Urban Growth:
A Synthesis of Agriculture and Architecture

by

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Abstract

A re-organization of how we produce food is necessary; if not now, then in the near future. Agriculture today is widely dominated by industrial methods. The main concern with agro-industry is that it has been masking the fundamental issues of unsustainable farming and inadvertently creating a false sense of food security among communities. The interrelationship between agriculture and architecture needs to be strengthened in order to sustain ourselves, especially in the urban setting. These micro projects of agro-architecture must be developed environmentally, socially and economically in order to use this untapped potential to achieve food security.

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I would also like to thank my mother for unconditional love and support (and food).

I dedicate my thesis to two farmers, my father Ken Marcynuk and grandfather John Marcynuk. Although I have not travelled down the traditional path, I can only hope that you are pleased that the Marcynuk farmer's spirit lives on.

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Introduction

There is a growing desire for sustainable urban development and the densification of city cores, however, in order to efficiently sustain urban growth, it is also necessary to examine the production processes which sustain the population biologically. This thesis proposes that agriculture must synthesise with architecture through design and technology to provide continuous food producing spaces in order to sustain urban life. This integration should be approached simultaneously from environmental, social and economic perspectives to overcome the unsustainable methods currently utilized in the production of food.

Architecture evolved out of necessity: to provide shelter from the elements and to create a sense of security. Architecture commonly encompasses three of the four basic necessities for survival: shelter, water and fire (or energy). Food, the remaining necessity, is generally found outside the architectural realm. This thesis suggests that there is a largely untapped potential in the interrelationship between agriculture and architecture, on the world scale (macro) and at the individual scale (micro), and will propose a solution that brings the fourth element of survival within the domain of architecture using innovative design and existing technological solutions.

Humanity is struggling to feed, house and provide energy for our current world population. Adding more pressure to the situation is the predicted 2050 world population of 9 billion individuals.[1] Urban populations cannot continue on with the current disconnection between food and living. Importing produce is not a long term solution because it creates a dependency on outside sources and is directly affected by rising oil prices due to the finite nature of fossil fuels. One option is to grow food within the city.

Along with the negative implications which drive our need to develop agro-productive urban spaces, there is a seemingly endless number of benefits such as: agro-tourism, affordable food (with flavour), healthier diets and lifestyles, reintroduction of seasons and natural cycles of life, cleaner air, a strengthening of our connection to place and a more bountiful life in general; to name but a few.

Agriculture today is widely dominated by industrial methods. The main concern with agro-industry is that it has been masking the fundamental issues of unsustainable farming and inadvertently creating a false sense of food security among communities. To understand how this occurred, one must look at the creation of agro-industry and the resultant disconnect between nature and agriculture.

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[1] The World Bank. Web. <http://data.worldbank.org/>

In the 18th century, farmers first began to feed organic compost back into their land. Eventually organic fertilizers were insufficient or running low (depending on the resource), prompting the invention of chemical fertilizers. In 1908 a chemist named Fritz Haber developed ammonia fertilizer based on experiments in the military. A second chemist named Carl Bosch furthered Haber's discovery by industrializing it; called the Haber-Bosch process. These chemicals wreaked havoc on the natural ecosystem of farmlands and began the process of transformation from traditional farming to agro-industry.

Today we are left with intensive resource-hogging factory farms that ship unripe, genetically modified, chemically filled produce long distances at the expense of the environment.

The desire and need for local produce is evident, especially in the environmentally conscious capital of Canada. There are many types of agricultural production that can be investigated and integrated into architecture such as Aeroponics, hydroponics, greenwalls, biorock, green roofs, folkewalls, forest gardens, urban parks, collective gardens and vertical farms.

But at what scale should agriculture blend with architecture? Dickenson Despommier, a university professor at Columbia University

World Population Chart

1960	2,982, 000, 000
1970	3,692, 000, 000
1980	4,435, 000, 000
1990	5,263, 000, 000
1995	5,674, 000, 000
2000	6,078,274,622
2008	6,707,000,000
2009	6,798,764,829
2020	7,675, 000, 000 (2008 est.)
2050	9,150, 000, 000 (2008 est.)

believes a large scale vertical farm is the solution and is working towards obtaining funding for a multi-storey prototype. [2] A vertical farm may simply relocate the factory farm into the city and it may not solve the issues inherent in large scale farming. Alternatively, working on the micro and meso scale can unleash the potential of urban agriculture, allowing it to spread throughout the city, building to building, and street to street

A re-organization of how we produce food is necessary; if not now, then in the near future. The interrelationship between agriculture and architecture needs to be strengthened in order to sustain ourselves, especially in the urban setting. These projects of agro-architecture must be developed environmentally, socially and economically; should we disregard the environmental aspect we remain at our current state, should we lack the social aspect, we jeopardize our sense of community, and should we lack the economic aspect, the concept will never be implemented.

Chapter 1: The Problems Plaguing Agriculture

Agriculture is the science, art or occupation concerned with production, preproduction and post production of goods. [1] Within agriculture there are five categories: Aquaculture (fish, seafood and fodder), horticulture (vegetables, fruits, medicine, herbs and compost), animal husbandry (milk,

[2] Despommier, Dickson The Vertical Farm. Reducing the Impact of Agriculture on Ecosystem Functions and Services Columbia University Department of Environmental Health Sciences

eggs, meat, manure, and hides), agro forestry (fuel, building materials) and other farming activities (decorative houseplants and flowers).[3] The objective of industrial agriculture is to minimize resources and space while maximizing crop yields and quality. The primary focus of this thesis will be on horticulture with a brief examination of animal husbandry.

Hunger has consistently been one of our species' oldest problems; from our primitive ancestors to underdeveloped countries today to our projected future.[4] With the projected population of the planet rising to 9 billion people on earth in only 40 years, there simply is not enough land on the planet to feed everyone, assuming we carry on with our current unsustainable methods of agriculture.[5] The amount of excess land required to feed 9 billion individuals is 10^9 hectares, a land mass the size of Brazil.[6] Furthermore, if this land was obtained or created in some way, there is no means of providing enough renewable water to support traditional or industrial farming practices.[7] This thesis sets itself as one possible solution to this crisis through the amalgamation of agriculture and architecture through innovative design solutions using existing technologies.

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[3] United Nations Development Programme *Urban Agriculture Food, Jobs and Sustainable Cities* United Nations Pubns (Dec 1996)

[4] Heiser, Charles B (Charles Bixler), Seed to Civilization The Story of Food 2d ed ed San Francisco W H Freeman, c1981

[5] Despommier, Dickson Reducing the Impact

[6] Despommier, Dr Dickson, and Dickson Despommier *The Vertical Farm Feeding the World in the 21st Century* Thomas Dunne Books, 2010

[7] Despommier Feeding the World in the 21st Century

The Moments of Separation

Figure 1.2:
Illustration depicting early agriculture between the 900 - 1,550 A.D.

To further comprehend the situation humanity is in, it is required to understand the path which brought us this far. There are three degrees of separation between agriculture and the closed-loop system of nature. This progressive problem begins with the development of cities, followed by agro-industry and then the monocultures that provide cities with food today.

Society as a collective consciousness is slowly realizing, through the use of networking and technology, that the world is a massive interconnected ecosystem that has been damaged solely by people. Never before in history have our resources been so limited and our planet felt so small.

The 1st Degree of separation

The Development of Cities

Archaeologists are unsure about the precise origin of agriculture, although they have developed many theories as to its starting point. Canadian writer and philosopher, Grant Allen speculated that early humans noticed plants grew exceptionally well on fresh graves.[8] Primitive man, unaware of the concept of fertilizer and tilling for fresh soil, would make a connection

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[8] Heiser, Charles B. *Seed to Civilization : The Story of Food*. 2d ed. San Francisco : W. H. Freeman, c1981. 26.

with the human body. Thus, sacrifices would be made to improve the growth of plants, ensuring a stable food source. If animals were to be sacrificed they would need to be kept alive, cared for and protected from predators.[9] Another hypothesis by archaeologist Carl O. Sauer is that fisherman in southern Asia already had a steady food supply of seafood and could afford the time to experiment with plant cultivation.[10]

Regardless of the exact inspirations, early societies on multiple corners of the earth made the connection between seeds, soil, water and sun. Archaeological research indicates that types of early agriculture were invented in six independent locations; the Eastern center, the central American center, the South American center, the New Guinea center, the Chinese center and the North American center. From these six locations the concept of farming spread throughout the world.[11]

Seeds and storage bins, a prerequisite to the development of agriculture, have been found in the near east dating to an age prior to the known existence of cities. For example, an archaeological dig in Dhra, Jordan uncovered storage bins with fragments of barley seeds and grindstones dated roughly to 11,300-11,175BC.[12] The presence of these storage bins indicates that their agricultural practices were both highly developed and quite

[9] Heiser, 27
[10] Heiser, 16
[11] Despommier. *Feeding the World in the 21st Century* 48
[12] Heiser, 45

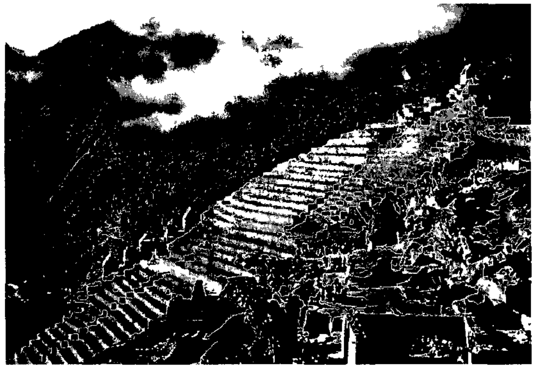

Figure 1.3:

"The Inca city of Machu Picchu is carved out of the Andes in Peru."

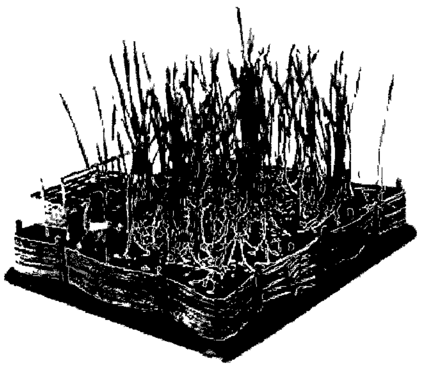

Figure 1.4:

Depiction of the floating raft system of the Aztecs called 'chinampas'.

successful. Cities could not exist without agriculture, therefore after the development of farming the first cities began to emerge.

The "lost city" of the Inca of Machu Picchu, built around 1430AD, was primarily terrace agriculture that utilized gravity to provide water.[13] Research on the "lost city" reveals that they had precise irrigation, fertilization methods, waste management, terracing, microclimate management (the technique of manipulating the climate, air and soil to lengthen the growing season), and the ability to create hybrid plants. They were self reliant in produce such as fruits, vegetables, grains and livestock. A large storage system within the city was uncovered and estimated to hold enough food for the population for 7 years.[14]

As each region's agricultural history is revealed, archaeologists discovered the farming methods to be rather unique and site specific, as opposed to the field farming of today. One of the most unique methods was developed by the Aztecs in Mexico who created artificial islands or 'floating gardens' called *chinampas*. These were 30 by 2.5 meter strips of mud covered - weaved grass floating in water.[15] This type of irrigation system increased

[13] United Nations Development Programme. *Urban Agriculture: Food, Jobs and Sustainable Cities.*

[14] Bingham, Hiram. Lost City of the Incas: The Story of Machu Picchu and its Builders. Phoenix Publisher. October 28, 2003.

[15] United Nations Development Programme. *Urban Agriculture: Food, Jobs and Sustainable Cities.*

the Aztec's crop yield from 2 per year to 3 per year. [16] Common plants grown in the floating gardens were corn, beans, squash, tomatoes and chilli peppers.[17] By the 16th century, utilizing 5 lakes in the valley of Mexico there was almost enough food produced to feed the 200,000 individuals living in the city.[18]

With a reliable source of food it is easier for large populations to congregate, providing a lifestyle free of scavenging and starvation. The presence of agriculture aided in the creation of the city. From cities developed society, culture, religion, astrology, written language and much more.

With the intelligence and resources available at the time, agriculture was a logical solution to ensuring the human species' survival. Early cities built by the Inca's and Aztecs demonstrated an environmentally specific city design that learned from local ecosystems and nature's closed-loop processes. Somewhere along the path of city development the lessons one derived from nature were disregarded and become lost. Crops would drain the land of fertile nutrients, attract mass amounts of pests, and form various strains of diseases that may otherwise not have existed. If the urban land became infertile, rather than relocate the population, food would be imported to the

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[16] "Aztec Agriculture - Rich and Varied" Aztec History.Web. 10/4/2010 < http://www.aztec-history.com/aztec-agriculture.html>.

[17] "Aztec Agriculture - Rich and Varied" Aztec History.Web. 10/4/2010 < http://www.aztec-history.com/aztec-agriculture.html>.

[18] United Nations Development Programme. *Urban Agriculture: Food, Jobs and Sustainable Cities.*

city center from external sources. Nature is a sustainable, closed loop system. Today there is no city that mimics this method; there is no city that lives within its means. If cities models were designed differently, humanity would not have set itself up for agricultural problems down the road, problems in which we increasingly face today.

The 2nd Degree of separation

Industrialization

Industrialization is the development of an industry on an extensive scale[19], it is the process of social and economic change that transforms a region from the pre-industrial state. Three key inventions made the industrialization of agriculture possible; the invention of dynamite, the combustion engine (discovery of oil) and chemical fertilizers. Unlike the first degree of separation, humankind had the technology and knowledge to understand this undertaking was creating mass destruction for the sake of economic profit.

[19] Sullivan; Steven M. Sheffrin (2003). Economics: Principles in action. Upper Saddle River, New Jersey, Pearson Prentice Hall. 472.

The Three Inventions

Dynamite, Combustion Engine and Chemical Fertilizers

In 1847 Ascanio Sobrero synthesized a highly explosive compound called nitro-glycerine.[20] Sobrero discovered that mixing this unstable chemical in clay slurry stabilized it, creating a marketable product. Dynamite became popular among farmers in clearing land for new fields.[21] It could remove forests at a fraction of the time and cost when compared to using horses and human labour.

Next came the discovery of oil and its many uses as well as the development of the combustion engine. Henry Ford in 1907 invented the gasoline powered tractor. This affordable and lightweight vehicle rarely got stuck in the wet fields and revolutionized farming, putting the 1800s heavy steam powered tractors to rest.[22]

Traditionally in the 18th century, farmers fed their own organic refuse back into their fields noticing that doing so would boost their yields.[23] As the family farms grew larger and more productive they required more and more organic refuse. Farmers began importing more natural fertilizers from other places to compensate. Eventually organic fertilizers were insufficient or

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[20] Despommier *Feeding the World in the 21st Century* 85
[21] Despommier *Feeding the World in the 21st Century* 86
[22] Despommier *Feeding the World in the 21st Century* 85
[23] Petrini, Carlo Slow Food Nation A Blueprint for Changing the Way we Eat Rizzoli Ex Libris, 2007 24

running low (such as Peruvian bat guano), prompting the invention of chemical fertilizers. [24] In 1908 a chemist named Fritz Haber developed ammonia fertilizer as an offshoot to experiments in military explosives. A second chemist named Carl Bosch furthered Haber's discovery by industrializing the method of production; resulting in the Haber-Bosch process.

The industrialization of agriculture, also known as agro-industry, allowed city populations to flourish. City dwellers could purchase all the food they desired without ever having to worry about its cultivation.

Although these inventions and the development of agro-industry provided urban individuals free time to pursue other ambitions, it also has been immensely detrimental and we are feeling the affects today.

Using dynamite to blast acres of forest out of existence obviously causes instantaneous damage to the surrounding area, but in the long term it also pollutes our rivers, oceans and drinking water.

Chemical fertilizers also create heavy pollution. When chemical fertilizers are used farming requires mass amounts of irrigation, today farms consume 70% of all freshwater on the planet. This mass irrigation produces mass run-off which along with water includes silt, pesticides, herbicides,

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[24] Petrini Slow Food Nation 24

animal waste, garbage and nitrogen fertilizers.[25] Once this runoff reaches major rivers and oceans it causes massive changes to those ecosystems. Nitrogen, for example, depletes water of its oxygen which in turn suffocates plants, crustaceans, fish molluscs etc. These high nitrogen levels force the United States to import over 80% of their seafood.[26]

The aim of this section is not to argue that agro-industry never should have been developed. People need food, plants need water and technology needed to advance. By employing current technologies, which are discussed in a later chapter, this project will engage growing methods that reduce water consumption from 70% to 7%.[27] [28] What agro-industry has done is given us the illusion that it could feed the human population and provide food security. The reality is that current practices in industrialized farming are not sustainable.

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[25] Despommıer *Feedıng the World ın the 21st Century* 95.

[26] Despommıer *Feedıng the World ın the 21st Century* 95

[27] 90% less water used wıth Aeroponıcs, 90% of 70% ıs 63% 70-63=7%

[28] **If the world is beginning to stress out about clean freshwater, reducing agriculture consumption and pollution is a logical solution.**

The 3rd Degree of separation

The Factory Farm & Agriculture Today

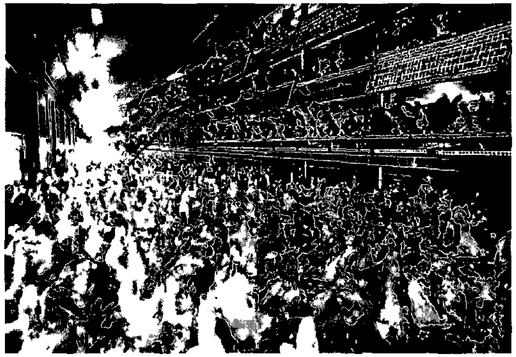

Figure 1.5:
Photograph of factory farmed chickens.

The first livestock factory farms were initiated by the development of improved nutrition, vitamins, vaccines and antibiotics through systematically growing animals such as chickens, pigs and cows.[29] More animals could be raised at a quicker pace and in smaller spaces while simultaneously reducing their risk of disease. This mass farming concept was soon replicated in the growth of vegetable and fruit crops. If a farmer had only one type of crop they could be come the expert at growing it; increasing yields by purchasing species specific pesticides, fertilizers and equipment. This systemized and specialized industrial agriculture of growing one single crop over a large area is called mono-cropping or monoculture.[30] Agriculture today consists of monocultures that are only valid from an economical point of view.

The History Continued

In the late 1900s, along with other industries, agriculture continued

[29] Gross R. and Solomons N. "The History of Factory Farming. United Nations.Web. 10/4/2010 <http://www.unsystem.org/SCN/archives/scnnews21/ch04.htm>.
[30] "Monoculture". Dictionary.com. 01/15/2011. <http://www.dictionary.com>

its development in mass production.[31] Pesticides have been used since at least 2000BC to protect crops, for example in ancient Mesopotamia it was common practice to sulphur dust crops.[32] In the 15th century pesticides escalated to include toxic chemicals such as lead, arsenic and mercury. In the 17th and 19th centuries more natural pesticides were examined and extracted from plants such as tobacco and chrysanthemums. Around the 1940s, chemicals that were originally developed for combat in WWII prompted the development of mass produced synthetic pesticides. The first commercial pesticides were a slightly modified chemical that is similar to nerve gas.[33] [34] [35] Although pesticides remove unwanted insects, they also deplete the area of beneficial ones that help the soil. Since insects and small animals reproduce so rapidly, they can quickly become immune to pesticide doses through the generations, which result in the spraying of stronger doses or brands. With the chemical advantages in this war on pests one would believe that we are producing more food than the previous farming methods. However, statistics show that wheat in the 1930s (prior to synthetic pesticides) lost 30% due to pests, while in 2000 (after the spaying of 2.5 million tons of pesticides in the United

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[31] Fraser, David *Animal welfare and the intensification of animal production An alternative interpretation, Food and Agriculture Organization of the United Nations*, 2005

[32] Miller, GT *Living in the Environment* (12th Ed) Belmont Wadsworth/Thomson Learning, 2002

[33] Fraser

[34] *The Future of Food* Dir Koons, Deborah Nov 13 2007 DVD Virgil Films and Entertainment

[35] *The True Cost of Food* The Sierra Club National Sustainable Consumption Committee 2005 DVD/VHS

States) 37% was lost due to pests. [36] These additive chemicals also create massive topsoil loss and other hidden consequences that will be discussed later under the section that looks into the environmental concerns with monoculture.[37]

"Frankenseed"

The Monsanto Monoculture Mess

Within systemized agriculture there is one company that stands above all others: Monsanto. Based in Missouri, Monsanto is a multinational agricultural biotechnology corporation. [38] In Canada their headquarters are located in Winnipeg, Manitoba, but other offices can be found across Canada. Monsanto is one the largest three agricultural companies North America, and these three companies are accountable for the production of more than 90% of all seeds used in single crop farming.[39]

In 1970 seeds and crops were allowed to be patented, among the first was an engineered oil eating microbe. The concept to patenting allows a

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[36] *The True Cost of Food.*

[37] *The True Cost of Food.*

[38] "Monsanto Company" <http://www.monsanto.ca>. 2010.

[39] Despommier. *Feeding the World in the 21st Century*.

developer to patent a unique gene,[40] and own the rights to that patented gene regardless of where the 'product' travels. In 1982, Monsanto became the first company to genetically modify a plant cell.[41] These seeds were modified with to be immune to the spraying of Monsanto's herbicide: 'Round up'. By using Monsanto's seeds and herbicides farmers can clear the field of all unwanted plants; in order to facilitate an increased crop yield.

Monsanto currently owns around 11,000 patents today (although not all are genetically modified seeds).[42] Once released into the environment genetically modified plants are hard to contain. This poses an issue because, according to patent laws, Monsanto owns the seeds and anything the seeds cross pollinate, regardless of how it occurred. An antibiotic marker in the seeds genes allow for testing to see if the plant is their patented product. [43] The company began to find that their patented seeds were being obtained illegally due to wind, passing trucks and pollinating insects. Trying to protect their product (like any company would) Monsanto in 1999 began sending letters to farms insisting that they pay a settlement fee for their infringement, otherwise they would be taken to court. Many farmers would rather pay a small fee than wage war with such a large company, of which the precedent

[40] *The Future of Food* Dir Koons, Deborah Nov 13 2007 DVD Virgil Films and Entertainment

[41] *The Future of Food* Dir Koons, Deborah Nov 13 2007 DVD Virgil Films and Entertainment

[42] *The Future of Food* Dir Koons, Deborah Nov 13 2007 DVD Virgil Films and Entertainment

[43] The medical community is terrified with the possible loss working antibiotics due to constantly consuming them within meat

court cases ended in favour of Monsanto.[44] Today it is difficult to find a field in western Canada that does not contain genetically modified seeds, and because of this, monoculture farmers across Canada are now afraid to save their own seeds in fear of being sued and losing their farm through bankruptcy.

With all the negativity around Monsanto, it is easy to place the blame onto them alone but it is not as straightforward as that. Monsanto is merely one example, a piece of the overall picture. The problem lies in the proliferation of monoculture farms and **all** the enabling inventions (pesticides, research in fertilizers/nutrients, genetically modified seeds, patent laws) that create the 3rd separation from nature.

Food Security

The Issues with agriculture today

Monoculture farms have fed city populations successfully thus far, but what price did the world pay for cheap food that is available year round. Potentially, patented seeds could become the only option and one would no longer be able to grow food without paying seed fees. Whoever controls the seeds controls food security. While this scenario is one of the most unlikely

[44] *The Future of Food*. Dir. Koons, Deborah. Nov 13 2007. DVD. Virgil Films and Entertainment

ones, food security is currently at risk from many different perspectives; the loss of knowledge on how to grow food, the quality of food and the impact on the environmental pose a serious threat to our urban way of life.

Figure 1.6:
Photograph of peanuts growing beneath the soil.

Peanuts Do Not Grow On Trees

The Loss of Knowledge

Peanuts do not grow on trees, banana trees are an herb and green bell peppers are really under ripe red bell peppers.[45] Perhaps the informed reader or avid gardener or farmer is aware of how these commonly consumed plants are grown. However, many public produce activists such as Darrin Nordahl, author of 'Public Produce', have found out first hand that far too many city dwellers are unaware of what the plants look like, where they come from and most importantly how to grow them.

There has been a disconnection in the immense wisdom that traditionally was passed down through the generations is no longer considered essential.[46] [47] Farming has been attracting fewer and fewer people

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[45] Nordahl, Darrin. *Public Produce: The New Urban Agriculture* . Island Press, 2009.

[46] Nordahl. *Public Produce.*

[47] *My father told me of a time when he was young; he would care for this one cow named 'Peanuts' on the farm where he grew up. He would feed' Peanuts' and other livestock, know their anatomy, how to harvest the meat, preserve it and cook with flavour. This knowledge was additional to learning about the farm's primary crop, grains (wheat, oat flax etc.) A generation earlier, my grandfather successfully grew a variety of crops and raised cattle on a larger scale. Although I personally know of how to grow and care for many plants on a hobby-farming scale, like many others of my generation the agricultural wisdom has never been fully acquired.*

since the 1930s when there were six million people in the United States considered themselves farmers. However, this number dropped to 2 million people by the year 2000[48] and 150,000 people in the year 2009.[49] Traditions and knowledge regarding agriculture have been lost because it is currently too easy to live without having to grow, harvest, or prepare food.

The result is that people in society who have little connection with food production have little to no conception of the issues that are currently surrounding it.[50] People without agricultural knowledge cannot criticize what has now become the norm for food production.

Juicy Red Nothings

The Quality of Food

For those who have ever gone strawberry picking, it is common knowledge that a big basket of these delicious fruits will only last a few days in the refrigerator. This poses a problem to mono-croppers as their products need to be transported around the world and still maintain their ripeness, ensuring maximum profit (environmental issues regarding this will be

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48 Nordahl *Public Produce*

49 Despommier. *Feeding the World in the 21st Century* 125.

50 Bohn, Katrin, and Andre Viljoen "Continuous Productive Urban Landscapes Urban Agriculture as an Essential Infrastructure " *Urban Agriculture Magazine* December 2006 21

discussed later). During the winter the two largest grocery stores in Ottawa receive their tomatoes from China and Mexico. How do these fruits survive the trip intact? At the beginning of the journey fruits are generally harvested before they have ripened, giving them the ability to be transported without spoiling.[51] Once delivered it is common for the produce to be gassed with ethylene, which chemically induces ripening, to provide a vivid fresh color but unfortunately without the taste of naturally ripened produce.[52] [53] Daniel Solomon, a new urbanist architect summarizes the situation when he writes that:

"foodies worry that masses of people will go through life and never taste a peach that tastes like a peach. The people will survive somehow—it's peachiness that is threatened with extinction. In the contemporary world, retaining the full-blown potential of the flavour of a peach as part of most people's life experience is no small matter.-------- In an agrarian society, where the peach trees are outside ones door, the perfect peach is commonplace. Delivering perfect peach to the modern metropolis is another question."[54]

[51] Nordahl *Public Produce* 22

[52] Nordahl *Public Produce* 21

[53] I remember being confused as a child that some peaches and strawberries looked ripe but tasted horrible Until recently I had just assumed they had 'gone bad' When in reality I had been fooled as they had never been ripe

[54] Daniel Solomon in Nordahl Public Produce PG 21

It is rare for city inhabitants to be well acquainted with their butcher or baker, as most of us shop in large commercial stores. Opportunities to feel, smell and evaluate food are scarce while grocery shopping.[55] If there was a option to taste before purchasing a food product, it would require mono-croppers to change production methods drastically in order to maintain a profit. The integration of fresh growing produce in an existing architectural program such as a grocery store could easily provide customers with the opportunity to taste before buying. This could allow for a direct comparison in flavour between what is available and what should be available to consumers. The money saved in transportation costs and chemicals by growing locally could be applied to the shelf price, perhaps even decreasing it below the mono-cultured products.

