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Mobile Technology as a Leverage Point for the Spread of Permaculture in the Food System

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MOBILE TECHNOLOGY AS A LEVERAGE POINT FOR THE SPREAD OF PERMACULTURE IN THE FOOD SYSTEM

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Introduction:

This thesis argues that the current food system is untenable in the long term due to its significant negative impacts on the global ecosystem and society. Permaculture is a sustainable alternative to the current food system that works on both the communal and individual level. Mobile and social media technologies take advantage of specific leverage points in the food system that can help permaculture spread most effectively and, in a manner most compatible with permaculture principles.

It will also provide a proof of concept full stack application that shows how permaculture can be implemented on the individual level with a variety of land types and sizes. The application will have three major parts: a project management software designed around permaculture, a set of educational nodes corresponding to the principles of permaculture, and a social media implementation. These different features focus on addressing what author Donella Meadows calls the "leverage points" of a system. She defines these as "places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything." (Meadows, p. 1)

This concept is pivotal to the method of implementing permaculture that this work will suggest. Longtime farmer and author Wendell Berry once noted in an interview with Bill Moyers the importance of "leadership from the bottom." Berry states that he's "convinced perfectly that it's happening, and that the leadership consists of people who simply see something that needs to be done and they start doing it." (Berry, 2013) It is through Meadows' leverage points that individuals acting on the local level are capable of changing an entire system. Specifically, the app tries to address "the structure of information flows" thus "creating the power to self-organize system structure." (Meadows, 1999, p. 3) These people, Berry notes, are already demonstrating

their own power to self-organize, and the app works to further support people and create an atmosphere for self-empowerment. However, before I can begin to demonstrate the benefits of permaculture and show how to disseminate it, I must first show why such a change is necessary.

Climate and Agribusiness: A Spiral of Decay

Although many works on permaculture and its practices take a short amount of time to convince the reader of the untenability of the current food system, instead, I will show the ways in which our current food system has entered into a spiral of erosion with the climate. Although there is a myriad of failings in the current food system, the climate has the most far reaching effects for people of all nations, social and economic backgrounds, skin colors, sexual orientations, etc.

However, before I begin, allow me to first explain what I mean by some of the terminology used above. The term “agribusiness” includes within its scope nearly the entirety of the current profit-based food system; from the land grant colleges, to the massive monocultures, to the supermarkets in our cities. The use of the term “spiral of erosion” comes from author and permaculturist Louise Macnamara. In her work *People and Permaculture,* Macnamara offers one of the most personalizable and adaptable presentations of permaculture. In this pursuit, she discusses the ways in which certain patterns that are unequivocally observed in natural systems, can be recognized as acting in man-made systems. In this thesis, I will be focusing on the pattern of a spiral. This structural pattern reflects a system with a self-contained feedback loop, either exponentially improving, or eroding.

Figure 1, (McNamara & Storch, 2014, p. 15)

Structural patterns

Pattern	Where it is found in nature	Human applications	Characteristics/benefits	Attitude as designer
Wave 	Water Heartbeats Sound Sleep Brain activity	Music Bio-rhythms	Measurement of time Building of momentum Eroding Repeating but each one is different Pulsation	Constantly changing Accepting ups and downs Time for action and time for rest Waves of activity
Spiral 	Snails Plant tendrils Inner ear Whirlpool Tornados	Herb spiral Corkscrew Springs Heating elements Seasonal living/ growth	Protection Acceleration or deceleration Can store energy Compaction Indefinite growth Supportive Efficient use of space Powerful Beautiful Concentrating or dispersing	Out a bit and round a bit Transcend and include Gradually improving or eroding Repeating to almost the same place Building on successes
Branching 	Trees and plants – above and below Evolutionary tree of life Blood vessels Waterways Antlers Capillaries	Transport Family trees Website design Mindmaps	Spreading Covers large surface area Creates lots of edge Stabilising Anchoring Gathering Can travel both ways Resilient Increases diversity and spreads over a wider area Exchange and transport	Can cut off parts and the rest survives Useful for gathering or distributing flows of nutrients, energy, information, water, air from or to a large area Can reach out in stages
Lobe/ Honey-comb 	Berries Hair and fur Reptile and fish scales Birds' feathers Pine cones	Roofing Jewellery Flooring Weather cladding Insulation	Lots of edge for exchange between parts Interlocking Can produce a large and strong structure from simple elements Uniform Protection Waterproofing Resilience	Small groups building to larger movement Protection and strength in numbers Multi-faceted More flexibility than just one large unit Modular Can sacrifice parts and the rest is undamaged
Net 	Birds' nests Leaf and plant tissue Bramble thicket Coral Bone structure Sponge Spiders' webs	Barriers Hedge-laying Straw-mulch Cob walls Nets Woven cloth Knitwear Sieves	Strong and light Big surface area Permeable Spreads the load – distributes tension Catches things Strengthens and reinforces Interconnected Resilience Resistance Repairable Supportive and protective Efficient use of space Creates lots of edge	Making connections Spreading the work load Harvesting yields Swifter communication than a chain-of-command Many routes to the same places

