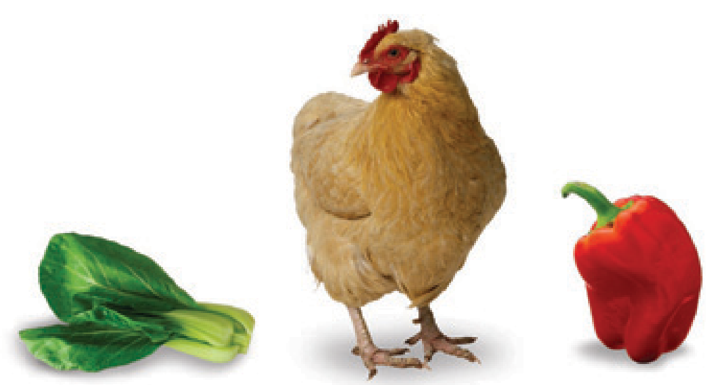
from dead space **to** food space.

designing a rooftop farm for urban sacramento.

by andrew emmert.



from dead space **to** food space.
designing a rooftop farm for urban sacramento.

A Senior Project
Presented to the Faculty of the
Landscape Architecture Department of the
University of California, Davis
in Partial Fulfillment of the Requirement
for the Degree of
Bachelors of Science of Landscape Architecture

Accepted and Approved by:

____
Senior Project Advisor, Professor Mark Francis

____
Faculty Advisor, Professor Stephen Wheeler

____
Committee Member, Raoul Adamchak

____
Committee Member, Josiah Cain

Andrew Emmert
June 12, 2009

abstract.

Feeding the world is a big job. And the methods of modern, industrial agriculture have appeared to be getting the job done. But, this success has not come without compromises. Over-farming has rendered shocking amounts of land that was once productive, useless. Equally astonishing amounts of potential farmland have been consumed by development to accommodate an expanding population. Agriculture's lifeblood, fossil fuel, is rapidly disappearing, making modern, industrial farming methods increasingly costly. And yet, world population is growing at an unprecedented rate, and the demand for food just keeps increasing. To meet this swelling need, agriculture must devise new ways to adapt to this rapidly changing world. One solution is to look to the rooftops. In urban centers, these dead spaces have the potential to become valuable agricultural real estate. Rooftop agriculture that is practiced in a sustainable manner may not only help to alleviate many of the problems associated with modern, industrial agricultural methods, but it also can create a host of additional benefits. In downtown Sacramento, the California Department of Food and Agriculture's building may be a promising location for one of California's first rooftop farms.

For my family and friends,
whose love and support has helped me weather the storms.

And for La Raye,
who has willingly endured it all with me.

contents.

list of figures.

acknowledgements.

This project would not have come together if it were not for the help of many selfless individuals:

Thank you to my various senior project advisors and committee members for guiding me throughout this entire process. To Professor Stephen Wheeler, who was willing to advise one more student despite the fact that he already had too many. Your input has been invaluable. To Raoul Adamchak, who with his expertise in farming, a field I knew absolutely nothing about before starting this project, helped to point me in the right directions. To Josiah Cain, who is responsible for introducing me to rooftop agriculture. If it hadn't been for your studio, this project would likely be about a topic much less interesting. And finally, to Professor Mark Francis, who was always willing to donate his time to discuss my many project ideas, and who made it a point to periodically check-in on my progress.

Thank you to my friends, both new and old, who gave me the support I needed to survive this past year. To my old friends: Ben, Wes, Mike, Toby, Flavius, Elizabeth, and Neal--you guys have been amazing friends to me even when I have been not so great back. I am not worthy of such love and loyalty. Thank you. And, to my new friends: Julian, Charles, Tim, Brian, Jim, John L., John D., Todd, and Mark--you guys have been great mentors. Thank you for encouraging and inspiring me. And a special thanks to Brad, who donated his Sunday afternoon to teaching me about structural engineering!

Thank you to my family for your unending love. Thank you Mom and Dad for letting me bounce all of my ideas off of you, and thank you Mom for donating so much time helping me edit my writing. Thank you Grammy and Granddad for giving me a wonderful place to stay, and for not charging me rent! Thank you Ryan, Megan, and Marianne for forcing me to take a break and hang out with you. I definitely needed it!

And finally, thank you La Raye for always standing by my side through thick and thin. Your belief in me has helped me to believe in myself. Thank you for being patient with me. You are truly a blessing in my life.

preface.

"…We eat by the grace of nature, not industry, and what we're eating is never anything more or less than the body of the world."

-Michael Pollan

A refreshing gust of air blasts me as I enter the local Nugget supermarket in Davis, California. The cool air is a welcome respite from the miserable heat outside. It is the dead of summer in Davis, and my car does not have air conditioning, so for me, stepping into the carefully controlled, arctic-like, conditions of a supermarket provides me with quite a rush. Pathetic, I know. However, I am not here to enjoy the comfortable climate, I am here for food.

And what food there is! My eyes are instantly confronted with a gleaming and glittering bounty of fruits and vegetables from around the world, and overflowing the shelves. The apples before me have been shipped in from Chile, and they have been shined so brilliantly, that only the glossiness of the floors can perhaps rival them for my attention (the floors really are that glossy!). What's more, is that these apples are perfectly stacked in the shape of pyramid, but before I am able to contemplate what mass quantity of apples (and time) is needed to be able to construct structures out of them, my eyes have already leaped on ahead. There are rich green watermelons sitting atop a precisely carved block of ice to the right, piles of plump, ripe mangoes to the left, and farther ahead, a heap of golden pineapples flown straight from Hawaii. As I wander in deeper, I am greeted by a colorful patchwork of yellow, orange, green, and red bell peppers, all organized by their respective colors (If you have ever visited a Nugget supermarket, then you know what I am talking about!). Who ever would have thought peppers could become art? I am surrounded by such an overwhelming wealth of food that it is as if I have discovered Eden. Only in this Eden, the food has seemingly been harvested by its own accord. All of the picking, cleaning, and polishing has been done for me, and I have but to select the best specimen amongst the abundance of choices. What is so odd about this whole experience though, is that in the back of my head I am recalling all of the books and articles that I have read that claim our nation, and our world, is supposedly amidst a serious food crisis. However, I never could have guessed this by looking around the Nugget. Who could guess such a thing when we are surrounded by such plenty? But, nevertheless, according to many experts, agriculture is in crisis. And, unless we drastically change the current way we do agriculture in America, and in the world, the crisis may very well turn into utter catastrophe.

This project is about one possible solution that could help to alleviate this crisis: rooftop agriculture. Wait, grow food on a rooftop? I admit, it sounds a little far-fetched, but believe it or not, widespread farming on rooftops might be in our very near future. Throughout the course of this project, I will be exploring the concept of rooftop agriculture through both research and design. In chapter one I go into more depth about the current dilemma in our agriculture system, arguing that the way we grow our food needs to drastically change, or else our world will be in some even more serious trouble than we are in now. Chapter two explores the myriad of reasons why growing food on a rooftop is really a good idea. Not only could it help alleviate many of agriculture's current problems, but it could also create a host of other benefits. In chapter three I switch gears from research to design. In this chapter, I introduce the California Department of Food and Agriculture building as the basis for my design of an educational rooftop farm. In chapter four, is my discussion of my design for the rooftop farm, along with an assortment of visuals to get those imagination juices going. And finally, in chapter five, the limitations of my design, and the conclusions of my research are discussed. My hope for this project is to build a straightforward case for rooftop agriculture, and to show how a rooftop farm could be retrofitted to a building in urban Sacramento. So, please enjoy. Now, let's get started.

one.

our present food dilemma.

Our world may be producing more food per acre of land than ever before, but we are doing so at a great expense. Our fragile food system has been pushed to its' very limits, and yet demand for food is only expected to grow. Food productivity appears to be hitting a ceiling despite ever increasing inputs. Crucial resources such as land and fossil fuels are being exhausted at an unprecedented rate. The price of food is rising, the security of our globalized food system is being questioned, and overpopulation seems to be only getting worse. The system is ultimately unsustainable. Collapse is inevitable.

Overpopulation

According to *Popular Science* writer Amy Feldman, Recent population projections state that our world's population will rise from the current 6.7 billion people, to an estimated 9.2 billion people by 2050 (2007). Geologist Dale Allen Pfeiffer, and author of *Eating Fossil Fuels*, noted that in the United States (U.S.) alone, population is expected to double by this date (2006). Aside from the tremendous amount of land that will be needed to simply house this many people, an even more tremendous amount of land will be needed to feed them. Just how much land will be needed to feed such a massive population? According to *Scientific American* author Mark Fischetti, the amount of additional agricultural land needed to support an extra 2.5 billion people is roughly equal to the size of Brazil (2008). It is hard to imagine where any of this additional land might come from, since agriculture already accounts for almost forty-one percent of the Earth's land area (Feldman 2007). However, if history is any indicator, then much of this land will continue to be acquired from our world's forests. Pfeiffer notes that sixty percent of the world's deforestation is caused by agriculture (2006). This is a saddening reality. Since many of us are aware of at least some of the additional consequences of rampant deforestation, I need not go into them here. It is clear, however, that alternative solutions to clear-cutting our world's forests so that we can grow food to feed a burgeoning population must be sought.

Rampant Development

Farmland already disappearing due to rapid, unbridled development only worsens this dilemma further. Pfeiffer noted that in the U.S., development in the form of urbanization, road building, and industry, claims one million acres of farmland each year (2006). According to *The End of Food* author, Paul Roberts, in the California Central Valley alone, fifteen thousand acres of farmland is consumed by residential and commercial development yearly (2008). As population grows, demand for housing and expanded infrastructure will continue to grow. This may encourage many developers and city officials to put more pressure on farmers to sell their land for development. For some farmers, being offered an attractive premium for their land is tempting. Current development strategies must be revised.

Soil Degradation

For the farmland not being eaten up by rapid development, unsustainable farming practices are degrading it at an astonishing rate. Pfeiffer noted that ten million hectares of viable farmland throughout the world are abandoned each year because of severe degradation (2006). World-renowned gardener and ecologist John Jeavons describes this loss in perhaps a more revealing way. He explains that for every pound of food produced by conventional agriculture methods, six pounds of soil is destroyed (2006). How can farming produce such disastrous effects? It is, in part, largely due to the industrialization of agriculture, which I will do my best to summarize in the subsequent paragraphs.

Today, industrialized agriculture is producing more crops per acre of land than at any other time in history. This realization has come about for a number of reasons, but one large contributor to this increase is, due to the addition of chemical fertilizers to soil. In an effort to speedup nature's pace of food production, Americans and European researchers discovered in the 1950's and 1960's that by applying chemical fertilizers to the land (and by applying chemical pesticides to the crops), yields could be increased dramatically. For example, world wheat production increased by 250 percent between 1950 and 1984 due to these methods (Pfeiffer 2006). The ability to produce previously unimagined amounts of crops led many farmers to throw out many traditional agriculture methods, such as crop rotation, which helped preserve soil fertility. Now, as pointed out by famous ecologists Nancy and John Todd, a particular crop could be grown multiple times a year, increasing productivity by two to three times over traditional agriculture methods (1993). Farming a variety of crops soon gave way to farming expansive fields of a single crop (an agricultural practice previously unheard of) because newly developed industrial equipment could turn a *farm* into a *factory* for food. Farmers were no longer limited by natural cycles, or hindered by complex ecosystem interdependences. They could now, as author Michael Pollan of *The Omnivores Dilemma* puts it, buy "fertility in a bag" (2006, p. 45).

However, this new approach to agricultural is seriously flawed. Over-farming and over-fertilizing seriously degrades the health of soil. Roberts emphasizes that healthy soil has a high presence of rich, organic matter left from decaying organisms. This presence of organic matter is imperative for successful crop yields year after year. Traditional farming practices strived to preserve the organic matter. But, modern, industrial farming practices are over-intensive, and prevent the vital organic matter from replenishing (2008). This phenomenon translates into a slew of serious problems, but Roberts identifies two problems in particular, that I would like to explain in greater detail.

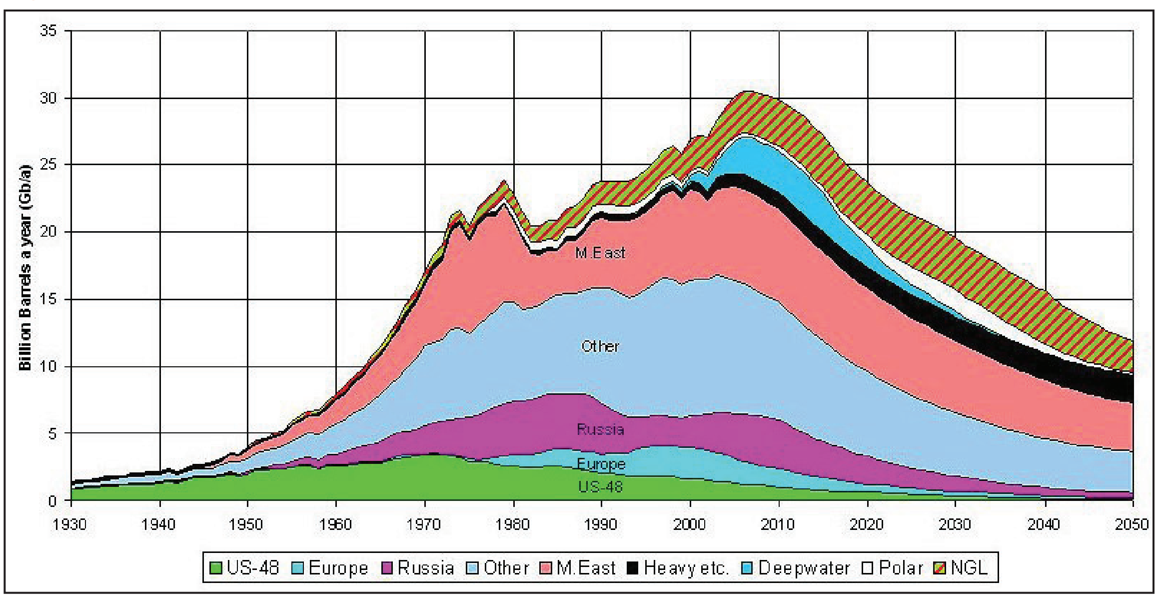
The first problem created by diminishing organic matter in soil is an increased rate of topsoil erosion. According to Roberts, organic matter in soil is responsible for helping soil particles stick together (2008). Without it, soil is vulnerable to being blown away by strong winds or washed away by heavy storms. According to Pfeiffer, two million acres of farmland is lost annually in the U.S. alone this way (2006). In fact, Jeavons claimed that topsoil is being lost across U.S. farms eighteen times faster than the rate at which nature is able to replenish it (2006). If you are like me, then the full impact of these statistics can be hard to comprehend. Todd and Todd perhaps paint a more understandable picture of what topsoil loss looks like on a worldwide scale. According to them, if you sprinkled a one inch layer of soil across half of the total area of China, then you would have the same amount of topsoil that is lost by farmers yearly (1993). That is a tremendous amount of soil.

The second problem caused by diminishing organic matter in soil is a reduction in the soil's ability to absorb additional nutrients. Roberts pointed out that when fertilizers are added to organic matter-rich soil, crop yields increase significantly (2008). This largely contributed to the crop boom in the 1950's and 1960's. But, when the soil's organic matter content is depleted by over-intensive farming practices, fertilizer's positive effect on crop yields is lessened. Today, this truth translates into quite a serious problem. As Pfeiffer pointed out, an *increasing* amount of fertilizer must be applied to degrading soils to simply *maintain* the new, higher crop yields (2006). What is worse is that these higher crop yields have enabled populations to rise to their current level, meaning we are increasingly dependent on this input. But this expensive trend cannot continue forever, because the production of chemical fertilizers is dependent upon another dwindling resource, which like land is vital to modern, industrial agriculture. This dwindling resource is fossil fuel.