Along with sacrificing flavour, we are also losing variety, favouring the ones that bruise less and can pack tighter. Many fruits and vegetables, such as june berries, cannot be found at the average local grocery store as they are not produced in mass mono-crops. [56] In fact, 97% of the vegetable varieties grown at the start of the 20th century are now extinct.[57] The crops we have managed to hold onto and 'perfect' through monoculture are becoming narrow in their

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[55] Petrini, Carlo. Slow Food: The Case for Taste. Columbia University Press, 2004.
[56] Nordahl. *Public Produce.*22.
[57] *Food, Inc.* Dir. Kenner, Robert. Nov 3 2009. NTSC DVD. Alliance (Universal).

gene pool diversity.[58] Limited differentiation between genes causes them to become more vulnerable to disease, pests and extreme weather conditions. Therefore, entire monoculture crops have a greater potential to be damaged or wiped out at once; resulting in an increase in cost per unit.

It is highly doubtful that as intelligent beings we will starve due to the concerns listed in this document. If cities continue to jeopardize food security in the future, then they will either become vacant or suffer an economic crisis, resulting in a situation similar to the abrupt decline in oil, fertilizer, pesticide and food imports which occurred in Havana, Cuba. [59] [60] In order to alleviate the situation, the Cuban people began to plant any crops they could in all unused corners of the city, from private gardens to state-owned research gardens. While this 'urban agriculture' does increase the quantity of local food available, it still does not provide food security to the citizens of Havana.[61]

With a decrease in taste, quality, health, variety, knowledge and resources the urban environments of the world are headed for a similar food crisis as experienced in Cuba. Fortunately, cities still have time to develop a

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58 *The True Cost of Food*

59 Bourque, M , and K Canizares "Urban Agriculture in Havana (Cuba) " *Urban Agriculture Magazine* July 2000 27

60 Prior to 1989, Havana, Cuba was dependant on imports from the Soviet Union and the Unite States With the United States economic restrictions and the Soviet Block collapse, Cuba found itself with a 50% decrease in imported agricultural resources and 70% decrease in food imports (Seeds in the City the Greening of Havana Documentary)

61 *Seeds in the City the Greening of Havana* Dir Phinney, Richard Knowledge in Action [distributed by] Sound Development, c2003

plan for their transformation an option being the integration of architecture and agriculture.

"Be fruitful and multiply, fill the earth and subdue it" [62]

The Environmental Impact

> *"We are facing ecological bankruptcy and our first possessions are already being pawned" -Antonio Cianciullo.* [63]

One of the biggest global concerns in recent news is climate change and greenhouse gas emissions. This issue is deeply interwoven with agricultural practices of today. Figure 1.7, obtained from the Emission Database for Global Atmospheric Research, offers a breakdown of the leading contributors of emissions. The leading sector is power stations at 21.3%, followed by industrial processes (16.8%), transportation fuels (14.0%), agricultural by-products (12.5%), fossil fuel retrieval, processing and distribution (11.3%), buildings (10.3%), land use and biomass burning

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[62] Be fruitful and multiply, and fill the earth and subdue it, and have dominion over the fish of the sea and over the birds of the air and over every living thing that moves upon the earth " Genesis 1 28 The Holy Bible

[63] Petrini, Carlo Slow Food Nation A Blueprint for Changing the Way we Eat Rizzoli Ex Libris, 2007

(10.0%) and waste disposal treatment (3.4%) .[64] If agricultural methods became sustainable in an urban environment, even if it is just a fraction more than they are now, it would affect the GHG emission on every single front. One solution to GHG emissions is a shift in agricultural practices.

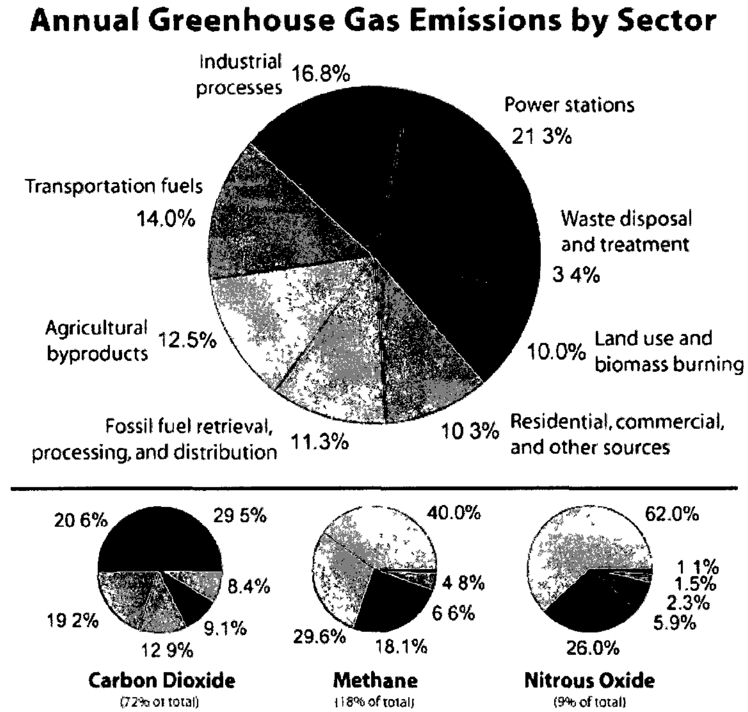

Figure 1.7 Pie graphs of annual greenhouse gas emissions from The Emissions Database for Global Atmospheric Research.

64 "Emission Database for Global Atmospheric Research (EDGAR)." European Commission JRC Joint Research Centre and the Netherlands Environmental Assessment Agency .Web. <http://edgar.jrc.ec.europa.eu/>. 2010.

Oil & Energy

Monoculture along with the processed food and packaging industries provide individuals with the food they desire in any location across the globe. When operating at such an immense scale, all environmental consequences (or benefits) are amplified at a comparable rate, impacting the global environment. Processed food and packaging are particularly harmful as they add additional transportation and pollutants to the already environmentally detrimental mono-cropping culture.

Agriculture today has created a noticeable spike in fossil fuel usage (transportation, use of tractors, harvesters, petroleum based pesticides and herbicides [65]). When evaluated today, it takes 10 calories of fossil fuel energy on average to produce a mere 1 calorie of grocery store produce. In the era before monoculture, 1 calorie of fossil fuel energy on average produced 2.3 calories of food energy.[66] With a limited oil reserve[67] sometimes taking millions of year to form[68] our method of growing food is shockingly distant from the ideal goal, global food security and sustainability. Society needs to re-align its priorities with their proper values; there are alternatives to oil but not food security

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[65] Nordahl *Public Produce* 6

[66] Nordahl *Public Produce* 6

[67] Fossil fuel energy such as coal, lignite, petroleum and peat are stored energy from past organisms (Petrini Slow Food Nation 2)

[68] Giant oil and gas fields of the decade, Volume 7 American Association of Petroleum Geologists 1990-99

Water

There is a direct link between food security and the quantity of available uncontaminated freshwater. Massive crop fields require a highly systemized irrigation system to produce a standard size product within a certain timeframe. This practice not only consumes roughly 70% of all obtainable fresh water, but creates an irrigational runoff pollutant that contaminates the soil, organisms, rivers and oceans. Pollutant runoff as previously mentioned can include garbage, herbicides, fungicides, pesticides, fertilizers and salts.[69] To demonstrate the impact that these types of pollutants can have one merely has to examine what has transpired in the Gulf of Mexico. In 1993, fertilizer nitrates contained in agricultural soil swept into the Mississippi river during a massive flood. [70] Nitrates deplete water of its oxygen[71] causing organisms such as fish and crustaceans to either relocate or suffocate. The flood is what created the original 'dead zone' in the gulf and since 1993 we have leaked hazardous oil into the water as well.[72] The entire fishing industry and ecosystem surrounding this area have now been destroyed for an indeterminate amount of time because of industrial agricultural methods. The situation in the Gulf of Mexico is not isolated

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[69] Despommier *Feeding the World in the 21st Century* 108

[70] Despommier. *Feeding the World in the 21st Century* 108 .

[71] As I have learnt first hand in my own freshwater aquarium adventures

[72] Despommier *Feeding the World in the 21st Century* 110

incident; agricultural pollutants are the number one source of pollution in all of the US rivers, and most likely Canadian bodies of water as well.[73]

To demonstrate how askew the agricultural industry has become, a campaign by The Sierra Club National Sustainable Consumption Committee set out to determine the triple bottom line cost of food, or 'true cost'. With a breakdown including pesticides, water pollution from runoff, topsoil loss, transportation and fertilizers they concluded that the true cost of **one** tomato in the United States was $375 dollars (beef is at $815.00 per pound).[74] [75]

Where are we going to grow from here?

Tomorrows Agriculture

"There is nothing wrong with change,
as long as it is in the right direction" --Winston Churchill

The discussion in this chapter is merely a fraction of the interconnected network of issues that revolve around today's agricultural practices and pose a risk to food security. [76] It is health, knowledge, happiness and life. The demonstrated unstable, environmentally damaging practices of

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[73] *The True Cost of Food.*
[74] *The True Cost of Food.*
[75] When asked in February 2011 to provide a specific dollar breakdown of how they obtained to their total number there was no reply.
[76] View figure __ for a mind map diagram of all the issues discussed in this chapter surround food security.

industrial agriculture are cumulative throughout the history of agriculture and are made evident due to the up-scaling to monocultures.

The benefits of developing urban agriculture are numerous, to integrate agriculture with architecture; making it as common in buildings as water, heating and natural lighting.

Chapter 2: Technology

The Matter of Meat

The Importance of Plants

> *"There is something about a beautiful fern or flower that strikes a responsive "chord" in the human brain."* --- *Author Unknown*

The term urban agriculture will surface numerous times throughout this document, but to be clear, for the purposes of this thesis, it is meant to exclusively refer to plant life (or small creatures such as fish). The intentional absence of the consideration of meat production is meant to situate plant life as a greater priority, seeing as they are the basis of all other life. Plants posses the ability to store the sun's energy within sugars, starches, cellulose, oils, fats and proteins.[77] Plants surpass the need for meat because they provide a full balanced diet while simultaneously cleaning the air, something animals cannot do. The mass amount of feed (10 lbs of grain for 1lb of meat), transportation (gallon of oil per 1 lb of beef), pollution (65lbs of manure a day, 184 billion cubic feet of methane a year) and resources surrounding factory farmed livestock will not remain stable for much longer, causing meat prices to rise. The triple bottom line cost of beef is actually $815.00 per

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[77] Petrini Slow Food Nation 2

pound.[78] When the breaking point is reached there will be two options: pay more for less; or the more likely option: be forced reduce the amount of large animal meat in our diet. Maintaining larger animals in a sustainable way can be resolved later once food security is under control.[79]

Soil-less Solutions

Introduction to Technologies

With technological advancements in solar panels, biodegradable plastics, waste-recovery, water-recovery and food production strategies, cities have the opportunity to construct a sustainable future.

Presently in Ottawa, Canada our farming methods consist of soil-less, contained or potted, and the most common, traditional field farming. Within the city, traditional farming takes place on smaller plots of land, averaging 20 square metres per household. The garden is usually located in the backyard or side yards of a property. The front yard is often avoided due to theft, vandalism and exhaust from cars.[80] Ottawa urban dwellers are not equipped with sufficient land, time and knowledge to be entirely self-sustainable and

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[78] *The True Cost of Food*

[79] And I say this while being an avid meat lover Cow, hog, chicken, rabbit, horse, shark, insects, you name the food and I'll most likely try it.

[80] United Nations Development Programme *Urban Agriculture Food, Jobs and Sustainable Cities* United Nations Pubns (Dec 1996)

therefore must rely on produce from outside of the city.

In soil-less farming there are two branches, one called hydroponics and the other called aeroponics. All other soil-less methods fall under these two categories and are often referred to as "controlled environment agriculture". In the early 19th century research concluded that plants survive through the absorption of mineral nutrients in the form of inorganic ions. [81] These inorganic ions, found naturally in soil, are collected as water moves through the ground. As the plants absorb water it receives the dissolved nutrients. The soil in and of itself provides plants with a source of nutrients and structural stability. Scientifically speaking, soil is not a requirement as there are alternatives methods available. It is odd to think of a plant growing properly without soil, but this is the key to successful aeroponics.

Hydroponics

A Brief History

Although the primary focus for this integration of agriculture and architecture is aeroponics systems, it is not the only method of highly productive agriculture. Hydroponics pre-dates the first aeroponic growth by

[81] Windterborne, Jeffrey. Hydroponics: Indoor Horticulture . Pukka Press, 2005.

Figure 2.1:

Photograph of a nutrient film technique (NFT) hydroponic system where roots have access to a slow moving stream of water and dissolved minerals.

at least four thousand years.[82]

An early example of hydroponics would be the Aztecs Chinampas utilizing the lake water to provide nutrients (as mentioned in previously in chapter 1). In the 1980s the idea of hydroponics expanded into the system and are used widely today in greenhouses and nurseries.[83] A combination of h*ydro*, the Greek word meaning water and *ponos* meaning labour, form hydroponics, a system in which plants are grown either in a static solution culture or a continuous flow solution culture where the water is constantly circulating past the roots.[84] Today there are many different systems available on the market, some catering to specific plants such as tomatoes or lettuce while others take on a role other than growing produce such as purifying grey water. A popular example of this is the *folkewall* or *greenwall*. The basic folkewall design is a wall of hollow concrete slabs containing openings. The openings in the wall are filled with a material like gravel or clay pebbles. The design and angling of the slabs should allow the water to trickle downward and filter through the roots of the plants. Hydroponic systems have numerous advantages, the obvious one being that no soil is required. By using a continuous flow solution culture the water in the system can be reused. Hydroponics makes it easier to control nutrition levels, creates stable and

[82] United Nations Development Programme. *Urban Agriculture: Food, Jobs and Sustainable Cities.* United Nations Pubns (Dec. 1996)

[83] Windterborne. Hydroponics: Indoor Horticulture .

[84] Windterborne. Hydroponics: Indoor Horticulture .

high crop yields (in comparison to traditional farming methods), has fewer pest and disease problems, extends the amount of cycles per year and does not indirectly pollute the environment with nutrition runoff. [85] [86] One of the most significant advantages of hydroponics over traditional farming is that it requires 1/10th (or less) water than field crops. [87] The drawback to using hydroponics is primarily the conditions it produces consisting of high humidity and optimum nutrient level for bacteria growth. However this disadvantage can be avoided if the system is monitored and cleaned properly.[88] Another negative aspect of this system is the high possibility of over watering soil-based plants. A plant could easily get 'water logged' and die. Aeroponics, the second branch of soil-less farming, provides a solution to the disadvantages of hydroponics.

Aeroponics

A Brief History

Aeroponics is derived from the Greek words *aero* meaning air, and *ponos* meaning labour.[89] Aeroponics is the method of growing plants in a soil-

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[85] Windterborne. Hydroponics: Indoor Horticulture .

[86] Despommier, Dickson. Reducing the Impact.

[87] Despommier. *Feeding the World in the 21st Century*.

[88] Windterborne. Hydroponics: Indoor Horticulture .

[89] Stoner, R.J. and J.M. Clawson A High Performance, Gravity Insensitive, Enclosed Aeroponic System for Food Production in Space. Principal Investigator, NASA. (1997-1998).

less medium such as air or mist, as opposed to hydroponics which submerges the roots in running water.

Figure 2.2:

Photograph of aeroponic system early in the growing cycle.

In the 1920s a botanist conducted a study on plant root structures by growing plants in a mist medium, making the roots easily visible for observation.[90] This is the first recorded case of a primitive aeroponic system, although the objective was not to provide food but knowledge. The idea of producing plants through mist for consumption did not take place until the 1970s. However, hydroponics at the time was increasing in popularity and overtook the aeroponic development. It wasn't until the 1990s when NASA funded a study for growing plants in space did aeroponics become developed and refined. [91]

Along with nutrient enriched water, plants also require a light source, carbon dioxide AND oxygen. This may seem odd since we have been taught that plants absorb carbon dioxide and release oxygen. Carbon dioxide is used to convert sunlight into sugars through photosynthesis. However, plants also require a small supply of oxygen in order to break these sugars into usable energy for the plant.[92] To put it simply, the more oxygen available the better the condition for the plant to grows. This is a fundamental reason why aeroponics is so successful and superior to hydroponics. It provides 100% of

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[90] NASA Spinoff. Progressive Plant Growing Has Business Blooming. Environmental and Agricultural Resources NASA Spinoff 2006. 68-72.

[91] NASA Spinoff. Progressive Plant Growing Has Business Blooming. 68-72.

[92] Windterborne. Hydroponics: Indoor Horticulture .

the required oxygen and is often been described in various articles as 'plant growth on steroids'.

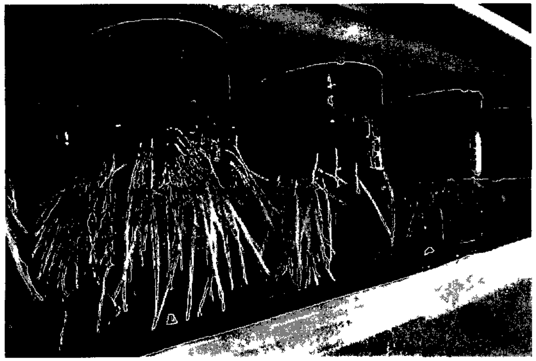

Figure 2.3:

Photograph of tomato roots within an aeroponic system

The Root of Matter

Advantages of Aeroponics

This type of system has proven to be successful in propagation, seed germination, and seed production, essentially the full cycle of the plants life. [93] For example, tomatoes traditionally begin their growth in pots, then farmers on average wait 28 days until the plant is stable enough to transplant them into the ground. [94] When using an aeroponic system growers can transplant their tomatoes into the ground only 10 days after germination. This produces six tomato crops per year as opposed to one or two crops per year.[95] An average of 45% to 75% increase in crops can be achieved depending on the plant species.[96] [97] Aeroponics includes every advantage that hydroponics offers; no soil needed, easy to control nutrition levels, no nutrition pollution to the environment, stable and high crop yields as well as fewer pests and

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93 NASA Spinoff Progressive Plant Growing Has Business Blooming 68-72
94 NASA Spinoff Progressive Plant Growing Has Business Blooming 68-72
95 NASA Spinoff Progressive Plant Growing Has Business Blooming 68-72
96 Despommier *Feeding the World in the 21st Century*
97 NASA Spinoff Progressive Plant Growing Has Business Blooming 68-72

Aeroponic Advantages:

1. Year round crop production
2. No weather-related crop failures
3. No agricultural runoff
4. Possible ecosystem restoration
5. No pesticides, herbicides or fertilizers
6. 70-95 % less water than field farming
7. Reduced transportation time
8. Control of food safety and security
9. New employment opportunities
10. Purification of grey water to drinking water
11. Animal feed from postharvest plant material.
12. Increase of public interest and knowledge
13. Healthy & high quality produce

Figure 2.4:

Advantages of aeroponics when compared to soil-based farming or hydroponics.

diseases. [98] [99] Some other benefits of utilizing aeroponics over hydroponics are: cleaner sterile growing environment, reduction in spread of disease and infection, better control over micro climate and better absorption of minerals and vitamins (increasing their nutrition value for ingestion). [100] Aeroponics also provides significant advantages when compared to traditional farming, where fertilizer usage is reduced by 60%, pesticide usage is reduced by 100% and water usage is reduced by 98%. [101] This is extremely significant considering current world issues with water consumption.[102] The system could be adapted to specific countries and villages providing an inexpensive method of producing food and clean water for areas suffering from shortages. [103]

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[98] Windterborne. Hydroponics: Indoor Horticulture .

[99] Despommier. *Feeding the World in the 21st Century* .

[100] NASA Spinoff. Progressive Plant Growing Has Business Blooming. 68-72.

[101] Despommier. *Feeding the World in the 21st Century* .

[102] As mentioned in a previous chapter traditional farming today consumes 70-80% of the world's renewable water.

[103] But is aeroponics unnatural? In short, no. A natural aeroponic system can occur within coral reefs. The floating coral islands in the Bahamas pump the water full of oxygen and nutrients resulting in abnormally large plants and creatures.

The Basic System

Figure 2.5:

Pea plants placed in a clay 'hydroton' filled mesh cup.

A basic aeroponic system consists of a nutrient enriched water reserve and a pump located in an enclosed container (to prevent water evaporation). The water in the reserve is pumped through tubing and misted out of fogger nozzles. The nutrient rich mist is then absorbed by the dangling roots of the plants above (Fig. 2.7). One can easily build their own aeroponic system at home for under $100.

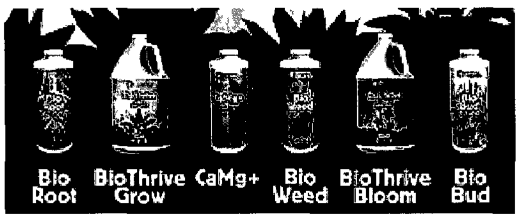

Figure 2.6:

General Hydroponics brand organic nutrients. Each nutrient is mixed to specific ml per gallon ratio depending on the plants cycle. Newly grown plants require more BioRoot and BioThrive Grow while plants that are ready to flower require only BioThrive Bloom.

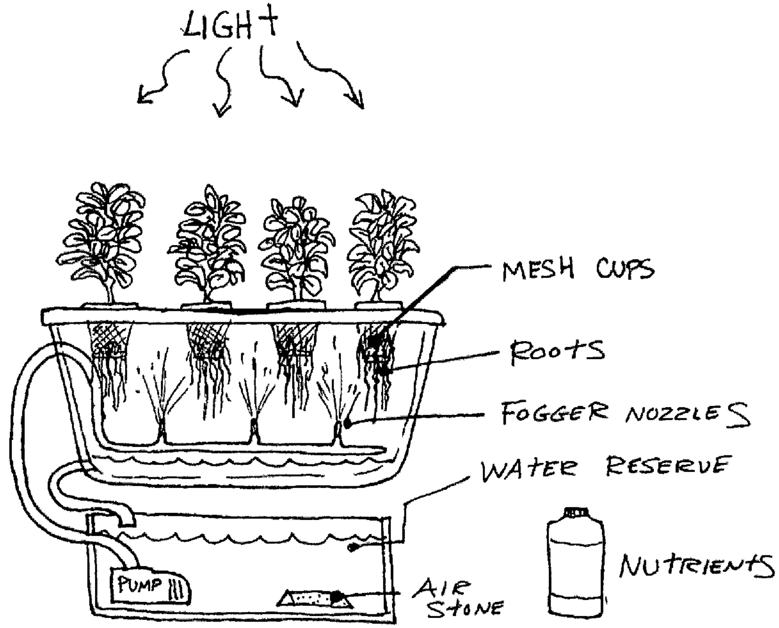

Figure 2.7: A sketch diagram of a basic aeroponic system.

The Prototype

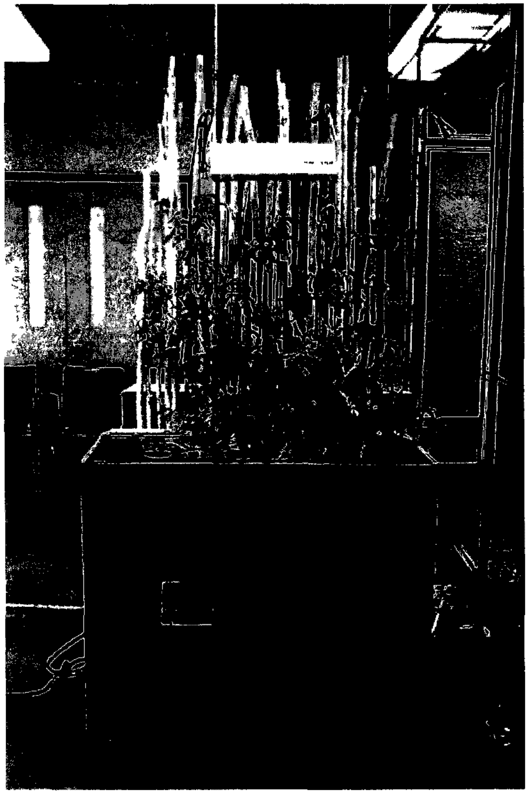

Figure 2.9:
Prototype aeroponic system growing tomatoes.

Inspired by a hearth, a prototype installation was constructed for this thesis. It is clad in plywood with a trellis of shaved branches. The front panel clips off to allow for easy access to the roots for maintenance and observation. Compartments on the sides and bottom of the wooden square provide storage for nutrients and cleaning supplies. The system was designed to accommodate a variety of plant types (climbers, bushers etc.) to determine their aeroponic needs, which will inform future designs. The first cycle, consisting of beans and peas, succumbed to deadly pythium root rot (however the plants put up a good four month fight). The second cycle consisted of tomato plants that eventually flourished once the nutrients and oxygen levels were appropriate.

Figure 2.8 (Right):

Photograph of the aeroponic prototype with the front removed to display the root system of the tomato plants.

Chapter 3: Integration

Food at Our Fingertips

Why Architecture

"If you want to seed a place with activity, put out food." [104]

The term 'Urban Agriculture' defined as 'the practice of cultivating, processing and distributing food in an urban area[105]', typically conveys images of exterior spaces, perhaps a backyard or community garden. Although these exterior gardens provide produce to urbanites, this is not the focus of discussion. These spaces, for the most part, reside outdoors.

As living beings our fundamental spatial needs correlate closely with that of plants. Natural light, air quality, heat, water and a pest-free environment are required in architectural spaces. Bringing the production of produce indoors will also relieve the landscape from intensive human intervention.

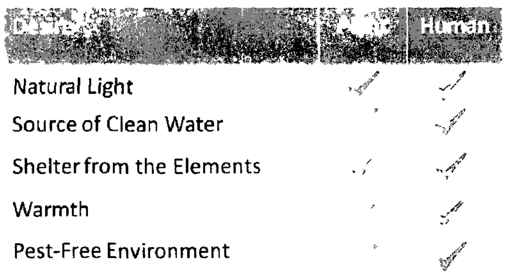

Figure 3.1:
Plant and human environment similarity chart.

The new urban agriculture concept proposed in this thesis is not secluded from public view in a single skyscraper and many vertical farming

[104] Nordahl. *Public Produce.*

[105] In this context, 'urban' will be defined as the entire area in which a city's sphere of influence (social, economic and ecological) comes to bear daily and directly on its population

proposals do. Vertical farm towers do not address the loss of knowledge issue, nor does it address the "moments of separation" issue as discussed in chapter 2. This proposal brings the immediacy of food production into the day to day existence of urbanites.

Social	Environmental	Economical
Cleaner air	No pesticides	Year round crops
Use of empty lots	No herbicides	No weather related crop failures
New employment opportunities	No fertilizers	Reduces cost by requiring less oil
Increase in food knowledge	Potentially organic	Increases land value of area
Strengthens connection with earth and nature	Leaves farmland to be restored to natural ecosystem	No factory farm monopolies
Health and fresh food	Reduces green house gas emissions	Efficient use of space
Better food quality	Potential to filter water	Profitable
Lower obesity rates	Requires less freshwater	Can be placed in any building
Hunger solution to suffering areas	Reduces fossil fuel with less transportation miles	Low maintenance when compared to traditional farming
Wider crop variety		Increased product shelf life
True food security		Yield & Quality Predictability

Figure 3.2: A triple bottom line breakdown of benefits that can occur with the integration of agriculture and architecture when using aeroponic and hydroponic technology.

