was something that they had enjoyed visually. By producing an overview of the agroforestry system and explaining the potential benefits of it over a longer period of time local people became convinced and the development could proceed.

The approach was not ‘slash and burn’, but rather to remove the trees and then reuse the timber in a variety of ways, for example, through biological trench, mushroom inoculation, and mushroom production. Nick Bailey Tree Services Ltd was commissioned to remove all the trees on the land (Portfolio of Works: 45). As they had been identified as hardwood species, it would be ideal not to lose the biomass but to re-use the timber for Hugelkulture beds (which are explained below under 5.4.2.5) or for inoculation with mushroom spores to create a richer soil on the land. Nick was asked to cut all the timber into small manageable sizes so the timber could be used for the latter. This produced over 100 timbers that could be used again on the land as part of the redesign. The removal of the trees also generated a large amount of woodchip, which was used for mulching. Therefore the land did not lose any biomass; the biomass was just used on the land in a different way.

The removal of the trees completely opened the land up, and for the first time it was possible to see the real potential of a full agroforestry system implemented on that land. A completely new platform had been created upon which to design the agroforestry system: a blank canvass where anything was possible (Portfolio of Works: 42).

5.4.2.3 Fence

Crime and anti-social behaviour had been a big issue within the local community, specifically with joyriding (cars, quads and motorbikes), nuisance parking, fly tipping and the abandonment and burning of stolen vehicles, particularly on East Philip Street on which Irwell House is situated. Therefore security of the land was a very important issue of concern to the local councillors and community. The community was particularly worried about the transition period, from the removal of the trees to the establishment of the new trees, as the land would be rather stark and it was felt that this might encourage more anti-social behaviour and crime. The community wanted to see planning to secure the site, with suggestions of knee railings, bollards, stones or a fence. The community had discussed this before the project had actually started, but it had been decided not to progress this as the landscaping provided a natural barrier.

Salford City Council and Urban Vision thought that it would be necessary to have a fence around the space so that local residents would not vandalize the space. This approach seemed counter-productive and would also undermine the notion that the land would be accessible for all people within the community to use independently and within their own time. Therefore, a low fence was put around the forest garden to designate the space, but ensuring that it was still accessible to the local community (Portfolio of Works: 46).

5.4.2.4 Solar Capture Survey

Before a detailed design of the forest garden could be made it was highly important to understand the solar capture possibilities of the different parts of the site in relation to the present and future environment. This was to highlight the sun-loving and shade tolerant areas of the land for planting different crops. In order to understand this a 12-month solar capture survey was carried out on the land. The survey created a visual representation of the hottest and coolest areas across the land over a 12-month period. To use this technique, the whole environment had to be built in a three-dimensional architectural software package. This meant designing Irwell house, the Vertical Village tower blocks, and the local trees. The information that this modeling provided was invaluable as it enabled solar capture to be related to the needs of each individual tree species, to determine where the shade tolerant trees should be planted. It also gave a clear understanding of the distance needed between the trees so it was possible to develop and design an efficient and comprehensive cropping system between the trees, a technique known as alley cropping (see Glossary). In a wild environment, solar penetration is a determining factor of the species at each canopy within a forest. This changes as the forest matures. These natural processes had to be incorporated into the creative design in order for the forest garden to thrive in the urban context (Portfolio of Works: 47).

Martin Crawford of the Agroforestry Research Trust was consulted about this solar capture technique to gain an in-depth understanding of where the trees should be planted and the distance between the biological layers. The technique was not one that he had seen before, and he recognised it as an innovative development, especially for urban systems as the built environment is completely different to a rural environment. He may not have considered the technique because he is an agroforestry expert and not an architect. This methodology emerged through the transdisciplinary process, by connecting areas of knowledge within professional architecture and agroforestry. So the importance of using solar capture to create the ecology of the forest garden within an urban setting became clear. Solar capture is already used as an architectural tool to build sustainable buildings, but this new research points to a future in which solar capture will also become a tool for ecological designers, specifically in an urban context.

5.4.2.5 Biological Trench

Once it had been decided where the trees should be planted, it was necessary to create the best soil conditions for them. The idea of creating biological trenches for the trees was developed, based on the idea of Hugelkultur. Hugelkultur, pronounced Hoo-gul-culture, means hill culture or hill mound. It is a technique to develop raised garden beds filled with rotten wood. The technique has been well-positioned by many permaculture practitioners, most notably, Sepp Holzer (2011), a worldwide expert in permaculture. This technique had been seen in operation at Eko Sense prior to the start of this research programme. The decomposition of rotting wood creates a dense and diverse ecological platform, which heightens the biodiversity within the raised beds. It was the Hugelkulture technique that led to the idea of developing the bio trench on the land.

In many ways the Biological Trench is the opposite of Hugelkulture. Instead of making a high mound from the top of the soil surface, a trench was dug by mini-digger (by the Groundwork company North and South) to a depth of 1m and a width of 30cms. Once the soil had been extracted, a team of volunteers worked to remove bricks and other rubble from the soil and trenches. A total of 4000 bricks were removed, filling four skips (Portfolio of Works: 48). The trenches were then back-filled with a range of organic materials such as logs, hay bales, twigs, leaves, brambles and nettles (Portfolio of Works: 49 - 50). The timber was also inoculated with fungal dowels, using Grey Oyster fungi spores. The wooded material under the ground acts like a sponge that absorbs water and releases heat as it breaks down. It also feeds and enriches the soil and creates a rich and complex environment for beneficial organisms including mycorrhizal fungi. The trenches were back-filled with the displaced soil, creating a small mound that was then raked off by the volunteer team to create a 1 metre wide flat top at a height of 15cm ready for planting the trees. Seven biological trenches were developed on the land, the longest being 29 metres and the shortest being 10 metres, running parallel to the western edge of the land. The trenches were sited at a distance of seven metres apart at their centre. The work took three days at approximately seven hours per day with teams of between six and sixteen people.

5.4.2.6 Fruit Tree Layer

It was then possible to plant the trees to create the fruit tree layer. The aim of the fruit tree layer was to develop a diverse range of fruit trees ideal for the northern temperate climate. Around 200 fruit trees were selected that are recognised as well-adapted for the northern climate by the Agroforestry Research Trust. Working with Martin Crawford this was narrowed down to a list of 80 trees that would be planted on this land. By using the biological trenches on the solar capture survey it was very easy to understand where these trees should be positioned.

5.4.2.7 Alley Cropping Design

The biological trenches were used for the development of the fruit tree layer (Portfolio of Works: 51 - 53). The space between the biological trenches developed the platform that would allow the alley cropping technique to be used, as seen in traditional alley cropping methods. This would allow for the traditional farming and tree production techniques to be integrated. Thus the alley cropping technique was formed by the development of the biological trenches. The spaces between the biological trenches and the lines of trees were intricately designed through the solar capture technique. The solar capture technique highlighted that we would need between five and seven metres between each trench. As the trees matured the sun would still be able to penetrate into the lower levels, enabling strong ground cover and shrub growth. In the first stage of the alley cropping process for the launch of the Manchester International festival it was decided to develop raised beds in the alleys, highlighting the perennials (such as Good Kind Henry, perennial Kale and Sorel) that would be used to plant in the ground itself in further development stages. This avoided the problems associated with soil contamination (Portfolio of Works: 54 - 56).

5.5 Vermiculture

The development of the vermiculture system was very straightforward in comparison to the other ecological systems at the Foundation (Portfolio of Works: 58). It was first thought that the vermiculture system should be developed in Irwell House, but this produced a number of problems mostly due to the fluctuations in temperature. As there is no heating system or cooling system the building is very warm in summer and very cold in winter. This environment would not have been ideal for the earthworms, and it would also have caused other problems. For instance, feeding the worms waste food from Whole Box or 78 steps in the summer months, pests would have been a problem, which would have created a health and safety issue. On the reverse the cold temperature in winter would affect the production system of the worms. Due to these considerations, it was decided to develop the vermiculture system outside as part of the agroforestry system.