These patterns finally bring me to the relationships between the climate and agribusiness. In his work *The Unsettling of America*, Wendell Berry offers one of the most compelling arguments against the current food system, made ever more compelling by its continued applicability some forty years after it was initially published. In it he perfectly describes the impact of a culture of future obsession upon the agricultural industry. He notes that a leading "reason for the dominance of the future over agriculture is that projected rates of population growth have become the all-purpose threat and justifier of the apologists of the agricultural establishment. Millions are threatened with starvation – so the argument runs – therefore we must continue to farm in larger monocultures on larger holdings with fewer farmers, larger and more expensive machines, more chemicals." (Berry, 2015, p. 59) In examining the cyclic and spiral nature of this relationship, it is worth noting here that Berry's 1977 statement is nowhere short of clairvoyant. In a 2018 report on "The State of Food Security and Nutrition in the World" published collectively by FAO (Food and Agriculture Organization of the United Nation), IFAD (International Fund for Agricultural Development), UNICEF, WFP (World Food Programme), and the WHO (World Health Organization), this sentiment is again reinforced. In its key messages noted at the outset of the report, it states that "New evidence continues to signal a rise in world hunger and a reversal of trends after a prolonged decline. In 2017 the number of undernourished people is estimated to have increased to 821 million – around one out of every nine people in the world" (FAO, etc, 2018, p. xii). Although this specific document goes on to extensively describe the ways in which climate change negatively impacts agriculture, this simple statistic is enough to be taken out of context and used as continued justification for the current food system. However, as Berry is sure to note, "no rational person can see how using up the topsoil or the fossil fuels as quickly as possible can provide greater security for the future;

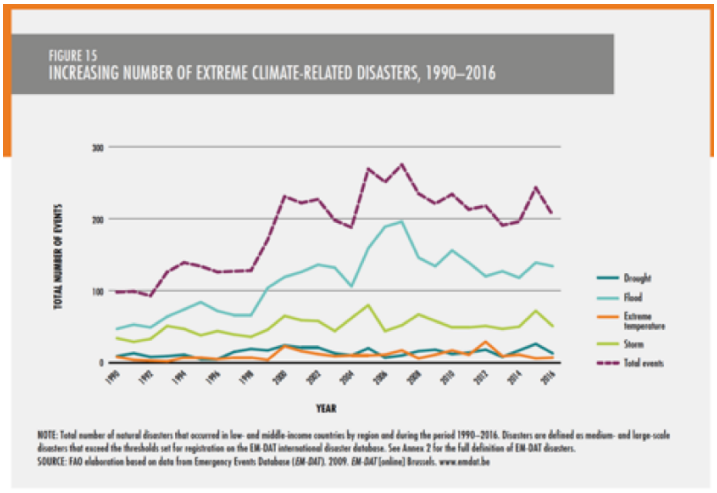
but if enough wealth and power can conjure up the audacity to say that it can, then sheer fantasy is given the force of truth; the future becomes reckonable even as the past has never been." (Berry, 2015, p. 58)

In that context, allow me to simply present my rational reader with the evidence of both human culpability in the growing crisis of climate change, and the immense resultant impact upon the agriculture system. In 2014 the IPCC (Intergovernmental Panel on Climate Change) published its fifth collective assessment of the environment. This work explicitly states "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history…. Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen. (IPCC, 2014, p. 2) This report does not mince words in its statement of both the human influence on climate change nor with the immense impact of that climate change. Despite the current political atmosphere and continued protestations of the oil companies, we are far past the point of scientific consensus on climate change. This problem is real, it is wide reaching, and it is of our own making. It has become abundantly clear that "continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks." (IPCC, 2014, p. 8) This statement, in conjunction with the evidence the UN provides on the astronomical effect of climate change on agriculture, effectively condemns any attempt to justify the perpetuation of the current food system.