Disappearing Fossil Fuels

Many people are aware that world fossil fuel reserves are declining. But, what many people don't realize is that the industry taking the biggest hit from this decline is agriculture. Going back to the historic increase in food productivity in the 1950's and 1960's, energy to create such an explosion had to come from somewhere. Obviously, it did not come from, as Pfeiffer sarcastically puts it, "from an increase in sunlight" (2006, p. 7). But rather, fossil fuels are responsible for this increase in food energy. This fossil fuel energy input primarily took the form of artificial fertilizers and pesticides, which are

Figure 1.1 Worldwide Peak Oil Production

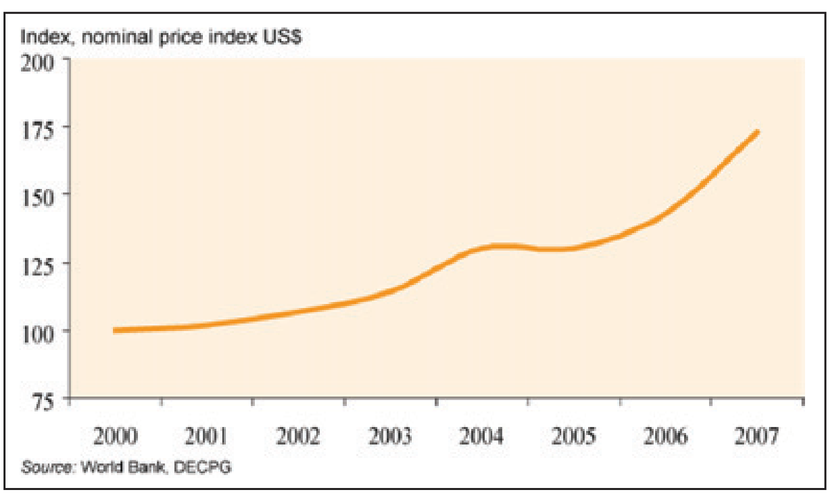


Graph chronicles past oil production for entire globe, and projects expected future production. According to this graph, peak oil production has already passed. *Source: http://www.planetforlife.com/oilcrisis/oilpeak.html* fossil fuel based, as well as fuel for both the farm machinery and the vehicles transporting the harvested food. In fact, according to Todd and Todd, when compared to other industries, agriculture uses the most petroleum (1993). Pfeiffer claimed that an estimated four hundred gallons of oil is used to feed one U.S. citizen annually (2006). Agriculture is utterly dependent upon an undependable resource. Such an "unhealthy" relationship is bound to have negative consequences.

One consequence of agriculture's dependence on diminishing fossil fuels is the negative effect on food prices. As the prices of fossil fuels continue to rise, so does the cost of the fossil fuel-based chemical fertilizers and pesticides that agriculture depends on. Farmers must spend increasingly more to keep producing the same amount of food. In addition, higher fuel prices drive up the cots of transporting food. All of these losses incurred by the farmers and transporters must be recouped somewhere. Consumers pay part of this extra cost, but according to the Pulitzer Prize winning columnist Thomas Friedman, governments are absorbing the majority. According to him, "Western industrial countries" expended $270 billion subsidizing agriculture in 2007. He goes on to conclude that these subsidies have "distorted" the recent market prices of food in favor of the consumer (2008, p. 41). In other words, we consumers have likely not yet felt the full effects that the rising cost of oil is having on food production.

In addition to higher food prices, the rising cost for fossil fuels puts our globalized, transportation-dependent, food system at risk. Like many other sectors of industry, agriculture has been transformed by the globalization and industrialization (as well as considerable government intervention) fueled by decades of cheap fossil fuels. As a result, the U.S. agricultural system has transformed itself into a highly complex, highly centralized, transportation-dependent, global and national network of

Figure 1.2 U.S. Food Prices Increase



Since 2000, the overall food prices in the U.S. have risen by 75% (does not account for domestic inflation) *Source: The World Bank* suppliers. Today's agricultural landscape looks much different than yesterday's agricultural landscape. According to Roberts, "the average American community produces just five percent of the food its citizens consume" (2008, p. 308). Pfeiffer observed that preparing the typical American meal requires the contribution of ingredients from at least five other countries (2006). In addition, food consumed in the U.S. also travels extreme distances. According to Bay Localize, a non-profit organization based out of Oakland, CA, one study found that the average distance conventionally grown food travels from its' production location to its' consumption location is 1,500 miles (2007). Although such a complex food transportation network may have at one time made economic sense, as Roberts points out, the system becomes increasingly precarious as fossil fuel costs rise (2008). Large regions of the nation are dependent upon these transportation networks to feed themselves. Without them, the effects on these areas could be devastating.

Is There Hope?

So what do all of these agricultural problems amount to? Land is being rapidly devoured by development, more land is being destroyed by unsustainable farming practices, the lifeblood of modern industrial agriculture—oil—is dwindling as its price rises ever higher, and the security of our complex, globalized food system is being compromised. Then when you throw in a burgeoning population that is both the product of, and dependent upon, many of the harmful practices that created these problems, you are left with an extremely fragile, national and world agricultural system that is teetering on the edge of disaster. Can our devastated food system still be salvaged? The future is unclear, but one thing is clear: change must occur. Rooftop agriculture could provide such change.

two.

the case for rooftop agriculture.

Why do agriculture on a rooftop? I admit, it sounds like one of those over-the-top kinds of ideas that you might hear being discussed on the *Discovery Channel* by some eccentric (and perhaps slightly delusional) “expert” whose only credentials are a few obscure science fiction novels. But, with farmable land becoming increasingly scarce, and a growing global population that needs to eat, even the most unusual places must be considered for growing food. And rooftops, lend themselves surprisingly well to this use. Rooftops in urban cities can provide additional “land space”, can decrease fossil fuel dependence, can create greater food security, can reduce environmental impacts, and can provide numerous economic benefits. However, before I get into the benefits of rooftop agriculture, I would first like to provide a brief explanation of what it is.

The Many Forms of Rooftop Agriculture

I told my uncle that the topic of my landscape architecture senior project was “rooftop farming”. When he heard this he asked me, “so when the farmer is driving the tractor up and down the crop rows, and he gets to the end of the roof, how does he turn around?” Clearly my uncle was joking when he said this, but it provides an example of the many different ways people may interpret the term “rooftop agriculture”, or “rooftop farm”. This isn’t a bad thing, as rooftop agriculture can take different forms. In an effort to help the reader gain better understanding about this topic, I will attempt to classify and explain the various forms of modern rooftop agriculture.

Figure 2.1 Hydroponic Container Gardening

The Rooftop Garden Project in Montreal, Canada, demonstrating their "affordable" hydroponic gardening containers. *Source: http://rooftopgardens.ca*

Figure 2.2 Hydroponic Greenhouse

Butter lettuce growing in a hydroponic greenhouse. *Source: http://thebackkitchen.blogspot.com/2009/02/local-greens-in-winter.html*

Container gardening is the simplest form of rooftop agriculture. It can often be done on a building's rooftop with little, or no, costly structural upgrading and retrofitting. This form of agriculture is also the oldest and most widespread. It is practiced in countries around the globe, and as landscape architect Anne Whiston Spirn noted in her book *The Granite Garden*, dates back to the wondrous and ancient hanging gardens of Babylon (1984). The biggest upside to container gardening is that there is no complicated or costly technology involved, except perhaps a simple drip irrigation system running to the various containers, and it can be done in very limited space. However, container gardening is not well suited for achieving high levels of productivity.

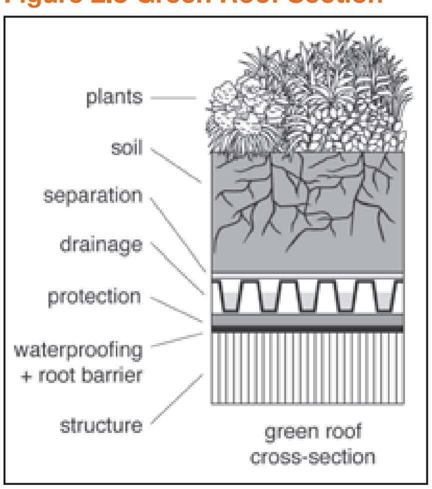
Soil-less, or hydroponic, gardening systems are the second form of rooftop agriculture. In hydroponics, plant roots are floated in nutrient-rich water instead of soil, creating a very efficient growing system. According to a publication by The Rooftop Garden Project in Montreal, Canada, growing plants hydroponically uses one-tenth of the water that soil-based gardens use, and is four times as productive (2006). In most cases, hydroponics is done inside a greenhouse, where temperatures can be controlled, creating a year-around growing season. However, The Rooftop Garden Project has managed to create a "simplified version of hydroponics that uses affordable materials and human power", in addition to not using a greenhouse (2006). The downside of some hydroponic operations is that they can be complicated and expensive to maintain.

Green roof gardening is the third form of rooftop agriculture. This type of growing system uses green roof technology, where the soil and its various layers are actually laid on top of the roof itself. Conservation Technology, Inc, a green roof supplier, lists the following layers in their product catalog as typical to green roofs:[1]

- **Sturdy roof structure:** concrete, steel, or wood roof that is designed, or reinforced, to support the weight of the green roof
- **Waterproof membrane:** prevents water leakage
- **Root barrier:** protects the waterproof membrane from being damaged by plant roots
- **Protection fabric:** protects the waterproof membrane and root barrier from damaged during construction and maintenance
- **Water-storing drainage layer:** allows rapid soil drainage while also providing some water storage
- **Non-clogging separation fabric:** a fabric that helps keep the soil in place while allowing excess water to filter through it
- **Engineered soil:** specially formulated soil to be lightweight and have good water storing capacity

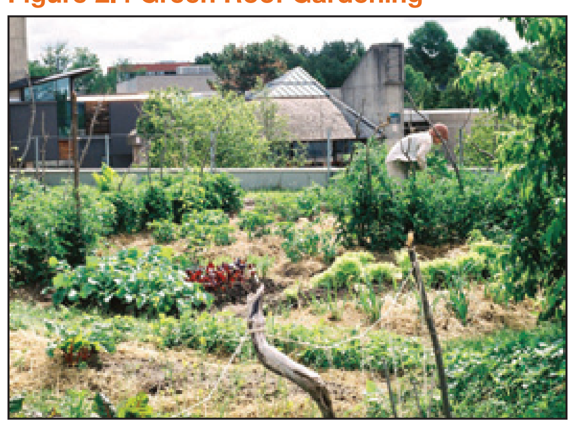
All of these layers are laid directly on top of the building's existing roof, becoming the roof's outer most layer. Green roofs can be classified into two categories: extensive and intensive. The main difference between the two types is the depth of soil provided. According to the City of Chicago, extensive systems have shallower soils, are lighter weight, and generally are planted with the most hardy of plants. Intensive systems have deeper soils, and therefore weigh more, but can feature a wider range of

Figure 2.3 Green Roof Section



Section of a green roof showing the various layers. *Source: Conservation Technology, Inc*

Figure 2.4 Green Roof Gardening



A rooftop farm atop the Environmental Sciences Building at Trent University in Ottawa, Canada. The farm supplies organic food to The Seasoned Spoon Cafe, an independent, student-run, campus eatery. *Source: http://www.cityfarmer.org/TrentRoof.html* plants (n.d.). For growing vegetables, an intensive green roof system is required, and must feature deeper soils than usual. Nigel Dunnett and Noel Kingsbury, authors of *Planting Green Roofs and Living Walls*, recommend a soil depth in the range of twelve to eighteen inches (2008). The biggest downside to a green roof system is high cost.

The Case For Rooftop Agriculture

Unutilized Land

In large urban cities an immense amount of land space can be found on the roofs of buildings. According to Pfeiffer, these spaces can account for "30 percent of a city's total land area" (2006, p. 71). That is a significant amount of space, especially in dense cities where open space is scarce. Adopting such a space for growing food has three clear advantages. First, you are preserving "wild" land, and whatever natural ecosystem is residing on it, on the ground plane from being developed into farmland, and ultimately degraded. Second, by creating a living, producing, farm "ecosystem" on a rooftop, you are actually *adding* life to a place that was barren and dead previously. In this way, one is creating, what Todd and Todd refer to as "wild ecological islands in the city" (1993, p. 124). This second benefit is best realized when the "land" on the rooftop is developed and farmed in a sustainable manner, with minimal environmental impacts. Thirdly, Pfeiffer points out that "rooftops enjoy the full benefit of sunshine and rainfall" (2006). This is a great advantage especially in cities, where ground-based urban agriculture may often be subject to heavy shade caused by the surrounding buildings.

What about traditional urban agriculture on the ground? Well, here too rooftop agriculture has two distinct advantages over traditional urban agriculture that is typically practiced in empty or abandoned lots. First, undeveloped plots of land in a dense city are often prime real estate, and securing them for agricultural use, against wealthy developers or tax revenue hungry city officials may be a difficult battle. Rooftops, on the other hand, are without such demand. For building owners, the space is, in a sense, *free*, and leasing could likely be done at a minimal price.

Secondly, it is not uncommon for soil in dense, urban areas to be severely contaminated. According to an urban soil contamination report by Alexandra Heinegg et al., soil contamination most often comes in the form of heavy metals, such as lead, cadmium, arsenic, and others, deposited by industrial and vehicle pollution (n.d.). The danger here is that plants can uptake these pollutants and become poisonous to the consumer. The advantage of practicing agriculture on a roof is that the soil is imported, and pollutants can therefore be avoided.

Of course, not every roof accounted for in the thirty percent statistic stated above is suitable for growing food. Some roofs may be too steeply sloped, inaccessible, or structurally unsound. In general, a flat roof, such as is typically found on most commercial and industrial buildings, and even many multi-unit residential buildings, such as apartment or condominium complexes, is ideal. Nevertheless, with all of these issues taken into account, every city is likely to have a handful of (or more) buildings that fit the criteria. For example, Bay Localize, in a effort to identify rooftops that could be harnessed for various environmentally benefitting uses, evaluated the City of San Francisco, and found that ten buildings would be suitable for an eight inch deep, soil-based, green roof system designed for growing vegetables. In addition, the organization identified eighteen more buildings that could support a hydroponic rooftop food garden. Altogether, Bay Localize estimated that among these eighteen buildings, approximately 273,373 pounds of vegetables could be grown annually (2007).

Fossil Fuel Independence

Rooftop agriculture could drastically help to reduce fossil fuel usage and dependence. As I discussed in a previous section, modern, conventional agriculture is highly dependent on fossil fuels to maintain high levels of productivity and efficiency. But, this is a dependence that must be broken, as fossil fuels are rapidly being depleted, causing the price of these fuels to skyrocket, and in turn increasing the price of food. Sadly, not much has been done to change this problem. According to Friedman, oil demand in the U.S. has still managed to grow by twenty-two percent since 1990 (2008). By growing food on the rooftops of buildings in dense urban environments, this dependency on fossil fuels could be greatly reduced by eliminating a large portion of the food transportation costs. Most industrial agriculture is highly condensed into the most economical regions of the country (or in many cases the world), often where corresponding population sizes are small, and transported into the higher population centers of dense cities often vast distances away. By locating a food source in the heart of a densely populated city, these costs are almost eliminated, as the harvested fruits and vegetables simply need to be taken downstairs and sold to the local community. Such a process could save countless gallons of fuel everyday.

Implementing sustainable farming techniques could decrease fossil fuel dependence even further. Pfeiffer explained that sustainable farming involves seeking to achieve a cycle of nutrients and energy within the agricultural system that can function independently, without additional outside inputs (2006). So, by farming sustainably, reliance on fossil fuel based fertilizers and pesticides could be eliminated. In addition, Pfeiffer noted that this type of farming tends to work best at a much smaller-scale than modern, conventional farming (2006). Fortunately, since rooftops are a considerably smaller space than most massive, modern, conventional agriculture fields, they lend themselves quite well to sustainable farming methods.

Increased Food Security

Rooftop agriculture can also greatly increase a regions food security by creating a more localized and independent agricultural system. The globalizing and centralizing of modern agriculture over the last fifty years has left many regions—dense cities especially—with little local access to freshly grown food. As mentioned in a previous section, food grown on a rooftop in a dense city would depend little on a complex transportation network to get from the location it is produced to the hands of the consumer. For this reason, an area that has a highly developed network of rooftop farms would be much less vulnerable to having its' food supply cut-off in the event of emergency, such as a severe spike in fossil fuel prices. The rooftop farms could be a local food source for the entire community, significantly reducing the amount of outside imports from. Such a system could, as Pfeiffer puts it, "cushion" a region "against the coming decline of hydrocarbon production" (2006, p. 2). This food safety net would be of the greatest benefit to cities, as the *majority* of population growth in the coming decades is expected to happen in these urban centers (Fischetti 2008).