5.5.1 The WormPod

The WormPod was donated from Steve Ross of the Worm Research Centre (WRC). It is a fully integrated, purpose-designed processing bed. The WormPods are capable of processing a wide range of materials from various waste streams and are modular in nature.

The first task was to set the WormPod at the south end of the agroforestry system, which enabled the team to have access to Irwell House so that the worms could be harvested and transported to the aquaponic systems and the roof to feed the fish and chickens with ease. The second task was to develop a comfortable environment for the worms that mimicked the layers of a soil environment. These layers were developed by adding soil, hay, cardboard and woodchip up to a foot deep. As it was to be a relatively a large community vermiculture system 48kg of worms (dendrobaena veneta**)** were purchased (Portfolio of Works: 59 - 60). The worms were placed on top of the bedding across the WormPod. The worms were then left in the WormPod without distraction for one week for them to get familiar with their new environment. After a week a layer of organic food was placed as the final layer for the worms to feed on. Over a 3-month period the worms were not touched, and food was added to the WormPod with no disturbance to the worms. This period was for the worms to get used to their new feeding pattern. The worms were fed from the waste produced through Whole Box initially and then as 78 Steps was developed, the worms were fed the green (food waste) and brown (cardboard) waste that was generated from the store (Portfolio of Works: 61 - 62).

5.5.2 Harvesting the Organic Matter

There are three products that the vermiculture system was aiming to create: worms, wormcast and worm tea (see Glossary). The worms were harvested to feed the fish in the aquaponic system. Wormcast and Worm Tea were used for the raised beds in the forest garden to provide nutrients for the plants. The key economic benefit of vermicomposting over other forms of recycling is the high quality of the final product, earthworm castings (Flores-Sanchez et al, 2011). Feeding the brown and green waste to the worms as described above, enables the system to produce these important products. Nothing else needs to be added to the system for the worms to be able to generate these. There are a number of stages needed to harvest the worms and organic matter.

The WormPod was 4 metres long by 1.6 metres wide, and the system was fed at either end on rotation every 12 weeks. Firstly feeding occured at one end of the system, which had 2-metre coverage, and then the feed was stopped for two weeks, which enabled the worms the time to eat all the food, and begin to get hungry again. Then the opposite side was fed for 12 weeks, which encouraged the worms to migrate to the feeding end of the system in order to begin the rotation again. As the worms migrated from the opposite end, they left behind the wormcast that they had produced. This could then be harvested without taking too many of the worms. The organic matter and some worms were then placed into the raised bed as a compost (wormcast) to enhance soil fertility, biodiversity and enhance plant growth. Through harvesting the wormcast in this way, it was easy to generate a low-cost means of generating organic matter locally, so there was no need to buy compost.

5.6 Mushroom Production

The aim of growing mushrooms was to develop a new way of producing food in the Biospheric Project whole system that would enhance the diversity of diets in the local community, and to research different possible substrates for growing them. The main questions addressed by the research were:

1. How would it be possible to grow mushrooms in Irwell House?
2. How could mushrooms be grown at the quality needed to sell at 78 Steps and the wider Greater Manchester market?
3. What would be the most efficient and cost-effective substrate to use within a Greater Manchester urban context?

5.6.1 Initial Steps

It was important to identify an expert mycologist and mushroom grower and so Ann Miller was approached with the aim of developing a long-term research programme around the production of organic oyster mushrooms at the Biospheric Project (for a profile of Ann

Miller see Manchester International Festival, 2013). Ann shared an understanding that mushrooms have a specific role to play in ecological development in city environments. Mushroom production provided a good platform for public engagement with the Foundation to enhance understanding of these issues, but was also an important part of the whole system design. It was important to develop something practical with the community that highlighted the processes needed to develop mushrooms rather than a theoretical overview of the processes, as this would be a comprehensive and fun way to engage local members of the community.

It was decided that engagement would have to provide a brief history of mushroom cultivation, and highlight the types that are easy to cultivate. The types of mushrooms included were shiitake, oyster, button and chestnut mushrooms, as these are the easiest mushrooms to cultivate. The intention was that the community would be taken through the steps needed to understand the processes involved in cultivating mushrooms at the Foundation. This would begin to develop a platform from which members of the community could cultivate their own mushrooms at home. The aim was also to create a small mushroom farm at the Biospheric Project, which would be initiated by providing the first mushroom course for the community.

5.6.2 Course Delivery

A two-day mushroom cultivation course was delivered with Ann Miller on Saturday 29th September and Sunday 30th September 2012. The first day provided an introduction and overview, with practical application, and the second day involved inoculation of timbers and substrate with a variety of mushroom spores. A range of cultivation techniques were shared, with step-by-step instructions and demonstrations of the processes involved such as how to take a spore print to begin the propagation process; how to use a spore print to inoculate a growth medium and to monitor the progress of different samples; how to create a growth body substantial enough to sustain fruiting bodies; cropping and second-cropping; pros and cons and recipes for the first stage of mycelial growth (in a petri dish), and for the second stage up to fruiting bodies.

5.6.3 Developing the Micro Mushroom Farm

The course with the community acted as the catalyst for the start of the mushroom farm. The course identified that the oyster mushroom species would be the easiest and most cost efficient mushroom to use. Ann Miller highlighted the fact that due to the lack of space and technical infrastructure (for instance not having a laboratory for inoculation or harvesting rooms with the right environmental conditions) we could encounter a high number of contaminations throughout the basic testing and growing programme. This was proved to be correct. For every 10 bags of mushrooms produced, there was around a 70% contamination rate, meaning that mushrooms were not edible. The programme successfully grew 420 bags of oyster mushrooms (Portfolio of Works: 64 - 69). This meant that it was indeed possible to grow mushrooms in Irwell House without any infrastructure, although in order to grow on a commercial scale this level of contamination would not be acceptable and better infrastructure would be required.

This action led approach enabled the development of a conversation with both Simon Rogan from the ‘French’ restaurant and David Fox, CEO of the Tampopo Restaurant. David Fox was invited to Irwell House with his head chef to try the Oyster mushrooms that had been grown on site. On the day that they visited, the mushrooms had not been harvested, so the head chef was able to do this. He cut the oyster mushroom off the substrate and cooked it in the Foundation kitchen. He felt that they were the best mushrooms he had tasted in a long time (personally spoken communication), suggesting that the mushrooms grown were of the quality required to sell into the Greater Manchester market.

Contacting Simon Rogan from the ‘French’ restaurant was motivated by the aim of developing the commercialisation of the mushroom enterprise. Simon Rogan highlighted the demand for a large selection of locally grown mushrooms, but said that in order to reach the necessary scale, a guaranteed supply chain would need to be developed. To be able to achieve this, a large mushroom facility would be needed, rather than lots of small programmes that exist already and do not supply the necessary scale.

The third question was to identify the right substrate. Growing the 420 bags of mushrooms highlighted that waste coffee would provide an effective substrate and a nutrient stream that is very accessible in an urban environment. This would utilise waste coffee that would otherwise be sent to landfill. In order to be able to action this, a conversation with Costa Coffee on Manchester Market Street was initiated. It became clear that there are possible waste coffee streams that could be accessed to use as a substrate to develop a large mushroom facility in Manchester to sell to locally based restaurants. The creation of a commercial mushroom farm is a potential future development of the project.