Scale Analysis

Macro: The Vertical Farm

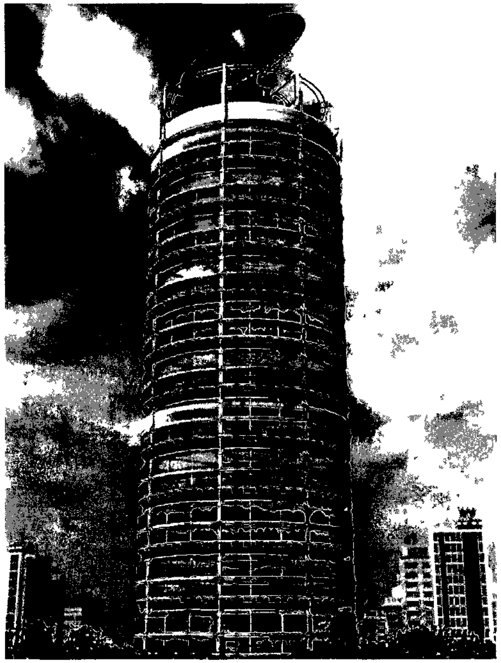

Figure 3.3:

Vertical skyscraper design by Chris Jacobs in cooperation with Dr. Dickson Despommier of Columbia University.

There is one outstanding conceptual precedent of the integration between agriculture and architecture. In 1999 a professor at the University of Columbia, named Dickenson Despommier, and his students formed the first conceptual 'Vertical Farm'; a large scale multi-story stacked greenhouse in an urban context. Ideally the building would be transparent to optimize natural lighting condition, allowing it to be off the grid. Dickenson and his students have calculated that a single vertical farm with a footprint the size of one New York block, rising 30 stories high, will provide enough food for 50,000 people[106]. With such potential in food production one has to wonder why large-scale vertical farming doesn't already exist, especially if it addresses all the agricultural issues presented in chapter 1.

One of the large hurdles vertical farms face is the optimization of the closed-loop system of solid and liquid waste (grey water, black water and sludge).[107]. It is not only the incorporation in terms of technology but the challenge of convincing the public that there is no health risk through

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[106] Despommier. *Feedıng the World ın the 21st Century*.

[107] United Nations Development Programme. *Urban Agrıculture: Food, Jobs and Sustaınable Cıtıes.* United Nations Pubns (Dec. 1996)

infection, disease or fecal contamination[108]. If the city approaches this concept on a smaller scale, it could build up the reputation of healthy waste management within the production of food.

A second significant reason that vertical farms have yet to be built is the cost, including design, construction and maintenance. Currently Dickenson is working with a Manhattan borough president named Scott Stringer developing the first pilot farm for New York[109]. They estimate that the cost of research and working out the design is between 20 and 30 million dollars[110]. This figure does not include the cost for actually building the experimental 30 story farm. Even Despommier himself states, *"Since the first vertical farms are likely to be prototypes hence experimental in nature, I don't think large numbers of people will benefit immediately from them, except for those research teams working in them."[111]* A high price with a limited benefit might result in abandonment of the urban agriculture concept (or at minimum result in massive delay in constructing the second building delaying the production of food). In addition, the cost of the building could increase the price of food, making it unaffordable and unable to compete with the current food market.

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[108] United Nations Development Programme. *Urban Agriculture: Food, Jobs and Sustainable Cities.* United Nations Pubns (Dec. 1996)
[109] Despommier. *Feeding the World in the 21st Century*.
[110] Despommier. *Feeding the World in the 21st Century*.
[111] Despommier. *Feeding the World in the 21st Century*. 222.

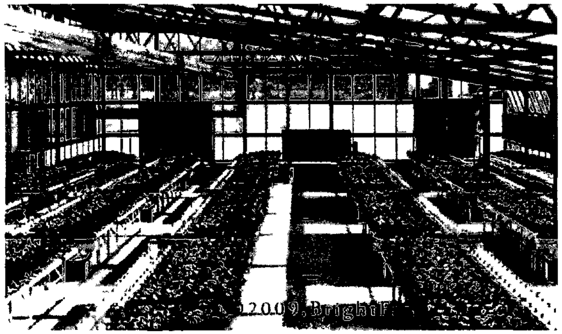

Figure 3.4:

Brightfarm Inc.'s conceptual rooftop design for South Bronx, New York.

A second concern, is the congregating all food resources into a single building. In terms of food security it is favourable to spread resources throughout the city. Converting existing spaces within the urban fabric will not only reduce costs while experimenting but allow the production market to remain open to competing companies.

As a recent experimental concept, vertical farming is not yet a practical. This thesis proposes smaller scale installations that can grow in small stages and adapt to their specific locations as a cost-effective and sustainable alternative to vertical farming.

Meso:

There are other case studies of urban agriculture that are not at such a monumental scale. BrightFarm Systems has been developing and designing urban buildings, as well as retrofit projects and designing installations for food production in urban locations. The majority of their projects are located in New York, utilizing hydroponic systems and other forms of sustainable farming. Figure 3.5 is an image of a rooftop design for South Bronx, NY. It will feature 10,000 square feet of integrated rooftop farming, and that amount of space will provide enough produce to feed 450 people a year.[112] Bright Farm

[112] "BrightFarm Systems". Commerical Company Website. <http://www.brightfarmsystems.com/> 2011.

Systems have also developed a rooftop module that can be applied to any high rise tower [113] (figure 3.4). This Vertically Integrated Greenhouse involves a double skin facade for farming. This rooftop greenhouse could provide an excellent solution to some of the downtown Ottawa buildings; however, this solution does not integrate with the architectural spaces or with inhabitants daily activities.

Closer to home, 15 minutes outside of downtown Ottawa is Suntech Tomato Greenhouse Limited. On a nine acre lot they currently have 2.5 acres of hydroponic greenhouse space[114]. SunTech uses a technique called interplanting, planting the old with the new to ensure a continuous crop harvest. Built in 1999, the business has been highly profitable and are have been purchasing more land and performing upgrades[115].

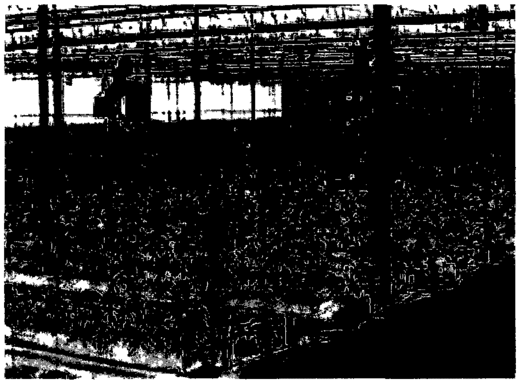

Figure 3.5:

BrightFarm Inc.'s vertically integrated greenhouse conceptual rendering.

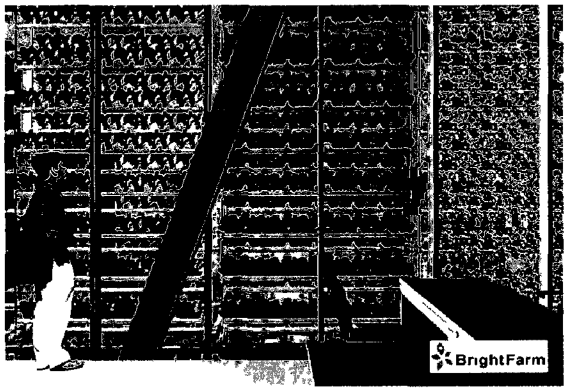

Figure 3.6:

SunTech greenhouse interior in Manotick, Ontario, depicting young tomato plants.

Micro : The Complexity of Aeroponics

Plants are complex and sensitive organisms that have a primitive nerve system. This system allows transmission of electrical signals for communication[116]. They are constantly communicating to one another and the

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113 "BrightFarm Systems". Commercial Company Website. <http://www.brightfarmsystems.com/> 2011.
114 "SunTech Greenhouse Limited". Commerical Company Website. <http://www.suntech.ca/> 2011.
115 "SunTech Greenhouse Limited". Commerical Company Website. <http://www.suntech ca/> 2011.
116 Supernatural: Unseen Power of Animals: Outer Limits. Dir. John Downer. Prod. John Downer Productions Ltd. 1999.

world around them. For example: Ocasciosias, a tree in Africa, releases a gas when being grazed upon. When the surrounding trees receive this signal, a toxic poison is spread to the leaves within 30 minutes, minimizing damage and forcing the grazing animal to feed elsewhere[117].

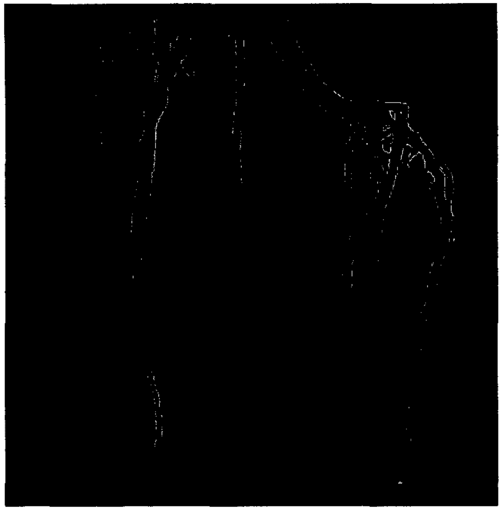

Figure 3.7:
Unhealthy aeroponic roots showing pythium root rot

Over watering (& root rot), under-watering, nutrient deficiency, sunlight deficiency, sun burn, wind burn, nutrient burn and fungus gnats are just a handful of the problems that plague potted house plants. Caring for plants is not difficult but it takes a certain amount of education and time to grow them properly. This poses a problem for the micro scale, namely the individual home aeroponic installations.

A small Aeroponic (or hydroponic) system is no more complex than owning a fish tank. And although many people own fish tanks, they tend to lean towards buying hardy and inexpensive fish instead of developing an understanding of pH, nitrates, ammonia levels etc. The same can be said for plants. Over the generations we have been providing plants with more nutrients than they could ever absorb and removing all competition (weeds, insects, disease). We have, in a sense, encouraged the development of weak and delicate plants. In Aeroponics the suspended roots are missing their pH and nutrient buffer, soil, making the roots extremely vulnerable. Temperature, water pressure, humidity, nutrient levels, pH, bacteria, light and

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[117] Supernatural Unseen Power of Animals Outer Limits Dir John Downer Prod John Downer Productions Ltd 1999

air all have to be monitored. For example, a drop in water pressure from a clogged mister can cause wilt within 30 minutes and kill a crop within 24 hours.

It is for these reasons that Aeroponics on a micro scale is not a viable solution to provide food for the city. Some eager urbanites will take to aeroponic systems in their homes quite well, producing lush plants and delicious yields, but the reality is that the majority of people in the city do not have the desire, time, patience or knowledge to grow their own food on a regular basis. However, even though the micro scale does not offer a solution to food security it should not be overlooked as it does remove the pressure on the food system as discussed in chapter 1. What is more, the small scale provides and shares knowledge, building up a desire to expand and nurturing individuals to become more proactive in agricultural issues.

The result of fulfilling an integral concept is immensely beneficial in terms of social, economical and environmental values. The approach proposed not designed to solve the problems instantly, it is merely a beginning. By addressing a portion of Ottawa's buildings at the micro and meso scale, the concept can be tested and subsequently built up towards a macro level across the city.

New Meets Old : Programmatic Layering

Common building resources such as heat, water, clean air and light can be utilized in existing buildings and potentially be transformed into a sustainable loop, designing the agricultural integration with characteristics of the city's existing buildings. This new agriculture is not about making room in the city by erasing urban tissue (although all new buildings should ideally incorporate this concept). It will target the existing fabric, keeping the characteristics of the city and the current programs while at the same time saving money, time, energy and materials.

The project proposed begins by creating interventions in existing structures, raising awareness and interest. Integration will begin with commercial programmatic spaces, and to a lesser extend individual avid gardeners who wish to supplement their grocery needs.

The first transformations will take place in restaurants and coffee shops. Ottawa's Bridgehead already accommodates for non-productive green walls, why not exchange the plants for locally grown sweet smelling teas and herbs? Restaurants are an obvious choice; the first few would develop special organic niches for themselves, making the business highly profitable.

Moving up in scale, Ottawa could then utilize its downtown parking

Figure 3.8:
Interior view of hydroton tray.

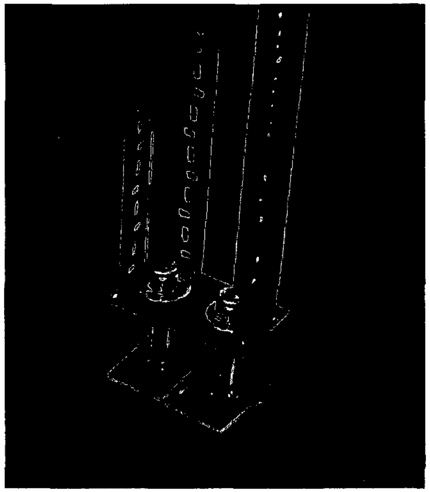


Figure 3.9:
Photograph of friction fitting.

lots, adapting them to host farmers markets without hindering parking space during the weekdays. Office spaces, after seeing the benefits, will layer their program seeking out a maintenance service to come in and tend to food producing plants (or grown non-editable plants to simply improve work ethic and air quality).

After the first experimental integrations, a larger grocery store could be developed, based on the knowledge from previous designs. If these transformations occurred within the same area in Ottawa, inhabitants would be emerged in these food producing spaces on a daily basis. Not all buildings in the city would need to produce plants, but tying them into this green expansion through the exterior spaces will allow them to participate in this food production transformation.

A Space You Can Taste
The Green Screen Module

The green screen module is a 5 inch wide friction fit aeroponic system. It features a transparent acrylic (or glass) panel that exposes the plant roots to the public eye while allowing for easy maintenance. The plant roots are not harmed by indirect lighting as long as they are kept in a moist environment. To clean the transparent box interior the plant tray can slide, lift or be removed completely. If minor cleaning is required, for example algae removal, there is a magnetic algae hand cleaner that allows one to wipe the inside without disturbing the plant growth (similar to aquarium cleaners). Weekly maintenance of the system is required consisting of cleaning the glass and changing the nutrients.

The transparent root box is framed by a steel structure that can adjust to various ceiling heights. The industrial steel encases the natural elements while supporting an adjustable wire trellis and recessed tube lighting. The seeds are sprouted separately in rockwool cubes and are not placed into the hydroton clay pebble tray until they are a few inches high. This particular screen is designed for plants such as peppers, beans, peas, tomatoes, cucumbers, soy, mint etc. These screens can be made in various widths or chained together to form an interior wall. This adaptability makes them ideal for apartment spaces, lobby's and rented commercial spaces as it leaves no permanent mark on buildings.

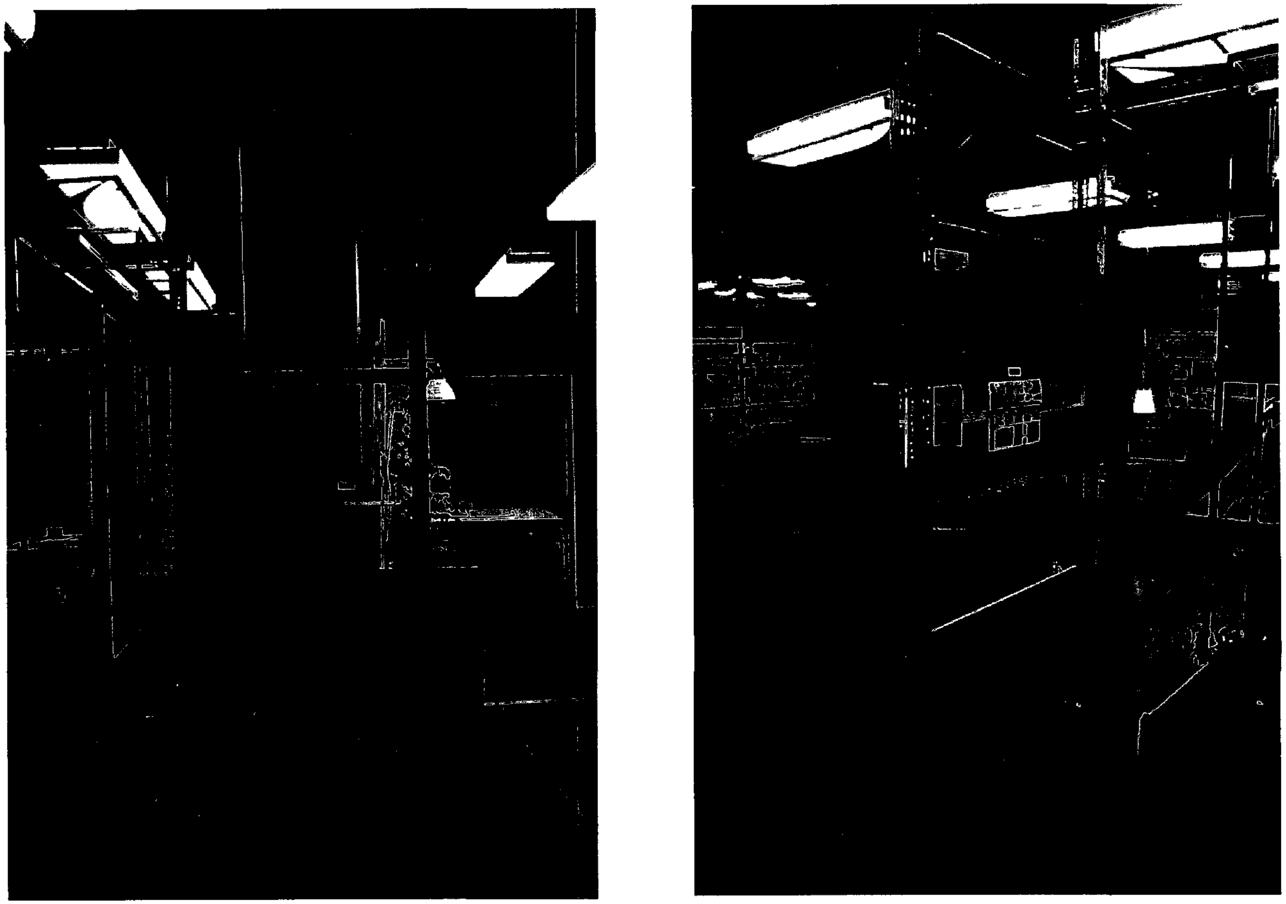


Figure 3.10: Two photographs of the screen module prior to the insertion of plants, water or growth medium.

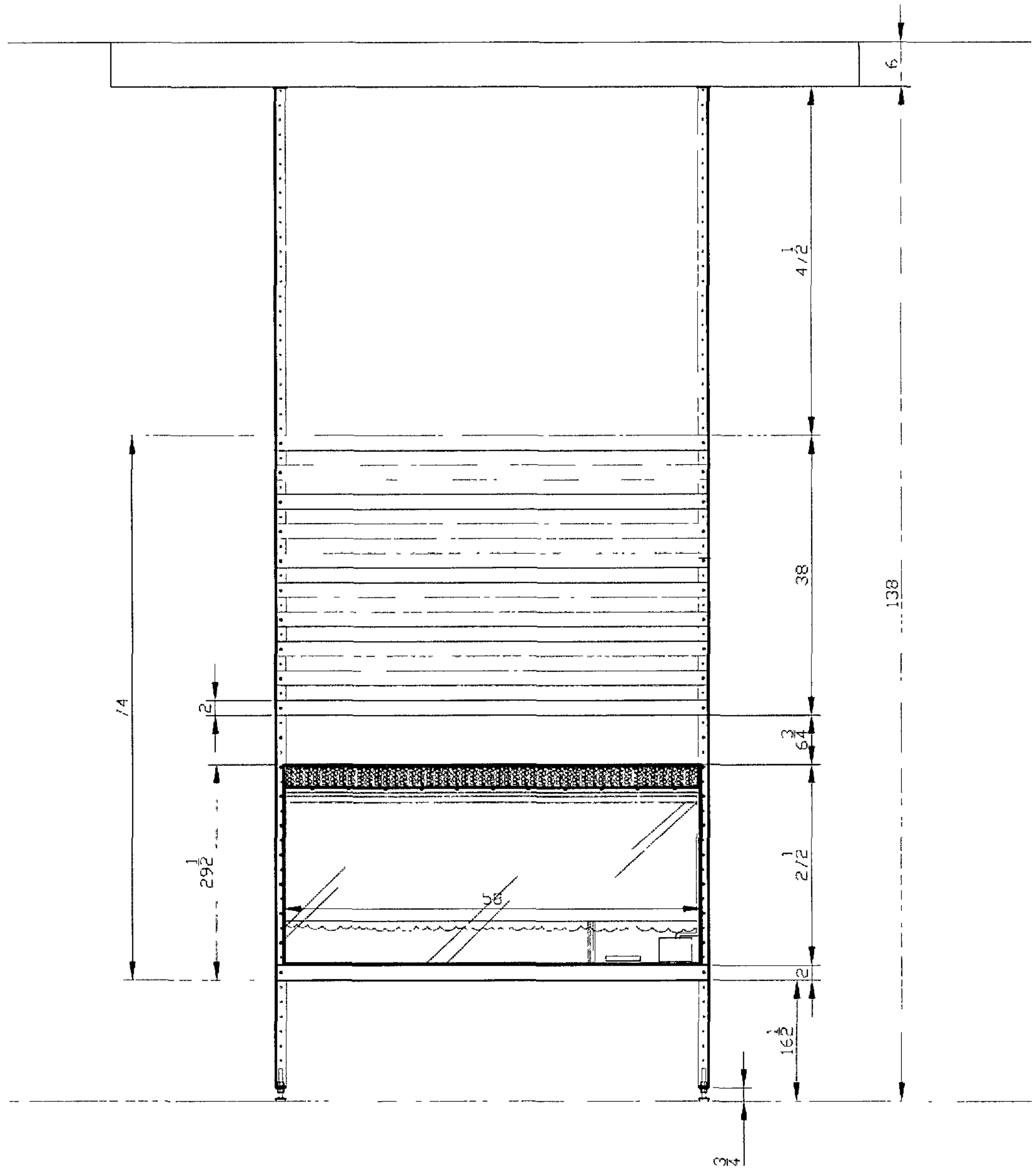


Figure 3.11: Sectional drawing of screen module.

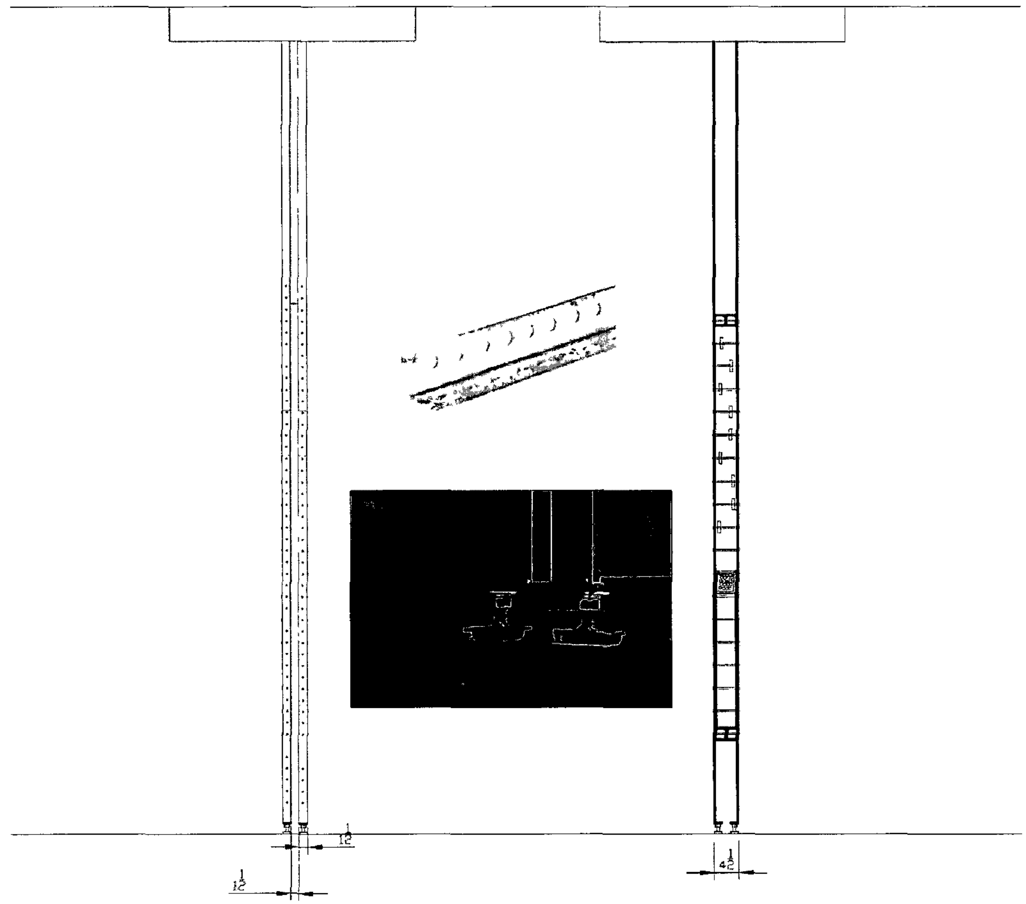


Figure 3.12: Side elevation and sectional drawing of screen module.

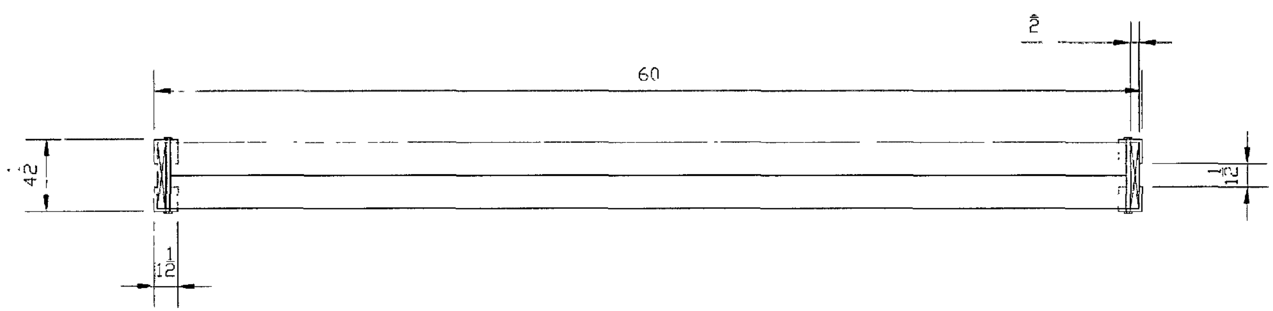


Figure 3.13: Plan drawing of screen module.

Money Matters

Financing is one of the larger hurdles to overcome in large scale vertical farming, even though the concept is widely popular and well known. On a smaller scale, funding can be manageable. One must acknowledge that concepts and ideas catch on quickly in our money driven society if proven to be profitable. Therefore to obtain the goal of sustainability, it would be beneficial for the economic aspect of integration to be investigated and if possible, profitable.