Reduced Environmental Impacts

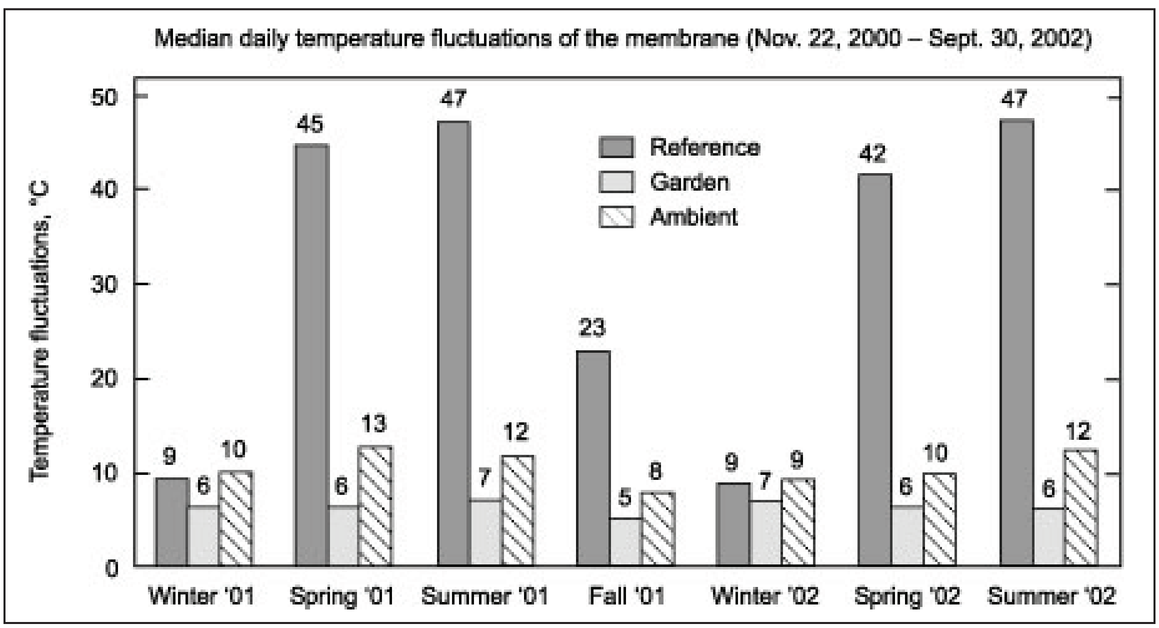
The environmental benefits of producing food on rooftops in urban cities are many. When it comes to land, doing agriculture on the dead, concrete landscape of a rooftop can help to preserve wild, natural lands from being deforested and developed into industrial farms and having their natural ecosystems destroyed. Also, when agriculture on a roof is done sustainably, you are eliminating more harmful fertilizers and pesticides from becoming water-bound and polluting rivers and streams. And thirdly, a healthy, sustainable farm ecosystem can potentially become habitat for bird and insect wildlife in the city.

A rooftop farm, similar to a regular green roof, amidst a city also has the benefit of cleaning the air and reducing storm water run-off. In a report compiled by the U.S.

Environmental Protection Agency (EPA) regarding green roofs, it was found that a 1,000 square foot green roof could remove "about forty pounds of particulate matter pollution from the air in a year" (n.d.). For storm water, a roof of soil and plants instead of concrete can capture and hold water instead of sending it into the storm drain where, once there, is no longer of use to plants. The U.S. EPA claimed that a green roof could reduce storm water run-off by up to seventy-five percent (n.d.).

One other environmental benefit of a rooftop farm worth mentioning is its' ability to reduce the urban heat island effect. According to Spirn, the urban heat island effect occurs when natural vegetation is superseded by large amounts of concrete, stone, brick, and asphalt. These materials retain heat from the sun by day, and then radiate the heat back out at night, creating a significant increase in temperature of nine to twenty degrees, as compared to the surrounding countryside (1984). Roofs can often be huge sources of this heat, and by re-vegetating it, the urban heat island effect can be reduced significantly. A study carried out by the Environmental Affairs Department of the City of Los Angeles, found that in re-vegetating fifteen percent of Los Angeles, in conjunction with "increasing the reflectivity of manmade surfaces", summer temperatures could be reduced by six degrees (2006).

Figure 2.5 Green Roof Ambient Temperature Reduction



This graph represents temperatures measured on a conventional "reference" roof, and a green roof. As compared to the reference roof, the green roof holds significantly less heat. *Source: Natural Research Council Canada, Institute of Research in Construction*

Economic Benefits

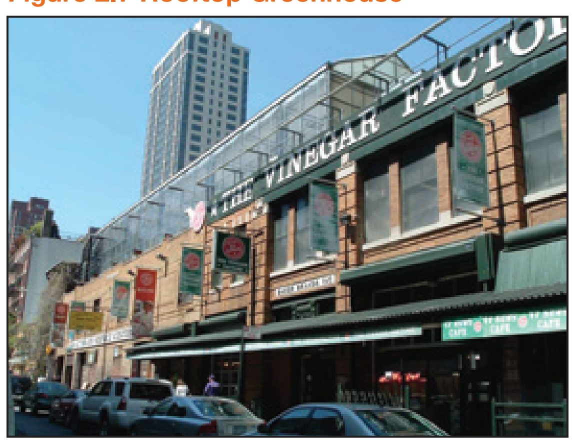
The economic benefits of a green roof are substantial, and when food production is thrown into the mix, the benefits only multiply. A roof is, in a sense, free land for the person who owns the building beneath it, capable of becoming a source of food, income, or both. Private owners can produce food on the roof for their own consumption, or if a business, for the consumption by their customers. According to Dunnett and Kinsbury, the Fairmont Hotel in Vancouver, Canada does just this. They grows culinary herbs on the roof of the building to be used in the hotel, and in so doing, the hotel offsets food costs and saves an estimated $20,000 to $24,000 per year in expenses (2008).

The food grown on the roof can also be sold for profit. Such a model can be very well suited for businesses that are already in the food business. According to Michael Ableman, author of *Fields of Plenty: A Farmer's Journey in Search of Real Food and the People Who Grow It*, The Zabar's Vinegar Factory in New York City is a great example of this.[2] Starting as a bakery and grocer, the owner eventually built a greenhouse complex on the roof that produces an array of fruits and vegetables year-around. The produce is sold fresh, or it is incorporated into the retailers many food products such as pizzas, jams, or bakery items. To further cut waste and expenses of this operation, the owner composts the wastes from the kitchens, and any waste from harvesting, and uses it to fertilize the greenhouse soils. In addition, the owner creatively harnesses the exhaust from his many bakery ovens on the bottom floor of his facility, channels it up to the greenhouses on the roof, and

Figure 2.6 Rooftop Tomato Greenhouse

Eli Zabar's Vinegar Factory grows organic tomatoes and sells them in his store. *Source: http://www.baylocalize.org*

Figure 2.7 Rooftop Greenhouse

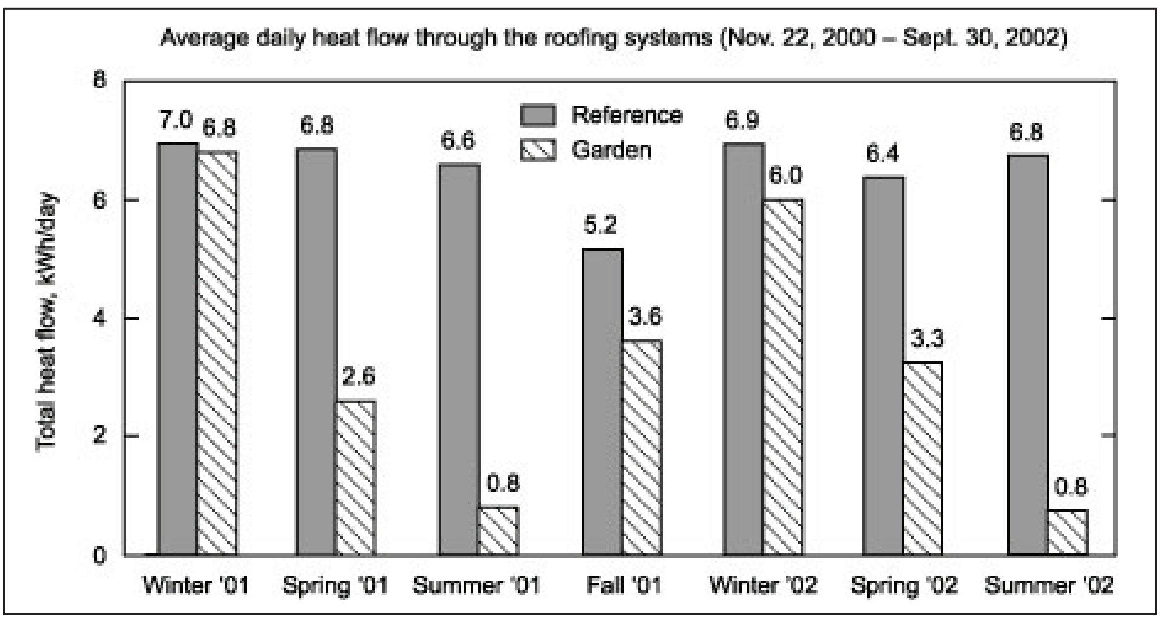


A view of the Vinegar Factory from the street in Manhattan, New York. *Source: http://www.baylocalize.org* heats them to the optimal growing temperature throughout the year, significantly reducing energy costs (2008).

For a building owner that doesn't have much of a green thumb for gardening, or who doesn't have the time (or patience) to cultivate the crops, leasing the land on the roof out to an individual, a non-profit organization, or a business can be a wise option. This way an owner is still generating additional income, but doesn't have to do the backbreaking work involved in cultivating food. Many non-profit urban agriculture organizations exist in major cities that lease multiple plots of land from various owners throughout the city, growing food, and selling it affordably in areas with poor access to fresh produce, or sometimes donating it to charities. According to Alex Wilson of BuildingGreen.com, In Portland, Oregon, a business called City Garden Farms practices what is called "SPIN Farming", "SPIN" standing for Small Plot INtensive.[3] This business leases out land in empty lots and residential backyards throughout the city, producing food that is then sold to customers enlisted in their community-supported agriculture (CSA) program (2009). Such farming models as these could similarly be adapted to rooftops as well.

Another, much less obvious, economic benefit of a rooftop farm comes in the form of insulation for the corresponding building, significantly reducing the costs of interior heating and cooling. This is a benefit well observed with standard green roofs as well. Soil and plants are superb insulators, keeping a building's interior environment

Figure 2.8 Green Roof Building Energy Usage Reduction



This graph shows the difference in building energy usage for maintaining the interior climate between a conventional roof and a green roof. *Source: Natural Research Council Canada, Institute of Research in Construction* cooler in the summer, and helping it to retain heat in the winter. The U.S. EPA cited that a green roof in Ottawa, Canada reduced the buildings spring and summer energy use by seventy-five percent. The U.S. EPA also highlights the energy reduction realized by the green roof recently installed atop The City of Chicago's City Hall, which saves the City approximately $3,600 annually (n.d.).

Costs and Limitations

It seems like almost every idea has its' negatives. But, with rooftop agriculture, the limiting factors are surprisingly few. Perhaps the largest limitation to building a rooftop farm, or any type of green roof for that matter, is cost. Construction costs to build a green roof are considerably higher than a standard roof, and a green roof that has deeper soil levels suited for agriculture may be higher still. However, Spirn noted regarding green roofs that the "combined aesthetic, climatic, and hydrologic benefits can repay the investment" (1984). And, in the case of a rooftop farm, the many other benefits discussed earlier in this section can be added to that list. The U.S. EPA cited that a green roof applied to a 21,000 square foot roof would cost $464,000, whereas a standard roof applied to the same area would only cost $335,000. However, due to higher longevity, as well as energy reduction, the green roof would save $200,000 over its' lifespan (n.d.). So, clearly, the hurdle of high initial investment of green roofs is a hurdle worth jumping.

There is an additional variable of cost that warrants mentioning. The total cost of constructing any type of green roof system can be greatly increased if the building requires significant structural reinforcing. The reason for this is that soil, when saturated, is very heavy, and although most modern green roofs utilize specially developed, lightweight soils, many buildings are not designed to withstand such weight on the roof. In a report by HolmesCulley, a San Francisco structural engineering and consulting firm, they give three general rules of thumb in selecting a building best suitable for handling the additional weight of a green roof system. First, newer is better, as these buildings are often more likely to be up to current earthquake codes. Second, buildings five stories or more, and two stories or less, as they typically are designed with stronger than necessary foundations and columns. And third, buildings built on "hard" or "stiff" soils, as these soils are less susceptible to liquefaction in an earthquake (n.d.). However, buildings not seismically or structurally qualified, can always be considered for retrofitting and strengthening. And although expensive, it may be justifiable if, as HolmesCulley pointed out, a building's seismic status is outdated anyway (n.d.). Perhaps the buildings that are the best candidates for a green roof though, are those not yet constructed, because these can be designed with a green roof in mind.

three.

project background and analysis.

As apart of this project, I chose to include a design of a rooftop farm in Sacramento. This design was first inspired in a landscape architecture design studio during the Winter Quarter at the University of California, Davis. In the studio class, we were looking at three sites located in the heart of downtown Sacramento. One of these sites was the California Department of Food and Agriculture (CDFA), located on N street between 12th and 13th. We met with a representative from the CDFA who explained to us the agency's interest in redesigning the planter beds located along the north and west faces of the building. The CDFA, being an agricultural agency, was particularly interested in having the redesign feature food crops. Our class took this concept of edible landscaping, and made it the subject for the rest of the studio, eventually producing design ideas of how food production could become an aspect of the public landscape.

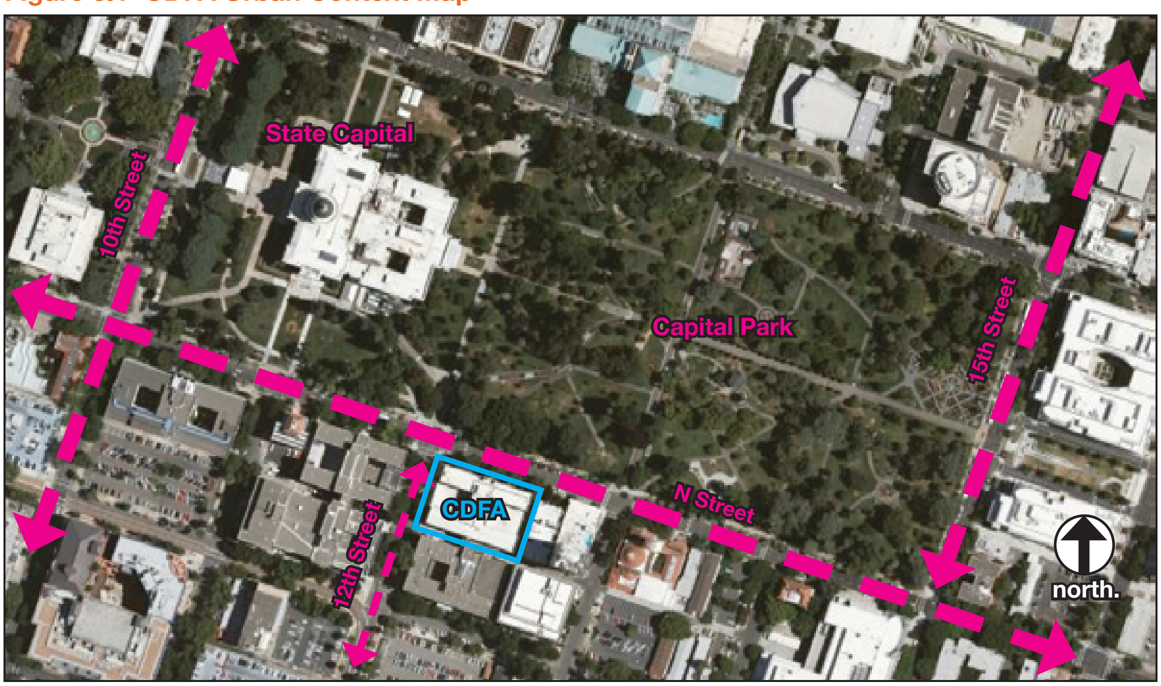
During that studio, I had focused on the CDFA building, exploring how edible plants could be incorporated not just into the planters along the building, but also on the roof. I soon became enthralled with the idea of making the roof a site for food production in Sacramento. As a result, after the quarter was over, and the studio class had ended, I had already developed a strong interest in taking the idea of rooftop agriculture farther. It was this experience that led me to adopt this subject for my landscape architecture senior project.

I chose to continue with the CDFA building as the basis for my design exploration of rooftop farming because of what it represents. According to the CDFA website, The California Department of Food and Agriculture is responsible for the "protection", and "promotion" of the largest and most productive agricultural system in the nation (2009). The CDFA is a symbol for agriculture in California. What they do affects the whole state, and in turn, the world. So, what better place to initiate a change in the way agriculture is done than at the head? As I discussed earlier in this project, the present way agriculture is practiced is deeply flawed. Productivity may be at an all time high, but it is coming at a great cost to our environment. A new form of agriculture must be promoted: agriculture that is sustainable, equitable regardless of social class, accessible regardless of locale, and free of dependency on fossil fuels. Disaster is on the horizon. Will we evade its deadly clutches? Or will we collide with it head-on? Isn't it time that our state wake-up, and lead the nation, and the world, in doing what is necessary to avoid this disaster?

The Greater Context

The CDFA building is located at 1220 N street, in downtown Sacramento, California. N street receives considerable automobile and pedestrian traffic, as it creates the southern border of the California State Capital Park. Capital Park spans roughly ten blocks, and is filled with lively activity, such as concerts, speeches, rallies, tours, protests, people running, and people picnicking, seven days a week. Additional state owned agencies line N street across from Capital Park. The heart of midtown Sacramento is just a short walk away, where majority of Sacramento's nightlife happens.