5.7 Aquaponics

The aquaponic system was the most technical and biological system that was developed through the research project (Portfolio of Works: 71 - 73). Professor Greg Keeffe and two PhD students from Belfast Queens University developed the aquaponic system in conjunction with Siemens and BDP Architects. The system developed was the first multilayered aquaponic in the UK, extending over the second floor of the warehouse and the roof. The main part of the system was made up of 12 large fish tanks, holding a total of 9600 litres of water. The tanks could hold up to 600 fish, which created the nutrients to feed the plants through the fish waste that was pumped around the building (Portfolio of Works: 77). The system allowed the nutrient-rich water to be pumped into the two main growing areas, the south-facing vertical space (window system) and the large polytunnel on the roof. The south-facing vertical space held 150 growing bags, allowing 150 crops to be grown at a time. The polytunnel had a 'nutrient film system', which consisted of 2800 plots, enabling 2800 individual plants to be grown at a time (Portfolio of Works: 78 - 82).

The whole system was connected by a series of filtration systems, pumps and pipes and consisted of over 1000 parts. Filtration in the system was designed using 98 green bowls, providing a worm-based mineralization system (Portfolio of Works: 74 - 75). A control and monitoring system pumped the nutrient filled water (4000 litres per hour) around the building to the growing areas and monitored the process (Portfolio of Works: 76). The automatic control and monitoring system was designed and implemented by Siemens, who provided a visual display unit that provided a range of information in an accessible way. Due to the weight of the tanks, an in-depth structural report was required for both floors of the building. This was performed by BDP Architects.

A series of diagrams demonstrate the development of the interconnectivity between these systems and the potential future development of the whole system (Portfolio of Works: 84 - 89). The Portfolio of Works also illustrated the public engagement activities that took place (Portfolio of Works: 91 - 98).

5.8 Outputs and Potential Outcomes

In this section the outputs and outcomes of the programme are assessed in terms of environmental, social and business impacts.

5.8.1 Environmental Impact

The development of The Whole Box and 78 Steps has meant that there has been a significant increase in access to healthy food within the local community in an accessible way that reduces food miles, packaging and emissions. Research by Coley et al (2009) found that total emissions from delivering vegetables to a customer's doorstep in a vegetable box system can be much less than from a whole food store in which customers are predominantly drawn from several miles away. There were some caveats in terms of reducing food miles, as it was decided to stock a full organic range including fruit and vegetables to ensure that pesticide heavy food was not stocked. Even though this was sourced from a local supplier, this supplier relied on food from further afield (outside the UK). This means that improvements could be made in terms of the environmental impact of the food distribution system by developing food infrastructures that supply local interventions.

The fact that 78 Steps is set within a local context connected to a food production system also has a powerful symbolic effect in being able to highlight the importance of reducing food miles and aiming to close the loop between food production and distribution. The fact that 78 Steps only stocks organic produce made it more efficient in terms of closing the loop between the waste produce and feeding the vermiculture system. It was no longer necessary to split the 'non-organic' from 'organic' nutrients, which reduces human resources and increases the productive flow within the whole system.

Through the development of the Forest Garden, discussions with the City of Salford were initiated to develop a range of agroforestry systems within the city. This could be a way to increase biodiversity and food production across the city, which could have significant environmental outcomes. A soil decontamination programme to decrease contamination on the Biospheric Project agroforestry site was initiated. This could potentially be used on the contamination sites across the city and could increase potential food growing on these sites.

The use of vermiculture has further enhanced the output of the food distribution system in terms of environmental impact. The Whole Box and 78 Steps do not just create greater access to local organic healthy food in the community, but are also connected to a wider system that produces waste that feeds the worms creating wormcast, delivering needed nutrients for the whole system. Using earthworms in this way has been an easy and low cost way to close the loop between social and ecological systems within the Blackfriars neighbourhood.

One of the aims of the mushroom production system was to understand the most sustainable substrates and growing environments for mushrooms within the Biospheric Project. This was achieved by developing 1400 mushroom bags with a mix of different substrates. This has supported the other focus on developing a large mushroom facility to increase mushroom production and reduce carbon emissions for local restaurants. After the 1400 oyster mushroom bags had been used, they were then mixed into the soil and woodchip of the agroforestry system as a way to build the fertility of the soil. This action has developed a comprehensive mushroom culture across the agroforestry system.

5.8.2 Social Impact

The Whole Box started with three customers, and was developed to fifty to eighty customers per week, meaning that access to local healthy food in the community was increased. Research by Wrigley et al (2003) in Leeds explored the impact of increased access to healthy food through retail intervention and found a positive but modest impact on diets. It was important, therefore, not only to increase access, but also awareness and understanding. In order to do this, a wide range of recipe cards were developed to accompany the Whole Box to enable people to learn to cook in new ways and with new food. 150 boxes were given away free of charge to members of the local community. These boxes contained ingredients and a recipe card with cooking instructions on how to make Quinoa Vegetable Paella, Homemade Pizza and Vegetable Pasta.

The Whole Box was an effective way of being able to engage with the local residents and encourage healthy eating, to inspire people to cook for themselves and try new ingredients. This was built on by developing 'Community Recipe Cards.' Four local residents submitted recipe ideas to help promote healthy living in the local community. These recipes were then printed onto 2,000 cards which were distributed around the local housing estates as well as being available to customers of 78 Steps and the Whole Box. The recipes included: Leek, Potato and Bean Soup; Oriental Aduki Bean Stir Fry with Buckwheat; Bean and Vegetable Pie; and Banana Cake. Whilst this increased demand from the local community and potentially represented health improvements to deliver social outcomes, it also stimulated the nascent market in organic fruit and vegetables.

78 Steps contributed further to the social impacts of the Whole Box, but had an additional impact in terms of developing the skills and confidence of local people. It provided them with an opportunity to volunteer within a retail setting and so provided much needed experience to move them closer to the labour market. 78 Steps has had a positive impact on many people's lives, including project volunteer Cormac Fulton:

> I've lived in the area for over a decade but it wasn't until I got involved with The Biospheric Project that I started to meet local people – it has really helped to install a sense of community spirit, which I wasn't aware of before. Being a naturally shy person, I wasn't particularly keen on the idea of working in 78 Steps, especially having to deal with customers. However, since my involvement it has really helped to boost my confidence and improve my interpersonal skills. I've also started to eat much healthier and take more interest in what I consume, which has also helped me to finally quit smoking, a habit I have been trying to conquer for some time. This in the long run could improve my life longevity, so I feel I have a great deal to thank The Biospheric Project for.

This quote highlights the connection between social, environmental and business factors.

The social impact of the forest garden derived from the workshops that were delivered at the Biospheric Project and across the city to enable local people to gain expertise in agroforestry. By increasing local expertise in the design and development of agroforestry systems, the aim was to increase access to healthy local food production in the longer term.

Vermiculture systems are a great introduction to understanding ecological systems and food production with children, and the aim is to develop a long-term engagement programme based on this system. There is also the connection as discussed above in terms of closing the loop between environmental and social impacts within the local urban community.

The potential for mushroom production to be a means through which to provide skills for local people was explored, in order to prepare for large-scale mushroom production in Salford and Greater Manchester. A comprehensive local production and distribution mushroom programme, which delivers new opportunities for local jobs for a rapidly growing market has significant potential and will hopefully be one of the future developments of the project.

Similarly, the aquaponic system developed during the programme of investigation enhanced understanding of the challenges of initiating a local system for the production of fish and leaf crops. The aim is to expand access and diversity of local organic food eaten, and hence the wellbeing of the community.