Figure 3.15 contains a rough economic breakdown comparison based on tomato prices in Ottawa's downtown Loblaws and NASA's aeroponic research data. The revenue for aeroponics is far greater than that of soil-based farming. This substantial difference in revenue allows for tweaking of the price per pound to undersell unsustainable produce, motivating people to buy local and potentially organic food. Underselling the competition and providing better quality food will draw interest and spread knowledge of this new urban agriculture. Although this calculation was for 116cm row (the width of one green screen module), a cluster of screens placed together it will have a greater impact. The initial start-up cost of one screen module is $711.14 (Fig. 3.16). The cost of system maintenance excluding labour for a single screen is $487.63 per year (Fig. 3.14). This gives a screen the potential yearly profit of $5189.57 (yearly revenue of $5677.20 – $487.63 yearly cost of running system). Labour costs depend on how many screens are in a given space. SunTech Ltd. hydroponic greenhouse grows plants on 2.5 acres of land and requires 16 employees for maintenance, harvesting, commercial shop keeping and tours.[118] Although skilled maintenance workers are required in order to obtain the maximum profit, the aeroponic screen module produces a large amount of food with a small start up and maintenance cost.

YEARLY MAINTENANCE COST

Item	Cost per unit	# of Units	Cost
Nutrients	$20.00	4	$ 80.00
Hygrozyme	$45.80	1	$ 45.80
Seeds	$1.99 per pack	3	$ 5.97
Hydro cost for lighting	$0.08 per KwH	39 Watt X 2	$ 27.34
Hydro cost for water pump	$0.08 per KwH	25 Watt	$ 17.52
Hydro cost for air pump	$0.08 per KwH	2 Watt	$ 1.40
Water	$1.30 per gallon	192	$ 249.60
Misc.	~15%		$ 60.00
Total Cost Per Year			$ 487.63

Figure 3.14: Yearly maintenance cost of one aeroponic screen module. The hydro costs are set to Ottawa Hydro's fee of 8 cents per KwH. A 15% contingency is added in case of equipment breakdown or small upgrades.

[118] "SunTech Greenhouse Limited". Commerical Company Website. <http://www.suntech.ca/> 2011.

2011 Economic Breakdown Comparison: Ottawa Tomato

	Soil-Based Farming	Aeroponics Farming
Germination	28 Days[1]	10 Days[2]
Cycles Per Year	2 Max.	6 Max.[3]
Tomatoes Per Row (1 Row = 116cm)	Spacing of 8cm per seed[4] 116cm / 8cm = 14.5cm **14 plants per row**	Spacing of 4cm per seed 116cm / 6cm = 19.33cm **19 plants per 'row'**
Pounds Of Produce Per Tomato Plant	A single soil-based tomato plant in cycle produces on average **12.5 lbs**[5]	60% increase in yield[6] with Aeroponics: average **20 lbs**
Pounds Produced Per 'Row' within 1 Cycle	14 plants X **12.5 lbs** of produce per plant = **175 lbs** of tomato per 'row'	19 plants X **20 lbs** of produce per plant = **380 lbs** of tomato per 'row'
Pounds Per Year	**175 lbs** per 'row' X **2** cycles = **350 lbs** per 'row' per year	**380 lbs** per 'row' X **6** cycles = **2280 lbs** per 'row' per year

(March 2011) current average price per pound in Ottawa (non-organic) = $2.49 per pound[7]

Revenue Per Row	**350 lbs** per 'row' X **$2.49** per pound = **$871.50** per a 116cm row	**2280 lbs** per 'row' X **$2.49** per pound = **$5677.20** per row of 116cm

Undersell unsustainable competition dropping tomatoes to **$1.49** per pound
2280 lbs per 'row' X $1.49 per pound = **$3397.20 revenue**

Undersell unsustainable competition dropping tomatoes to **$0.49** per pound
2280 lbs per 'row' X $0.49 per pound = **$1117.20 revenue**

1 Germination information on OSC 'Tomato - Cluster Grande Hybrid" seed packet. Waterloo, Canada
2 NASA Spinoff. Progressive Plant Growing Has Business Blooming. Environmental and Agricultural Resources NASA Spinoff 2006. 68-72
3 Despommier, Dr Dickson, and Dickson Despommier. The Vertical Farm: Feeding the World in the 21st Century . Thomas Dunne Books, 2010.
4 Recommended plant spacing information on OSC 'Tomato Cluster Grande Hybrid" seed packet. Waterloo, Canada.
5 "Grit" magazine: Gardening Good for the Soul and the Wallet; Paul Gardener: July/August 2010
6 Despommier, Dr Dickson, and Dickson Despommier. The Vertical Farm: Feeding the World in the 21st Century . Thomas Dunne Books, 2010.
7 Price obtained from local downtown LoBlaws store on March 20, 2011.

Figure 3.15: A 2011 economic breakdown comparing an the potential revenue of growing a tomato in Ottawa using soil-based farming and aeroponics farming.

Item/Product	Cost	
Acrylic box	$	350.00
Steel Angles	$	104.00
Steel Square Tubes	$	25.00
Hydroton	$	8.99
Tube Lighting	$	69.60
Water pump	$	34.15
Air pump	$	13.74
Air stone	$	5.00
Misters	$	14.37
Fishing Wire	$	3.00
Elbow Connector	$	4.40
Nuts	$	5.00
Washers	$	5.52
Steel Rod	$	17.94
Steel Plates	$	4.00
Paint	$	26.46
Light Timer	$	14.97
Hose	$	5.00
Total	$	711.14

Figure 3.16: Material costs for building one aeroponic screen module.

Chapter 4: Demonstration of Integration

The Project of Architecture

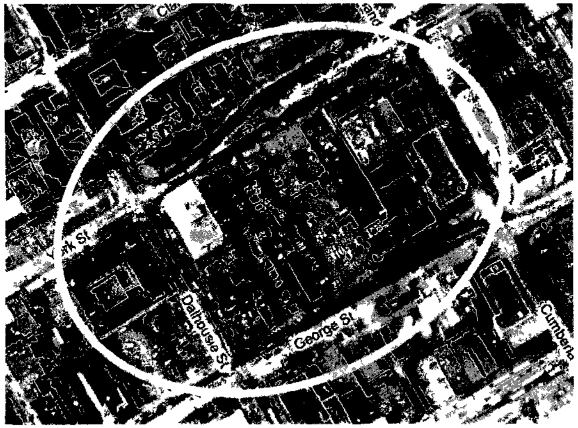


Figure 4.1:

An Aerial Site map of York Street and Dalhousie Street in downtown Ottawa, Canada

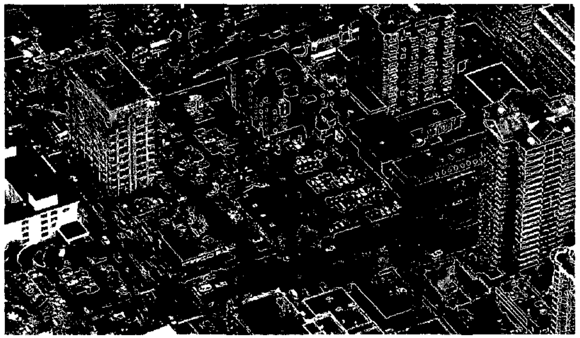


Figure 4.2:

An Aerial perspective view of York Street and Dalhousie Street in Ottawa, Canada.

To demonstrate how agriculture and architecture can be integrated, a site has been selected within downtown Ottawa, Canada. As the capital city of Canada, Ottawa should be at the forefront of design and innovation, providing a model for other cities to follow.

Situated in Lowertown, East of the Byward Market, the site selected includes a series of buildings on the city block defined by York Street and Dalhousie Street (Fig. 4.1). This particular area was selected due to the wide variety of programs already located on the site: offices, apartments, an organic grocery store, townhouses, studio spaces, restaurants, clubs, pubs, parking and commercial stores. The purpose of selecting this site is to demonstrate that flexibility of urban agricultural design on a wide range of programmatic spaces.

Light Analysis

The architectural integration begins with addressing the lighting conditions; it is the point at which all future design movements follow. A

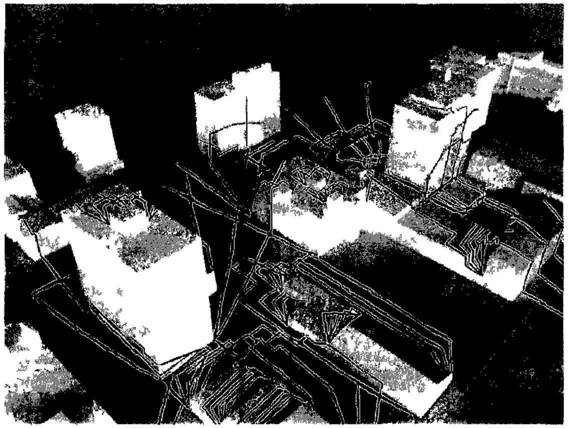


Figure 4.4:
Site sun path tracing.

designer should always strive towards providing as much natural light as possible in order to facilitate lower energy costs before implementing artificial lighting.

There are four factors one must look at when addressing natural lighting in a downtown city core; the seasons, the time of day, building orientation and the shadows cast by existing buildings. The existing urban tissue consists of a mix of medium to large high rise buildings, in which deep shadows are cast across the site. Using computer software and the sites geographic coordinates, sun paths are mapped and superimposed for the two extreme seasonal conditions throughout the course of one day (Fig. 4.3 & 4.6).

High 8 Hours and over	Medium 4-6 Hours	Low 4 Hours and under
Tomato Pepper Squash Eggplant Corn Pumpkin	Broccoli Cauliflower Peas Beets Radishes Swiss Chard Salad Greens Beans Cabbage Potatoes Turnips Onions Garlic Chives Mint Other Herbs	Mosses Lichen Ferns Raspberries Blackberries Strawberries Goose Berries

Figure 4.5:

Chart of recommended lighting requirements of various plants.

June **December**

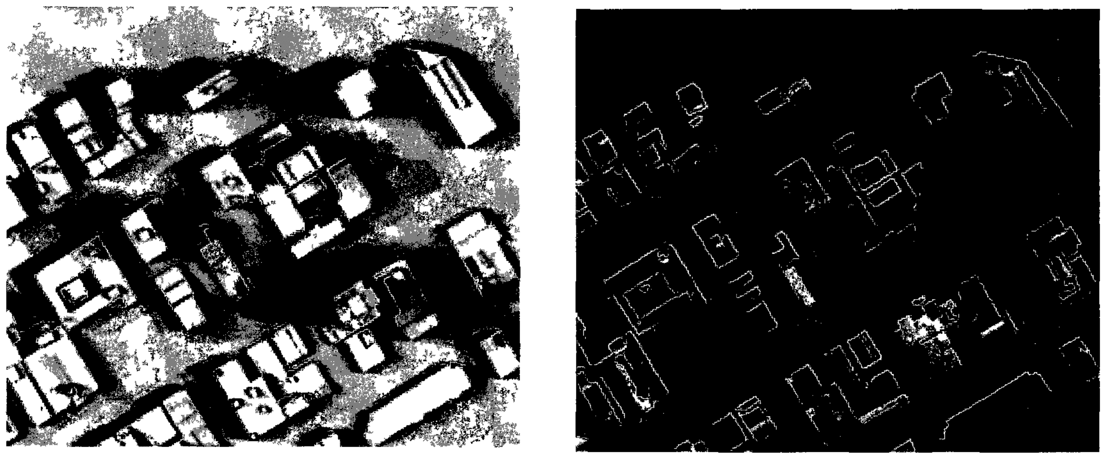


Figure 4.3: Superimposed sun path studies throughout the course of one day.

Most agricultural plant species require a minimum of 3 hours of direct sunlight per day; however optimal results occur in the 6-7+ hour range of sunlight exposure (Fig. 4.5). With the data derived from the sun map analysis an in depth hour-based diagram was developed. The '7+' bright green areas and angles are the prime growing locations, and these areas will be the points of agricultural and architectural integration (Fig. 4.7 & 4.8).

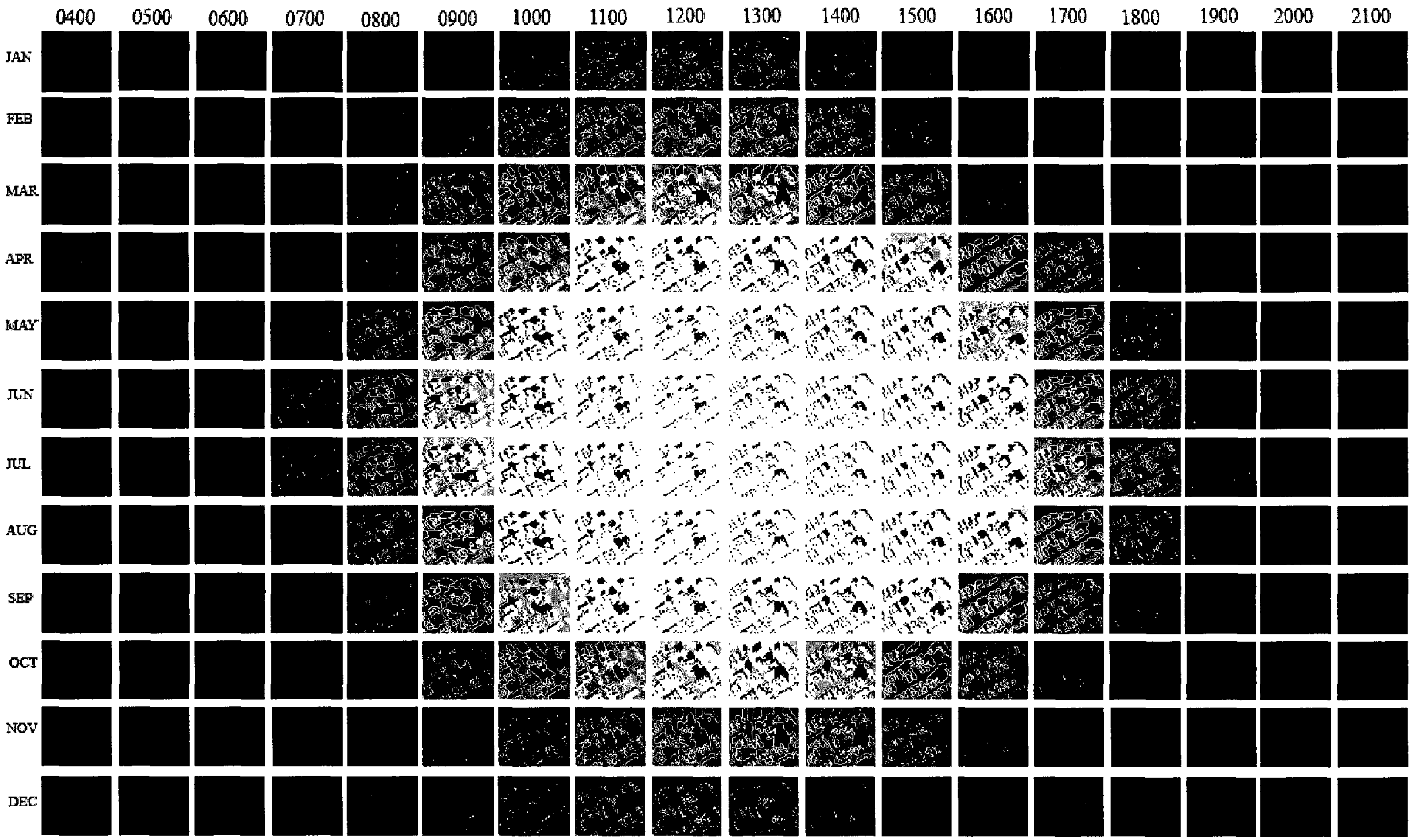


Figure 4.6: Site specific light studies throughout the course of one day for every month.

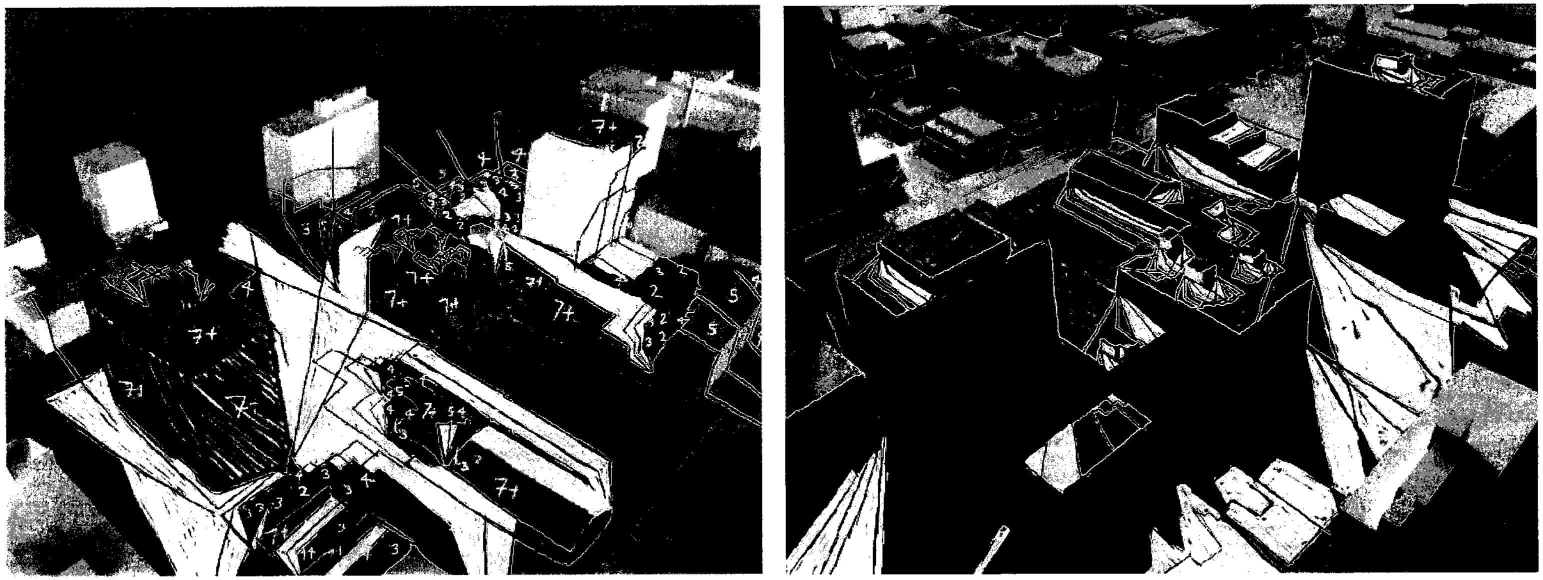


Figure 4.7: Site specific light studies throughout the course of one day during **December**.

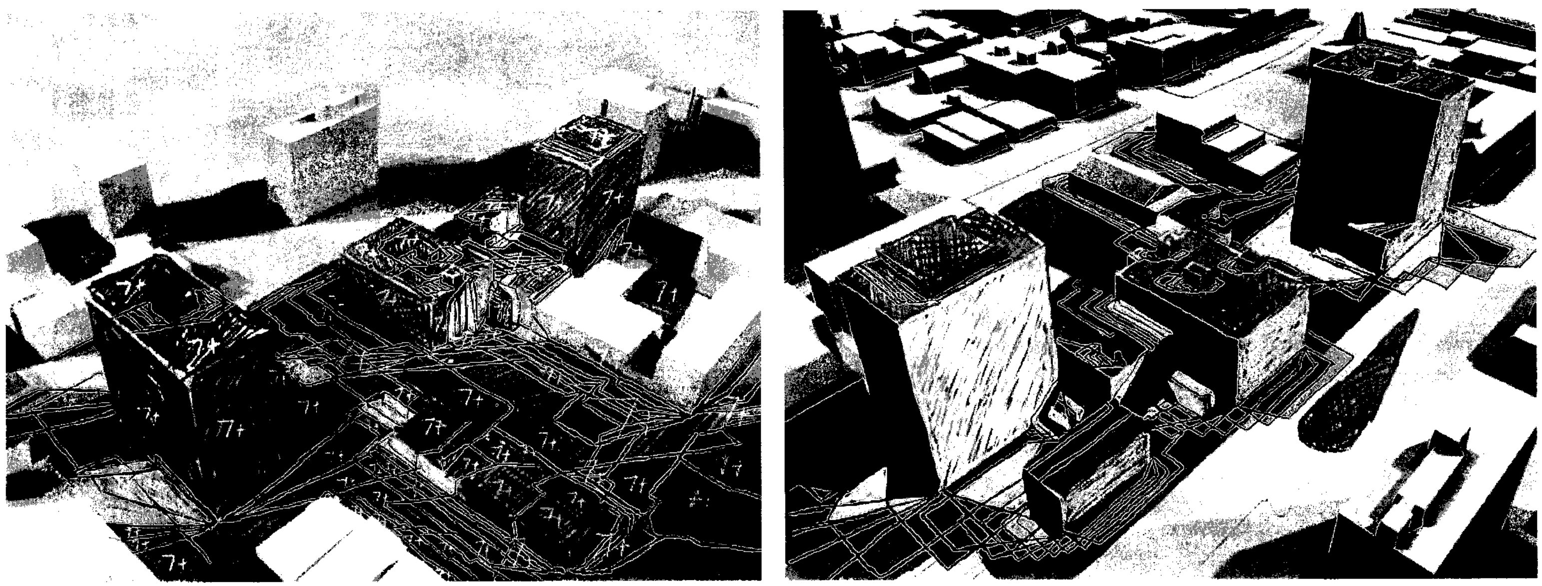


Figure 4.8: Site specific light studies throughout the course of one day during **June**.

The south side of the site is bordered by low density buildings, a rather unique situation in terms of lighting conditions for a downtown core, and one that offers favourable conditions for plant growth. However, while a large portion of the site allows for abundant natural light, in this proposal some buildings will require the use of high quality mirrors and supplementary artificial lighting, while other buildings that lie in complete shadow will be repurposed as water purification and aquaponic centres.

Once the sun analysis is complete and the areas which offer the best lighting conditions are located, the buildings are 'cut' and stripped down to the structure to allow for light penetration. After the consideration of natural

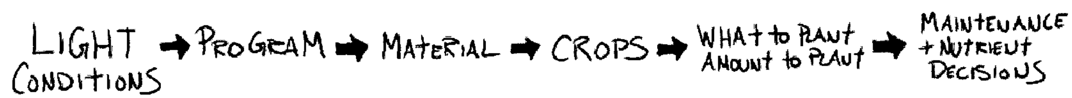


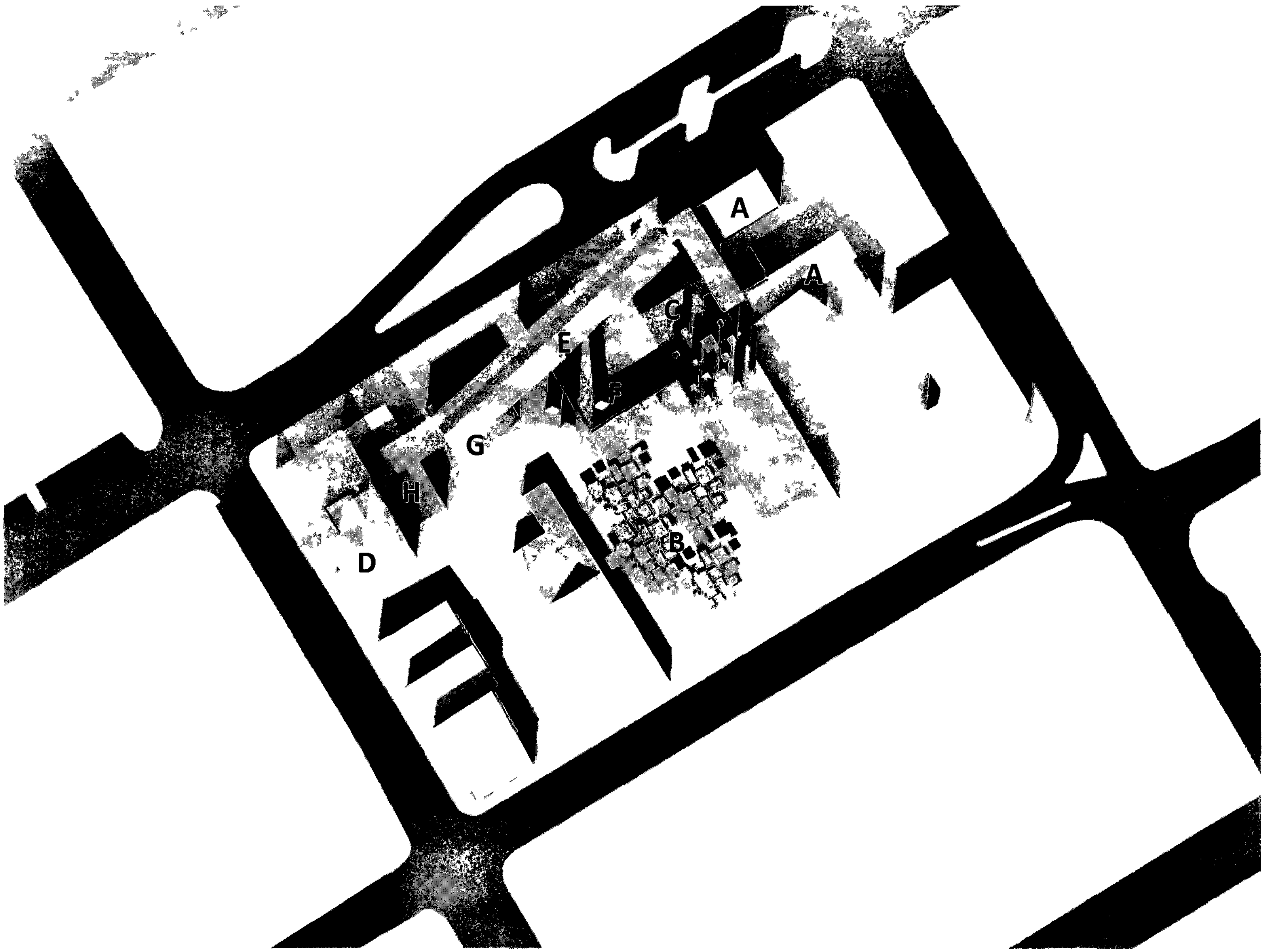
Figure 4.9: Design method diagram.

The design must allow for layering; an integration of agricultural and architectural programmatic functions and structure. This integration will create a unique symbiotic relationship between the two practices resulting in varying benefits depending on programmatic details. Based on the proposed programs and future projected inhabitants, variation and material is determined. For example, a restaurant would need a wide variety of edible plants while an office would require plants with higher oxygen production levels. Once the plants have been selected the aeroponic system is designed to facilitate the ideal growth of these specific plants. One must account for the plants' root size, growth size and growing style (low lying vs. climbing vines).

Townhouses & Condos **'Liquor Store' Club** **Offices & Organic Grocery Store** **Parking** **Restaurant & Pub** **Offices & Ground Floor Commercial Space**

Figure 4.10: Initial North street view and existing programmatic labels (top).