Figure 3.1 CDFA Urban Context Map



The Building

The CDFA building is bordered by 12th street on the west, N street on the north, and a multi-story residential property on the east. An alleyway separates it from an additional departmental building along the south, of which a walking bridge connects the two. The building itself is four stories, and according Assistant Secretary David Pegos, was built in 1936 (personal communication, June 4, 2009). The building is loosely styled in the art deco motif. In total there are nine entries surrounding the building, two in the rear (south) alleyway, three on the east, and three on the west, with the main entry located on N. street and facing The California State Capital Park. Many large windows dot every face of the building. A row of smaller windows runs along the north face of the building, rising just barely above ground level. These windows posed a particular design challenge because the planting beds reside directly below them. However, these windows are non-opening.

The Roof

The CDFA buildings roof is broken up into three areas. The largest section of the roof is formed in the shape of an “H”, and sits the full four stories up. Aside from a slight built-in slope for drainage, this part of the roof is flat. A large utility room sits near the center. The two smaller sections of the building’s roof are lower, rising only a single story, and filling in the remaining space of the “H” shape. Unfortunately, I was not granted access to the roof by the building manager, nor was I able to obtain architectural plans of the building, but as far as I was able to determine, these two lower roof sections are not level with the building’s second floor, and the only access appears to be through the second story windows. In addition, I ascertained that access to the upper “H” part of the roof was by means of two overhead-opening hatches that, I assume because of their long, rectangular shape, are each reached via a small access staircase.

The Street Level

There are four planter beds in total surrounding the building. The two largest beds reside on the building’s north side, and stretch the full length of the building minus the entry walkway. The western of these two planter beds wraps around the building’s northwest corner and borders a portion of the building’s west side. A narrow, dirt maintenance pathway runs along the back of these planters, slightly separating the plant able area from the building base. The two remaining planter beds are significantly smaller, reside on the building’s west side, and are each located next to a build-

Figure 3.2 East Corridor

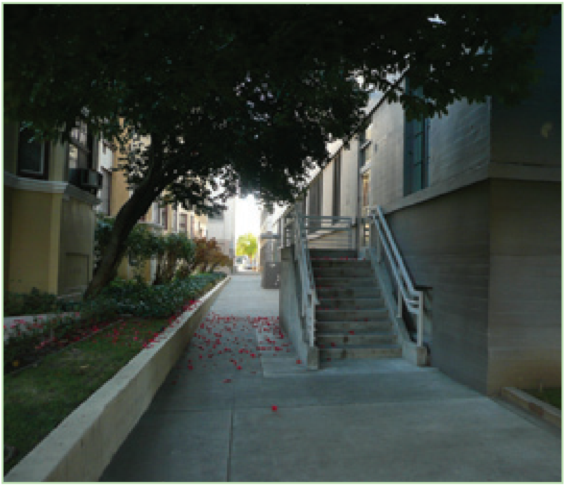


Figure 3.3 N st. Sidewalk Looking West

Figure 3.4 Main Entry From Capital Park

Figure 3.5 N st. Sidewalk Looking East

Figure 3.6 12th st. Sidewalk Looking South

Figure 3.7 West Side Across 12th st.

\All Images Credited to Andrew Emmert, Laurie Fong, and Sandy Thai

Figure 3.8 12th st. Entry 1 (West)

Figure 3.9 12th st. Ramp & Entry 2 (West)

Figure 3.10 12th st. Entry 3 & Utility Pad

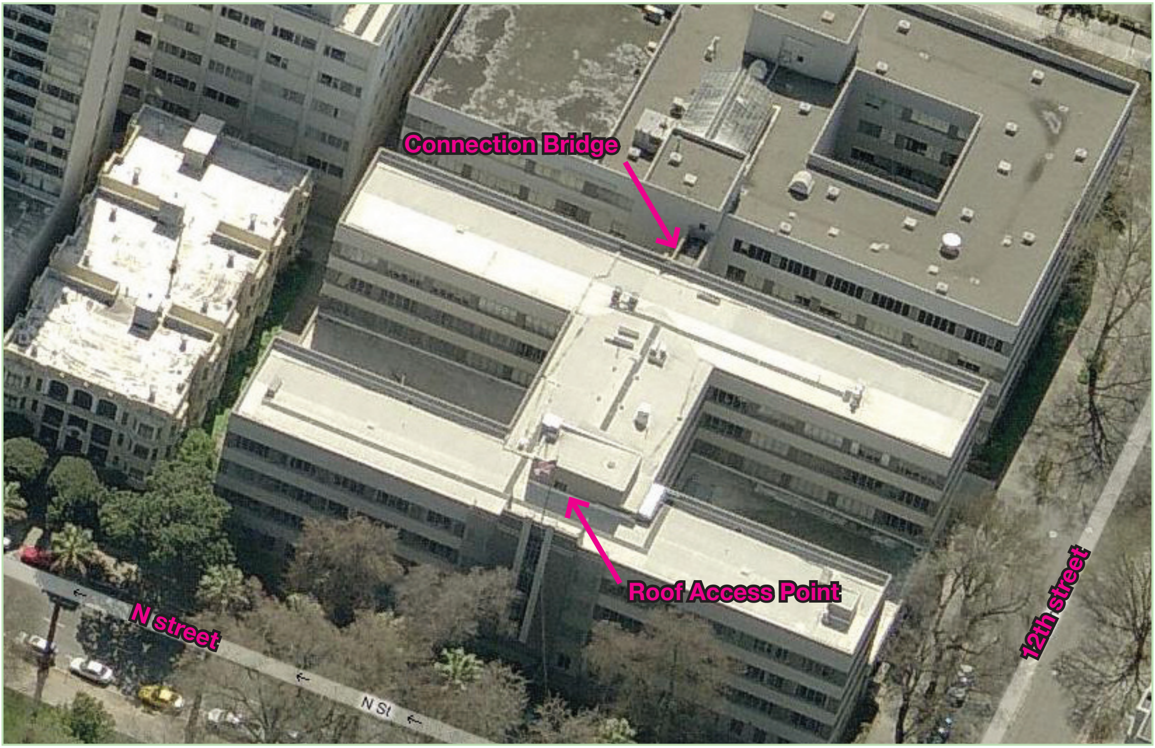
Figure 3.11 South Alleyway (Looking East)

Figure 3.12 CDFA's South Building

Fig. 3.13 South Building Roof & Alley

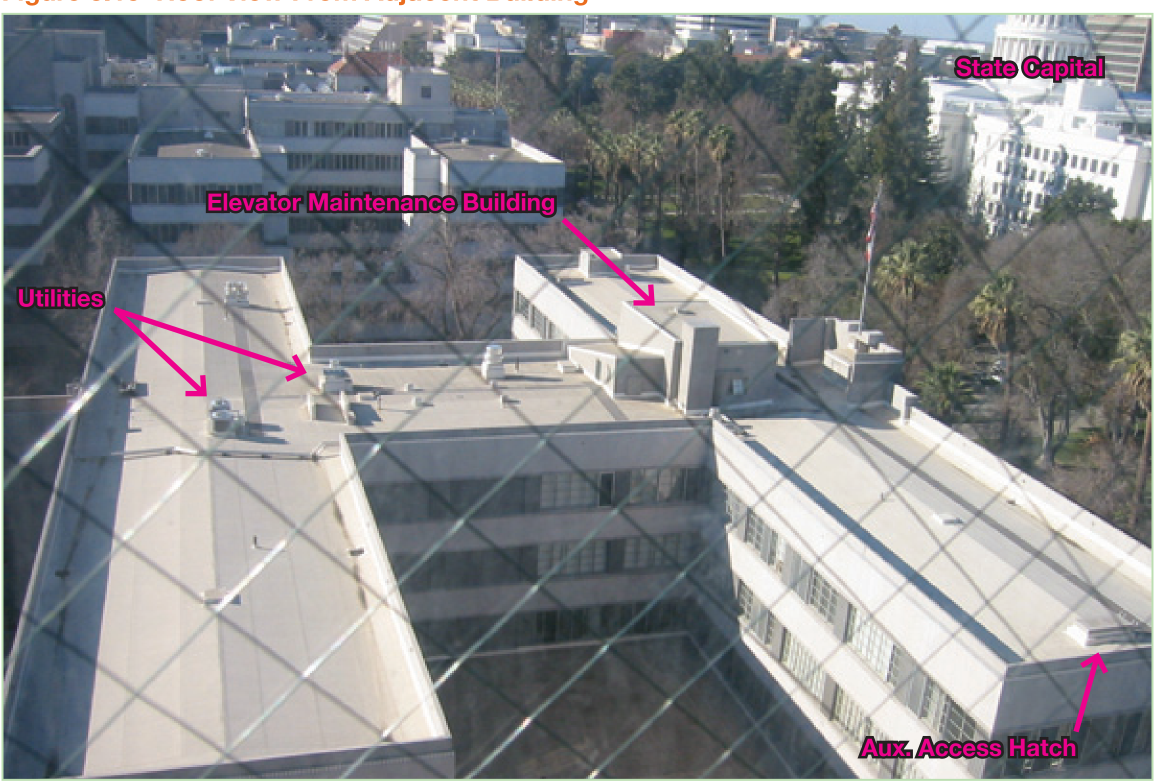
IAll Images Credited to Andrew Emmert, Laurie Fong, and Sandy Thai

Figure 3.14 Birds Eye View



The roof of the building is accessed by a stairwell from the 4th floor. On the CDFA's south building (rear) a greenhouse already exists on its roof, although it is no longer in use. *Source: Google Maps*

Figure 3.15 Roof View From Adjacent Building



The roof has the benefit of receiving full sun year around. Capital Park can be viewed from the roof. *Image Credit Sandy Thai, UCD LDA* ing entrance. Upon my most recent visit, I noted that the plantings around the building were sparse. However, the plants I did observe include hydrangeas, azaleas, camellias, dwarf periwinkle, English ivy, spider plants, a sword fern, and a plant in the Lily family that I was unable to identify. Some very mature, deciduous elm trees also border N street and 12th street along the building. Most of these plants appeared to be doing well despite the dense shade caused by the CDFA, and surrounding, buildings, but the camellias and hydrangeas seemed to thrive the best.

The Problem of Shade

The ground-level planters are subject to dense shade created by the CDFA, and surrounding, buildings. When on a field trip with my landscape architecture studio course during the Winter Quarter, the Assistant Secretary David Pegos informed us that the dense shade had prevented many plants from thriving in these locations (personal communication, January 15, 2009). This fact represents quite a limitation when it comes to planting any type of traditional food-producing plants. Before I began researching particular shade-tolerant edible plants for the design phase of this project, I decided to ascertain the full extent of the shade problem in these planters. I developed a 3-D model in Google SketchUp of the CDFA building that could provide me with relatively accurate sun and shade patterns across the planting bed surrounding the CDFA.

I compiled the data separately for both the north-side planters and the west-side planters. In the end, I determined that the north-side planters get a minimum of about twenty minutes of partial sun in the months of February and October, a peak of just over six hours of full and partial sun in the month of June, and unfortunately, no direct sun for the entire months of November, December, and January. The west-side planters faired better throughout the year, with a minimum of just less than two hours of full and partial sun in the month of January, and a maximum of five hours of full and partial sun in the month of June. For a detailed explanation of exactly how this analysis was carried out, along with the complete results, see *Appendix 1*.

four.
the design.

Design Goals

I began the design process for this project with four main goals at the forefront of my mind. The first goal was to develop a design that was context appropriate. To me, this meant three things. First, creating a landscape that incorporated edible plants, especially traditionally grown food crops, to reflect the CDFA's agricultural spirit. Second, making sure the design was slightly formal in nature, so as not to detract from the fact that the CDFA is a government agency. And third, tying in the art deco motif of the building itself.

The second main goal I had for this project was to minimize maintenance. The reason for this is because the CDFA is first, and foremost, a government agency, whose job is to *oversee* agricultural, not to *do* it! I doubt state employees, who are already being forced to take furloughs and pay cuts in this slumped economy, would be very keen on having to harvest crops as well! With food crops however, maintenance is impossible to avoid, so for this reason, reducing maintenance meant possibly scaling back the amount of crops used in the design.

My third goal was to create year-around interest. I added this goal shortly after discovering that few food crops could survive in the full shade that the north-side planters endure during the winter months. What a sorry sight it would be to walk by the CDFA and see just dirt on a crisp December morning! So, to create year-around interest, the idea of using a greater range of plants, not just food crops, would have to be considered.

Finally, my last goal in this design was to be realistic. This was probably the hardest of all, because attempting to sell the idea of building a farm on the roof of a government agency is in itself quite a feat. However, I wanted to try my best to develop a design program that was at least to some degree realistic, and that could perhaps fit into the work scope that the CDFA already does.

Introducing The CDFA Rooftop Farm

The CDFA's Rooftop Farm is a ground-breaking farm model that features edible landscaping along the street, a native planting green roof, a compost teaching greenhouse, chickens, vegetable plots, and small fruit trees. The farm produces vegetables, fruits, and eggs, in a self-sustaining, nutrient cycling, "farm ecosystem". The CDFA's Rooftop Farm takes a revolutionary stance against the commonly held belief that farming can only be done on the ground plane. By tapping into the CDFA's impressive reservoir of accomplished scientists, veterinarians, economists, and other skilled staff, this rooftop farm can provide the optimal foundation for developing a cutting-edge research program. One that seeks to gain understanding into some of agriculture's most pressing problems. In addition, the rooftop farm prototype offers the perfect environment for educating people of all ages about the importance of developing a sustainable and solid future for our state's (and our nation's) agricultural system.

The Design Program:

(1) Street-level Art Deco Planters:

The street-level planters have been split into three sections, raised slightly, and arranged into an attractive art deco sun motif. Concrete pavers create pathways that draw one into the plantings. Educational signs identify and describe the historical significance and use of the various plants, providing a learning opportunity for passersby. Maintenance to the planters, such as harvesting or planting, is made easy by the various pathways. A rear pathway provides access, and assures that the low windows are unobstructed and accessible. A rich, stainless steel panel encloses the planting areas shaped like a half-circle. Traditional, food crops, aligned in neat, formal rows, emanate from the circle's center and span out toward the perimeter. Crops include shade-tolerant varieties, such as lettuces, cabbages, arugula, and chards (for the complete shade-tolerant plant list, see *Appendix 2*).

The Outer planter sections that feature the suns “rays”, are enclosed by a concrete wall that rises in tiers with the intersection of each “ray”. The “rays” are stainless steel panels, and separate the beds into various tiered levels. The plants featured in this area are drought and shade tolerant, medicinal and edible natives, specifically selected for historical significance or use by local Native Americans.

② California Native Landscape Green Roof

This is an intensive green roof system depicting a native, Californian, landscape. The purpose of this green roof landscape is threefold. It will provide an educational opportunity for visitors to learn about the flora and fauna of a native California landscape, it will create an “ecological island” of insect and butterfly habitat in the city that will encourage pollination of the food crops. And, it will provide a research opportunity to monitor the green roof ecosystem and its’ affects on the CDFA building’s energy usage. Plants making up this landscape consist solely of native grasses, shrubs, and perennials that are drought-tolerant and hardy. Decomposed granite pathways loop through the landscape, allowing tour groups to experience it. The native landscape continues to the southern side of the roof, forming a border around the vegetable plots.

③ Rooftop Group Seating Area

Amphitheatre style seating area can accommodate a group of up to eighteen visitors. Seats are cast of lightweight concrete. This area has been designed as a starting point for tours, or an area to provide teaching about the rooftops various systems and biota.

④ Compost & Seed Propagation Learning Greenhouse

This is a teaching greenhouse featuring various forms of composting, as well as space for seed propagation. The purpose of the greenhouse is to allow visitors the opportunity to have a hands-on learning experience with the process of nutrient recycling, and seed propagation. Two forms of composting systems are featured: worm composting in bins (vermicomposting), and composting with black soldier fly (BSF) larvae in BioPods.[4] Visitors are able to don gloves, poke around in the compost, and observe the process of decomposition right before their eyes. In another section of the greenhouse, visitors can participate in the process of propagating seeds in flats, and learn about seed germination.

5 Chicken Strawyard & Tractor System

The chicken strawyard includes a coop and fenced in space for egg-laying hens to live. The main pen is connected to two fenced corridors that run along the length of the vegetable plots. Gates open to the various vegetable plots, which can be enclosed with a moveable fencing system, containing the chickens into the preferred designated area. This creates a rotating "chicken tractor" system where chickens are able to graze, while in turn providing the benefits of eating weeds, controlling pests, tilling the soil, and fertilization. In addition, the hens will provide eggs that can be sold to visitors, taken home by employees, or used for food in the CDFA's employee cafeteria. Visitors can enter the strawyard to feed and interact with the chickens, and learn about how chickens can contribute to a healthy, sustainable, agriculture system.