5.8.3 Business Development

The Whole Box provided the means to develop the market in the local community and raise awareness of the food distribution and production that was being undertaken. The customer base increased consistently to reach up to 80 Whole Boxes per week, which totaled £400 per week. The overarching aim of Whole Box was to build a market, and ultimately to develop a whole foods shop in the form of 78 Steps, and this ambition was achieved. This was an essential means through which to slowly build up the business of food distribution. By developing a model of consumer demand, the connection was made to the food production system as part of the whole system ecology and possibilities for a closed loop system were increased.

The development of new stock lines within 78 Steps increased sales and the customer base and so increased business viability. The Biospheric Project was successful in developing a commercially viable whole food store in one of the most deprived areas in the UK. This is a major output from the programme of investigation and has been a significant achievement. This success has made it possible to approach other funding streams to negotiate increased financial support and build on the vision of 78 Steps in the future. There is potential to develop a larger community shop at the Biospheric Project. The new shop may become a cooperative, which would ultimately shift the business, social and environmental factors towards an integrated set of ecological relationships.

The relationship with local organic suppliers also develops a stronger local economy. Every pound that was spent with suppliers, and every pound that customers spent in 78 Steps stayed in the local economy, building the potential for a more resilient adaptive ecological community. 78 steps has also become a supplier of organic produce for local sandwich shops in Salford, and this has now become a core part of the strategic model for viability of the business. This reflects the development of a much broader business model than could possibly have been achieved through the Whole Box model alone.

Through the increase of local production and use of agroforestry new avenues for local ecological enterprise have been developed that aim to increase local food production. This has potentially contributed towards an increase in the local expertise in the design and development of agroforestry systems.

From a commercial point of view, vermiculture is an efficient way to reduce waste costs within a local context, while also providing different business opportunities. For instance, selling worms to the local fishery group in Salford created a revenue stream for the Biospheric Project. Within a city context, the reduction of the amount of waste being sent to landfill has a number of advantages. Liability for landfill tax is reduced and so the overall cost of dealing with waste is reduced. The aquaponic system closes the ecological loop between the other systems, reducing the volume of organic matter and so reducing the cost of waste disposal to enhance business viability

The business impact of mushroom production derives from the potential to develop large-scale production. Discussions have been held with the New Economy and Manchester Growth Hub, developing a business plan and investment strategy for the largest mushroom production facility in Greater Manchester.

5.9 Conclusion

In this chapter outlines the process of implementation of the different systems that have made up the whole Biospheric Project. The implementation of these systems underlines the amount of organisation and technical knowledge that was required across structural, engineering, architectural, social, ecological, economic, cultural and research partners to be able to realise the whole system, and the fundamental need to collaborate with a wide range of different stakeholders to be able to deliver the project. Without developing the methodology of visiting expert practitioners, developing the technical teams, working with the local community and developing the funding streams, the implementation of the whole system approach would not have been possible, and the research project would not have been put into practice.

The success of this approach is clear from the assessment of the outputs and ecological outcomes of the project in terms of its impact on the local environmental, society and business. The implementation acted as a catalyst to discuss how future developments could be delivered along more commercial lines. It also allowed a design and research team to work within a transdisciplinary whole system approach, which was a very important learning experience providing the practical and human skills needed to deliver such a programme.

6 Discussion

‘The whole is greater than the sum of its parts.’

— Aristotle

6.1 Introduction

The Biospheric Foundation was established as a site for action-led research to identify and address some of the challenges of urban food production in the twenty-first century and to overcome some of the gaps within existing local alternatives to the industrialised model of food production by developing a whole system approach. It has been geographically situated in the Blackfriars neighbourhood in Salford, which is an area of multiple deprivation and one in which local residents disproportionately experience poor health and have a poor diet.

The aims and objectives of the research programme were as follows:

1. To design a whole system ecological approach to urban farming.
2. To establish a working model of such in an area of high social deprivation.
3. To create a centre for ecological research.
4. To contribute to public awareness of health food and ecological systems in urban environments.

To implement this, a network of different food production and distribution systems were developed: a forest garden, a mushroom production system, an aquaponics system, the

Whole Box delivery service, 78 Steps whole food store, and a vermiculture system. These different systems were connected to understand the relationships between the networks, creating an ecological whole system that has been developed through applied research. The following section sets out some of the major learning from the programme of investigation and includes a critical evaluation of how these were achieved. It also points towards original knowledge developed in terms of system thinking within the context of urban food production and distribution in an existing urban community.

6.2 The Systems

Firstly it is important to understand that no system is completely closed apart from the biosphere itself, and even that is influenced by the Sun and the moon. The ambition for this programme of investigation, however, was to close as many loops as possible, as this reduces the loss of energy and natural resources, thereby creating the potential for a more adaptive and resilient urban ecological system. To achieve this it was necessary to understand the different singular systems and their possible inputs and outputs that could connect to other systems – an ecology of inter-connected, inter-dependent systems. Observation and discussion with experts connected to each system enabled the development of an action-led approach. Being able to work with experts and see the systems work in practice was more informative than secondary research.

All of the systems developed at the Biospheric Project built upon this collaboration with experts, who in many senses became consultants for each of the singular systems. The task was to creatively bring them together to enable an ecological whole system to emerge. Each singular system had it's own complexity and design demands. For instance, the implementation of the agroforestry system produced challenges arising from the location of Irwell House adjacent to contaminated post-industrial land. The design of the aquaponics system was equally challenging, but from architectural, engineering and structural perspectives. With 78 Steps, there were challenges due to the lower levels of demand for whole foods in an area of urban deprivation. So by implementing the systems in a geographically situated context rather than within a traditional research environment, new knowledge was acquired. The key issues and areas of learning related to each system are outlined below.

6.2.1 Retrofitting Irwell House

The research investigation was grounded on being able to access a building in which to implement the different systems. The fact that Irwell House was situated in a deprived community with adjacent and available land was fundamental to the delivery of the programme, as it addressed the second research aim. Opportunities were opened up because of its location within a community. It also enabled the delivery of a project that brought in commercial partners to develop systems within a non-commercial building that would not be possible within the commercial sector. Irwell House proved to be a useful site, but it became clear that the physical integrity of the building limited the full potential of the project. It would have been more effective to lease a more efficient building that was able to house larger experiments. This would have enabled the production of more crops and the development of more activities throughout the building.

It is perhaps worth considering what would be necessary to construct an efficient urban farm for a temperate climate. This research has led to the conclusion that designing and constructing a building with food production and distribution as its prime function, may be a more innovative way to develop enhanced ecological systems that will enable buildings and cities to become truly ecologically efficient. When we consider the emergence of new technologies, new opportunities will arise in the way that we can connect technical infrastructure with ecological systems.

Alberti (2005) states that earth ecosystems are becoming increasingly dependent on urban growth. He argues that building on the existing evidence of urban ecology and urban planning, it is possible to develop research on the mechanisms that connect ecological urban patterns to function. Population density places huge pressures on urban areas. Constructing buildings that have the prime function of housing ecological systems, then, has significant potential to bring about a radical transformation in the way that we think about cities as ecological systems.

6.2.2 Agroforestry

The site for the agroforestry system was contaminated land due to the historical legacy of industrialisation. This meant that the produce grown in the forest garden directly in the native soil could not be eaten by the local community and so could only be used for limited research purposes. While this undermined the initial aims of the project, it created significant potential for understanding processes of bioremediation within post-industrial landscapes.

Iverson's (2010) research in Vancouver identified a site assessment guide for converting brown field sites into community gardens. There is also potential to develop new approaches specifically for the use of contaminated land. In a study of an area of post-industrial land adjacent to a river in Pennsylvania, Beal (2012) suggests an industrial-ecology approach that creates a biogas-greenhouse-agroforestry system. In this, inputs and outputs are controlled to create a closed loop system that uses the agroforestry system for biomass. Whitefield (2004) has suggested that poplars can be grown and used for biomass, and also can clean contaminated land over a period of time.