Figure 4.11a: New and old: A programmatic breakdown of the spaces within the site With the introduction of urban agricultural integrations, some of the initial programs have been redistributed but still remain within the city block



A. Housing

B. Farmers Market & Parking

C. Restaurant/Pub

D. Office & Commercial

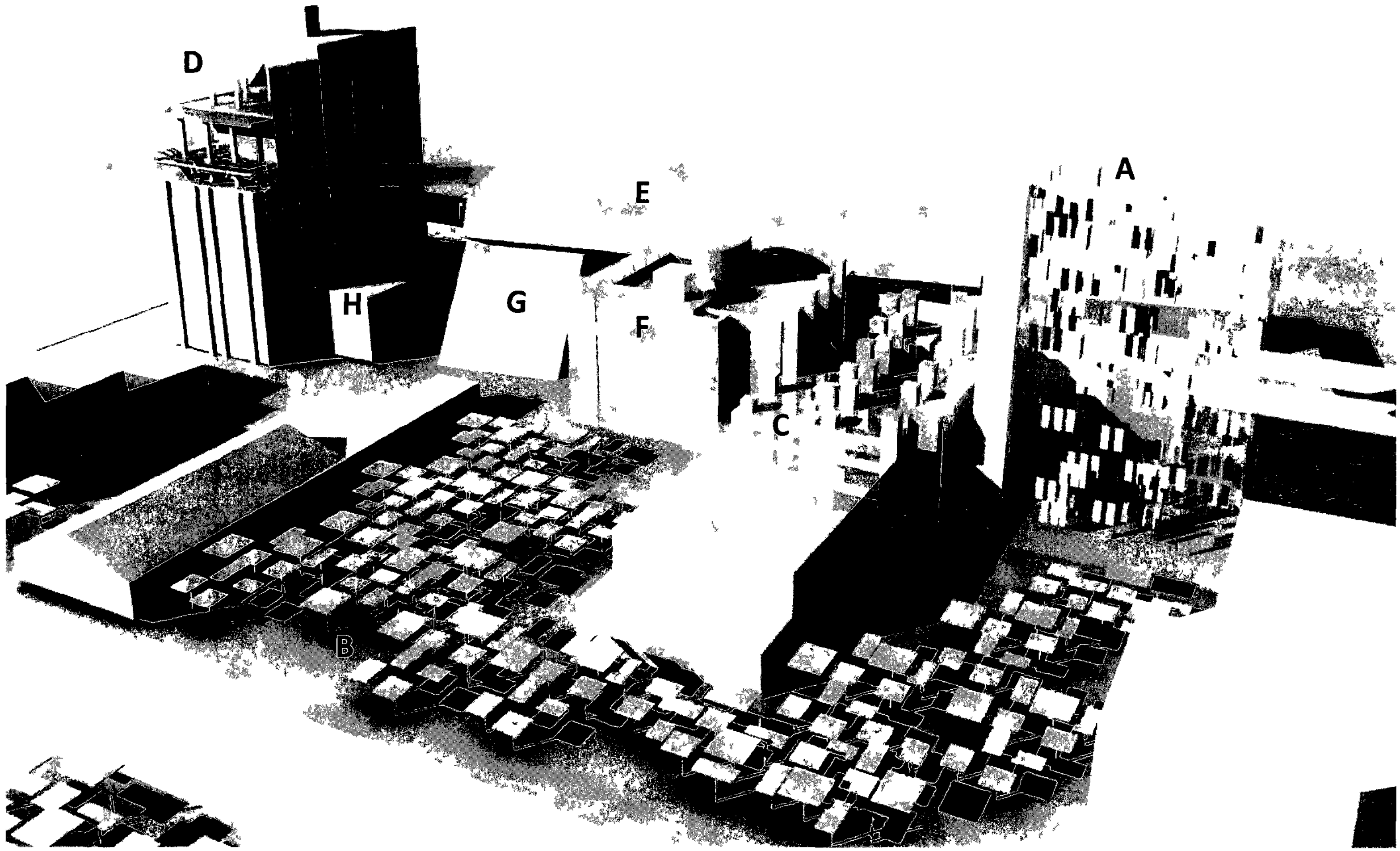
E. Solar Wall & Library

F. Grocery Store & Educational Centre

G. Nursery & Maintenance

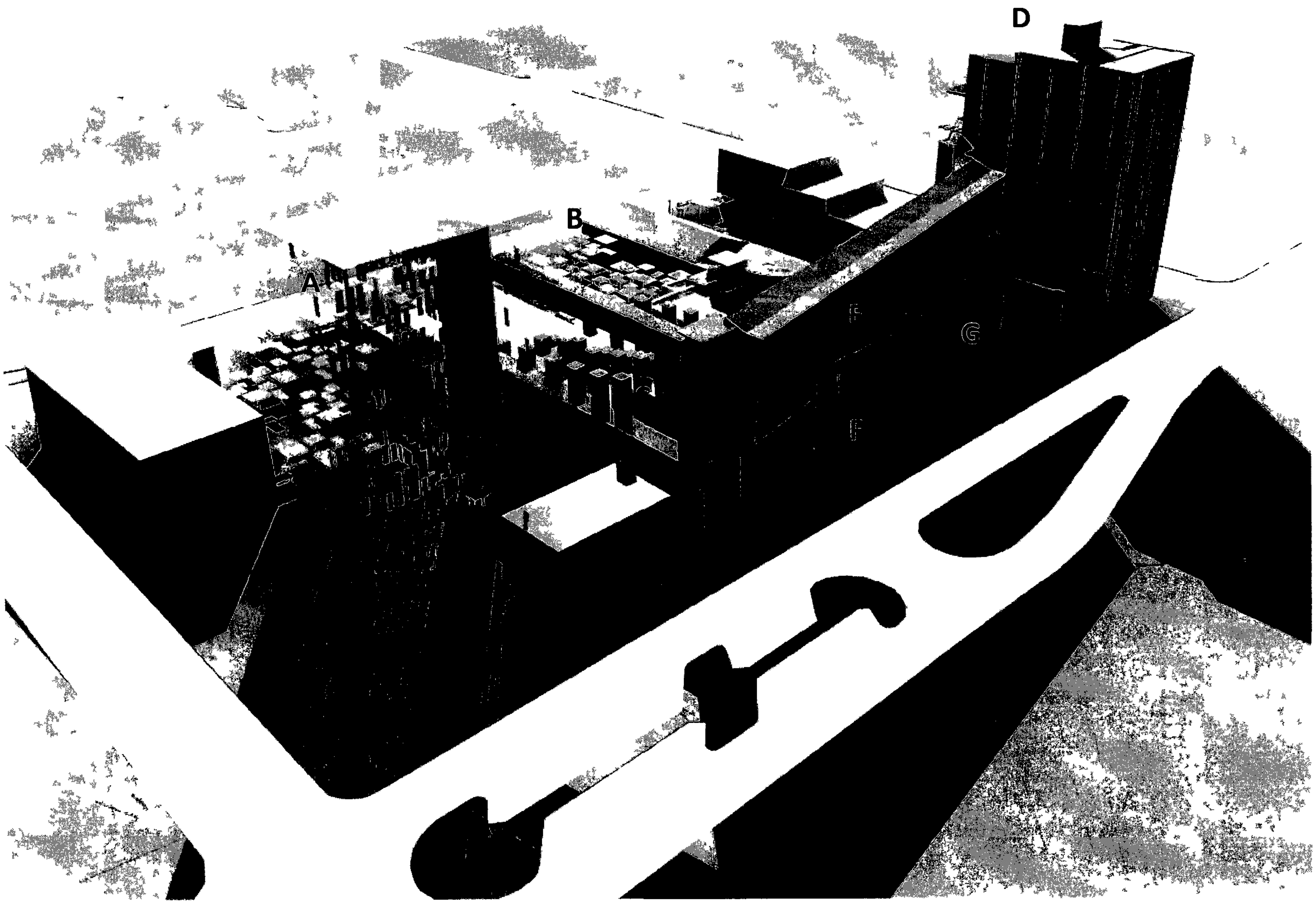
H. Water Filtration Centre

Figure 4.11b New and old: South perspective view and programmatic breakdown of the spaces within the site. With the introduction of urban agricultural integrations, some of the initial programs have been redistributed but still remain within the city block



A. **Housing**
B. **Farmers Market & Parking**
C. **Restaurant/Pub**
D. **Office & Commercial**
E. **Solar Wall & Library**
F. **Grocery Store & Educational Centre**
G. **Nursery & Maintenance**
H. **Water Filtration Centre**

Figure 4.11c New and old North perspective view and programmatic breakdown of the spaces within the site With the introduction of urban agricultural integrations, some of the initial programs have been redistributed but still remain within the city block



A. Housing
B. Farmers Market & Parking
C. Restaurant/Pub
D. Office & Commercial
E. Solar Wall & Library
F. Grocery Store & Educational Centre
G. Nursery & Maintenance
H. Water Filtration Centre

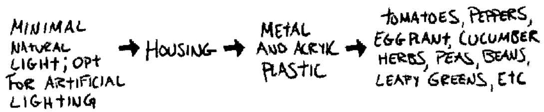


Figure 4.12:

Screen design method diagram.

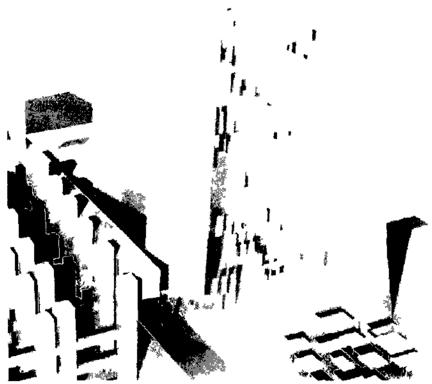


Figure 4.13:

Screen module design-build discussed in Chapter 3.

The Apartment Screen

Although aeroponic screens within individual inhabitants' homes are not a sole solution to food security, they can satisfy the desires of avid gardeners, supplementing their food purchases as well as spread knowledge about the food system. The agricultural integrations within the existing building consist of a roof garden, an atrium aeroponic greenwall and the applied concept of the green screen module as discussed earlier (Fig. 4.13).

The existing apartment building is located on the East side of the block. Due to neighbouring high rise buildings the South side area in December receives 6 hours of direct sunlight while the roof receives 7+ hours per day. The roof in this situation provides optimum growing conditions for plants requiring high light-intensity such as tomatoes, where as the south side of the building can only grow plants requiring medium to low intensity light (See plant lighting requirements chart mentioned earlier; Fig. 4.5).

Supplementary artificial lighting is required for interior dwelling spaces, such as the kitchen or hallway, that are not positioned to receive adequate natural light. The emphasis of the individual screen is to promote knowledge and understanding of the growth mechanics, with the root system exposed for observation. The aeroponic system is used as a partition wall between designated spaces within a unit and within the lobby (Fig. 4.14). The

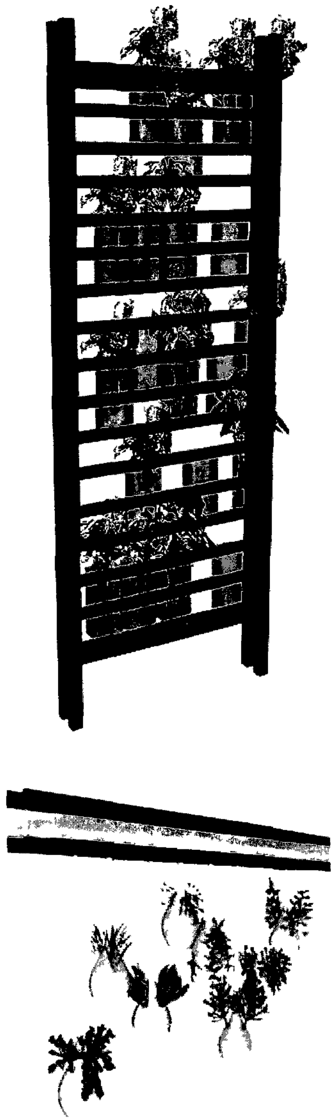


Figure 4.15:
Two screen module adaptations.

system can be relocated within the space and also be adapted and installed within other apartment buildings in the area. With the need for flexibility, the modular system is designed to be situated in any space and grow many crop varieties (Fig. 4.15), regardless of how the existing building addresses natural lighting. Because of this, minimal 'cuts' have been made to this existing condo building (Fig. 4.16).

There is one large integration element within the apartment building on the south west corner. It is a green lounge atrium that features medium to low light-intensity plants such as lettuce, spinach, beans, peas, celery, swiss chard and other leafy greens. On the main floor of the atrium, plants such as raspberries, blackberries and strawberries are grown. In nature these berry plants are normally found in partially shaded areas near forest edges. The aeroponic green wall is maintained by the employees hired to work in the onsite nursery and water filtration buildings. These workers can either provide a weekly service for maintenance of the screens or simply offer their expert advice to inhabitants' indoor garden explorations. Many of the employees hired to maintain the grounds would be encouraged to live within this building, perhaps exploring and designing variations on the screen module systems.

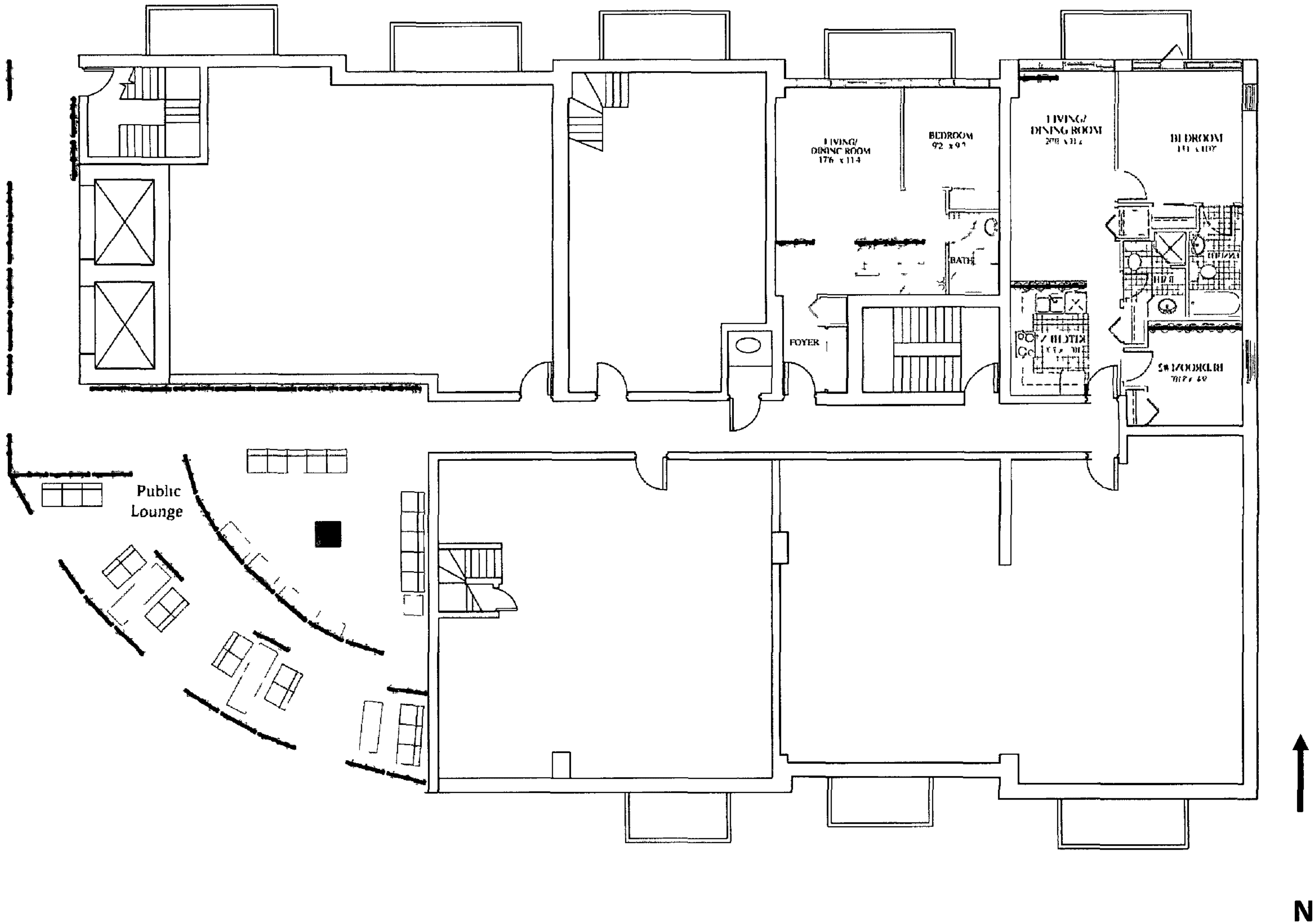


Figure 4.16· Floor plan of apartment building with possible screen integration placements

The Farmers Market

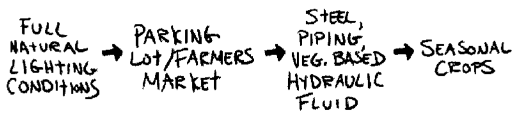


Figure 4.17:

Parking lot design method diagram

The parking lot integration consists of a series of aeroponic 'tree' systems. These 'trees' are metal cylinders that support an aeroponic platform. The parking lot still functions normally during working hours by allowing cars to be parked in the shady spaces beneath (Fig. 4.19). During the afternoons and weekends the aeroponic platforms that are ready for harvesting are lowered to table height. This integration layers the functional aspects by transforming the lot into a fresh farmers market event. One could enter the lot after work, walk up to one of these tables and pick their vegetables fresh for dinner that night.

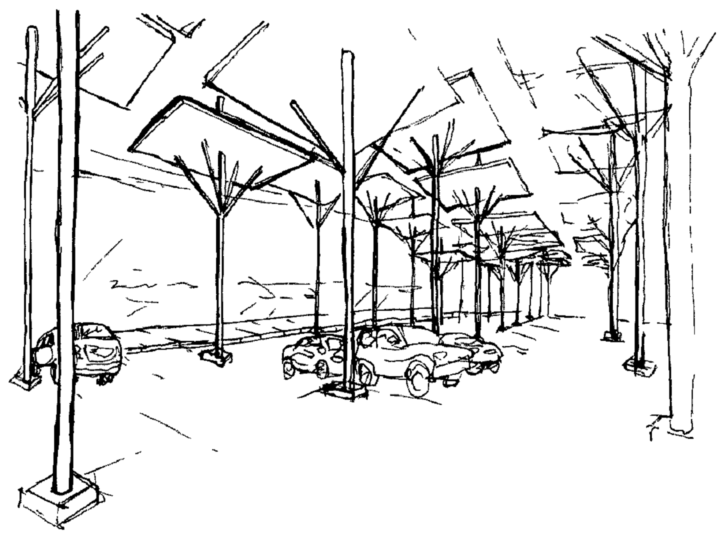


Figure 4.19: A sketch of the farmers market during the day.

With optimal lighting conditions of 7+ hours per day, a wide variety of vegetables can be grown. Along with common vegetables there is an emphasis on seasonal plants such as pumpkins, squash, watermelon and strawberries. These products are in high demand during the specific months that the market will be functional (Fig. 4.21). At the end of the each day the tables are shifted upward again for safety and weekday parking.

The platform, possibly heavy with pumpkins, uses a double acting hydraulic cylinder to move smoothly from position A to position B. Hydraulic cylinders get their power from pressurized fluid, in this case vegetable based oil, so if a leak occurs the crop is not damaged (Fig. 4.22). The steel tubes' interior consists of a cylinder barrel where a piston connects to a piston rod and moves back and forth. The hydraulic pressure acts on the piston, moving the rod and platform in a linear motion. Both the vegetable based hydraulic fluid and aeroponic nutrients are kept in chambers just below the ground level (Fig. 4.23). The platform itself is supported by corrugated steel covered in a water proof membrane. The nutrient water is misted through a series of PVC pipes that are strapped to the corrugated steel. The platforms are placed at varying heights to transform the vast flat space into a productive terrain-like landscape, especially when viewed from above grade.

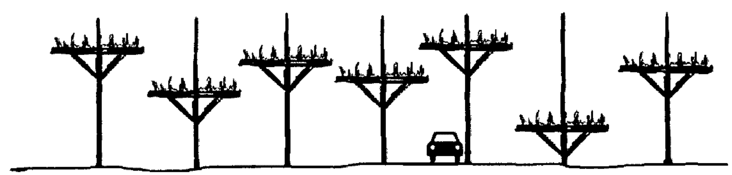


Figure 4.2(Conceptual diagram of parking lot / farmer's market.

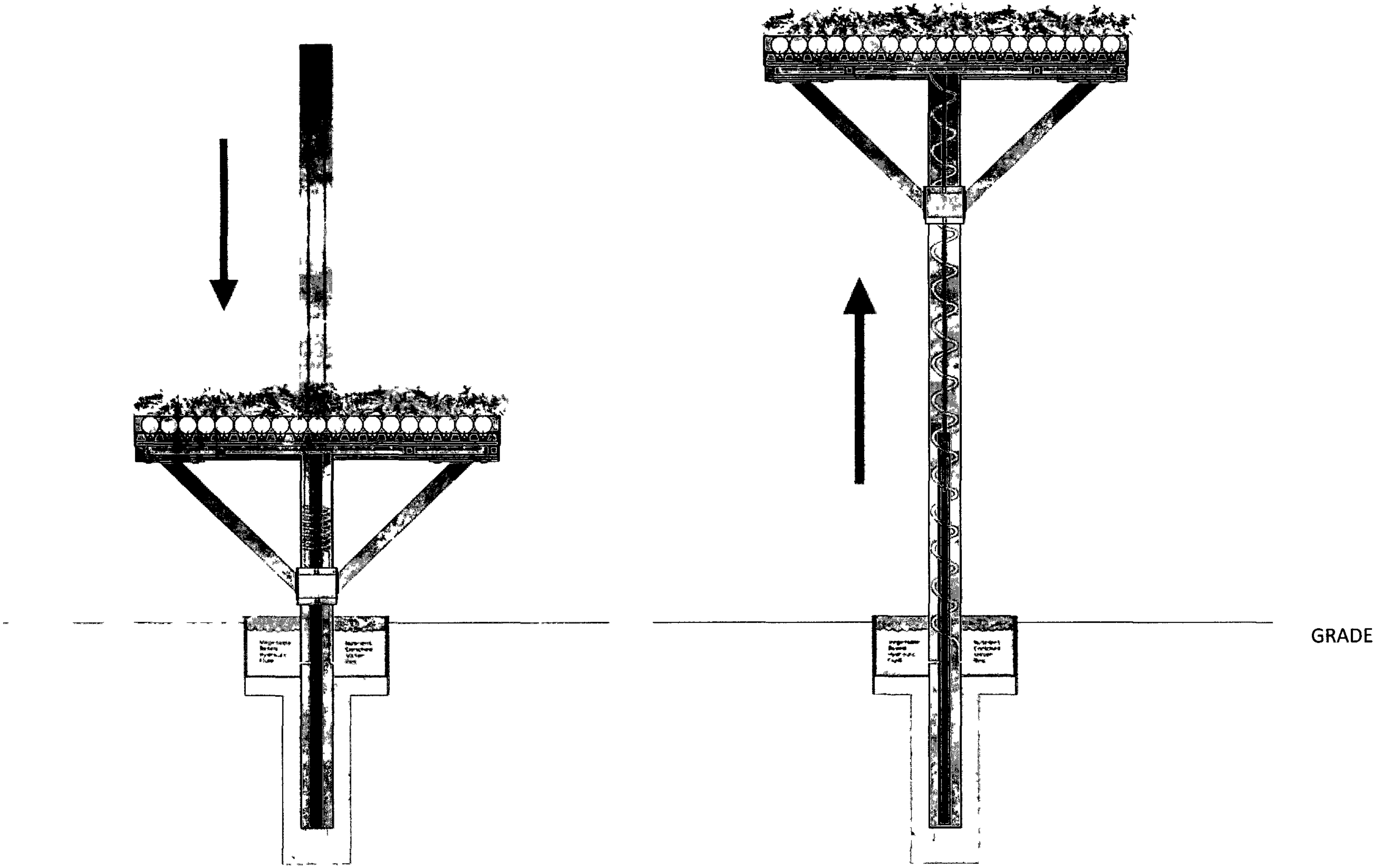


Figure 4.22: Farmers market agricultural integration section diagrams.

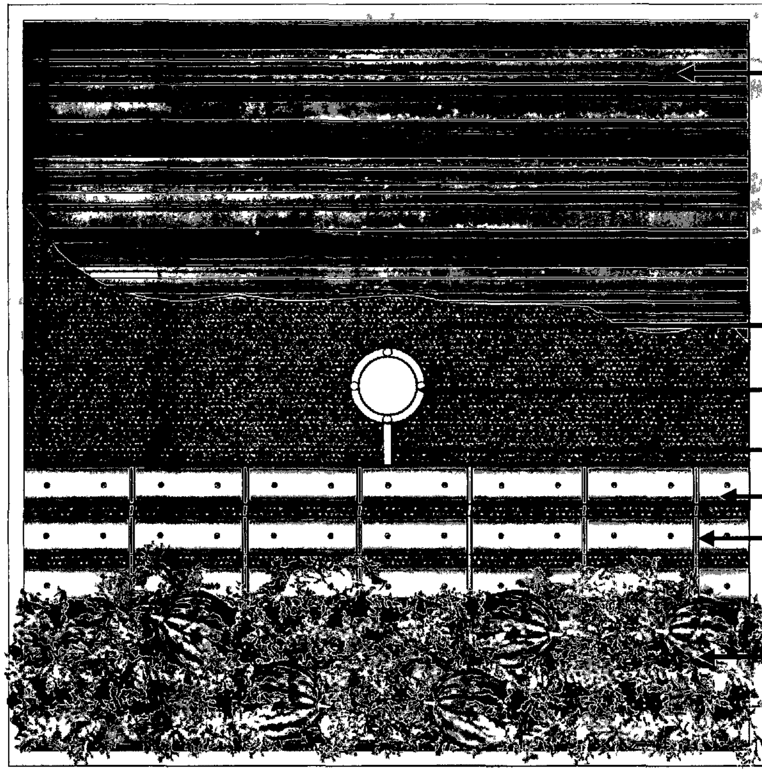


Figure 4.23 Material plan diagram of farmers market integration

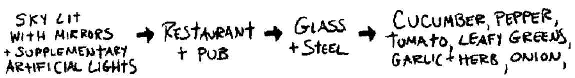


Figure 4.24: Parking lot design method diagram.

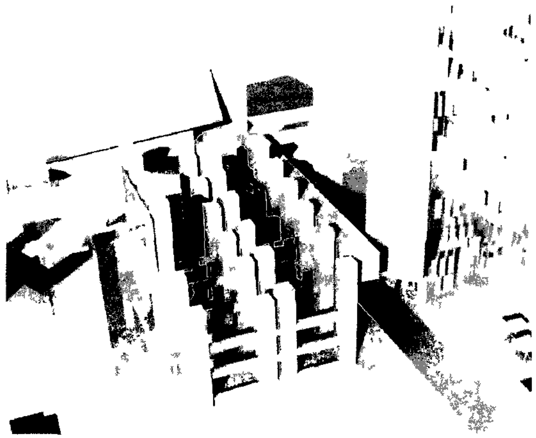


Figure 4.25:
Restaurant light duct placement.

Figure 4.26:
Photograph of the highly reflective surface within the light duct.

The Restaurant and Pub

The restaurant and pub are located within an existing brick clad building, previously known as 'The liquor store' bar, and seats a total of 220 people (128 in restaurant, 92 in the pub). Sandwiched between two buildings onsite and backed up against a third building from the south, the restaurant and pub's natural lighting is limited to rooftop skylights and supplementary artificial lights.