6 Vegetable Plots

The vegetable growing area is raised and divided into five sections that can be enclosed with a moveable fencing system to allow the chickens to forage the soil directly after a harvest. This is assisted by numerous gates that open into each of the vegetable plots, allowing the chickens from the strawyard to seamlessly enter and perform their agricultural duties. This system also encourages sustainable farming practices by enabling various crops to be rotated from plot to plot across the seasons. The plots themselves are planted with many traditional, sun-loving food crops such as tomatoes, peppers, herbs, and squash (for the full list of recommended rooftop food crops, see *Appendix 3*).

7 Fruit Tree Orchard

The final area of the rooftop is a fruit tree orchard. The orchard consists of many dwarf, fruit tree varieties grown in containers for minimal weight. Some of the trees include dwarf citrus, fig, pomegranate, and guava (for the full list of recommended rooftop food crops, see *Appendix 3*).

8 Solar Power Generation

The roof of the elevator maintenance building has a flat roof and receives full sun, making it an ideal spot to locate solar panels, which can help offset any additional energy costs created by the farm.

Figure 4.1 CDFA Rooftop Farm Master Plan

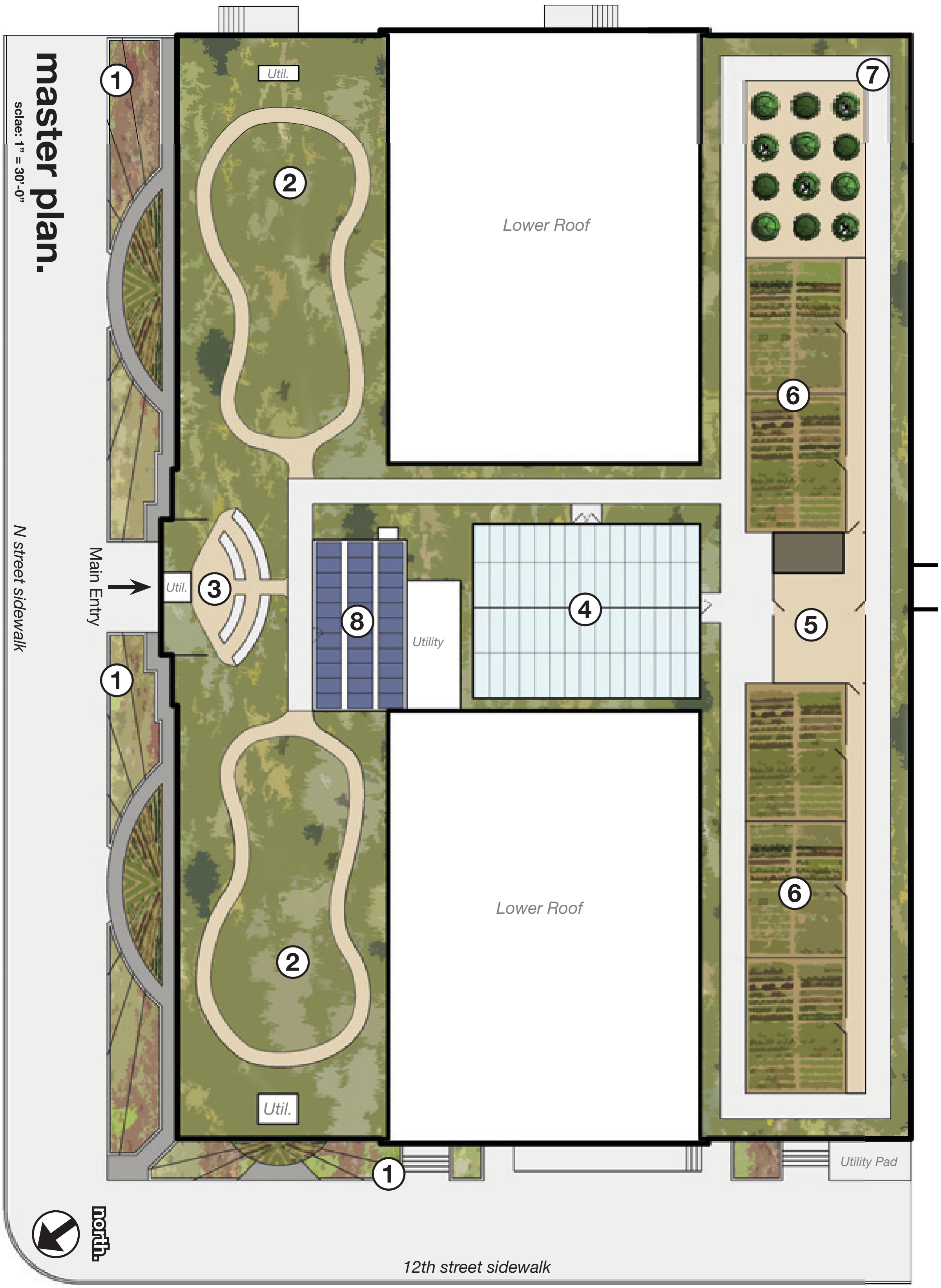
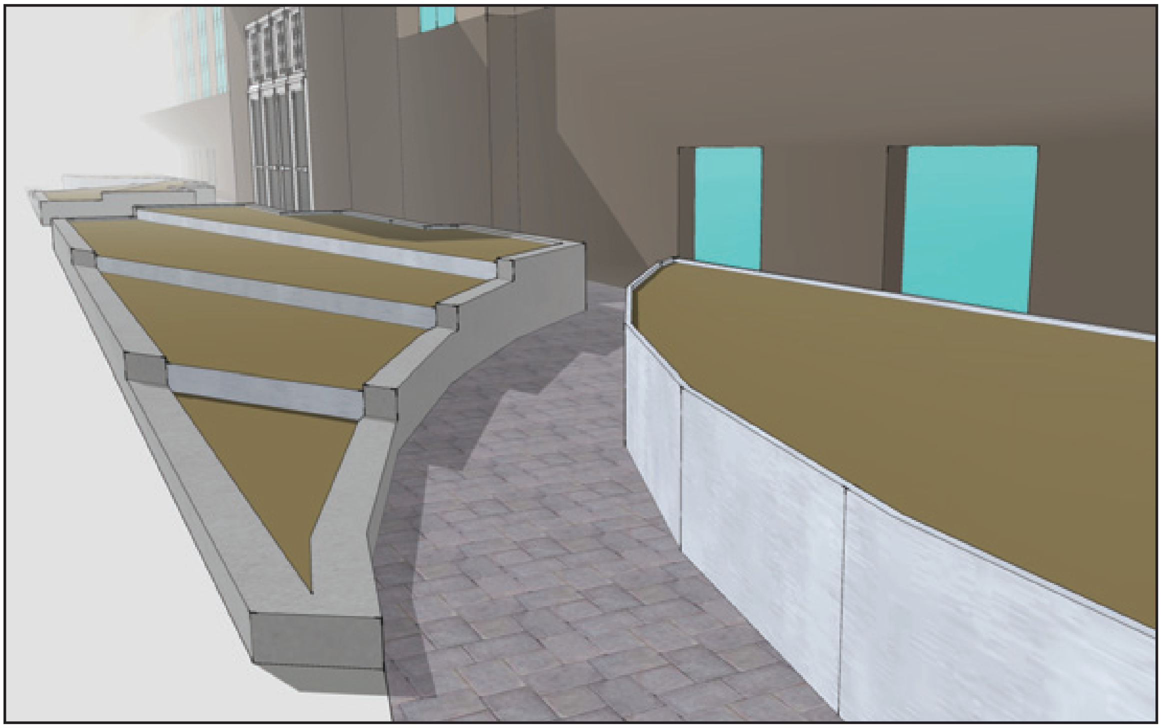


Figure 4.2 N st. Sidewalk Rendering

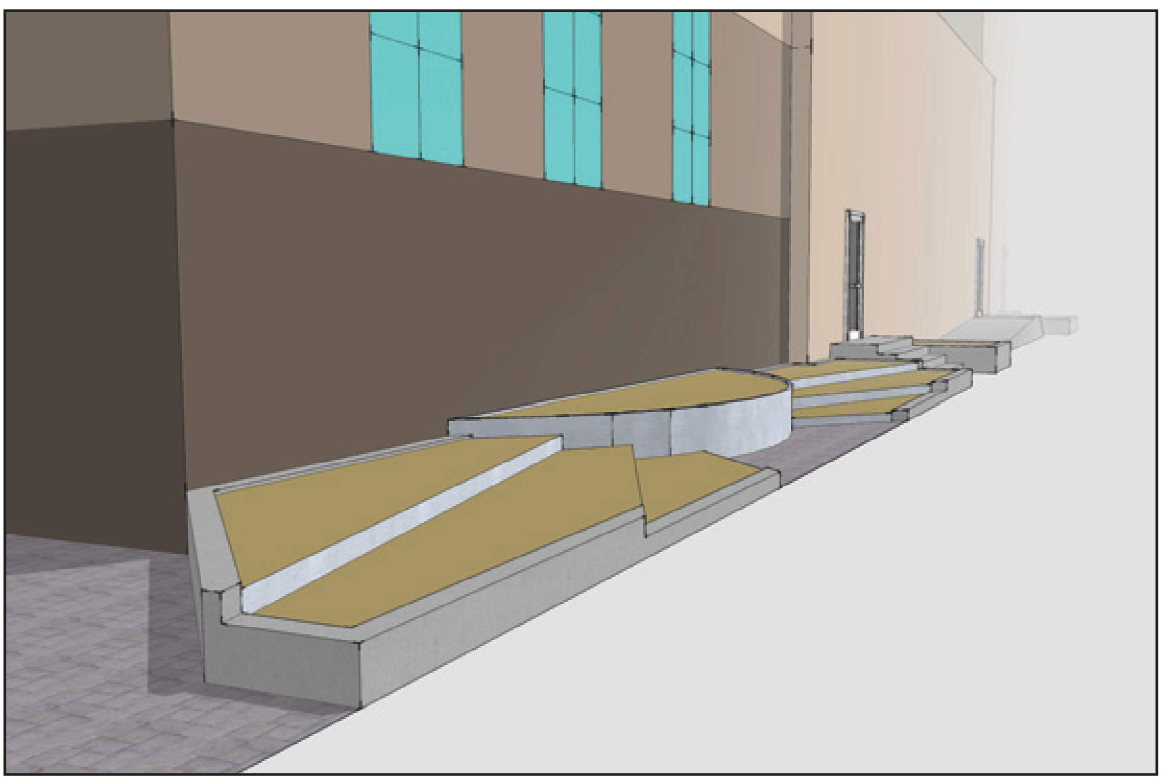
Figure 4.3 Planter Rendering With Traditional Food Crops & Educational Signs

Figure 4.4 Planter Rendering Without Plants, N st. View



The outer planting beds feature stainless steel edgers that represent the sun's rays to compliment the art deco style of the building.

Figure 4.5 Planter Rendering Without Plants, 12th st. View



The central, half-circle planting bed is also enclosed in stainless steel panels.

Figure 4.6 Composting in the Greenhouse

Figure 4.7 Chicken Strawyard

Education & Visitor Interaction Walkthrough

The CDFA Rooftop Farm would lend itself especially well to educational field trips by students of all ages, from kindergarten up to college. But, the rooftop farm could really be open to anyone desiring to see it. One of the benefits of incorporating an educational, edible garden in front of the CDFA building next to the sidewalk is that it can act as an enticing advertisement to passersby for what is happening on the roof! However, tours of the rooftop farm would have to be well regulated for such a program to work, as the CDFA is an active government building, and cannot tolerate scores of visitors wandering its hallways and rooftop! I will try my best to provide a walkthrough of how such a process could possibly work.

Figure 4.8 Educational Sign

The street-level planters could feature educational signs similar to this one in courtyard of the Robert Mondavi Food and Wine Institute at U.C. Davis. *Image Credit: Andrew Emmert*

First, the CDFA could create a tour schedule, providing a few tours per week, a few tours per month, or even one tour a month, depending on demand. These tours would be consistently offered, and open to the general public. A reservation would need to be made in advance to secure a spot, as the number of visitors allowed on the rooftop at a time would need to be limited. For larger groups, such as school classes, private tours could be set up on an individual basis, and designed with various curriculums depending on the particular groups needs or interests. For example, a tour for a junior high science class might feature slightly different curriculum, and follow a slightly different pattern, than say, a tour for kindergarteners. A tour fee would be charged on a per person basis, and additional charges could be made for private group tours. This way, many of the expenses, or maintenance, associated with the rooftop farm could be partly offset by revenues from the tours.

The basic format for a tour could be as follows: Visitors would meet in CDFA foyer, sign-in, and then be led by the tour guide to the fourth floor, where they would climb one final stairway to a door that leads them out to the roof. Once on the roof, the visitors would be amidst the California native landscaping. A gravel path would lead them through the various plants, to the group seating area. At the seating area, the tour guide might tell them about the green roof, its various benefits, as well as about the various plants and insects living on the roof.

The next stop of the tour would be the learning greenhouse. Here, visitors would learn about how nutrients are cycled throughout the farm, and be able propagate a seed. Visitors would be able to don gloves and sift through the decomposing organic matter, picking out worms, or decomposing pieces of food. When the BioPods are opened, the more squeamish individuals would probably gasp or scream at the sight of the plump black soldier fly (BSF) larvae eating away at the kitchen food waste. The tour guide would then guide individuals in how to propagate a seed. Visitors could take the organic matter that has been thoroughly composted, pick out the worms, mix it with some soil, and plant a seed in it. Visitors would be able to plant one seed in a small container, which they could take home with them to plant in their own garden once the seed has properly germinated.

After the greenhouse, the visitors would be lead to the chicken strawyard. Here, they would learn about the various functions chickens provide in a sustainable agricultural system. They could let the hens eat some feed out of their hand, or perhaps the braver ones could feed a hen the special treat of a plump BSF larva. Others might try their hand at harvesting an egg or too.

Visitors would then proceed to the vegetable plots and fruit orchard. Here, visitors would learn about the various vegetable crops and fruit trees, and how they are farmed and managed in a sustainable manner. If it is the right timing, visitors may even be allowed to harvest a vegetable and take it home with them. Or, those who prefer fruit could pick a ripe mandarin orange, or pomegranate. Here, the tour would then end. The visitors would be led back down through the access hatch and out to the foyer, where they could buy some fresh produce or a souvenir to commemorate their trip to the CDFA rooftop farm.

Research Opportunity

In addition to the many educational opportunities for visitors, the CDFA rooftop farm also provides many opportunities for CDFA employees to conduct

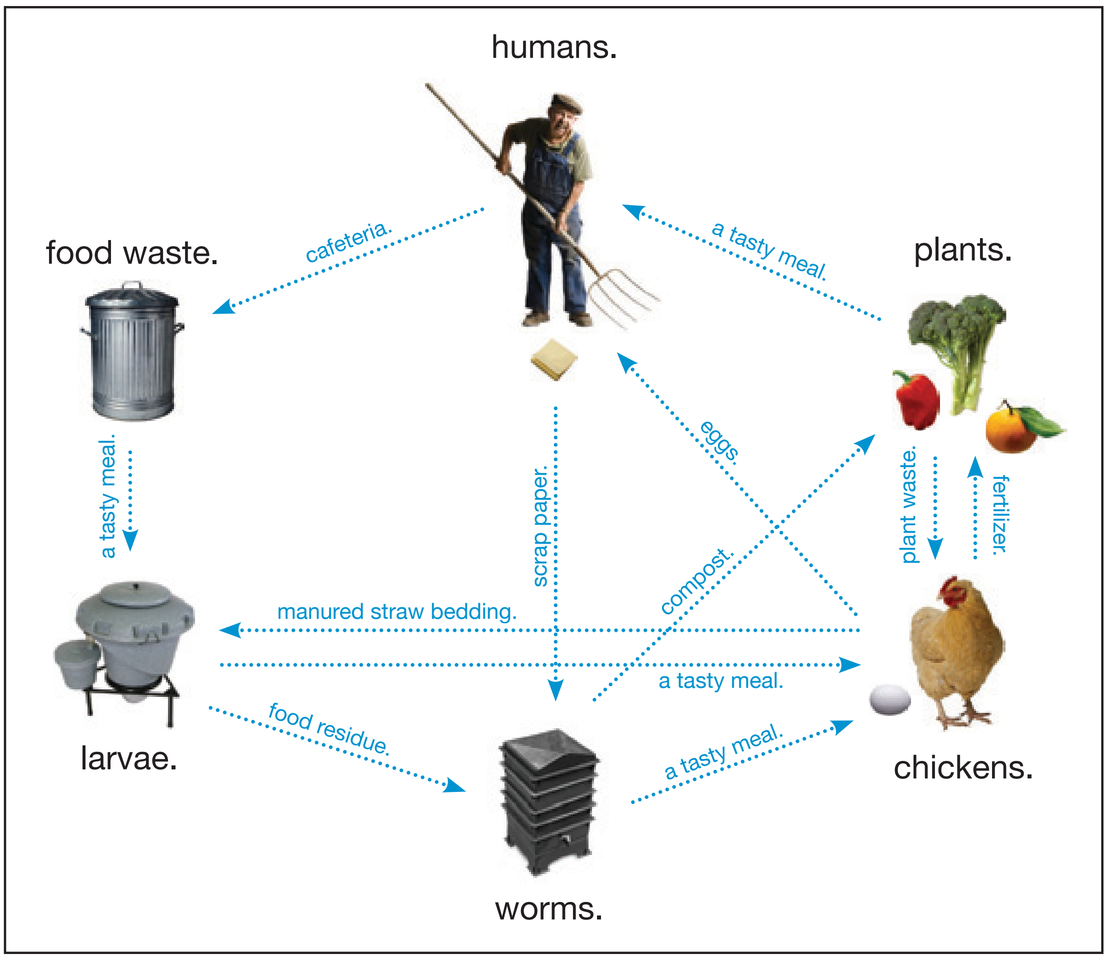
Figure 4.9 City of Chicago City Hall's Green Roof

Green roof data is used to advise future rooftop gardening projects in Chicago. *Source: The City of Chicago* research. Research conducted on the continuing health and productivity of the rooftop farm could provide an abundance of information about rooftop farming that could significantly benefit future rooftop farm projects. The Chicago City Hall's green roof is a great example of this. According to the City of Chicago, the green roof is monitored by scientists for its' air quality benefits, affect on building energy usage, and temperature reduction (n.d.).