The agroforestry system that was created as the Biospheric Project was the first to be developed in Salford. The same system could be developed as an ecological system across Salford, with the main objective of cleaning contaminated soils rather than food production. This approach would also support soil carbon sequestration in urban land. Furthermore, the development of the agroforestry system led to conversations with a range of different housing providers to consider how they could use their green space in a way that is more socially, ecologically, economically and culturally sound.

6.2.3 Mushroom Production

Sanchez (2004) has argued that the improvement of mushroom technologies will lead to an increase in the potential and productivity of mushroom cultures. This research has developed knowledge of how to commercialise mushroom production, but in a community context. The challenges were that it was necessary to develop a low-tech way of growing mushrooms to avoid the cost of developing a full mushroom farm. This was overcome by training members from the local community with a view to gaining employment with the potential development of a larger-scale mushroom production facility. This answers some of the questions posed by Mount (2012), who argues that ‘scaling up’ is the next major challenge for the local food movement. While the Biospheric Foundation was not able to address this issue, the research did provide an insight into increasing direct participation of communities in both food production and consumption.

6.2.4 Aquaponics

The challenge here was the structural weakness of Irwell House. This meant that there was a limit on how much load the building could support, so the size of the system within it had to be reduced. This reduced the scale of the aquaponic system, and therefore the scale of production volume. Despite this, it was possible to develop an innovative and multi-layered aquaponic system in Irwell House, which is the first of its type in the UK. The growing area of the aquaponic system was situated on the roof of Irwell House and so it relied on natural sunlight (current) instead of ancient sunlight (oil). This provided critical learning about the development of aquaponic systems in multi-story systems in an urban context.

A further interesting learning point relates to the type of fish used. The system started with Tilapia fish, as these are most commonly used for aquaponic systems. The building had no heating, so small heating systems were put into each of the tanks to create the right environment for the Tilapia. These were not efficient enough to heat the necessary volume of water, so Common Carp and Mirror Carp were used instead, as they could thrive in the unheated temperatures, and there was an energy saving, as no additional heating was required.

6.2.5 Vermiculture

The use of vermiculture enhanced relationships within the community and provided an accessible means for people to recycle green waste within their local community in the Blackfriars area. Li et al (2010) argue that there is significant potential for vermiculture to be more widely used as a means of maintaining ecological balance and using ‘waste’ resources most effectively. The implementation of this research project has pointed to some potential areas for further exploration. There was an increase in participation as local people dropped off green waste to the open access vermiculture system that was established outside of Irwell House. This in turn created more nutrients for the whole system. So providing access to a vermiculture system for members of a deprived community can enhance the recycling of green waste, and the production of nutrients for an urban farm.

6.2.6 Food Distribution: the most critical system

Food distribution is critical to the functioning of the whole system, yet there are difficult challenges to be faced when developing social infrastructure to stimulate demand for whole foods in an area of deprivation. Simply providing access to organic food does not necessarily mean that people demand it, which may be why Wrigley et al (2003) only found a modest impact of retail intervention on diets. What is needed is a public engagement programme around healthy food cultures to support behavioral change, which will in turn stimulate demand and create a more robust market.

As the Argument and Contextualisation highlights, there were chronic problem in Blackfriars in relation to food culture. The distribution model Whole Box gave the project the chance to be directly connected with people in the community. In the global food market, very few people are connected with food production, but they are inextricably connected with distribution through shopping for food. Supermarkets are the front of the business, the point of sale, which customers are directly engaged with. Similarly in this context, the Whole Box was the project front, the point of sale, which connected with communities in a very immediate sense. Distribution was started before the Biospheric Project was producing food on site. In this sense, the Whole Box enterprise was a marketing tool to highlight the forthcoming urban farm. The Whole Box was established to increase the demand for healthy food and to develop a functional commercial network of distribution, thereby creating demand for the potential supply.

There is evidence of behavioral change from an evaluation conducted following the Manchester international Festival. It established that many local people, despite their interest in affordable locally grown produce, have found it difficult to access. Having had an opportunity to try such foods through the project's Whole Box scheme, the majority reported an increased likelihood of buying local produce in future. 85% of Whole Box customers lived in neighbourhoods that are among the ten percent most deprived areas nationally. These results indicate the project reached and engaged people from amongst the most socially and economically disadvantaged groups, who may not otherwise have the opportunity and/or inclination to access locally sourced, fresh produce or to engage in research into sustainable food production systems. They are also amongst the groups most likely to benefit from access to affordable fresh food sources and knowledge of how to source, produce and prepare the ingredients for healthy meals.

A survey of WholeBox customers as part of the MIF evaluation indicated a range of reasons why people became customers (Corkery, 2014). The highest proportion of customers took part to support local food production and also because it was initially free. This suggests that demand for locally grown food within areas of deprivation could well be there, but that financial constraints are a major reason preventing people from buying healthier food. This suggests that by providing access (both geographically and financially) as well as raising cultural awareness then we can begin to address some of these issues.

Many customers continued to use the scheme after it was no longer free. As can be seen from the evaluation report, once engaged, customers were much more likely to engage in healthier choices around food, including trying different recipes, cooking more fresh food and also spreading their knowledge through their social networks within the communities (Corkery, 2014). Story et al (2008) have demonstrated that there are many factors that influence demand for healthy food. These include a complex relationship between individual, social, physical environment, and macro-level environments, which all relate to each other in both direct and indirect ways to influence food cultures within communities. This research has shown that by geographically positioning research, it is possible to take an ecological approach that considers all of these particular factors and opens up a research agenda for better understanding food cultures through action-led research at a local level that can draw out the relationships between the different factors.

6.3 Interconnected Systems

It is important to note that research into the volume of nutrients between each system was beyond the scope of this PhD. Whilst the value of this is recognised, this research was more concerned with how the systems connected in a wider sense to provide more knowledge on how to connect sophisticated systems and closed loop processes with the potential necessary at local scales within an urban context (Picket et al, 2001).

When developing interconnected food systems, this programme of investigation has indicated that it is important to develop a number of networks simultaneously as nested systems, within a community (which in itself is a system). This in turn creates a wider and interconnected whole system that allows nutrients to flow back and forth, creating feedback loops. This allows the larger system to begin to self-regulate like a living organism, to feed itself and potentially become self-sustaining, adaptive, and resilient from outside forces. The important idea here is the **relationships** between networks that create a large self-regulating system. It is also important to develop the networks and allow them to emerge with different complexities.

Nothing is fixed in a system made up of small networks: particular levels of the network will need to be made small or large depending on the outputs of the other networks. Therefore the building or platform that is chosen to develop an interconnected urban farm needs space to grow and retract, as it is very difficult to understand how the networks will develop until they have been designed and implemented. Below, some of the most critical connections between particular networks are highlighted, to describe and analyse the challenges and opportunities that are presented.

6.3.1 78 Steps and Vermiculture

In the ecological whole system approach the food distribution system and the vermiculture system were connected networks in which inputs and outputs were in a direct relationship. The vermiculture networks had to be increased as the outputs from the food distribution increased. In 2014, as a result of building works, the shop had to shut. This decreased the output from the shop and so decreased the inputs to the vermiculture system. When developing complex systems nested within each other, one network can affect the next or indeed, the whole system. It is important to recognise that interconnected living systems are always in flux, and being able to respond to this is an important part of systems thinking in the context of an urban farm. As Kelly (1994) points out, when developing a whole system approach to urban farming, this relationship between networks - inputs and outputs - is essential to the functioning of the whole.