One company that specializes in natural light penetration within buildings is SunCentral Inc. , whose light systems automatically track, collect and concentrate sunlight before guiding it to a maximum of 20 metres within a space.[119] The system also seamlessly counteracts cloudy weather with artificial lighting. (Fig. 4.26-4.27) The restaurant and pub design readapts SunCentral's system to a vertical orientation through a series of skylight boxes, raised high enough to avoid the shadows of neighbouring buildings (Fig. 4.25). These ducts run downward along the columns and reflect the sunlight to plants growing from an aeroponic system anchored to the concrete girders. These beams of sunlight also run across the restaurant to illuminate the washroom sinks, staff room and front reception desk area.

The interior, stripped down to the structure, consists of exposed mechanical and aeroponic systems in a double height space. Plants such as

[119] *"The Technology". SunCentral Inc. <http.//www.suncentralinc.com/sunlighting.html>. 2010*

tomatoes, cucumbers and peppers grow downward providing a screen between dining tables,[120] while lettuce and other leafy greens grow upward on the second floor (Fig. 4.28a)

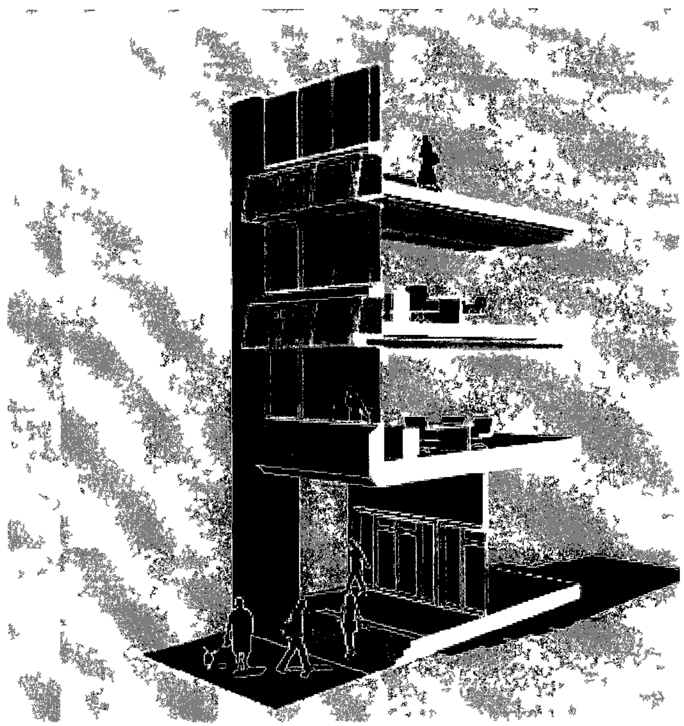


Figure 4.28 Diagram of standard SunCentral light ducts

[120] To grow plants upside down in an aeroponic system the plants must be trained to bend around curves and down By doing this there is no risk for the leakage of nutrient water dripping down the stem (Fig 4 28b)

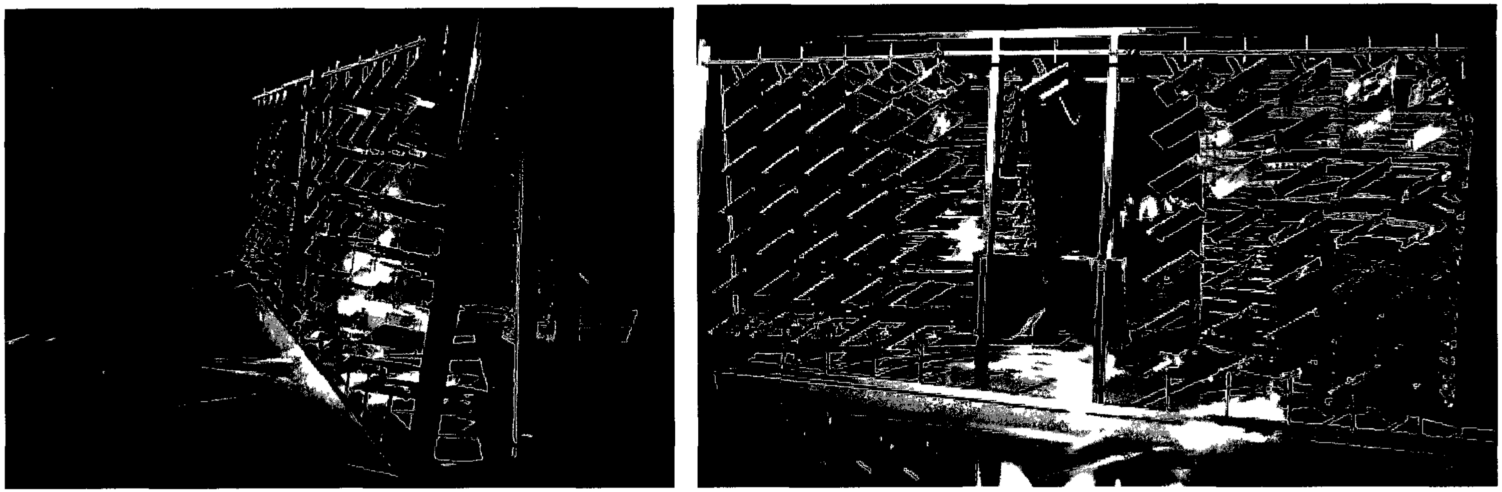


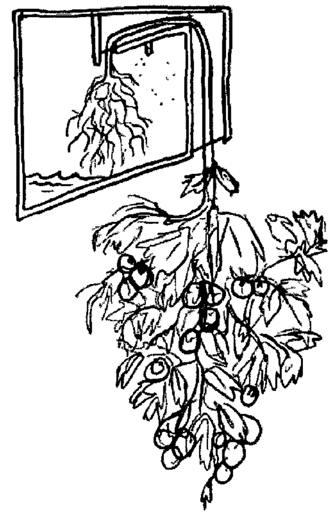
Figure 4.27:

Photographs of SunCentral's light capturing mirrors Each mirror is suspended by moving rods that direct the sunlight towards the light duct

Figure 4.28a Sectional diagram of restaurant integration depicting light ducts, glass partitions and plant growth orientation

Figure 4.28b:

An aeroponic system design that grows plants such as tomato and cucumber upside down. Growing plants upside down has only been done with soil based methods, not with aeroponics.



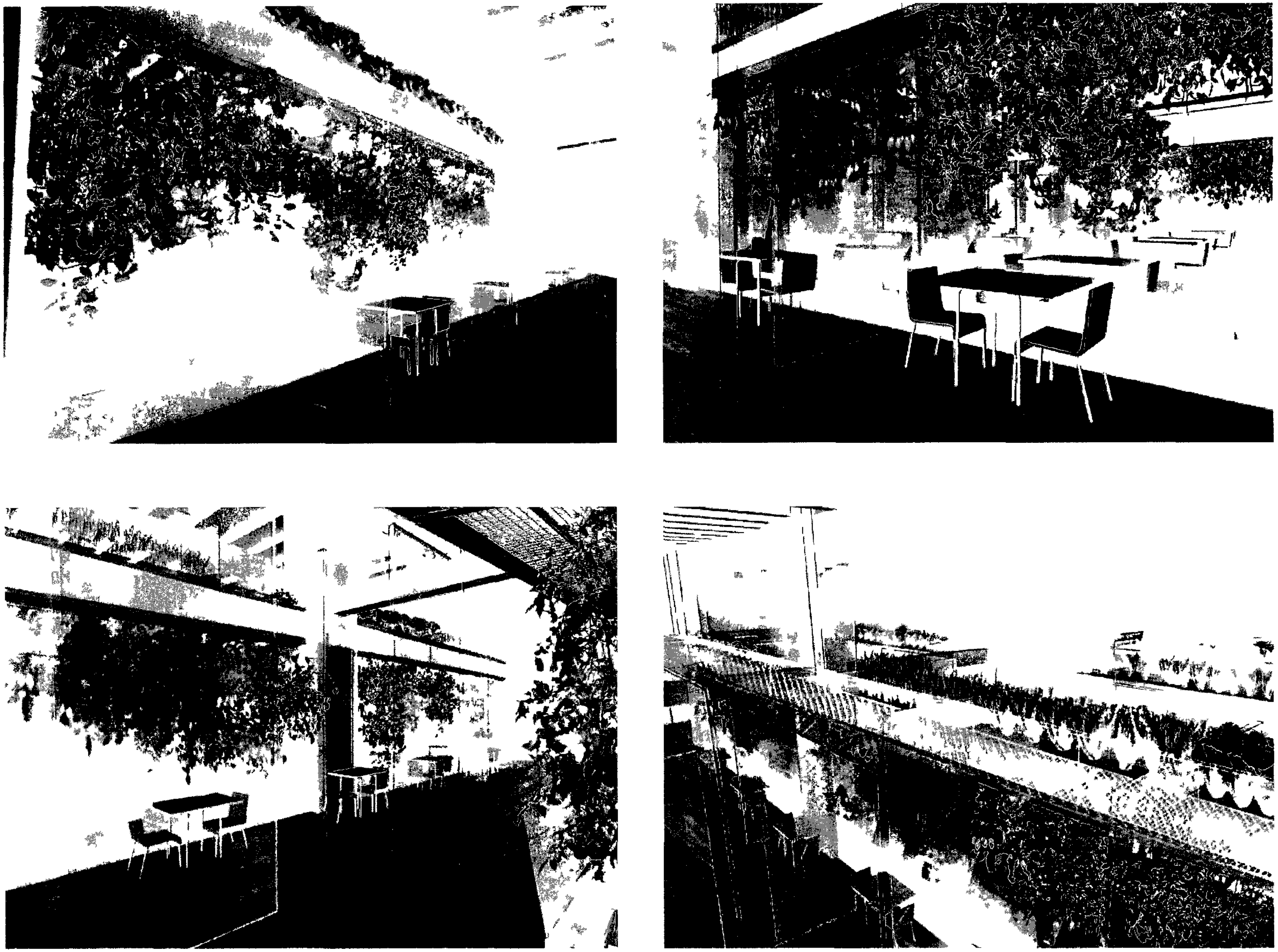


Figure 4.29a Four perspectives renders of the restaurant integration

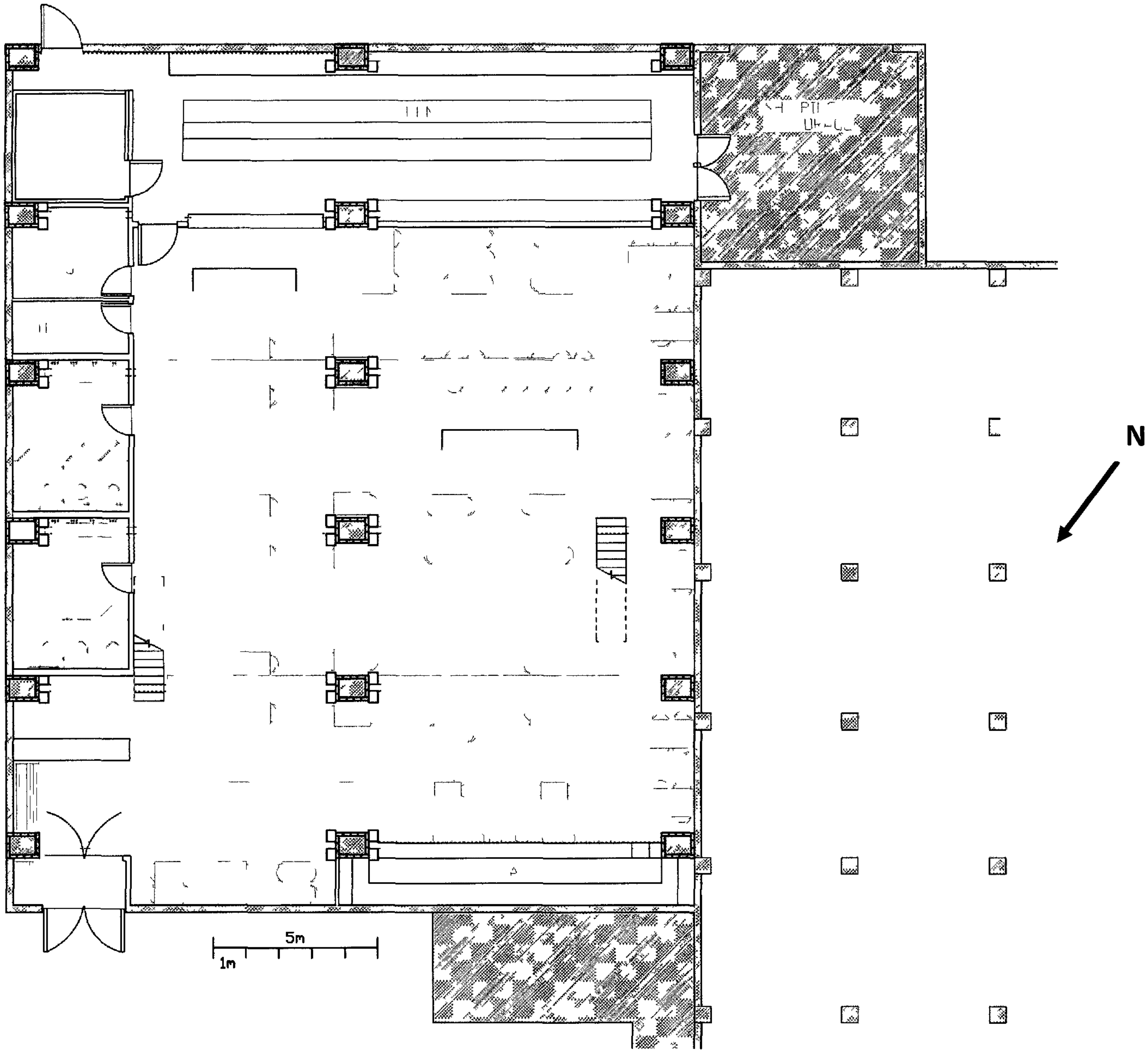


Figure 4.30a "The dining area is a labyrinth of glass panels and greenery, offering a different perspective the concept of greenhouses "
The dashed lines represent the concrete supports underneath the aeroponic systems (in green)

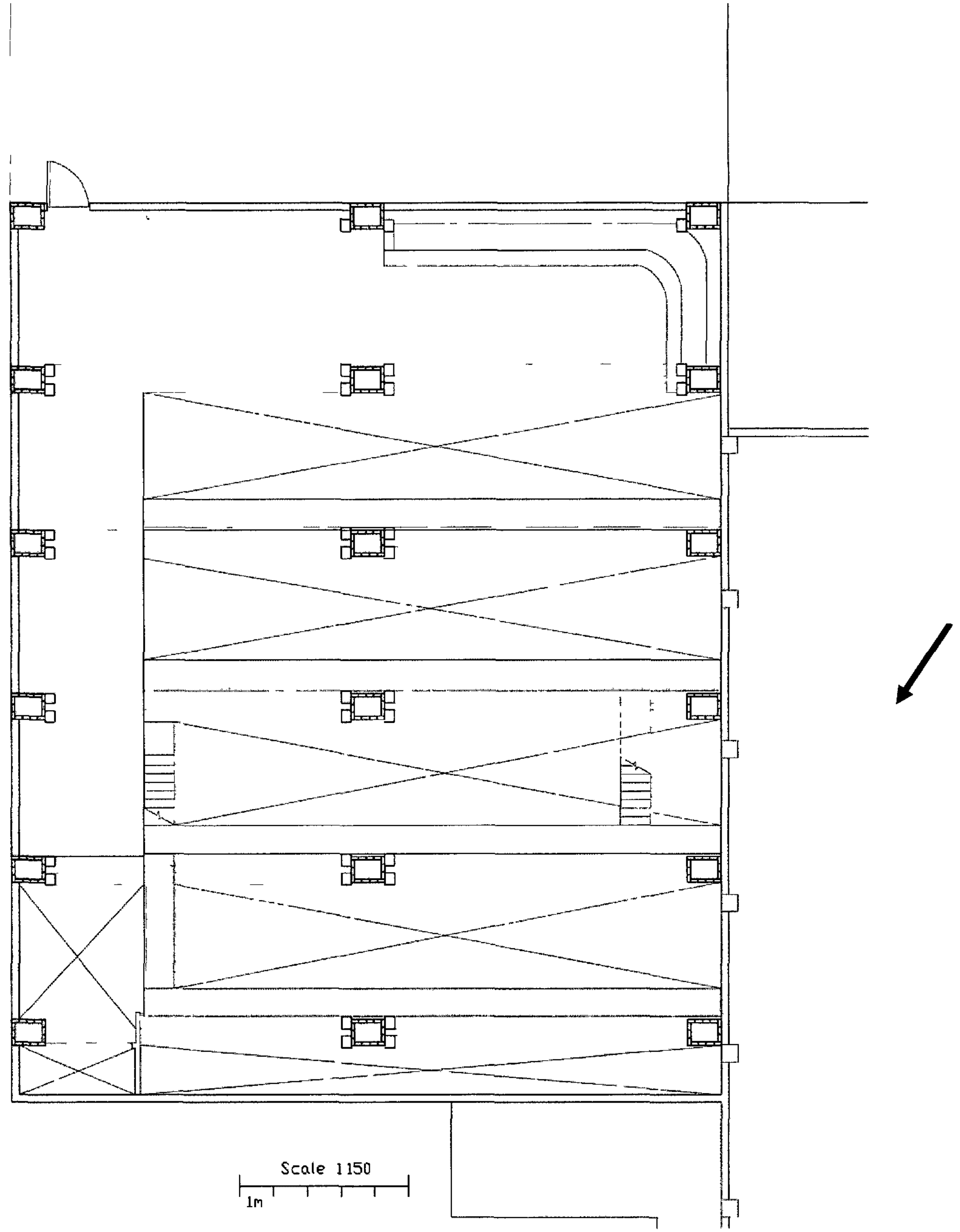


Figure 4.30b: "The second floor provides a small lounge and bar area as well as steel grate catwalks These catwalks invite the visitor to investigate the produce and systems in place, providing a transparent form of food production."

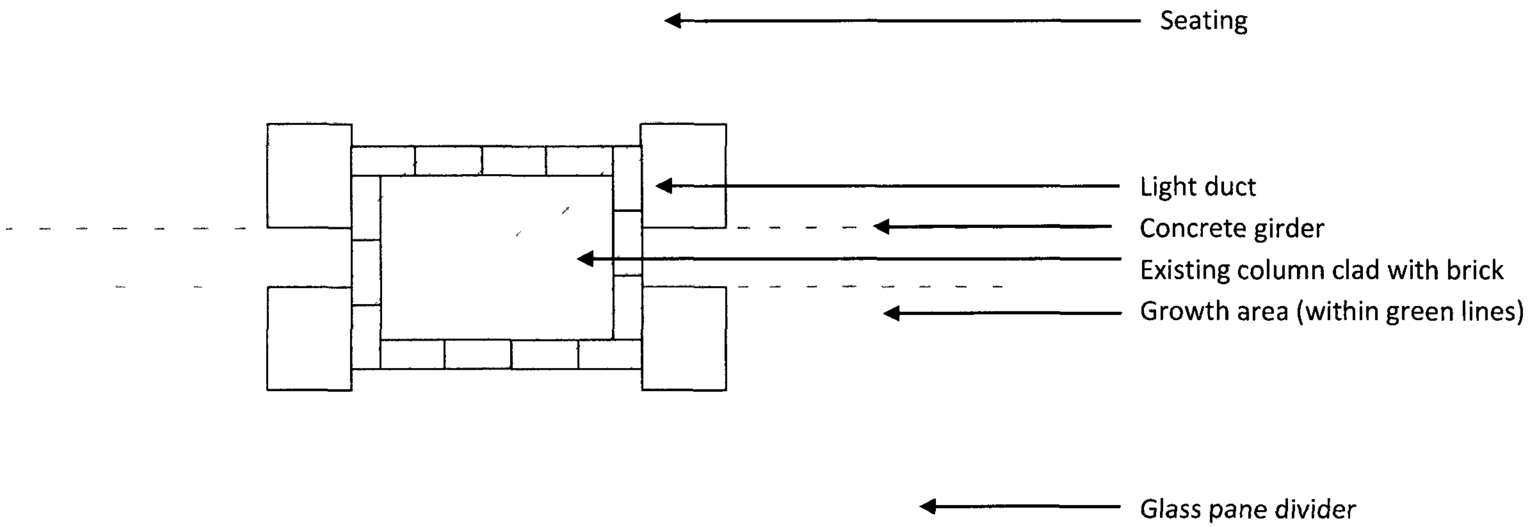


Figure 4.31 Plan view of a single column. There are four light ducts that anchor onto the existing brick clad column. The light is reflected outward towards the girders and then reflected once again towards the plants.

The dining area is a labyrinth of glass panels and greenery, offering a different perspective on the concept of greenhouses. The second floor provides a small lounge and bar area as well as steel grate catwalks. These catwalks invite the visitor to investigate the produce and systems in place, providing a transparent form of food production. The catwalks also provide the restaurant staff with easy access for harvest and maintenance (Fig. 4.29 & 4.30). This aeroponic garden restaurant establishes a healthy and sustainable balance of production and consumption.

The Office

Figure 4.32 Office design method diagram.

The office building has uninterrupted natural lighting conditions from the East, South and West. Within the building is a green roof and small food 'oducing spaces for a café, but this is not the focus of the design. The focus is on beneficial by-products that are not edible, yet are still highly desired; clean air and oxygen. The office (Fig. 4.33 - 4.34) adapts existing bio-filter systems by Naturaire[121] into a space that emphasizes these specialized air ducts. These ducts actively draw air in through plants such as ferns and mosses where beneficial microbes degrade pollutants in the air. The clean air is then

[121] The Naturaire® indoor air biofilter is an interior plantscape that effectively removes contaminants and improves the living environment. ("Nedlaw Living Walls". Nedlaw Roofing Limited. <http://www.naturaire.com/index.php>. 2011)

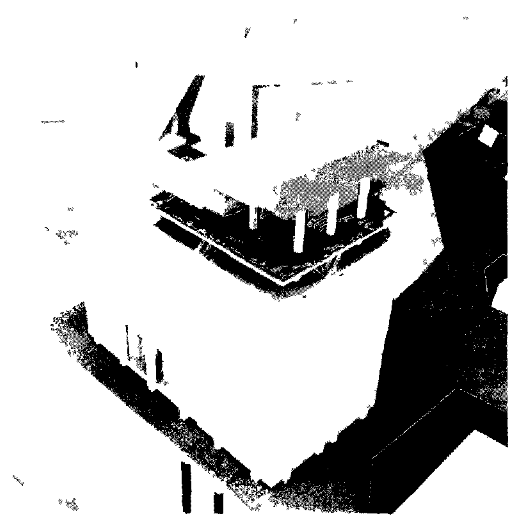


Figure 4.33:
Exterior perspective of office building.

distributed from the underside of the ducts to the spaces below (Fig. 4.35). This differs from existing models of bio-air purification because it is not secluded to a vertical green wall office (Fig. 3.36).

The reconfigured air ducts utilize existing structure by either anchoring onto or suspending from concrete beams and girders. The variety of angle placements and their positioning allows for light penetration and offers a landscape, or terrain like feel to the office. The ducts weave up and down through the space transforming into walls, partitions, ceilings, floors and seating (Fig. 4.39). The new office hallway runs through the centre of the space, elevating inhabitants a few inches over the plants with a glass catwalk. ıe absence of a duct in the circulation pathway creates an entry point into ırious office areas (Fig. 4.40). On the second level the floor is composed of glass, allowing employees to hover above this green interior terrain below. In some instances the air ducts from below angle sharply upward and penetrate the glass floor (Fig. 4.39).