The Nutrient Cycle

The CDFA rooftop farm would have a self-sustaining nutrient cycle. Let's begin the journey first at the CDFA cafeteria. The cafeteria provides food for the numerous employees at the CDFA. The food scraps, which would normally be discarded into the trash, instead would be collected in bins. No careful sorting would be necessary as this food waste is destined for the BioPods, where the hungry BSF larvae can break down almost anything, including meat (Wilson 2009). In addition to the unsorted food

Figure 4.10 The Rooftop Farm Nutrient Cycle



waste, the old, manure-covered straw from the chicken coop, which is cleaned periodically, can be added to the BioPod. The BSF larvae in the BioPods break down the food waste and straw in a matter of hours. The residue left behind by the larvae has been both decomposed and sterilized of any harmful bacteria or pathogens. This residue is then added directly to the worm bins, in addition to some paper waste from the CDFA offices, where red worms further break it down and turn it into a nutritious soil amendment, which can be added directly to the vegetable plots and the fruit tree containers.

Meanwhile, the BioPods are "self-harvesting"—meaning that the BSF larvae collect themselves in a small container next to the BioPod when they are ready to morph into flies (yes, they do actually do this by their own accord). But, before they are allowed to morph, they are fed to the chickens, along with some red worms when they are too abundant. The chicken's diet is also complimented with plant waste, which they peck from the post-harvested vegetable plots while performing their "tractor" duties. During this process, the chickens further fertilize the soil with their manure. At the end of this cycle, the rooftop farm produces fresh vegetables, fruit, and eggs, which can be sold, donated, or incorporated back into CDFA cafeteria's meals.

The Organisms

Black Soldier Fly (BSF) Larvae

According to Wilson, the black soldier fly (*Hermetia illucens*) larvae are little grubs with "voracious" appetites that can break down massive amounts of organic material in just a matter of hours (Wilson 2009). According to ESR International, inventors of the BioPod, larvae can reduce the weight and volume of a given amount of food waste by up to twenty times in just twenty-four hours (2008). They are also extremely resilient. ESR International added that the larvae can break down meat and dairy products, can survive in extreme conditions, and can go with out food for weeks (n.d.). This makes these larvae extremely efficient at breaking down any type of waste, and turning it into a usable soil amendment.

Figure 4.11 Black Soldier Fly Larvae

Mature black soldier fly larvae. *Source: http://www.thebiopod.com*

Figure 4.12 BioPod

The BioPod comes in a range of sizes. This one is a 2 foot diameter residential version. *Source: http://www.thebio-pod.co*

This whole process might sound messy, but ESR International claimed that while the BSF is in its' larval stage, it releases odors that actually drive away other "filth-bearing" flies, but that are imperceptible to humans. In addition, if the BSF larvae are able to pupate, and turn into a fly, because their fly form has no mouth, they don't bother pestering anyone (n.d.). Scott Kellogg and Stacy Pettigrew, authors of the *Toolbox for Sustainable City Living*, the BSF larvae have never been known to spread disease, do not pose any type of health risk to humans or animals, and they tend to stay away from "human dwellings" (2008, p. 59).

According to ESR International, the BioPod is a circular container made of tough polyurethane. It functions without any energy inputs. Food waste is dropped inside the BioPod along with the larvae, and a lid seals it in. The BSF will eat during their entire larval stage, which lasts a minimum of two weeks. After this period, the larvae seek out a dark, dry place to pupate. The BioPod is designed with ramps along the side of it that guide the larvae to a separate container outside the main container, where they can be easily collected and fed to chickens or fish. Amazingly, the larvae climb the BioPod ramps and fall into the collection container by their own accord. The food residue left behind by the larvae is the perfect food for red worms to further break down into a beneficial soil amendment. (n.d.).

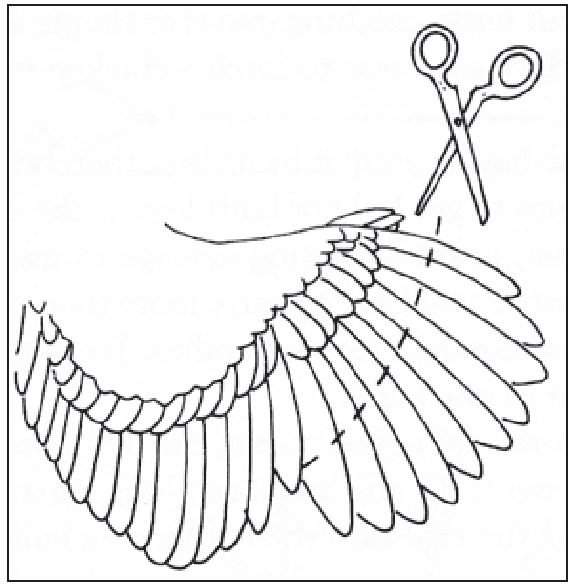
Red Worms

Using red worms in composting is called "vermicomposting". The benefit of using worms is that the food scraps can be broken down much quicker than if simply left to decompose alone. According to Kellogg and Pettigrew, worms produce "castings", a nutrient-rich, and microbe-rich manure, which makes an excellent soil amendment. In addition, the best-suited worms for composting are "red wigglers" (*Eisenia fetida*), because their skin secretes a bacteria-killing substance, which is useful in disinfecting

Figure 4.13 Temporary Chicken Fence

This fencing is lightweight and can be easily moved around to contain chickens in a desired location. *Source: http://www.premier1supplies.com*

Figure 4.14 Chicken Wing Clipping Diagram



Clipping a chickens wings involves only clipping the outer feathers where no nerves reside. *Source: http://www.backyardchickens.com/*

food waste (2008, p. 118-119).

Generally, red worms are used to only break down fruits and vegetables. However, according to ESR International, the food residue left behind by the BSF larvae, even though it may have contained products that worms can't break down originally, is suitable to give to red worms (n.d.). Kellogg and Pettigrew suggested doing vermicomposting inside where temperatures are more moderate. In addition, if done correctly, the compost should not attract flies or produce any foul odors (2008).

Chickens

Chickens may seem like the strangest addition to this rooftop farm environment. But, according to urban agriculture expert Richard Britz, "chickens are integral to the urban farm ecosystem" (1981, p. 180). Kellogg and Pettigrew explained that chickens could provide many benefits in a farm ecosystem. Chickens aerate and till the upper layer of the soil through constant scratching, their manure makes a great fertilizer, they can help keep weeds in check, and they can help control insect infestations (2008). One downside to raising chickens in an urban environment though, is as Britz pointed out, they are not always legal (1981). For Sacramento, these laws would have to be explored.

According to Kellogg & Pettigrew, chickens require both plant food and protein.

They can be fed seeds, insects, worms, maggots, kitchen scraps, produce, weeds, and garden greens. Commercial chicken feed can also be added to a chickens diet to help increase egg production, which sometimes can drop during the winter (2008). For an urban farm, Britz suggested selecting chicken breeds that are docile. The breeds he recommends are Rhode Island Reds, New Hampshire Reds, Sex-Links, and Barred Rocks, because they are known to lay more than 250 eggs a year (1981).

In order to make sure the chickens are prevented from getting out of their enclosure and flying off the roof of the CDFA building and surprising pedestrians down below, Kellogg & Pettigrew recommend clipping the tips of the chickens wings. According to them, this process doesn't harm the birds in any way, and it can prevent them from escaping their enclosures (2008).

The Green Roof System

For the green roof, an intensive system that could provide adequate soil depths to grow crops, along with minimal weight, is necessary. Conservation Technology, Inc is an American supplier of Optigreen green roofs, and they offer three main green roof models. The difference between the three is in the way they drain water. From their catalog, the model I chose is "Type P", which is a blend between providing good water storage capabilities, and being lightweight. This model features a drainage plate, which has a honeycomb-like structure that both stores water, and drains excess water. This water storing capability will be beneficial for the water-hungry food crops especially.

Since there are two different types of planting on the CDFA green roof, weight can be saved by choosing varying soil depths. For the California native landscaping areas, Conservation Technology, Inc recommends eight inches of soil to accommodate perennials, grasses, and shrubs. With fully saturated soil, this system has a cumulative weight of fifty-seven pounds per square foot, and an overall thickness of about ten inches (n.d.)

For the vegetable planting areas, a deeper soil depth is needed. Dunnett & Kingsbury recommend twelve to eighteen inches of soil for "meaningful cropping" of vegetables (2008, p. 83). To error on the side of more versus less, I chose to go with eighteen inches of soil. According to Conservation Technology, Inc, this green roof system with fully saturated soil weighs 126 pounds per square foot, and has a total cumulative thickness of twenty-one inches. Because of this difference in thickness between the two planting areas, the vegetable plots are raised ten inches above the ground, and encompassed with a concrete brick border with a step for access.

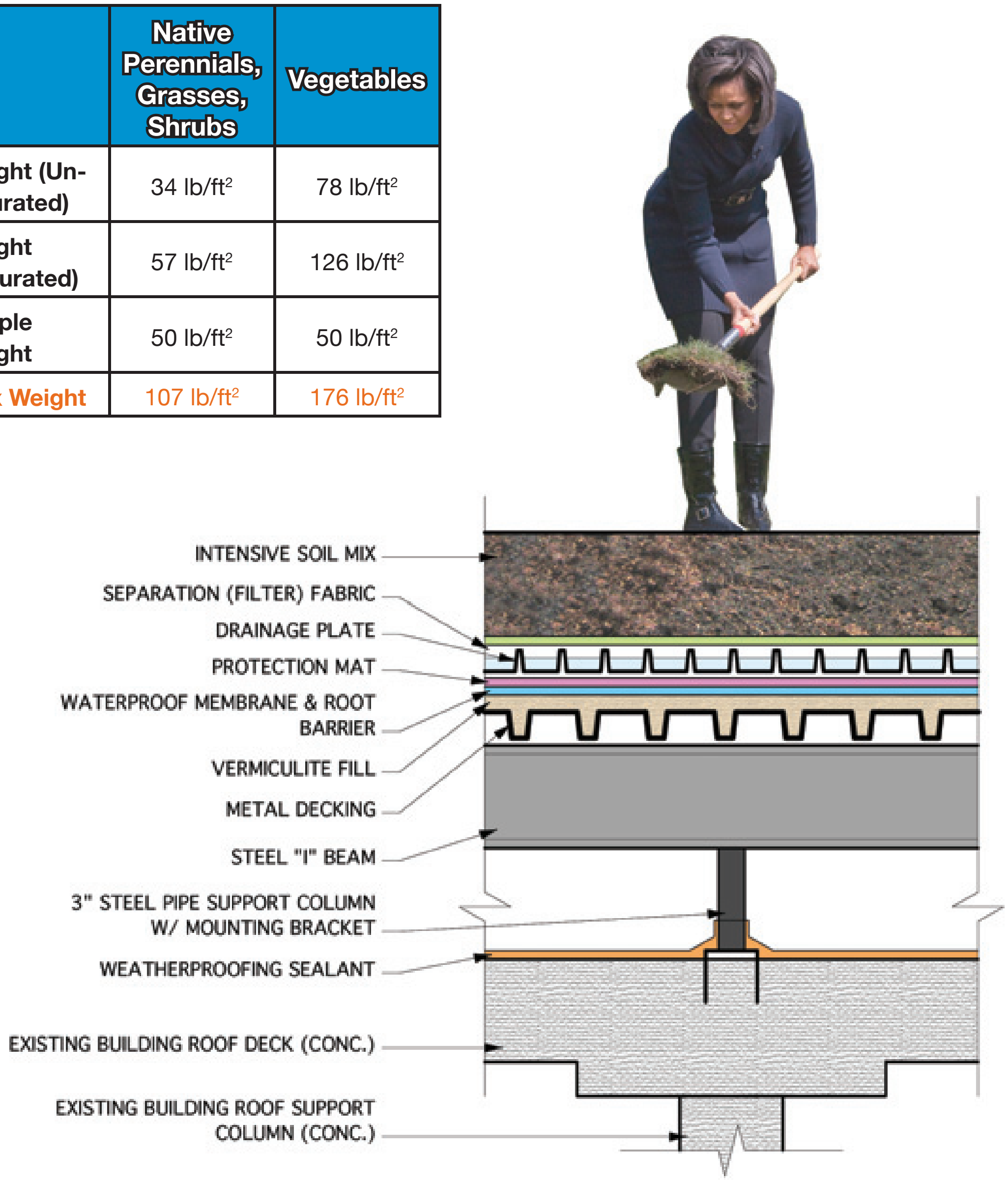
Figure 4.15 Green Roof Thicknesses

	Native Perennials, Grasses, Shrubs	Vegetables
Intensive Soil Mix	8"	18"
Filter Fabric	1/8"	1/8"
Drainage Plate	1 1/2"	2 1/2"
Protection Mat	1/4"	1/4"
Total Thickness (nominal)	**10"**	**21"**

Figure 4.16 Green Roof Weights

	Native Perennials, Grasses, Shrubs	Vegetables
Weight (Un-saturated)	34 lb/ft²	78 lb/ft²
Weight (Saturated)	57 lb/ft²	126 lb/ft²
People Weight	50 lb/ft²	50 lb/ft²
Max Weight	107 lb/ft²	176 lb/ft²

Figure 4.17 Layers of the Green Roof



Statistical data sourced from the *Green Roof Handbook,* a product catalog produced by Conservation Technology, Inc. *(http://www.conservationtechnology.com)*

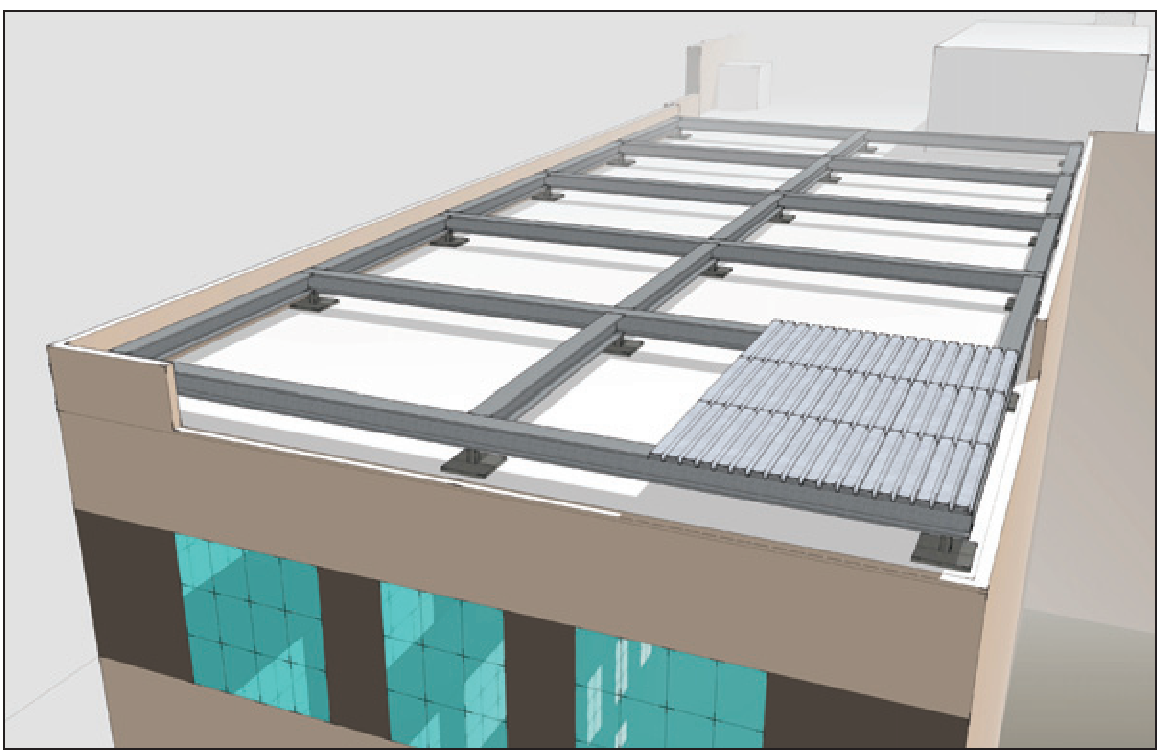
Structural Reinforcement

The heaviest section of the green roof system is the vegetable planting areas. Therefore, in total, the CDFA building's roof needs to be able to support 126 pounds per square foot of weight. In addition, structural engineer Brad Friederichs recommended adding an additional fifty pounds per square foot to this number to safely support the moderate foot traffic that is planned to occur on the roof (personal communication, March 29, 2009). The total amount of weight that the CDFA building's roof needs to support comes to 176 pounds per square foot. This is a significant amount of weight.