To make up for the lower outputs from 78 Steps, the food from the aquaponics system that couldn’t be sold in 78 Steps was used to supplement the inputs for the vermiculture system. This shows the advantage of developing a more complex network of systems, as it creates more opportunities to regulate the system within the closed loop. While developing more complex systems is initially difficult, it does allow for novel ways of connecting the systems that keeps the nutrients in the system and ensures a steady flow of nutrients around the whole system in a way that is self-sustaining. In contrast to a singular system, the complex system does not rely on external inputs, which means that it is more sustainable, resilient and adaptive. This reveals the importance of density to a whole system approach. The dense ecological system created provides more opportunities for self-regulation.

6.3.2 Vermiculture, Agroforestry and Aquaponics

It cannot be underestimated how important the vermiculture network is in the whole system. As explained above, the inputs to the vermiculture system come from 78 Steps. In turn, the outputs from the vermiculture system provide nutrients for the agroforestry and aquaponic systems. This shows that the vermiculture system is a major intersection between a range of different systems, and so its success is critical to the whole system approach. This departs from existing research on vermiculture that is concerned with turning over organic material or with soil restoration (Butt, 2008). Through the research it has been shown how it can support both of these things, but also that it can act as the intersection between different ecological networks. In terms of the wider conceptual basis for a whole system approach, this highlights the need to consider the particular elements that are fundamental to the regulation of the entire system and to understand that there are ways of being able to scale up and down a system and circulate nutrients in different ways across the different networks.

6.3.3 Agroforestry and 78 Steps

Crops grown in the raised beds in the agroforestry system were mostly perennials rather than annuals. This gives 78 Steps a unique selling point – as the shop could provide UK perennial crops such as Good King Henry and perennial kale. This provided customers with crops that are not commonly found in supermarkets, and received pre-orders for these more unusual perennials. This shows the connections between the systems, as produce would have been taken directly from the forest garden and into the food distribution network through 78 Steps. In reality this could not happen because of the contamination of the soil. By locating the shop and the forest garden next to each other, this relationship would be apparent to the local community, who would then feel more of a connection not just with the shop, but also in terms of being able to understand where the food is actually coming from. 78 Steps was the front for the whole project. It was expected that the farm would be of more interest to people, but in fact the community's interaction with the Biospheric Project occurred much more regularly at 78 Steps. Therefore from a social perspective, the shop became the intersection and so being to be able to connect it back to the project and food production, acts as a social feedback loop. By re-thinking about how food is produced, reclaiming land that was previously vacant and 'de-alienating' urban dwellers from their food, McClintock, (2010) argues that urban agriculture can begin to solve the disconnections between ecological, social and individual forces. This research suggests that connecting food production and distribution at a local level is one means of being able to achieve this.

6.3.4 Gaps between systems

Despite these connections, there were also several gaps between the systems. For instance, as a result of constant evaporation from the aquaponic system, the system had to be refilled with tap water. It would have been much more efficient to close the loop by developing a water capture system to clear the water up and put it back in the system. Similarly, energy consumption for the whole building was relatively high and it would have been ideal to close this energy loop early on in the project by finding ways to generate energy on site. What it is important to understand, however, is that no system is entirely closed and there will always be room for improvement within a whole system approach.

There is a need to find innovative ways to connect the systems in order to close the gaps. Understanding how to do this is best facilitated through action-led research and experimentation that allows for tangible learning that moves beyond theoretical constructs. This enables consideration of structural, ecological, cultural, social, architectural and economic thinking that cannot be replicated by developing visualisations or models in laboratories. Williams (2010) argues that there is a need for a much more robust evidence base around the 'intersections' of social and technical knowledge and practice. This will lead to better understanding of how social contexts and processes can enable the development and use of sustainable technologies and how technologies can inform social and community development. It is clear that it would not have been possible to answer the aims of this programme of investigation without using the action-led research approach.

6.4 A Platform for Self-Initiated Community Enterprise

The ecological whole system approach meant that it was necessary to bring together different actors with expertise in particular systems to create the whole. In order to achieve this, a high capital stream had to be developed, firstly to secure the building and carry out the retrofit and then to be able to design and develop the systems and also deliver a public engagement programme. A legal structure needed to be created to ensure that funders were confident to support the programme. A Community Interest Company was established to do this.

In total over £800,000 was brought in to implement the programme of research. In order to do this substantial time had to be dedicated to work with funders and more importantly to understand the different languages and approaches that were required to connect with each particular stakeholder. While the focus of the thesis has been on the development of an ecological whole system approach to urban farming, the commercial side of this proved just as integral to the project. The amount of time given specifically to researching some of the systems was diminished as a result. It has been shown, however, the importance of including commercial activity and fundraising within the whole ecology to achieve the aims and objectives of the project. The total amount of capital required seemed unrealistic at the beginning of the programme of investigation, and perhaps would even have been seen as unachievable. The project has therefore been built upon the creative imagination of possibilities and the drive to realise these, rather than an existing and definite knowledge of the approach.

6.5 Engagement of deprived communities

Reynolds (2014) argues that urban farming can actually perpetuate social inequalities. As discussed in the Argument and Contextualisation, many of the existing local alternatives to food production are situated in more affluent areas and so do not engage with the most deprived communities. By situating this research within an area of urban deprivation, and delivering a range of engagement activities, the Biospheric Project has delivered a more inclusive approach than many existing models. The benefits of community-based food production and distribution systems are well evidenced, but there remain access issues for people who live in areas of socio-economic deprivation. Markow et al (2014) suggest that there must be changes to how these systems operate in deprived communities, citing the need to improve the flow of information about the food system, as well as exploring issues of affordability and convenience to improve access. Evidence from the evaluation conducted following the Manchester International Festival (Corkery, 2014) shows that this was achieved more successfully through the food distribution system than through the different events and public engagement platforms that were created. The evaluation suggests that the Biospheric Project was successful in being able to reach people that had previously had a low level of engagement with local food production and distribution.

6.5.1 Public Engagement

One of the most interesting elements in relation to the public engagement was in relation to the diversity of systems developed and their interconnectedness. Most people initially accessed the project with an interest in just one part of the whole network – the shop or agroforestry - with no or little interest in the other parts. The public tour delivered the project as one large network, made up of systems reliant on each other, which meant that visitors were introduced to systems and ideas that they had not considered. So people who engaged with the project were challenged in relation to their existing knowledge and understandings of systems and networks.

The public engagement activities tended to attract people who were from outside the City of Salford. While this was valuable in terms of increasing public awareness of the Biospheric Project, one of the key aims was to engage with deprived communities and this was not achieved as successfully when specific awareness sessions were offered without direct engagement. This was achieved more effectively through the Schools' Programme, which was designed particularly to connect with local people.

6.5.2 The Schools Programme

The map in the Portfolio of Works illustrates the location of schools that participated in the programme in relation to the Income Deprivation Affecting Children Index (IDACI 2007). It shows the project's coverage of those communities in which children are most at risk from income deprivation. Children and their families in these communities are likely to have much poorer diets than those in other areas and are therefore most likely to benefit from being educated about healthy foods, and how to access, grow and prepare these on limited budgets. Working directly with schools made it more likely that children and young people from deprived backgrounds engaged with the project compared with activities that were open to the general public. This provides some invaluable learning for the development of local alternative approaches to food production.

The public engagement of the Biospheric Project with deprived communities is also evident from the high proportion of children in participating schools eligible for free school meals, which is used as an indicator for poverty and low income. This currently averages 45 per cent across the schools that visited the Biospheric Project and over half the children in two of the schools. The involvement of local schools has brought about increased engagement and excitement amongst pupils, and feedback from the teachers revealed that the visit to the Biospheric Project had 'grabbed the children's attention, instilled interest, engaged, inspired and excited them' (Corkery 2014: 21).