That evidence is provided by the aforementioned UN report on food security and nutrition. In the second of two parts entitled "The Impact of Climate on Food Security and Nutrition" it goes in depth into the myriad of ways in which "climate variability and exposure to more complex, frequent and intense climate extremes are threatening to erode and even reverse the gains made in ending hunger and malnutrition" and "are a key driver behind the recent rise in global hunger and one of the leading causes of severe food crises." (FAO, etc, 2018, p. 38). Although climate change is typically framed as being an issue of the future, this document does well to bring this crisis into the here and now. It begins by stating outright the ways in which climate change affects our world today. It states that "the number of extreme events, including extreme heat, droughts, floods and storms, has doubled since the early 1990s, with an average of 213 of these events occurring every year during the period of 1990–2016 (Figure 2)

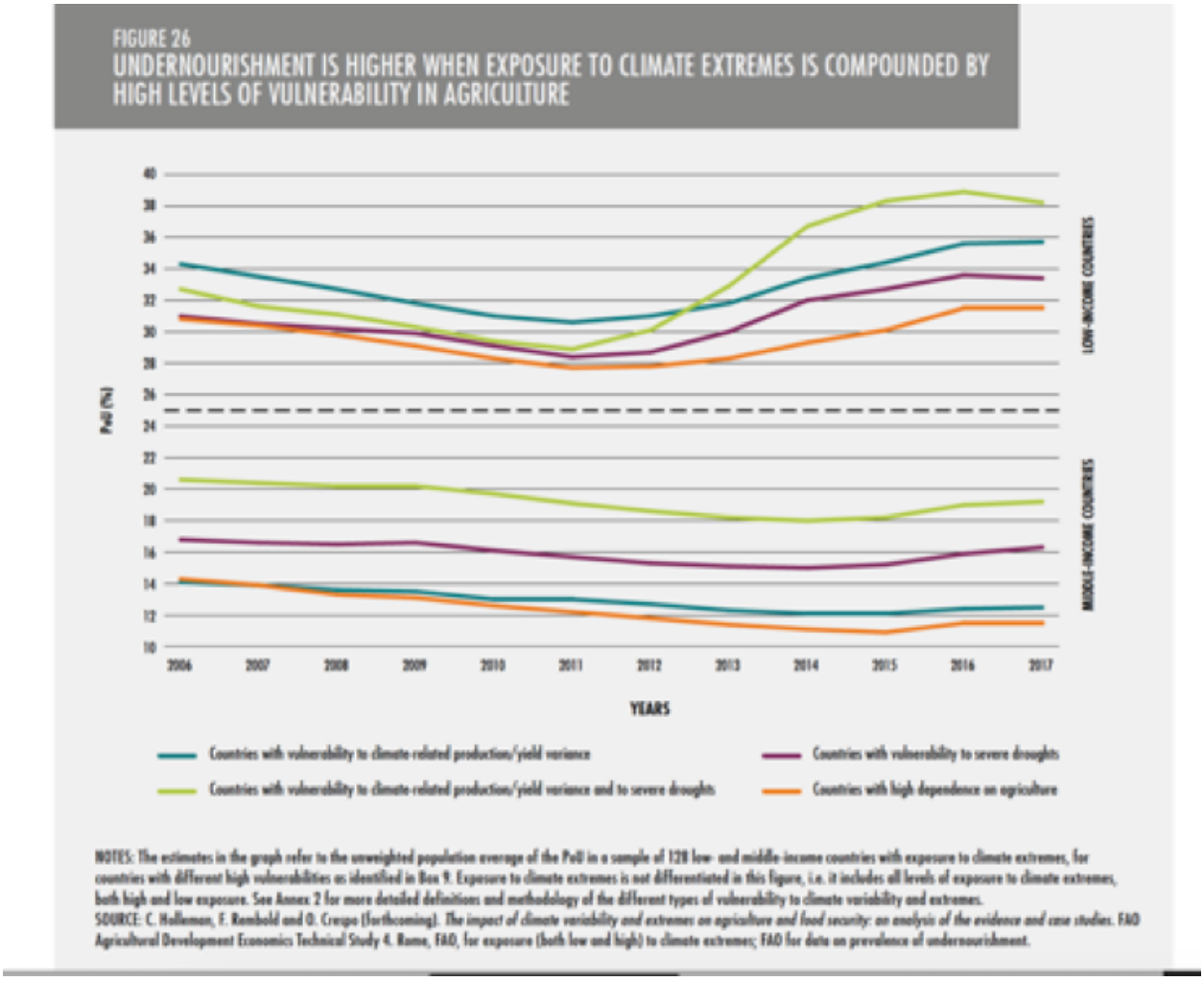
Second, while climate change occurs over a period of decades or centuries, what people experience in their daily life is climate variability and climate extremes, regardless of whether or not these are driven by climate change. Third, unsurprisingly, all dimensions of food security and nutrition, including food availability, access, utilization and stability, are potentially affected even in the short term by climate variability and climate extremes." (FAO, etc, 2018, p. 39).