As mentioned in an earlier section, the CDFA building was likely built in 1936. According to Brad Friederichs, the age of the building suggests that it has a purely concrete internal structure (as opposed to steel, which is common on modern buildings). Such an internal structure, although strong enough for its' original purposes, would need additional reinforcement to support the extra 176 pounds per square foot (personal communication, March 29, 2009).

Counter to how it sounds, the reinforcing of the roof is actually a fairly straightforward process. Structural engineer Brad Friederichs explained it to me. First, slim steel column footings are anchored into the tops of the buildings own concrete columns at where they intersect with the roof. Secondary steel columns are also anchored at the

Figure 4.18 Green Roof Structural Reinforcement System



roof's edges. These steel footings help to direct all weight into the main structure of the building. Then, twelve inch steel I-beams are laid across the columns, forming a square pattern. On top of the I-beams, is placed metal decking, which is filled in with an insulating concrete, creating the new, reinforced, roof surface. This type of reinforcement system can be designed to accommodate any desired weight. However, in addition to roof reinforcement, the building itself would need to be evaluated for its' load-bearing capability, and seismic integrity, by a licensed structural engineer (personal communication, March 29, 2009).

five.

limitations and conclusions.

Design Limitations

For my design to be implemented, numerous limitations would first need to be surmounted. The first of these limitations is the age of the CDFA building. According to Friederichs, it is highly likely that the building is not up to current earthquake codes (personal communication, March 29, 2009). This could pose a serious safety risk if the weight of the green roof system was added to the roof and no seismic strengthening was done. However, bringing the building up to current codes would likely be an intense and very costly process. The only positive aspect of this limitation though, is that the building should probably be brought up to code regardless for safety, and a rooftop farm proposal could be a good initiator in this process.

The second limitation to this design is maintenance. Although the California native landscape area of the green roof would require little to no maintenance once the plants were established, moderate maintenance will be required for the edible landscaping on the street-level, and lots of maintenance will be needed to attend to the compost system, the chickens, the vegetable plots, and the fruit orchard. Perhaps the only way to make this level of maintenance worthwhile for the CDFA, is if there are extensive benefits from the research conducted on the roof, and if some level of revenue is generated from the tours.

The third limitation to this design, and probably the biggest, is cost. According to my estimates, the area of the designed part of the CDFA roof is about 21,600 square feet. The U.S. EPA estimated that the average cost for an intensive green roof system is $25 per square foot (n.d.). In addition, HolmesCulley, estimated that the structural improvements required for putting an intensive green roof on a four-story office building costs about $150 per square foot (n.d.). The total cost of these two estimates when calculated for the CDFA building, come out ton $3,780,000! Granted, these numbers are just very general estimates, but nevertheless, that is an outrageous amount of money! Judging by the current fiscal status of the state, the chances of this project ever being constructed on the roof of the CDFA building is slim to none. But, perhaps a solution to this dilemma is to incorporate the rooftop farm project into a new building project, where the necessary weight requirements could be designed into the structure. This is likely the only solution to making this rooftop farm a reality.

Final Thoughts

Today, rooftop agriculture is no longer a fringe idea. In places all over the world, the way agriculture has been done is being rapidly reconsidered. At Trent University in Canada, students cultivate a rooftop farm that uses its' produce in a student run café.[5] The Rooftop Garden Project has been promoting community rooftop agriculture in Montreal, Canada for years now.[6] The Zabar's Vinegar Factory provides the freshest, rooftop-grown produce to grateful residents in Manhattan, New York. The True Nature Foods Rooftop Victory Garden in Chicago, Illinois, is attempting to build a safer, and more secure source of food for the local community.[7] In Mt. Gravatt Central, Australia, the local government is evaluating a project for a rooftop "microfarm", that would produce a wide assortment of foods, including vegetables, herbs, fish, rabbits, and crustaceans.[8] Even closer to home, a non-profit organization called Bay Localize, based out of Oakland, recently conducted a feasibility analysis of growing food on San Francisco rooftops.[9] Clearly, farming is no longer restricted to the ground plane.

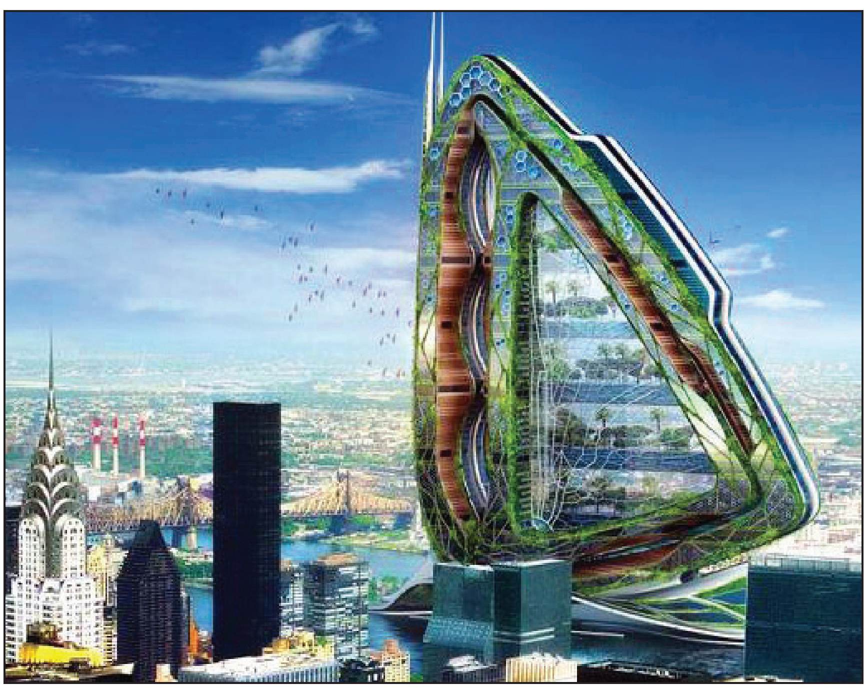
Figure 5.1 Rooftop Victory Garden

This Chicago, IL, rooftop farm is a joint project between organic food producer True Nature Foods and the non-profit organization Urban Habitat Chicago.
Source: http://www.urbanhabitatchicago.org

Yet, perhaps the most visionary ideas concerning rooftop farming are coming out of Columbia University in New York City. According to an article by Gretchen Vogel in *Science Magazine*, Professor Dickson Despommier is proposing what he calls "vertical farms"—massive sky-scraper-like structures that house floor after floor of fruit and vegetable crops grown in a nutrient-rich, hydroponic slurry, and assisted by grow lamps. Renewable energy would power these visionary "farms", nutrients could be sourced from a city's sewage system, and even livestock could be reared inside (2008). According to an interview in *Popular Science*, Despommier claimed that a thirty story vertical farm, covering just one city block, could feed up to 50,000 people, and produce no waste! Despommier hopes to have the first vertical farm prototype up and running in the next five to ten years (2007).[10]

The building momentum behind rooftop farming may be surprising, but it should not be surprising that alternative solutions to ground-based agriculture are being sought. The decaying state of modern, industrial agriculture is a serious problem, and the tougher times are still likely ahead. With all of our world's dwindling resources, environmental destruction, and economic strain, it may appear that there is no hope. Author Paul Roberts compares this risky time for civilization to standing on the edge of a cliff. In *The End of Food*, he stated that "we are closer to that precipice than we have ever been, yet perhaps more capable, ultimately, of stepping away" (2008, p. 322). I think that he is right. Our agriculture system may be in trouble, but we are still capable of saving it. Hopefully this project has proven that agriculture can be done even in the most unlikely places. It only requires a little bit of imagination, a touch of humility, and the courage to try.

Figure 5.2 Dragonfly Vertical Farm for New York



This Vertical Farm concept by Belgian architect Alexandra Kain spans 600 meters high with 132 floors. Inside there are offices, research labs, housing, communal areas, and 28 agriculture fields producing meat, dairy, vegetables, fruits and grains. *Source: http://www.inhabitat.com*

appendix 1.
google sketchup sun/shade study explained.

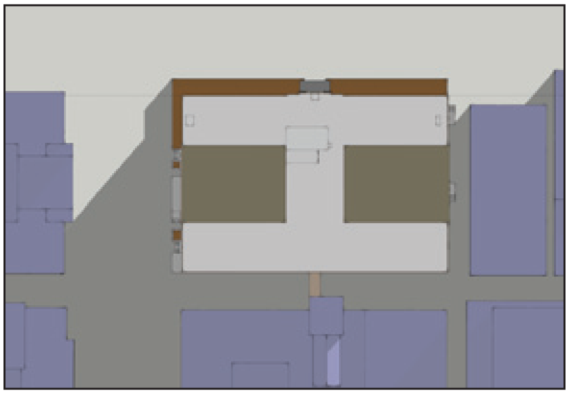
The amount of sunlight that reaches the planters is very low. In an attempt to quantify this amount I made a 3-D model of the CDFA building and the buildings within its direct vicinity that appeared to potentially affect the sunlight reaching the street-level landscaping. By using a Google Earth map that I imported into CAD, I traced the various footprints of the buildings. Then, I estimated the building's heights by "eyeing" pictures of them in the "street view" feature of Google Earth. Obviously, this measurement method is not 100 percent reliable by any means, but for the purpose of observing shade patters it is good enough (As a side note, after I developed the 3-D model I went to the site and measured the building using a tape measure and found my approximations using Google Earth accurate to within one foot of the actual dimensions).

After I had my measurements, I built a block model in Google SketchUp and located it using the actual, real-life coordinates, and by designating the direction of north. By locating the model in Google SketchUp, one is able to get realistic sun patterns, and can observe the model at different times during the day, 365 days a year. After the model was set-up, I chose dates by first selecting the two equinoxes (spring and fall), the two solstices (winter and summer), and the twenty-first of every month in between. This gave me twelve, equally spaced out dates for the entire year.

From there, I defined the varying amounts of sunlight into three categories: no sun, part sun, and full sun. Then, I set the SketchUp calendar for the desired date and proceeded to move the sun throughout the entire day, denoting the time that a particular sunlight category was crossed. For the no sun category, I determined that the planter must be covered in shade by 90% or more. For part sun, I determined that the planter be between 90% and 50% shade coverage. And, for full sun, the planter had to have less than 50% shade coverage (or in other words, more than 50% sunlight). After I got through each day, I was left with the windows of time that each type of sunlight persisted, which I could then add up for a total amount of light for each category. This process was done separately for both the north side planters, and the west side planters, as the position of the building creates a unique environment for each side. On the next page there are image example of the various sunlight categories for June 21, 2008, the summer solstice.

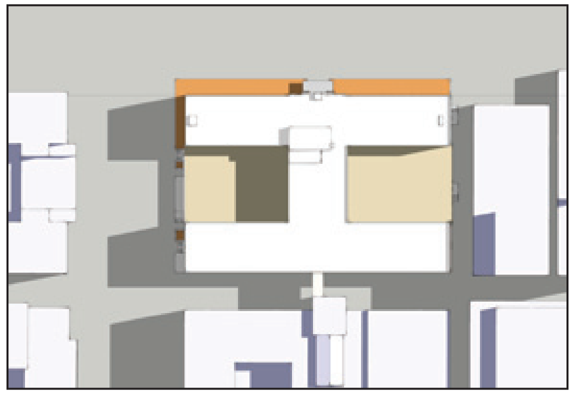
sun/shade example study for june 21, 2008.
north side planters.

4:50 AM / No Sun



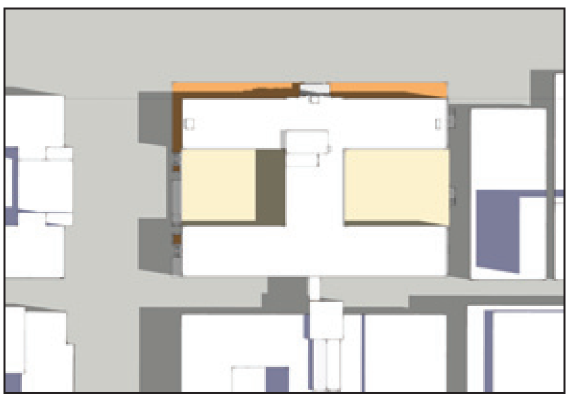
Planters are completely covered by shade.

9:07 AM / Full Sun



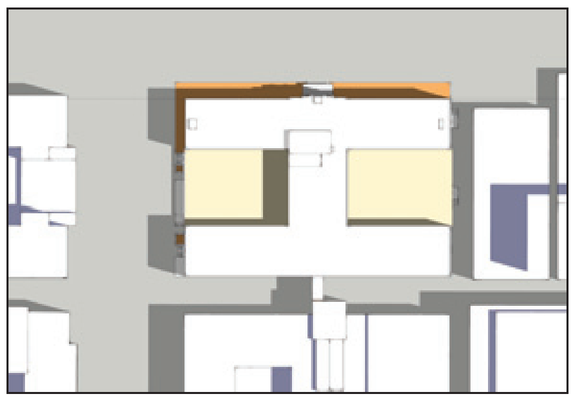
Planters are receiving 100% sunlight.

10:28 AM / Full Sun



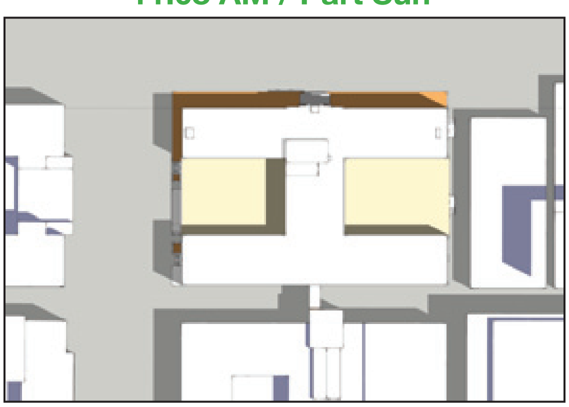
Planters just under 50% shade cover.

10:45 AM / Part Sun



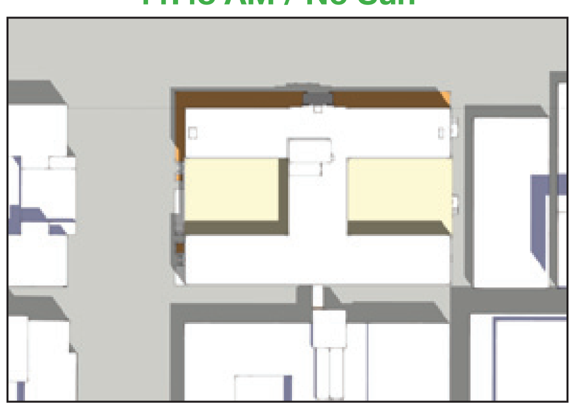
Planters clearly shaded by more than 50%.