The bio-filter is expected to remove 50% of air compounds per pass through the system. These compounds can consist on benzene, formaldehyde, methylethylektone as well as carbon and other air contaminates produced by human activity.[122] Normally these gasses are ventilated outward into the environment and new air is brought in as a replacement, requiring the heating

[122] "Nedlaw Living Walls". Nedlaw Roofing Limited. <http://www.naturaire.com/index.php>. 2011.

and cooling of exterior air. Along with filtration and purification of air, studies have proven that the presence of plants in a work environment improves the occupants well being in both physical and psychological realms.[123]

Figure 4.34

Sectional view

[123]Professor Lohr at Washington State University demonstrated that the inclusion of plants in computer classrooms reduced the stress levels and led to a 12% increase in the productivity of the students In another two year study at an Oslo office building, Professor Fjeld found a 20% reduction in fatigue levels and a 30% reduction in occurrence of headaches after the greening of the indoor space ("Nedlaw Living Walls" Nedlaw Roofing Limited <http //www naturaire com/index php> 2011)

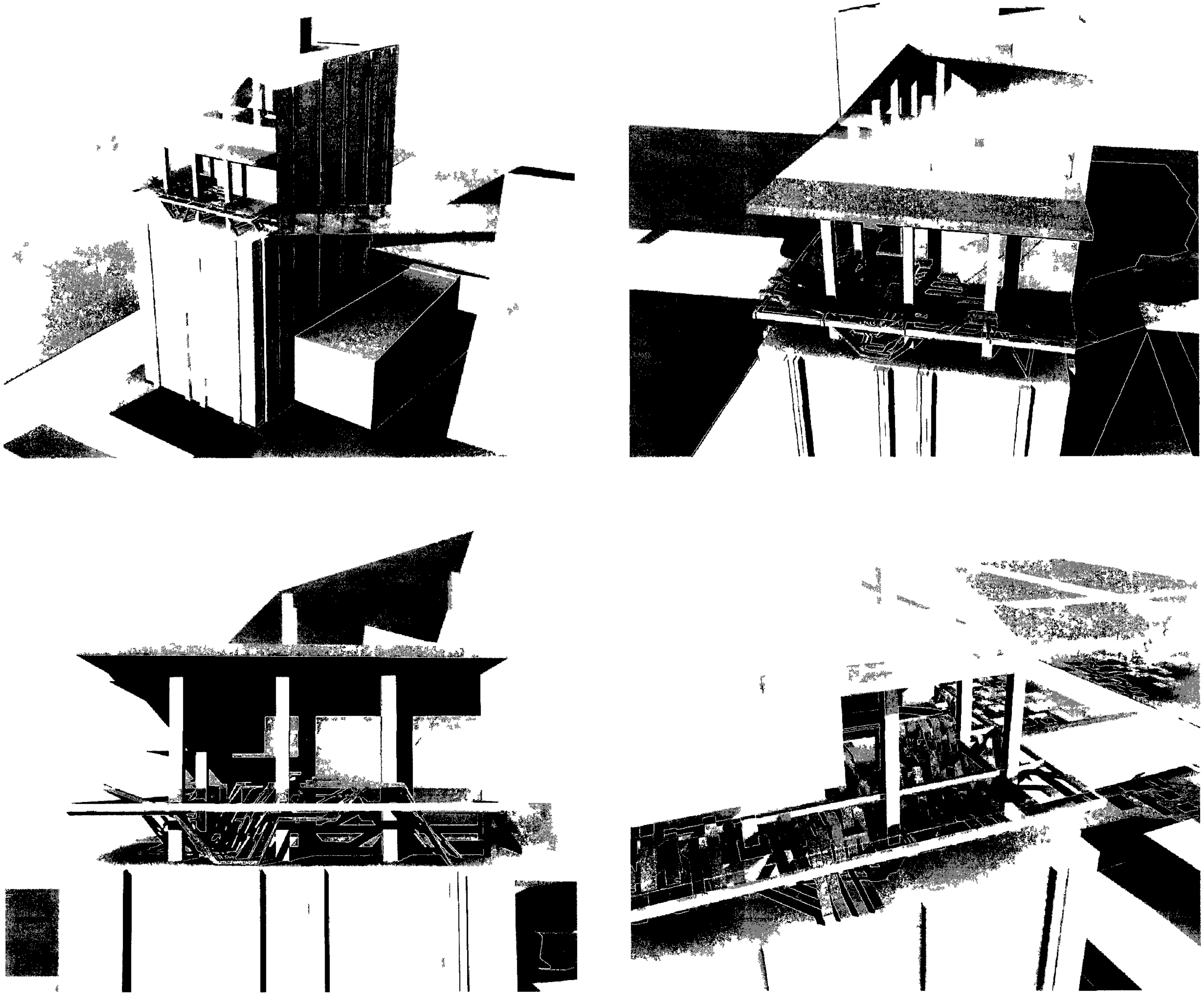


Figure 4.34 Old vs new (green) office building exterior perspectives

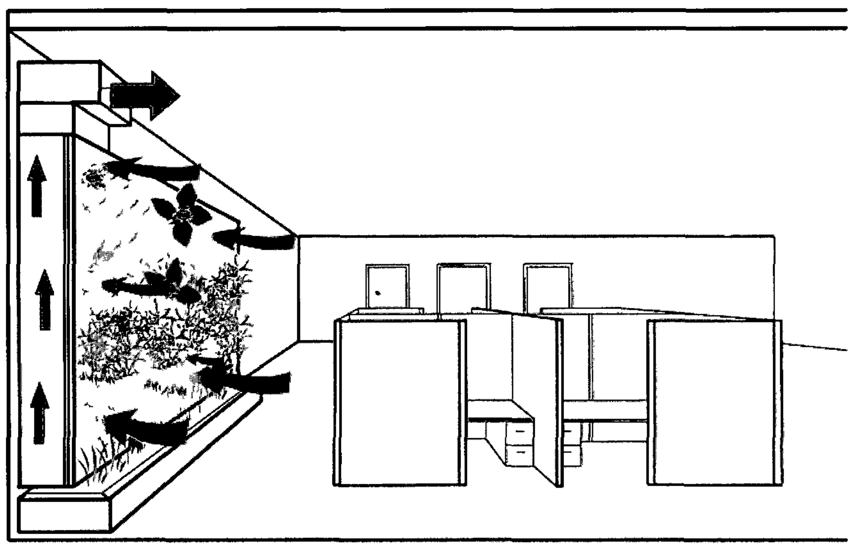


Figure 4.35: An existing plant based air purification systems photograph and diagram This system typically consists of a small green wall that does not utilize the current mechanical air system

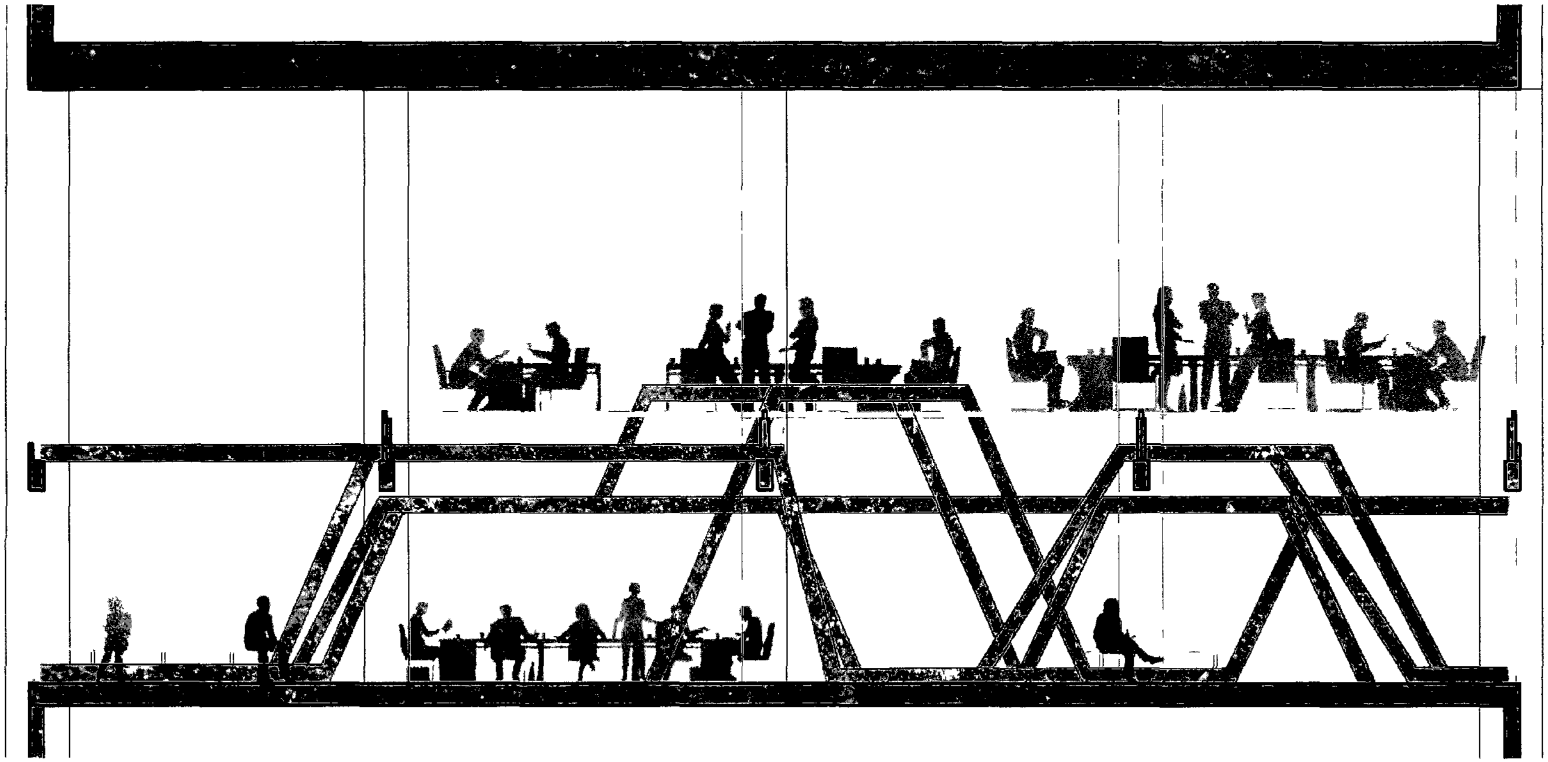


Figure 4.39: Sectional diagram of office space.

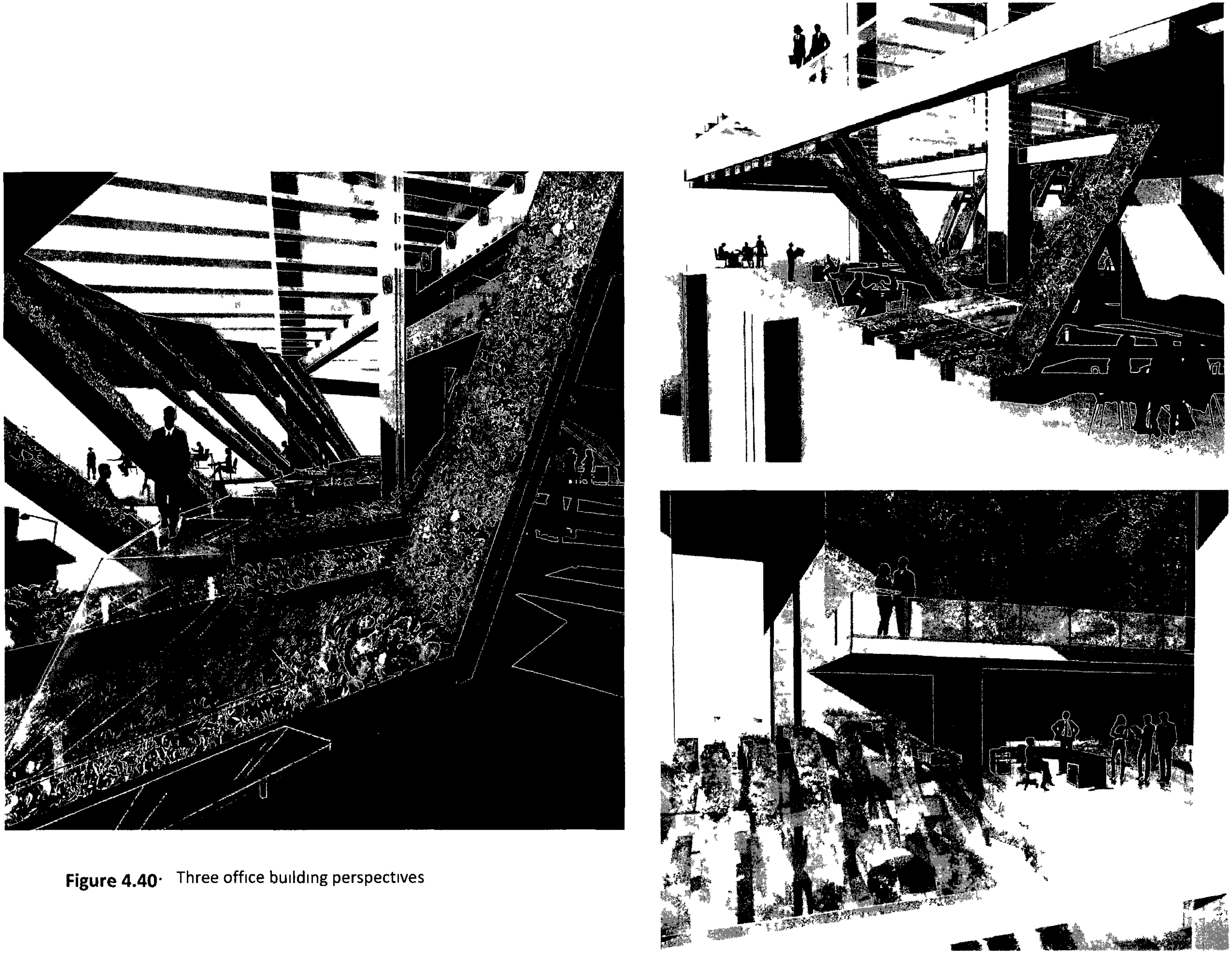


Figure 4.40· Three office building perspectives

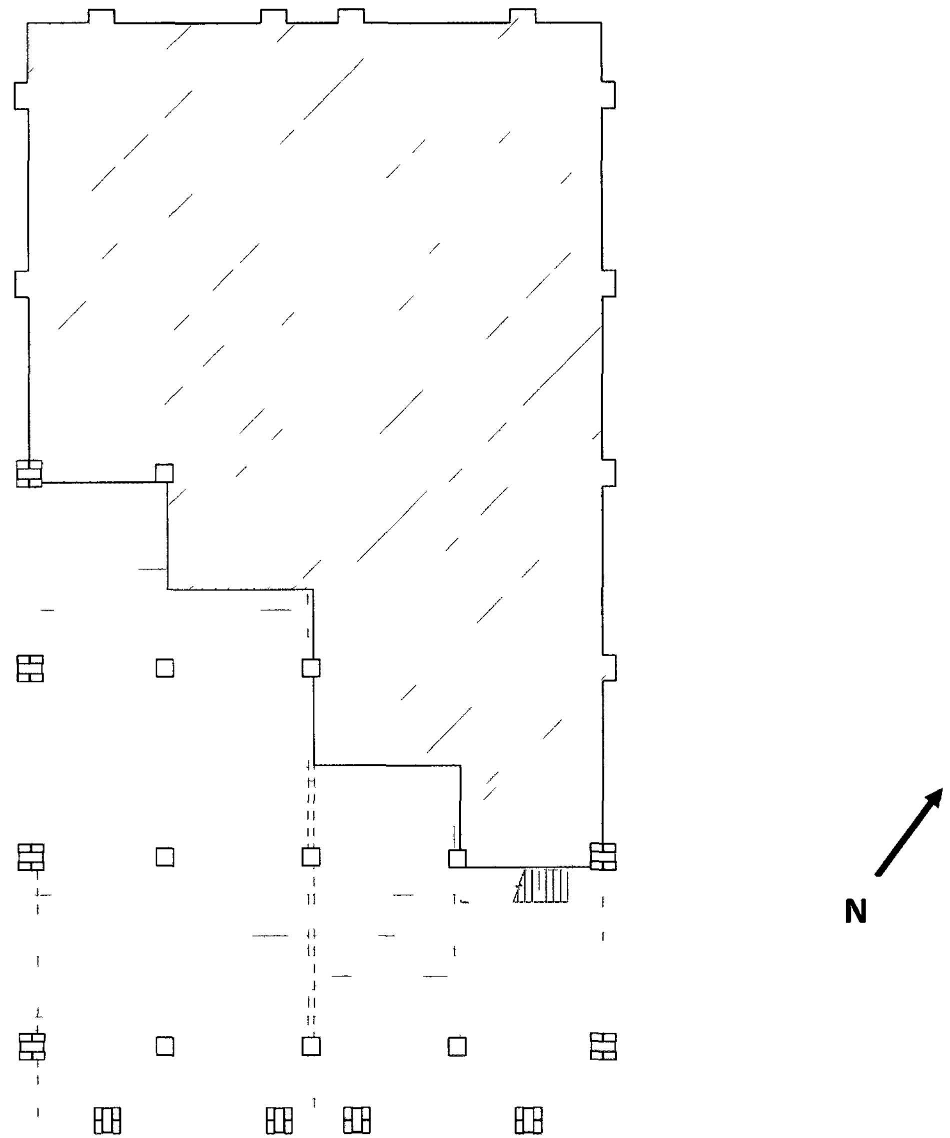


Figure 4.41 Floor plan of office building

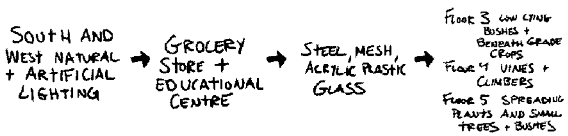


Figure 4.42:

Grocery store & educational centre design method diagram

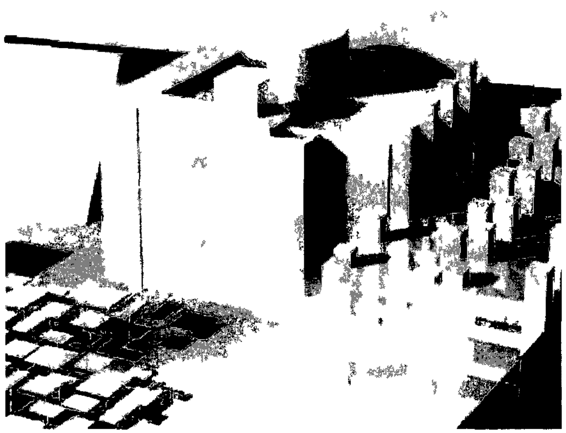


Figure 4.43:

Grocery store & educational centre design conceptual diagram where green is the installation and white is the existing

The Grocery & Educational Centre

As the largest interior integration on site, the grocery store and educational centre resides in the south end of the existing building. On the north side of the building the existing offices are kept intact. Within the building there are two opposing elements: one being the library / solar panel wall and the other a sky lit cone shaped atrium which is open to the public (Fig. 4.44). The exterior on the south and west sides of the brick clad building are encased with glass to protect the green wall from Ottawa's winter climate. This casing wraps around the building covering the roof in order to protect the public garden (Fig. 4.45).

The sectional view of the grocery store displays the variety of aeroponic and hydroponic growth throughout the building. Within the glass casing, a multi-story greenwall is anchored to the once exterior brick, growing leafy green plants such as lettuce or spinach (Fig.4.46). Each level of wall growth is accessed by a series of steel walkways that are only available to grocery store employees and aeroponic/hydroponic maintenance specialists.

Within the grocery store there are three variations of aeroponic modules made of steel and acrylic panels. Each variation is designed for specific plant types and are supported by an I-beam grid anchored to existing columns (Fig. 4.44). On the lower floor, there is a series of horizontal aeroponic systems for growing ground-dwelling plants and low lying plants

(Fig.4.47). A level up, the module is adapted to grow climbing plants such as peas, beans and soy. The top level specializes in growing spreading plants and small trees such as tomatoes, watermelons, cucumber, eggplant and squash. These plants grow upward onto a mesh netting that gives heavy produce such as watermelon some extra support until its harvest.

In the centre of the activity is a large circular atrium for the public to enter freely, perhaps on the way to the garden or library, here they are able observe the workers and the farming methods on display (Fig. 4.48). This cone-like 'cut' through the building funnels downward to the main level where the educational activities take place. Classes on a variety of urban gardening techniques and sustainable practices occur on this level to build up the agricultural knowledge of urbanites. A small commercial space selling fresh cuttings from aeroponic systems, seeds and equipment is also present on ground level.

Aside from growing produce this grocery store alters the standard shopping experience. If plants were freely available to pick from in a grocery store, many of them would become damaged or over picked. To ensure optimum plant health, a better approach is to have an order system. Located on the ground floor within the encasing glass atrium, urbanites can place their produce orders then wander through the educational space. This order system is similar to how a deli or a bakery functions in existing grocery stores.

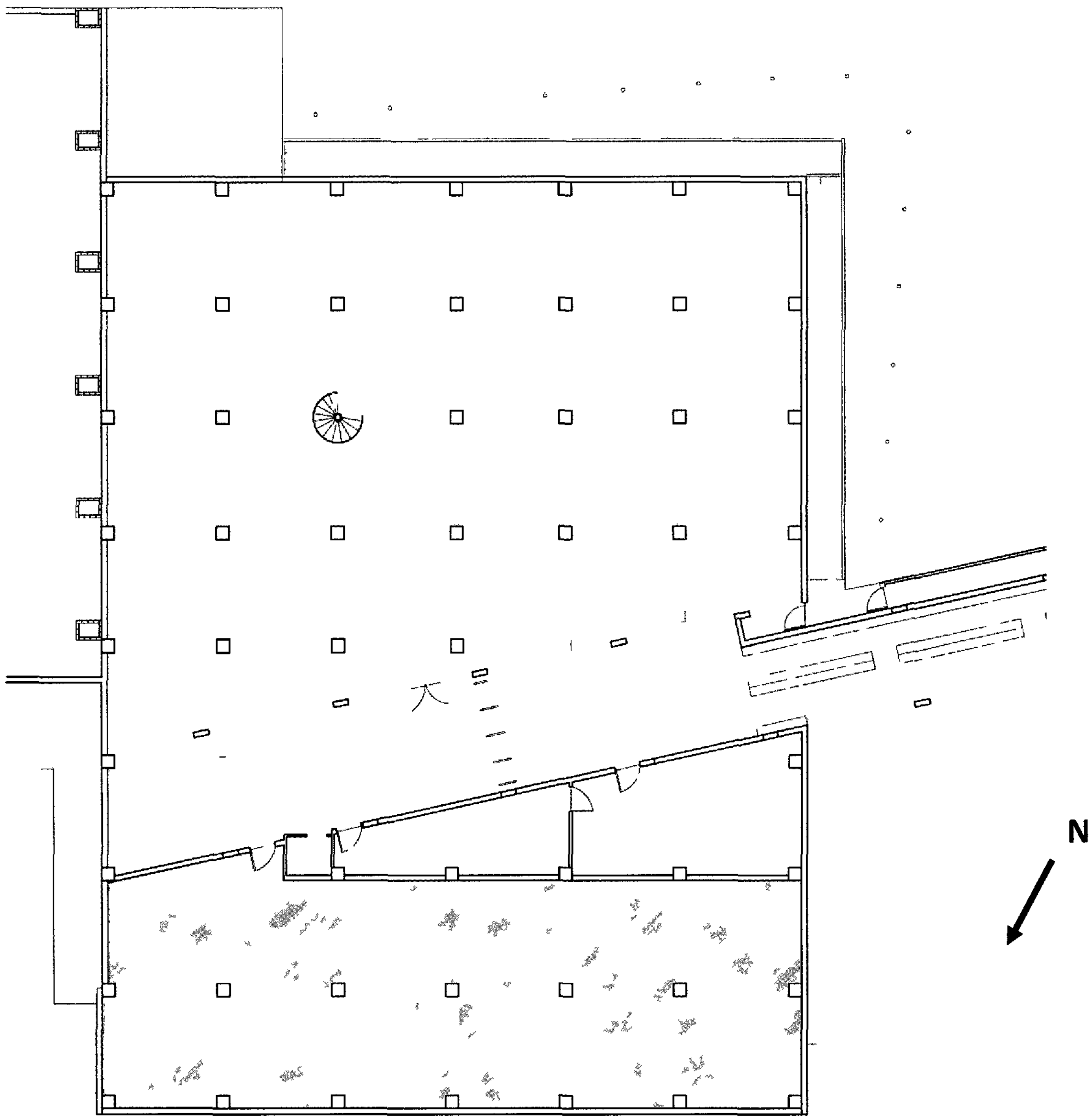


Figure 4.44: Floor plan of grocery store & educational centre

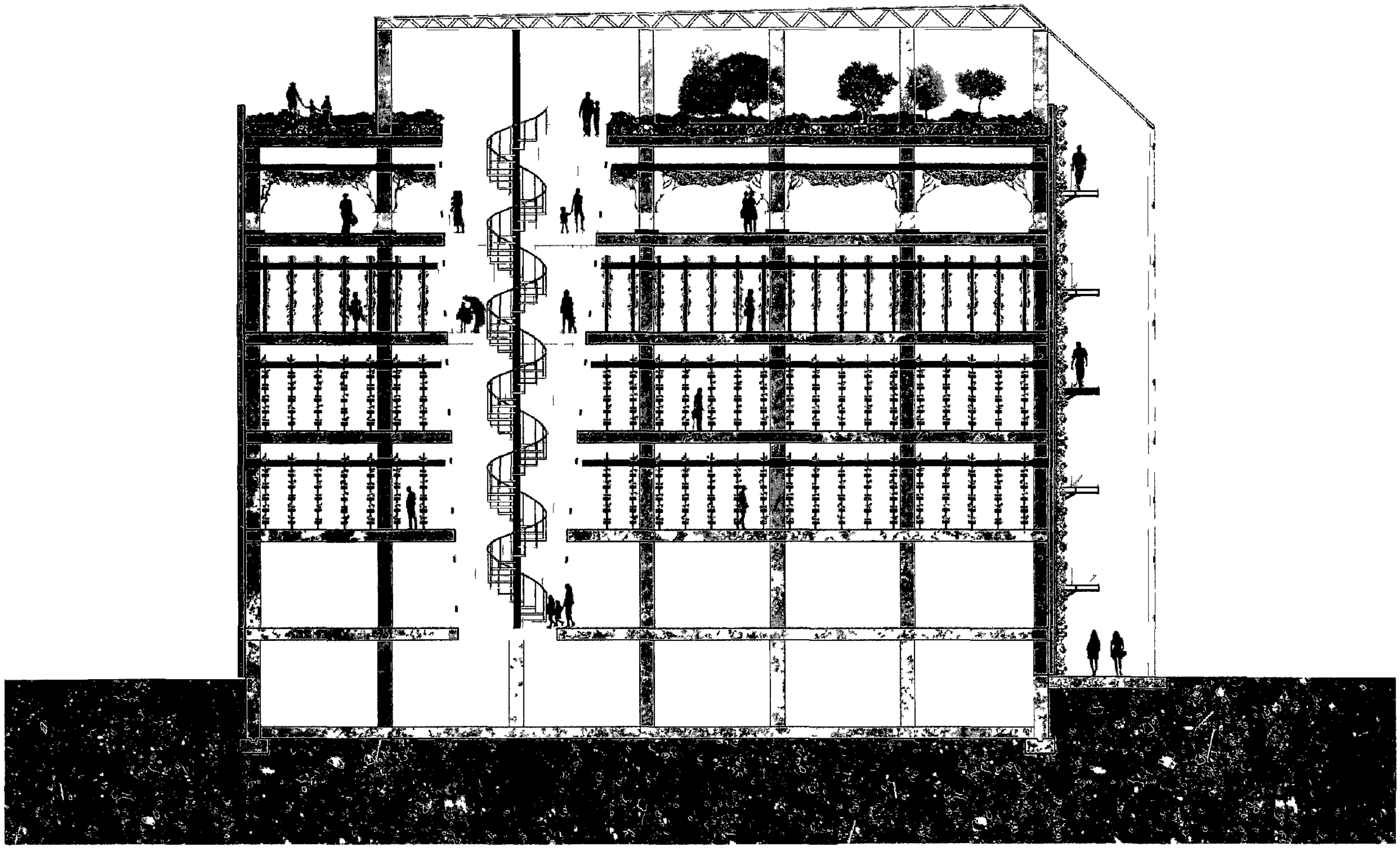


Figure 4.45: Sectional diagram of grocery store & educational centre

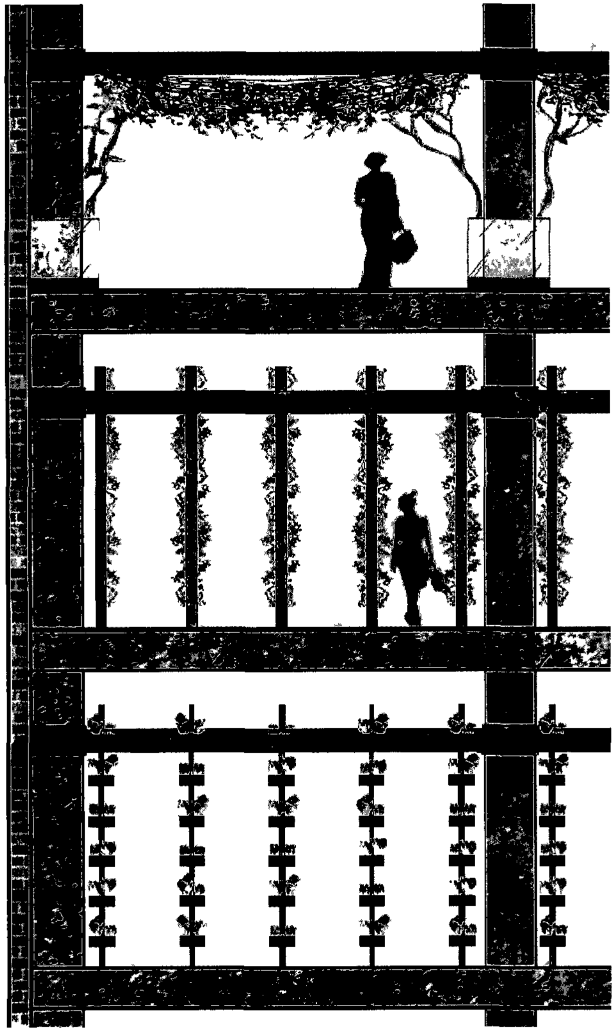


Figure 4.46: Close up of sectional grocery store diagram depicting the three different aeroponic systems.