Furthermore, it was reported in the evaluation that following the visits many children had actively continued to learn. This is highly significant in terms of delivering fundamental and long-term change to a more sustainable urban future. If the children growing up in deprived communities are more actively engaged within sustainable urban food production, and are thinking more critically about the existing model of industrialised food production, then the potential for change is increased.

This is an example of practice-based learning occurring with children who would previously not have had the opportunities to be able to do so. As one teacher explained:

> We were impressed not only by the project but about the discussion and enthusiasm it generated amongst the children. They weren't just walking round like little sheep staring at something, they were really actively involved in what was going on around them and having little discussions... They were completely amazed by what they were presented with.
> (Corkery, 2014: 22)

Similarly, another teacher reported that, 'since The Biospheric Project the volunteers in our garden club have become very populated by the children who took part in the project' (Corkery, 2014: 22). We can see that the Biospheric Project has achieved things that are not common within local alternatives to food production in terms of engaging with deprived communities. This has been through the connection of food distribution and production systems at a local level.

6.6 Commercial/ Research Engagement

Holling (1993) argues that the issues and problems that face sustainability are essentially systems problems, in which aspects of behaviour are complex and can be difficult to predict. Scoones (1999), states that the very uncertainty and complexity of social-ecological systems means that we must recognise that prediction, management and control are extremely unlikely, if not ultimately impossible. The programme of investigation has shown that while prediction may well be difficult, as a result of action-led research we are better able to understand both the complexities that exist and highlight the potential pathways for reducing the gaps between systems and how they can most effectively complement each other - for instance being able to draw in the different actors that are necessary to begin to solve the problems.

One of the substantial areas of knowledge that has emerged through this programme of investigation has been the lack of potential research being developed by commercial organisations such as Siemens and BDP Architects. It is evident that both of these organisations view sustainability in cities as an emerging market in the form of 'smart cities.' However, neither of them currently have action-led research platforms to develop actual systems in existing buildings, not for commercial outputs but purely for research. This has been one of the unique selling points of the Biospheric Project within the commercial sector, creating partnerships that brought in significant funds to be able to implement research activities.

Siemens played a vital part in the development of the technology infrastructure. It has been asked many times why Siemens would invest capital and time into an urban farm project in Salford? This happened because the project was positioned not just as an urban farm, but rather in terms of the relationship between technical and ecological infrastructures, and how to create interconnected systems that may ultimately allow cities to become ecological, resilient and adaptive. Furthermore, a major human resource problem for organisations such as Siemens is the lack of pathways for young people to develop skills and expertise in engineering. It is difficult for Siemens to provide practical development for apprentices and graduates on their large-scale commercial projects. Therefore, the possibilities that the Biospheric Project provided in terms of small-scale research opportunities within a real world context appealed to them. It enabled the young people to be able to gain the necessary experience, while also being enthused about an exciting platform with the aim of connecting them with future employment opportunities. The Biospheric Project provided this opportunity and the young people developed their practical knowledge of water circulation, temperature, pH and conductivity systems in relation to the aquaponic system.

BDP Architects were integral to the development of the structural engineering of Irwell House to understand the scalability of the aquaponics system for the top floor. The Biospheric Project gave BDP their first opportunity to develop practical ecological systems with the possibility of failure that is not an option in a purely commercial environment. This was the main reason that BDP Architects wanted to support the project, as they were keen to understand better how to integrate ecological systems within an existing building and the potential market for developing this in the future.

The partnerships with commercial organisations have demonstrated the potential for continuing transdisciplinary research in the private sector. This connection has more scope for drawing in the resources, and for developing to the necessary scale, than it would if it was exclusively delivered through a university alone.

6.7 Conclusion

Retrospectively it can be stated that the PhD research needed £800,000 pounds, a building, land, a shop unit, 15 funders, support from social, ecological, economic, cultural, and educational partners, 10 ecological experts, and 60 hours of my time each week for 4 years. This enabled action-led research to develop the first ecological whole system approach to urban farming in the European Union, which brought together an array of different singular systems into an ecological and technologically advanced network of systems.

The action-led research approach has allowed the identification some of the real life opportunities and challenges that exist, and has enabled the holistic approach that is required to develop conversations across social, ecological, economic, technical, cultural and funding actors. This collaborative and transdisciplinary approach has proved to be essential to the research project. Without this form of creativity, the manifestation of the Biospheric Foundation and the Biospheric Project (MIF) would not have been realised.

Until research is practically applied it is difficult to predict the real challenges that are faced. One example of this is the discovery of contamination of the land. This did not undermine the programme of investigation, but actually created a whole new pathway of potential research and land use. As discussed in the Argument and Contextualisation, the urban environment is becoming increasingly populated. This means that we have to take every opportunity to create ecological systems across the urban landscape, either for food production to feed a growing urban population, or to create complex ecological systems to reduce contaminated land and to increase carbon store in urban soils. Agroforestry systems can make a significant contribution to these three important issues.

Even though considerable amount has been achieved within a short space of time it is evident that much more development is needed with the local community in Blackfriars to eradicate the unhealthy food culture that exists. This would mean the development of more holistic public engagement programmes across food production and distribution. There needs to be a continuation of the collaboration between food experts, research institutes, commercial actors and communities to bring about fundamental change.

The commercialisation of systems is a very important part of the next step for two interlinked reasons. Firstly, local food production needs to develop a strong economic model. This means scale-up of the singular systems (such as the mushroom farm), or developing ecological systems within residential buildings. Secondly, this commercialisation would support the Biospheric Foundation's continued research, as it is important to create strong revenue and capital streams to be able to continue the research and innovative activities at the Biospheric Project.

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Glossary

Agroforestry can be a very complex design process, including forest gardening, silvopasture, farmstead, livestock windbreaks. Due to the complexity of Agroforestry method, a range of systems can be adapted to sit within rural and dense urban settings.

Alley cropping is planting rows of trees at wide spacings with a companion crop grown in the alleyways between the rows. It can diversify farm income, improve crop production and provide protection and conservation benefits to crops.

Aquaponics is a food production system that combines conventional aquaculture with hydroponics in a symbiotic environment. Water from an aquaculture system is fed to a hydroponic system where the by-products are broken down by nitrification bacteria into nitrates and nitrites, which are utilised by the plants as nutrients. The water is then recirculated.

Bio-analogous structures are similar in function or appearance, but not in evolutionary origin or developmental origin.

Bioproductive Façade is achieved through the design of a double skinned facade that could be retrofitted onto an existing building. The double skin facade provides the structure for housing vertical growing systems. The twin skin facade allows space for not only for planting zones, but also creates a void that improves thermal and sound insulation properties.

Biotic components are the living things that shape an ecosystem. A biotic factor is any living component that affects another organism either by consuming it, or by acting as food for it. Biotic cycles describe the links between these biotic factors. In contrast abiotic factors are non-living things such as heat and light.

Closed loop system is a system that is materially closed and energetically open. This means that all waste products from the system are re-used as nutrients for another part of the system so that no matter either enters or leaves the system. Energy may, however, enter and leave the system.

Ecological niche is the role and position a species has in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces. A species' niche includes all of its interactions with the biotic and abiotic factors of its environment.

Ecology Gregory Bateson saw ecology as the 'pattern that connects' (Bateson, 2000). Here the term is used as a metaphor to connect different networks and systems together to create a more complex whole. The concept of ecology sits across the individual systems, bringing together the social, economic and biological relationships between them.

Entropy is a measure of the disorder in a system. In isolated systems, entropy can only ever stay the same or increase.

Forest Gardening is a low maintenance, sustainable plant-based production and agroforestry system based on woodland ecosystems, incorporating fruit and nut trees, shrubs, herbs, vines and perennial vegetables which have yields directly useful to humans.