11:08 AM / Part Sun



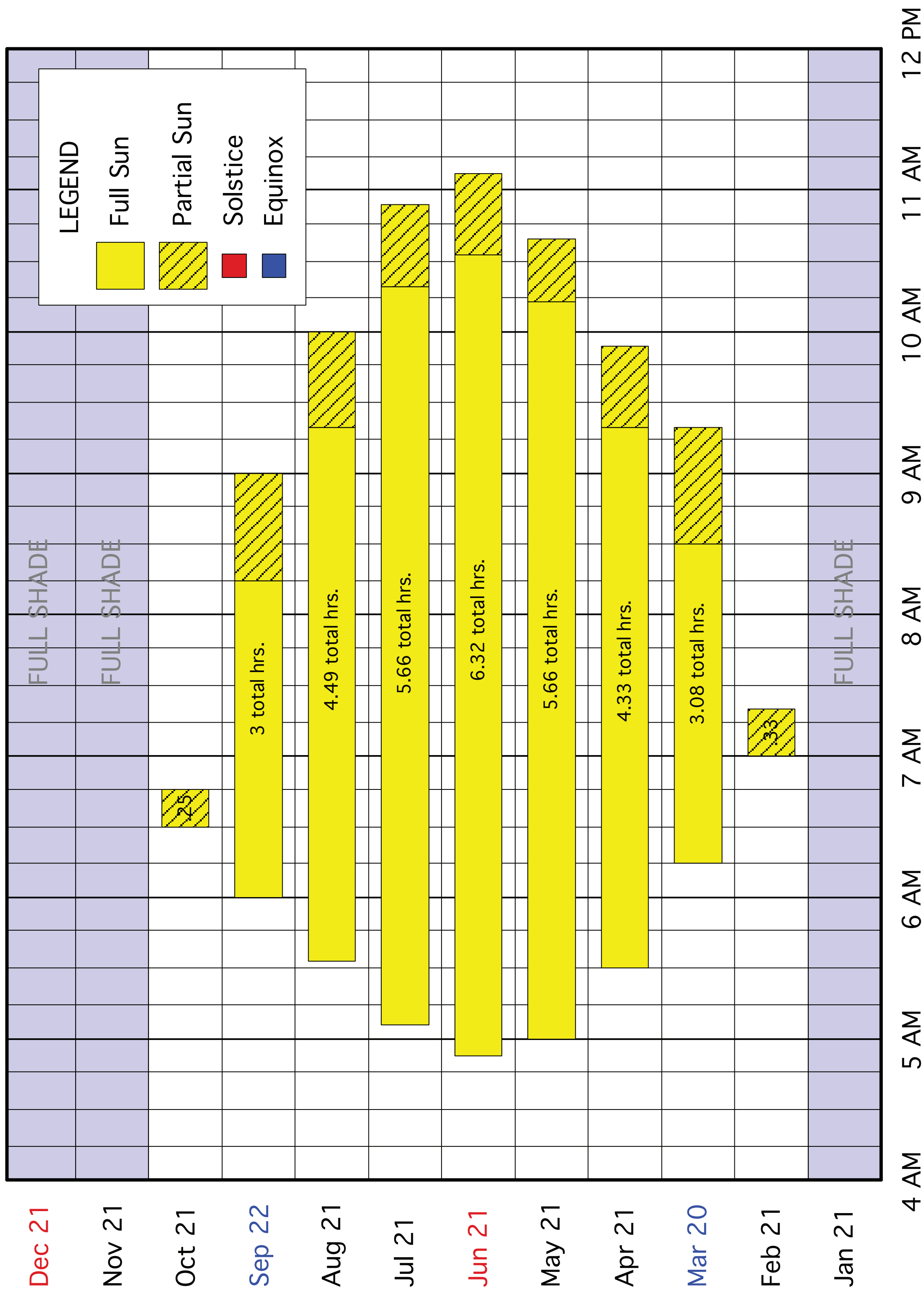
Planters approaching brink of 90% shade cover.

11:48 AM / No Sun

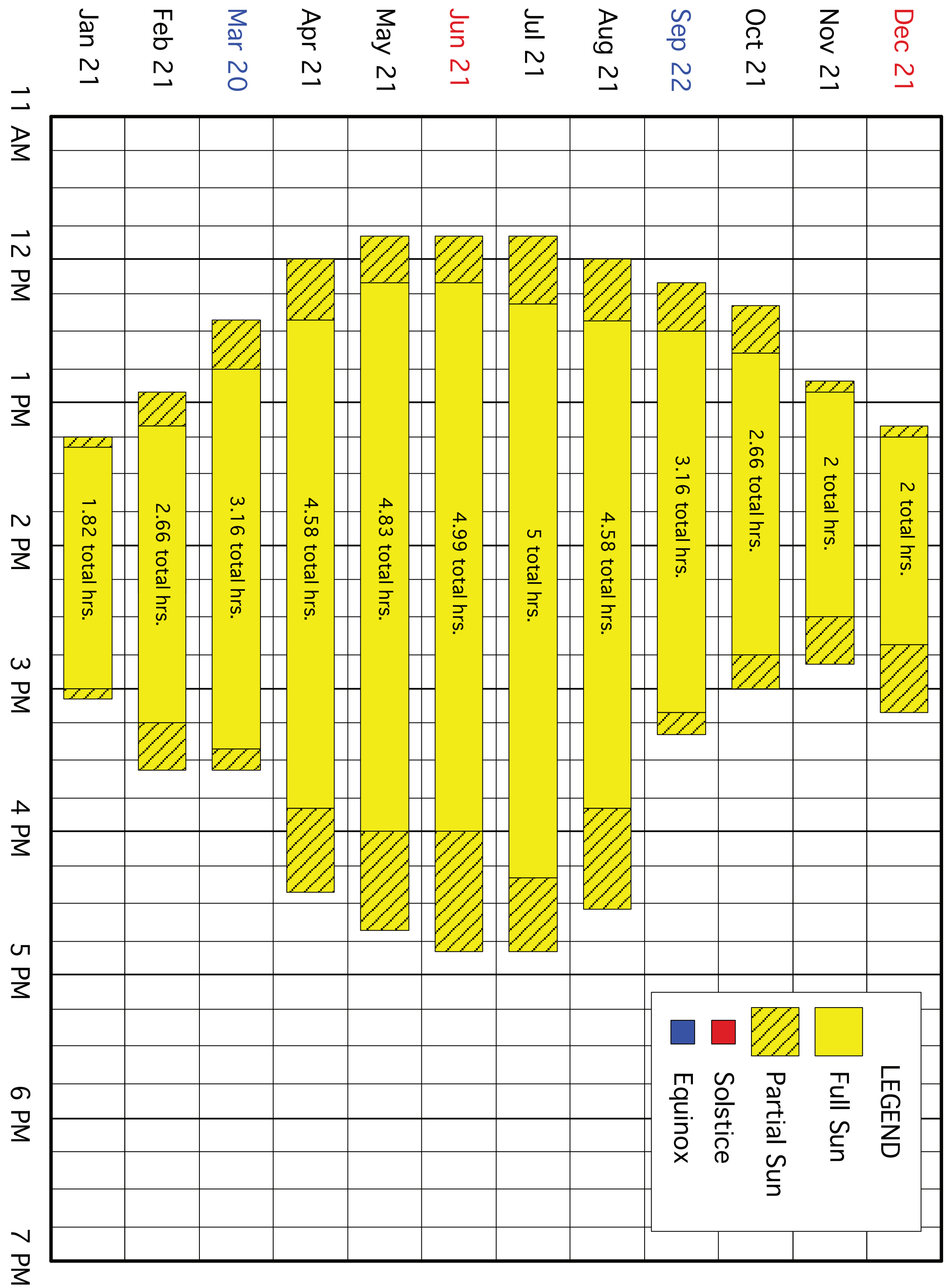


The planters are more than 90% covered in shade.

sun/shade graph for cdfa's north-side planters.



sun/shade graph for cdfa's west-side planters.



appendix 2.

shade-tolerant edible plants.

Annuals			
Hamburg Parsley	*Petroselinum crispum var. tuberosum*	Apiaceae	SP, SU, FA, WI
Endive	*Cichonum intybus 'Rollelof'*	Asteraceae	SP, SU, FA
Leaf Lettuce	*Lactuca sativa 'Lollo Rossa'*	Asteraceae	SP, SU, FA, WI
Butterhead Lettuce	*Lactuca sativa 'All Year Around'*	Asteraceae	SP, SU, FA, WI
Romaine Lettuce	*Lactuca sativa 'Little Gem'*	Asteraceae	SP, SU, FA, WI
Radish	*Raphanus sativus 'Long Black Spanish'*	Brassicaceae	SP, SU, FA, WI
Turnip	*Brassica rapa 'Purple Top Milan'*	Brassicaceae	SP, SU, FA
Land Cress	*Barbarea verna*	Brassicaceae	SP, SU, FA, WI
Cabbage	*Brassica oleracea 'January King 3'*	Brassicaceae	SP, SU
Cabbage	*Brassica oleracea 'Dynamo'*	Brassicaceae	SU, FA
Swiss Chard	*Beta vulgaris ssp. cicla 'Vulcan'*	Chenopodiaceae	SP, SU, FA
Swiss Chard	*Beta vulgaris ssp. cicla 'Fordhook Giant'*	Chenopodiaceae	SP, SU, FA
Arugula	*Eruca vesicaria ssp. sativa*	Brassicaceae	SP, SU
New Zealand spinach	*Tetragonia tetragonoides*	Aizoaceae	SP, SU, FA
Miners Lettuce	*Montia perfoliata*	Portulacaceae	SP, SU
Perennials			
Thyme	*Thymus spp.*	Lamiaceae	
Oregano & Marjoram	*Origanum spp.*	Lamiaceae	
Comfrey	*Symphytum officinale*	Boraginaceae	
Salad Burnet (small)	*Sanguisorba minor*	Rosaceae	
Great Burnet (large)	*Sanguisorba officinalis*	Rosaceae	
Red Currants	*Ribes sativum*	Grossulariaceae	

Sources: Personal communications with Raoul Adamchak and Margaret Lloyd, as well as the book *Vegetables, Herbs, & Fruit: An Illustrated Encyclopedia* by M. Biggs, J. McVicar, & B. Flowerdew.

appendix 3.
rooftop edible plant list.

Annuals			
Kale	Brassica oleraceae	Brassicaceae	SU
Eggplant	Solanum melongena	Solanaceae	SU
Green beans	Phaseolus vulgaris	Papilionaceae	SP
Tomatoes	Lycopersicon esculentum	Solanaceae	SU
Onions, bunching	Allium cepa	Alliaceae	SP, SU, FA
Peppers, bell, chile	Capsicum annuum	Solanaceae	SU
Zucchini	Cucurbita pepo	Cucurbitaceae	SU
Sunflowers	Inula helenium	Asteraceae	SU
Lettuce	Lactuca sativa	Asteraceae	WI
Perennials			
Basil	Ocimum basilicum	Lamiaceae	
Oregano	Origanum spp.	Lamiaceae	
Thyme	Thymus spp.	Lamiaceae	
Lavender	Lavandula spp.	Lamiaceae	
Rosemary	Rosmarius spp.	Lamiaceae	
Container Trees			
Dwarf Citrus	Citrus spp.	Rutaceae	
Figs	Ficus carica	Moraceae	
Olives	Oleo europaea	Oleaceae	
Pomegranates	Punica granatum	Lythraceae	
Guava (Feijoa)	Acca sellowiana	Myrtaceae	

Sources: Personal communication with Margaret Lloyd; *Vegetables, Herbs, & Fruit: An Illustrated Encyclopedia* by M. Biggs, J. McVicar, & B. Flowerdew.; *How to Grow More Vegetables* by John Jeavons.

notes.

1. For more information on Conservation Technology and their green roof products, visit http://www.conservationtechnology.com. To download their product catalog, visit http://www.conservationtechnology.com/documents/GreenRoofHandbook1008.pdf.
2. For more information on Zabar's Vinegar Factory in New York, visit http://www.elizabar.com/zabar.
3. For the City Garden Farms website, go to http://www.citygardenfarms.com. For more information on SPIN Farming, visit http://www.spinfarming.com.
4. The BioPod was created by ESR International. The BioPod website is http://www.thebiopod.com. Or, visit the ESR International website at http://www.esrint.com.
5. A good article on the Trent University Rooftop Garden can be found at http://www.cityfarmer.org/TrentRoof.html.
6. The website for The Rooftop Garden Project in Montreal is http://www.rooftopgardens.ca/en.
7. The True Nature Foods Rooftop Victory Garden is a joint effort between True Nature Foods and Urban Habitat Chicago. The True Nature Foods website is http://www.truenaturefoods.com. However, better information on the rooftop garden can be found on Urban Habitat Chicago's website, at http://www.urbanhabitatchicago.org/projects/true-nature-foods.
8. A good article on the Mt. Gravatt "Urban Rooftop Integrated Microfarm" can be found at http://www.cityfarmer.org/rooftopmicrofarm.html#microfarms. The original proposal for the microfarm to the Queensland government can be downloaded at http://www.aph.gov.au/House/committee/environ/cities/subs/sub119.pdf.
9. The Bay Localize website is http://www.baylocalize.org.
10. For more information on Vertical Farms, such as design proto-types, go to http://www.verticalfarm.com.

bibliography.

Ableman, M. (2005). *Fields of Plenty: A Farmer's Journey in Search of Real Food and the People Who Grow It.* San Francisco, CA: Chronicle Books.

Bay Localize. (2007). *Tapping the Potential of Urban Rooftops: Rooftop Resources Neighborhood Assessment.* Oakland, CA: Author.

Biggs, M., McVicar, J., & Flowerdew, B. (2006). *Vegetables, Herbs, & Fruit: An Illustrated Encyclopedia*. Buffalo, NY: Firefly Books, Inc.

Britz, R. (1981). *The Edible City: Resource Manual.* Los Altos, CA: William Kaufmann, Inc.

California Department of Food and Agriculture. (2009). *California Department of Food and Agriculture – 90 Years Protecting and Promoting Agriculture in the Golden State.* Retrieved June 1, 2009, from http://www.cdfa.ca.gov/CDFA-History.html

City of Chicago, The. (n.d.). *Chicago's Green Rooftops: A Guide to Rooftop Gardening.* Retrieved February 17, 2009, from http://egov.cityofchicago.org/webportal/COCWebPortal/COC_ATTACH/GuidetoRooftopGardening_v2.pdf

City of Los Angeles, The: Environmental Affairs Department. (2006). *Green Roofs – Cooling Los Angeles: A Resource Guide*. Retrieved April 25, 2009, from http://www.fypower.org/pdf/LA_GreenRoofsResourceGuide.pdf

Conservation Technology, Inc. (2006, May). *Green Roof Handbook*. Retrieved February 24, 2009, from http://www.conservationtechnology.com/documents/GreenRoofHandbook1008.pdf

Dunnett, N., & Kingsbury, N. (2008). *Planting Green Roofs and Living Walls.* Portland, OR: Timber Press.

ESR International. (n.d.). *Bio-Conversion of Putrescent Waste*. Retrieved June 7, 2009, from http://www.esrint.com/pages/bioconversion.html

Feldman, A. (2007, July). The Vertical Farmer. *Popular Science.*

Fischetti, M. (2008, October). Growing Vertical. *Scientific America*.

Friedman, T. L. (2008). *Hot, Flat, and Crowded: Why We Need a Green Revolution, and How It Can Renew America.* New York, NY: Farrar, Straus and Giroux.

Heinegg, A., Maragos, P., Mason, E., Rabinowicz, J., Straccini, G., & Walsh, H. (2006, August). *Soil Contamination and Urban Agriculture: A Practical Guide to Soil Contamination Issues for Individuals and Groups.* Retrieved February 2, 2009, from http://www.ruaf.org/sites/default/files/guide%20on%20soil%20contamination.pdf

HolmesCulley. (n.d.). *Rooftop Resources: Structural Discussion*. Retrieved February 17, 2009, from http://www.baylocalize.org/files/Structural_Report_Final.pdf

Kellogg, S., & Pettigrew, S. (2008). *Toolbox for Sustainable City Living: A Do-it-Our selves Guide.* Cambridge, MA: South End Press.

Pfeiffer, D.A. (2006). *Eating Fossil Fuels: Oil, Food, and the Coming Crisis in Agriculture*. Gabriola Island, B.C.: New Society Publishers.

Pollan, M. (2006). *The Omnivores Dilemma: A Natural History of Four Meals*. New York, NY: Penguin Press.

Roberts, P. (2008). *The End of Food*. New York, NY: Houghton Mifflin Company.

Rooftop Garden Project, The. (2006, May). *The Rooftop Garden Project: Liberating Spaces for Healthy Cities (Brochure).* Retrieved February 2, 2009, from http://rooftopgardens.ca/files/4pagerenglishWEB.pdf

Spirn, A.W. (1984). *The Granite Garden*. New York, NY: Basic Books, Inc, Publishers.

Todd, N.J., & Todd, J. (1993). *From Ecocities to Living Machines: Principles of Ecological Design.* Berkeley, CA: North Atlantic Books.

U.S. Environmental Protection Agency. (n.d.). *Reducing Urban Heat Islands: Compendium of Strategies*. Retrieved April 25, 2009, from http://www.epa.gov/heatisland/resources/pdf/GreenRoofsCompendium.pdf

Vogel, G. (2008, February). Upending the Traditional Farm. *Science Magazine.*

Wilson, A. (2009, February 1). Growing Food Locally: Integrating Agriculture Into the Built Environment. *BuildingGreen.com*. Retrieved February 12, 2009, from http://www.buildinggreen.com/auth/article.cfm/2009/1/29/Growing-Food-Locally-Integrating-Agriculture-Into-the-Built-Environmnet