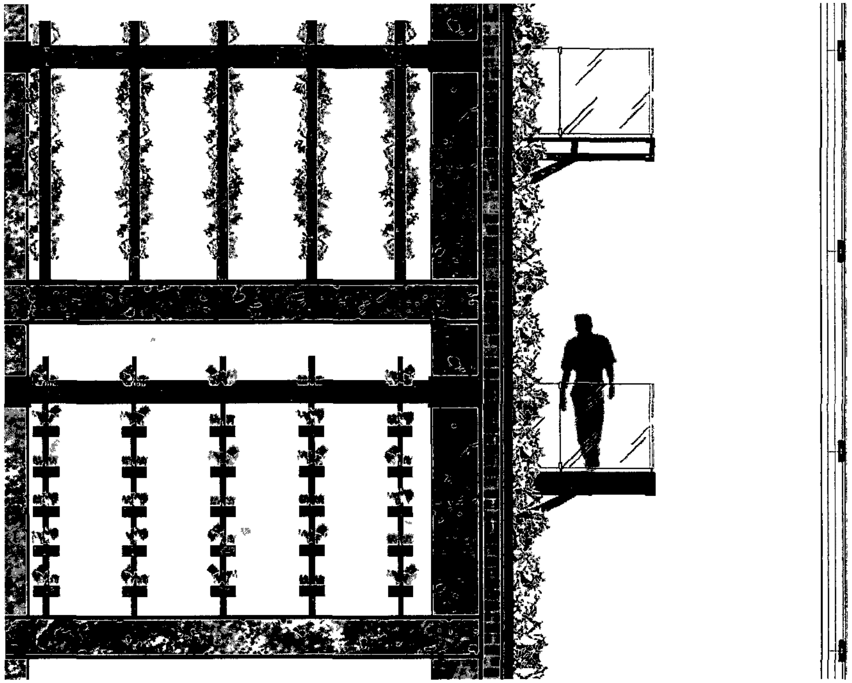


Figure 4.47: Close up of sectional grocery store diagram depicting the atrium green wall.

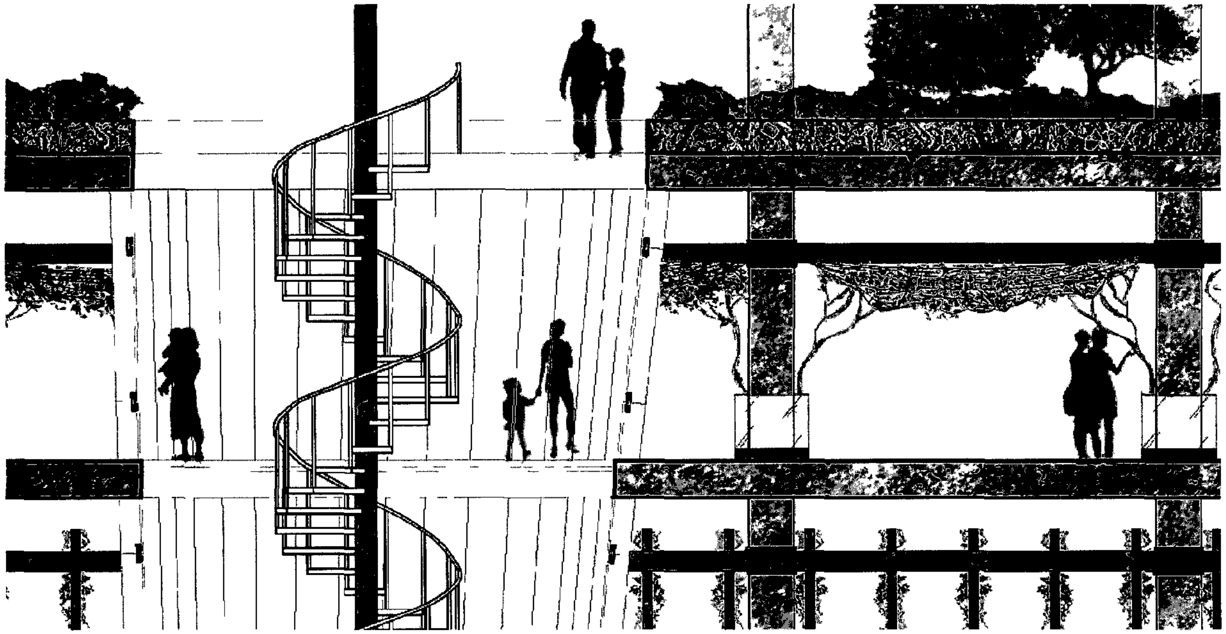


Figure 4.48: Close up of sectional grocery store diagram depicting the public atrium

Maintenance Spaces

There are a number of required maintenance spaces and circulation paths incorporated within the site design. These include a nursery and maintenance building, a water filtration building and a large photovoltaic screen. Enclosed bridges for agricultural specialists and the general public connect the integrations throughout the site (Fig. 4.49).

The existing 'Whiskey Bar', located in the shadows of the office building, is converted to a natural water purification centre. The plants along with bacteria that the live in symbiosis with the root systems can remove undesirable chemicals, materials, biological contaminants, heavy metals and other pollutants from the water.[124] This building can also actively experiment with aquaponic techniques to incorporate fish into urban agricultural systems safely while maximizing potential benefits.

Adjacent to the water purification centre is the main nursery and maintenance building. Plants will always require maintenance because with aeroponics they do not have access to rain and fresh soil nutrients. The systems also require plants to be germinated in a sponge-like material called rock wool. Once the plant is germinated it is placed directly into the aeroponic or hydroponic systems along with the rock wool cube. Having a nursery onsite will ensure quick replacement for plants that have ended their life cycle or have been damaged. The maintenance building also contains a seed depository, areas for nutrient mixture and the reuse of organic refuse and storage. Labs and testing rooms within the maintenance building will help provide space for experimentation and the development of new agricultural methods.

An additional energy resource is needed to power supplementary lights, air pumps and water pumps for the integrations throughout the site. A large solar panel screen supported by a steel grid is anchored to the library's exterior south facing wall. The panels rotate to track the suns movements

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[124] Országh Joseph. "How to Become Independent of Public Water Supply and Wastewater Networks". Eautarcie. <http://www.eautarcie.com>.2011

throughout the day. There are numerous perforations between the solar panels allowing for controlled light to enter the library space behind. With the solar wall absorbing the majority of the natural light it creates ideal lighting conditions for a library, providing daylight from the north façade while blocking direct sunlight from the south (Fig. 4.10 on a previous page).

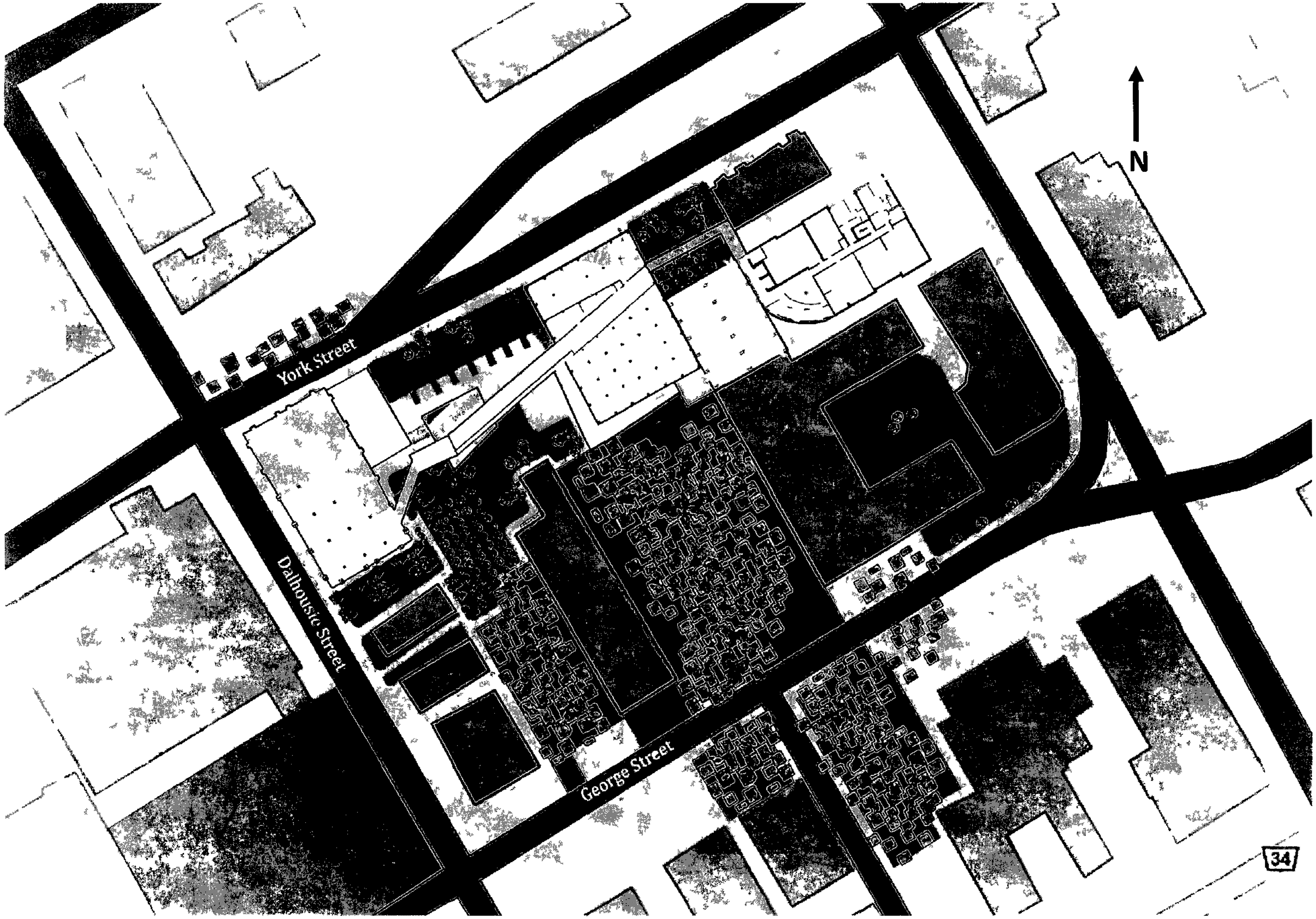

Figure 4.49

The Final figure-ground diagram: a series of agricultural integrations within a variety of existing spaces transform the site The productive agricultural spaces flow from interior to exterior (both public and private), linking the buildings within the block as a larger organism, and most importantly, addressing the issues surrounding urban food security and health

An untapped potential exists in the integration of agriculture and architecture. The designs proposed in this thesis are just a few of the many possibilities that can be developed and expanded upon in the future. With the exploration of agricultural advancements throughout history, the deeply rooted unsustainable practices that began with the start of cultivation and the development of cities. As cities formed agricultural practices became refined. Innovative man sought to improve efficiency through the industrialization of farming to further stabilize food security. The methods of innovation, which overlook their environmental impacts, eventually lead to our current food system; importing unripe, genetically modified and chemically filled produce. The majority of agricultural practices exist within unstable and intensive factory farms, also known as monocultures. This importation of produce is not a long term solution for food security, because within an urban setting it creates a dependency on outside sources.

These issues that extend throughout history to the present day can be addressed in part through architectural interventions by integrating interior urban spaces with a new agricultural system. Architecture evolved out of the necessity to provide shelter from the elements and to create a sense of security. We are in a situation where we have sufficient design and technological capabilities to restore the old relationship between the two practices, a relationship that dates back to our species' first civilizations.

Nothing evolves in isolation. With current agricultural methods posing a risk to food security, architecture should extend and include food within the many securities it already provides. By re-shaping new and existing spaces, and reconnecting them with their agrarian roots urban life can be fully secure and sustained.

Currently within cities there are very few interior urban agricultural spaces and the ones that do exist are limited to rooftops or greenhouses on the edge of urban landscapes. In order to accomplish the goal of sustaining urban life, not only does design have to take into consideration the spatial needs of plants by re-thinking building resources such as natural light, freshwater, heat, material etc. but also needs to be approached from environmental, social and economic perspectives to receive optimum benefits from these integrations.

(1) An office that purifies air to prevent the release of pollutants to the outdoors while improving the occupant's environment, productivity and health. (2) A restaurant that specializes in producing food while intriguing urbanites with growth orientation, technology and material selection. (3) A parking lot, normally void of design becomes a gathering place. (4) A grocery store which not only grows its own products, but is fused to a centre of knowledge and aims to share sustainable methods with the city.

The proposal on York Street and Dalhousie Street provides examples of possible integrations, demonstrating the flexibility of applying advanced growing methods on various programmatic spaces. Not only do these spaces provide environmental and social benefits, but if managed and organized properly they can become highly profitable when looking at the advantages of aeroponics in comparison to soil-based farming. However, the integration cannot remain on a single city block; it must expand further to reach the final objective.

Urban agriculture within the macro scale was conceived over ten years ago, but research and funding have not yet developed to tackle such a large scale. There are many elements that must be considered and require testing on a smaller scale before developing the large scale solutions that affect people, the planet and economics. This integration can be approached through smaller installations and through the spreading of information, demonstrated by the screen module design-build presented in this thesis. For example, a method of developing and manufacturing these screens locally would build a client market and could develop interest throughout Ottawa.

When the advantages of this new architectural function become known and accepted, the methods developed can spread and evolve throughout the downtown cores interior and exterior spaces. The aim is to move towards larger integrations, from building to building and then street to street until the entire city consumes produce within its means. These integrations provide a unique symbiotic relationship between the two practices for the benefit of urbanites and the environment. Society must apply the lessons taught by nature to the city and re-examine its place within it; It is time to evolve, it is time to grow.

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Figure 4 9 “Design method diagram ” Image copyright to Ashley Marcynuk

Figure 4 10 “Initial North street view and existing programmatic labels (top) ” Image copyright “Google Maps” <http //maps google com> 2011

Figure 4 11a “New and old A programmatic breakdown of the spaces within the site With the introduction of urban agricultural integrations, some of the initial programs have been redistributed but still remain within the city block ” Image copyright to Ashley Marcynuk

Figure 4 11b “New and old South perspective view and programmatic breakdown of the spaces within the site With the introduction of urban agricultural integrations, some of the initial programs have been redistributed but still remain within the city block ” Image copyright to Ashley Marcynuk

Figure 4 11c “New and old North perspective view and programmatic breakdown of the spaces within the site With the introduction of urban agricultural integrations, some of the initial programs have been redistributed but still remain within the city block ” Image copyright to Ashley Marcynuk

Figure 4 12 “Screen design method diagram ” Image copyright to Ashley Marcynuk

Figure 4 13 “Screen module design-build discussed in Chapter 3 ” Image copyright to Ashley Marcynuk

Figure 4 14 N/A

Figure 4 15 “Two screen module adaptations ” Image copyright to Ashley Marcynuk

Figure 4.16: "Floor plan of apartment building with possible screen integration placements. " Image copyright to Ashley Marcynuk.

Figure 4.17: "Parking lot design method diagram." Image copyright to Ashley Marcynuk.

Figure 4.18: N/A

Figure 4.19: "A sketch of the farmers market during the day." Image copyright to Ashley Marcynuk.

Figure 4.20: "Conceptual diagram of parking lot / farmer's market." Image copyright to Ashley Marcynuk.

Figure 4.21: N/A

Figure 4.22: "Farmers market agricultural integration section diagrams." Image copyright to Ashley Marcynuk.

Figure 4.23: "Material plan diagram of farmers market integration." Image copyright to Ashley Marcynuk.

Figure 4.24: "Parking lot design method diagram." Image copyright to Ashley Marcynuk.

Figure 4.25: "Restaurant light duct placement." Image copyright to Ashley Marcynuk.

Figure 4.26: "Photograph of the highly reflective surface within the light duct." Image copyright "The Technology". SunCentral Inc. <http://www.suncentralinc.com/sunlighting.html>. 2010.

Figure 4.27: "Photographs of SunCentral's light capturing mirrors. Each mirror is suspended by moving rods that direct the sunlight towards the light duct." Image copyright "The Technology". SunCentral Inc. <http://www.suncentralinc.com/sunlighting.html>. 2010.

Figure 4.28: "Diagram of standard SunCentral light ducts." Image copyright "The Technology". SunCentral Inc. <http://www.suncentralinc.com/sunlighting.html>. 2010.

Figure 4.28a: "Sectional diagram of restaurant integration depicting light ducts, glass partitions and plant growth orientation." Image copyright to Ashley Marcynuk.

Figure 4.28b: 'An aeroponic system design that grows plants such as tomato and cucumber upside down. Growing plants upside down has only been done with soil based methods, not with aeroponics." Image copyright to Ashley Marcynuk.

Figure 4 29 "Four perspectives renders of the restaurant integration " Image copyright to Ashley Marcynuk

Figure 4 30a "The dining area is a labyrinth of glass panels and greenery, offering a different perspective the concept of greenhouses " The dashed lines represent the concrete supports underneath the aeroponic systems (in green) " Image copyright to Ashley Marcynuk

Figure 4 30b "The second floor provides a small lounge and bar area as well as steel grate catwalks These catwalks invite the visitor to investigate the produce and systems in place, providing a transparent form of food production " Image copyright to Ashley Marcynuk

Figure 4 31 "Plan view of a single column There are four light ducts that anchor onto the existing brick clad column The light is reflected outward towards the girders and then reflected once again towards the plants " Image copyright to Ashley Marcynuk

Figure 4 32 "Office design method diagram " Image copyright to Ashley Marcynuk

Figure 4 33 "Old vs new (green) office building exterior perspective " Image copyright to Ashley Marcynuk

Figure 4 34 "Old vs new (green) office building exterior perspectives " Image copyright to Ashley Marcynuk

Figure 4 35 "Existing plant based air purification systems typically consist of a small green wall that does not utilize the current mechanical air system " Image copyright "Nedlaw Living *Walls" Nedlaw Roofing Limited <http //www naturaire com/index php> 2011*

Figure 4 36 N/A

Figure 4 37 "Old vs new office building exterior perspective ' Image copyright to Ashley Marcynuk

Figure 4 38 N/A

Figure 4 39 "Sectional diagram of office space " Image copyright to Ashley Marcynuk

Figure 4 40 "Three office building perspectives ' Image copyright to Ashley Marcynuk

Figure 4 41 "Floor plan of office building " Image copyright to Ashley Marcynuk

Figure 4.42: "Grocery store & educational centre design method diagram." Image copyright to Ashley Marcynuk.

Figure 4.43: "Grocery store & educational centre design conceptual diagram where green is the installation and white is the existing." Image copyright to Ashley Marcynuk.

Figure 4.44: "Floor plan of grocery store & educational centre." Image copyright to Ashley Marcynuk.

Figure 4.45: "Sectional diagram of grocery store & educational centre." Image copyright to Ashley Marcynuk.

Figure 4.46: "Close up of sectional grocery store diagram depicting the three different aeroponic systems." Image copyright to Ashley Marcynuk.

Figure 4.47: "Close up of sectional grocery store diagram depicting the atrium green wall." Image copyright to Ashley Marcynuk.

Figure 4.48: "Close up of sectional grocery store diagram depicting the public atrium." ." Image copyright to Ashley Marcynuk.

Figure 4.49: "The Final figure-ground diagram: a series of agricultural integrations within a variety of existing spaces transform the site. The productive agricultural spaces flow from interior to exterior (both public and private), linking the buildings within the block as a larger organism, and most importantly, addressing the issues surrounding urban food security and health. Image copyright Ashley Marcynuk.

Figure 4.50: Watercolor drawing. Image copyright Ashley Marcynuk.

Bibliography:

1. Alter Llyod. "The Urban Farm." Azure : Design architecture art. (May 2010): 58.
2. Attlee, James, and Lisa Le Feuvre. Gordon Matta-Clark: The Space between . Nazraeli Pr, 2003.
3. Avila, Cesar. "The Economics of Urban Agriculture." Urban Agriculture Magazine August 2002.
4. Benton-Short, Lisa, and John R. Short. Cities and Nature. Milton Park, Abingdon, Oxon ; New York : Routledge, 2008.
5. Bingham, Hiram. Lost City of the Incas: The Story of Machu Picchu and its Builders. Phoenix Publisher. October 28, 2003.
6. Blumenthal, U. "Reducing the Health Risks of using Wastewater in Agriculture." Urban Agriculture Magazine March 2001: 27.
7. Bohn, Katrin, and Andre Viljoen. "Continuous Productive Urban Landscapes: Urban Agriculture as an Essential Infrastructure." Urban Agriculture Magazine December 2006.
8. Bourque, M., and K. Canizares. "Urban Agriculture in Havana (Cuba)." Urban Agriculture Magazine July 2000: 27.
9. Brown, Allison. "Commercial Horticulture." Urban Agriculture Magazine December 2001: 15.
10. Cohen, Marc J., and Jennifer Clapp . The Global Food Crisis : Governance Challenges and Opportunities. [Waterloo, Ont.] : Wilfrid Laurier University Press, c2009.

11. Cooper, Adam. "Food for Thought = Alimenter Le débat." Plan Canada 49.2 (2009): 59-62.
12. Despommier, Dickson. the Vertical Farm: Reducing the Impact of Agriculture on Ecosystem Functions and Services. Columbia University: Department of Environmental Health Sciences.
13. Despommier, Dr Dickson, and Dickson Despommier. The Vertical Farm: Feeding the World in the 21st Century . Thomas Dunne Books, 2010.
14. Dobereiner, David. The End of the Street : Sustainable Growth within Natural Limits. Montreal ; New York : Black Rose Books, c2006.
15. Doron, Gil. "Urban Agriculture: Small, Medium, Large." Architectural design 75.3 (2005): 52-9.
16. Drescher, A. "Urban Agriculture, a Response to Crises?" Urban Agriculture Magazine July 2000:8.
17. Food, Inc. Dir. Kenner, Robert. Nov 3 2009. NTSC DVD. Alliance (Universal).
18. Fosket, Jennifer, and Laura Mamo . Living Green : Communities that Sustain. Gabriola Island, BC : New Society Publishers, c2009.
19. Fraser, David. Animal welfare and the intensification of animal production: An alternative interpretation, Food and Agriculture Organization of the United Nations, 2005.
20. Gross R. and Solomons N. "The History of Factory Farming. United Nations.Web. 10/4/2010 <http://www.unsystem.org/SCN/archives/scnnews21/ch04.htm>.
21. Haller, Ginny, Isabelle Groc, and Greg Flisram. "A Serious Flirt with Dirt: Urban Farming Makes a Comeback." Planning 75.8 (2009): 14-9.
22. Heiser, Charles B. (Charles Bixler),. Seed to Civilization : The Story of Food. 2d ed. ed. San Francisco : W. H. Freeman, c1981.

23. Hoek, Wim van der. Urban Wastewater : A Valuable Resource for Agriculture, a Case Study from Haroonabad, Pakistan. Colombo, Sri Lanka : International Water Management Institute, c2002.
24. Irving Knobloch, ed. Selected Botanical Papers., 1963.
25. Lee, Pamela M. Object to be Destroyed: The Work of Gordon Matta-Clark . New edition ed. The MIT Press, 2001.
26. Lee-Smith, Diana. "Carrot City:Designing for Urban Agriculture." Urban Agriculture Magazine June 2009: 43.
27. Lim, C. J. "Cultivating Smartcities." Architectural design 80.2 (2010): 96-103.
28. Mendes, Wendy. "Using Land Inventories to Plan for Urban Agriculture: Experiences from Portland and Vancouver." Journal of the American Planning Association 74.4 (2008): 435-49.
29. Miller, GT. Living in the Environment (12th Ed.). Belmont: Wadsworth/Thomson Learning, 2002.
30. Mock, Terry. "Building a Sustainable Urban Forest." Urban Agriculture Magazine December 2004: 29.
31. Mougeot, Luc. "Urban Agriculture: Concept and Definition." Urban Agriculture Magazine July 2000: 5.
32. Mubvami, Takawira. "Availability, Access and Usability of Land for Urban Agriculture." Urban Agriculture Magazine December 2003: 1.
33. NASA Spinoff. Progressive Plant Growing Has Business Blooming. Environmental and Agricultural Resources NASA Spinoff 2006. 68-72.
34. Nordahl, Darrin. Public Produce: The New Urban Agriculture . Island Press, 2009.
35. Országh Joseph. "How to Become Independent of Public Water Supply and Wastewater Networks". Eautarcie. <http://www.eautarcie.com>.2011

Perf. Judy Garland, Ray Bolger, Bert Lahr and Jack Haley. Metro-Goldwyn-Mayer, 1939.

36. Perf. Judy Garland, Ray Bolger, Bert Lahr and Jack Haley. Metro-Goldwyn-Mayer, 1939.
37. Petrini, Carlo. Slow Food Nation: A Blueprint for Changing the Way we Eat . Rizzoli Ex Libris, 2007.
38. Petrini, Carlo. Slow Food: The Case for Taste. Columbia University Press, 2004.
39. Samanian, Sanam. "Carrot City: A Recent Exhibition at Toronto's Design Exchange Presented a Cross-Section of Current Ideas Associated with Urban Agriculture Exhibition Review." Canadian architect 54.6 (2009): 26-8.
40. Saundry, Peter. "Haber, Fritz." The Encyclopedia of Earth.Web. Chemical Heritage Foundation. 10/4/2010 <http://www.eoearth.org/article/Haber,_Fritz>.
41. Seeds in the City the Greening of Havana. Dir. Phinney, Richard. Knowledge in Action : [distributed by] Sound Development, c2003.
42. Stoner, R.J. and J.M. Clawson A High Performance, Gravity Insensitive, Enclosed Aeroponic System for Food Production in Space. Principal Investigator, NASA. (1997-1998).
43. Stromberg, Meghan. "Toronto Mandates Green Roofs." Planning 75.7 (2009): 6.
44. Supernatural: Unseen Power of Animals: Outer Limits. Dir. John Downer. Prod. John Downer Productions Ltd. 1999.
45. The Future of Food. Dir. Koons, Deborah. Nov 13 2007. DVD. Virgil Films and Entertainment

46. The True Cost of Food. The Sierra Club National Sustainable Consumption Committee. 2005. DVD/VHS.
47. Urban Agriculture: Diverse Activities and Benefits for City Society . Earthscan Publishers, 2010.
48. Viljoen, A., K. Bohn, and J. Howe. Continuous Productive Urban Landscapes: Designing Urban Agriculture for Sustainable Cities. 1st ed. Architectural Press, 2005.
49. Wekerie, Gerda. "Planning for Urban Agriculture in Suburban Development in Canada." Urban Agriculture Magazine July 2001: 36.
50. Wilson, Geoff. "Can Urban Rooftop Microfarms be Profitable?" Urban Agriculture Magazine August 2002: 22.
51. Windterborne, Jeffrey. Hydroponics: Indoor Horticulture . Pukka Press, 2005.
52. Wojcik, Jan,. The Arguments of Agriculture : A Casebook in Contemporary Agricultural Controversy. West Lafayette, Ind. : Purdue University Press, 1989.
53. Wolf, Kathleen. "Economics and Public Value Or Urban Forests." Urban Agriculture Magazine December 2004: 3
54. "Steven Holl Architects."Web. <http://www.stevenholl.com/>.
    "Aeroponics: High performance Aeroponic Systems. Agri-house Inc. Web. <http://www.aeroponics.com/>.
55. "Aztec Agriculture - Rich and Varied" Aztec History.Web. 10/4/2010 < http://www.aztec-history.com/aztec-agriculture.html>.
    "BrightFarm Systems". Commerical Company Website. <http://www.brightfarmsystems.com/> 2011.
    "Emission Database for Global Atmospheric Research (EDGAR)." European Commission JRC Joint Research Centre and the Netherlands Environmental Assessment Agency .Web. <>. 2010.

56. "Monoculture". Dictionary.com. 01/15/2011. http://www.dictionary.com

"Monsanto Company" <http://www.monsanto.ca>. 2010.

57. "Nedlaw Living Walls". Nedlaw Roofing Limited. <http://www.naturaire.com/index.php>. 2011

58. "The Technology". SunCentral Inc. <http://www.suncentralinc.com/sunlighting.html>. 2010.