Horizontal system. This term is used to highlight the lack of layers in a monoculture system in contrast to vertical systems that have multiple layers.

Hugelkultur, pronounced Hoo-gul-culture, means hill culture or hill mound. It is a technique to develop raised garden beds filled with rotten wood and is promoted by many permaculture practitioners. The decomposition of rotting wood creates a dense and diverse ecological platform, which heightens the biodiversity within the raised beds.

Hydroponics is a method of growing plants using mineral nutrient solution, in water, without soil. Terrestrial plants may be grown with their roots in the mineral nutrient solution only or in an inert medium such as gravel or perlite.

Life Support System is a group of devices that allow a human being to survive in space.

Mulching is the laying of decaying organic matter on the ground. It occurs naturally in all forests. Mulches are applied to improve nutrient and water retention in the soil, to encourage soil microbial activity and worms, and to suppress weeds.

Mycelial growth is the formation of the vegetative part of a fungus consisting of a mass of branching, thread-like hyphae.

Mycoremediation/ Mycorestoration is the use of fungi to restore contaminated wild, rural or urban environments.

Nested systems. The biosphere is made up of systems that are nested within other systems. Each separate system has its own integrity, but is also part of larger systems. Changes within any system can affect the both the systems that are nested within it as well as the systems within which it is itself nested.

Peer-to-Peer Systems. The World Wide Web is a peer-to-peer system allowing information to be transferred between different platforms i.e. computers without a hierarchical structure. Fungi exist in a similar peer-to-peer system.

Photosynthesis is the process by which green plants use sunlight to synthesize nutrients from carbon dioxide and water. Photosynthesis in plants generally involves the green pigment chlorophyll and generates oxygen as a by-product.

Polyculture is agriculture using multiple crops in the same space, an imitation of the diversity of natural ecosystems, and avoiding large stands of single crops, or monoculture. It includes multi-cropping, intercropping, companion planting, beneficial weeds, and alley cropping.

Rhizosphere is the fifth layer of a forest garden system. It is part of the soil make up and brings together microorganisms and secretions.

Sheet mulching is a technique used in permaculture in which layers of weed suppressant material (such as cardboard) are combined with layers of compost, grass cuttings, straw and so on to create a well-structured, water retaining and fertile soil without any need to dig.

Substrate is the substance that is used to grow mushrooms to provide them with nourishment. Various materials can be used as a substrate. Two examples would be wood chippings and spent coffee grounds.

Suppression is the technique by which weeds are prevented from growing as a result of mulching.

Symbiosis is the relationship between two different kinds of living things that live together and depend on each other.

Transdisciplinary. As Nicolescu argues, 'as the prefix "trans" indicates, transdisciplinarity concerns that which is at once between the disciplines, across the different disciplines, and beyond all disciplines' (Nicolescu, 2008: 2). In using this approach it is not entirely possible to plan a methodology because transdisciplinarity emerges from the process of implementation. The whole becomes more than the sum of the parts, so the full understanding of the outcomes of this programme of investigation could not be predicted in the methodology. The new thinking about how the systems could be designed and connected and how to circulate the nutrients required to create a whole system approach to urban farming had to emerge from the creative process of implementation.

Vermiculture literally means 'worm growing' or 'worm farming'. When earthworms are used primarily for the production of compost, the practice is referred to as vermicomposting.

Wormcast and Worm Tea are the solid and liquid outputs from a vermiculture system.

Whole System Approach. This approach aims to understand the gaps between systems and tries to connect them in practical ways into an integrated whole network, creating a more efficient urban farm model.

Appendix 1: Funding

Funding Partnership	Funding Award	Funding Use
Cultural and Technical		
Manchester International Festival	£400,000	Development of ecological systems and public engagement
Siemens	£135,000	Technical equipment and human resources
BDP Architects	£100,000	Structural engineering and implementation of systems
Community		
Initial Investment Vincent Walsh	£300	
UnLTD	£4,000	Support the community development
Salix Homes	£4,800	Support the development of the food network
Postcode Lottery Fund	£91,121	Public engagement programme across East Salford around Urban Farming.
Salford Council for Voluntary Services	£1,000	The development of Whole Box and volunteering opportunities for local residents in East Salford
Manchester Community Foundation	£1,000	Developing local waste/resources (brown/green waste to feed systems)
Research/Academic		
MMU PhD funding	£36,000	Funding of PhD Studentship from MMU

Belfast Queens University	£50,000 (plus time)	3 Year Investment to design and implement technological food systems throughout Irwell House/Biospheric Headquarters Plus 2 PhD students over 3 years
University of Manchester	£15,000 (plus time)	Provision of Conferences Researching Climate Change in a localized context (People) and social interaction and engagement with CC Issues. LED research for growing systems research.
Durham University– Energy Institute	£50,000 (plus time)	PhD Student over 3 years – energy systems in local communities

Appendix 2 Community Organisations

Vertical villages: an independent voluntary body that represents the interests and needs of the local community living in the Tower Blocks in the Blackfriars / Greengate area of Salford (http://www.verticalvillages.co.uk).

Bridgewater Residents Association: an organisation with the aim of representing the interests of members in matters concerning the Blackfriars area and to work to better the Blackfriars area as a place to live (http://www.bridgewater-residents.org.uk).

Broughton Trust: provides adult learning, youth work, support with employment and community development across East Salford. Most of its employees and volunteers live locally (http://www.thebroughtontrust.org.uk/About-The-Broughton-Trust.asp).

The Angel Centre: aims to inspire local people to lead happier and healthier lives (http://theangelcentre.org.uk).

East Salford Community Committee: aims to support the residents in Salford and make decisions about priorities for the area (http://www.salford.gov.uk/ccmeetings.htm).

St Sebastian's Community Centre: a community centre in East Salford providing space for local activities.

Appendix 3 List of Main Collaborators

Main Biospheric Foundation Team

Tree Dietrich - PA to Vincent Walsh

Brendan Walsh - Assistant Producer

Sophie Thompson - Designer

Dave Oldroy - Urban Farmer

Rob Austin - Woodwork

Benjamin van Ooij - Designer

Steve Coles - Wholefood Manager

Sonya Lopez - Assistant Producer - Mushrooms

Julia Whitehead - Assistant Producer - Forest Garden

Agnieszka Aggi Katniak - Lead Consulting

PhD Team

Professor Phil Wheater

Dr David Haley

Professor John Hyatt

University

Professor Greg Keeke - Queen's University Belfast - Design of Aquaponic System

Andy Jenkins - PhD Student Queen's University Belfast – Design of Aquaponic System

Till Hall - PhD Student Queen's University Belfast – Design of Aquaponic System

Dr John Silver - Durham University - Research

Dr Beth Perry – University of Salford - Research

Practitioners

Gavin Elliot - BDP - Director and Head of Manchester Studio

Steve Merridew - BDP - Environmental Engineering Director

Justin Kelly - Siemens – Business Development Director

Martin Catlow – Siemens - Engineer

Dmitry Ignatyev – Siemens - Engineer

Ray Wong – Siemens - Engineer

Martin Crawford – Agroforestry Research Trust

Ann Miller – Ann Miller's Speciality Mushrooms Ltd

Manchester International Festival

Jennifer Clearly – Creative Learning Director

Kate Houlton - Assistant Producer

Sarah Hiscock – Creative Learning Manager

Karenna McClarnan - Assistant Producer

Business Team

Phil Roberts - Beaver & Struthers - Accountants

Andy Spinoza - SKV Communications - PR Team

Danny Heaton - Craghoppers - Marketing Manager

Mercy Mba – Hill Dickinson LLP – Legal Team