Figure 2, (FAO, etc, 2018, p. 39)



Although this kind of evaluation tends to neglect the long term dangers we face from climate change, it does make the issue manifest in our lives. It is extremely important to note that the report also details extensively the ways in which these effects are disproportionately felt by more "vulnerable" people and nations. First, given the already demonstrated increase in climate extremes, it shows very simply the correlation between undernourishment and agriculturally vulnerable nations. (Figure 3)

Figure 3, (FAO, etc, 2018, p. 56)



However, it does not stop there. The issue of food is a local issue and is therefore too varied and complex to be looked at solely from the national level. When looked at from the

subnational level it becomes clear that climate shocks can cause widespread food insecurity without affecting aggregate national production. “For example, Ethiopia has experienced large increases in national cereal production in recent decades, yet it regularly reports acute and localized food insecurity and malnutrition crises, often associated with droughts. The greatest adverse impacts occur in the most marginal livelihood zones in the drier east of the country. Drought incidences are usually relatively local, with serious impacts on local production and livelihoods that leave people unable to meet their food needs by buying from other regions, even though, on the whole, the country is no worse off than in any other year.” (FAO, etc, 2018, p. 64-65).

This cognitive dissonance created between the “growth” of Ethiopia’s cereal production and the simultaneous increase in localized food insecurity is artfully explained in Vandana Shiva’s *Stolen Harvest.* Shiva begins her work by stating that “what the industrial economy calls ‘growth’ is really a form of theft from nature and people.” (Shiva, 2000, p. 1) In support of her statement, she points to a similar phenomenon occurring in India in 1943. During the Bengal Famine more than 3.5 million people starved to death and more than 20 million were affected. However, this famine was not true scarcity as much as it was created scarcity. Shiva also notes that “80,00 tons of grain were exported from Bengal in 1943, just before the famine” and that “the starving Bengal population gave up over two-thirds of the food they produced” (Shiva, 2000, p. 6)

Between these national and subnational statistics, it becomes evident that climate change disproportionately affects impoverished nations and peoples. If continued pollution will continue this increase in climate disasters as mentioned above, then pollution becomes an elitist and racist

act. It is those nations and people, notably predominantly white nations and people, that contribute the most to climate change that feel its immediate effects the least.

The statement that "agricultural production and food systems are major sources of GHG emissions *and* are particularly sensitive to climate" (my emphasis) neatly sums up the absurdity of the current food system. Climate shocks cause food shortages, food shortages cause greater industrialization of the food system, the industrialized food system causes more climate shocks. It is a cycle without end if conscious action is not taken to "increase agricultural production in ways that are both more sustainable (for example, through enabling sustainable healthy diets) and more climate-resilient, while at the same time reducing emissions." (FAO, etc, 2018, p. 40).

Introduction to Permaculture:

Permaculture is, in many ways, a bonding of the past and present as a way of planning for the future. Although the term itself was coined in the 1970's, it can trace its origins back as far as people have been farming. It is founded upon the local practices developed over time by indigenous people and it is upon that traditional knowledge the modern authors and practitioners of permaculture build. If that local traditional knowledge is lost, permaculture cannot exist.

Today, permaculture typically consists of three main ethics: Care of Earth, Care of People, and Give Away Surplus. (Permaculture Institute, 2) Implicit in these ethics is the concept that every living organism has intrinsic value beyond its instrumental value to humans, and this will serve as a guiding concept throughout permaculture ethical theory. The ethic of Give Away Surplus can be seen as a method for achieving the other two ethics, allowing permaculture to be nominally split between social and physical permaculture. In practice one is woefully incomplete without the other, however for the purpose of discussion the separation proves beneficial.

Physical permaculture design is a complex analytic process that requires a number of considerations. It is based in systems theory and so it will be useful here to define some key terms going forward. Aranya gives the excellent summary: “elements are individual things that make up a system when connections exist between them. Several systems can also connect up to create bigger systems. Either elements on their own, or complete systems, perform (one or more) functions. A function is what you want to achieve and the system or element is the means by which you achieve it.” (Aranya, 2015, p. 94)

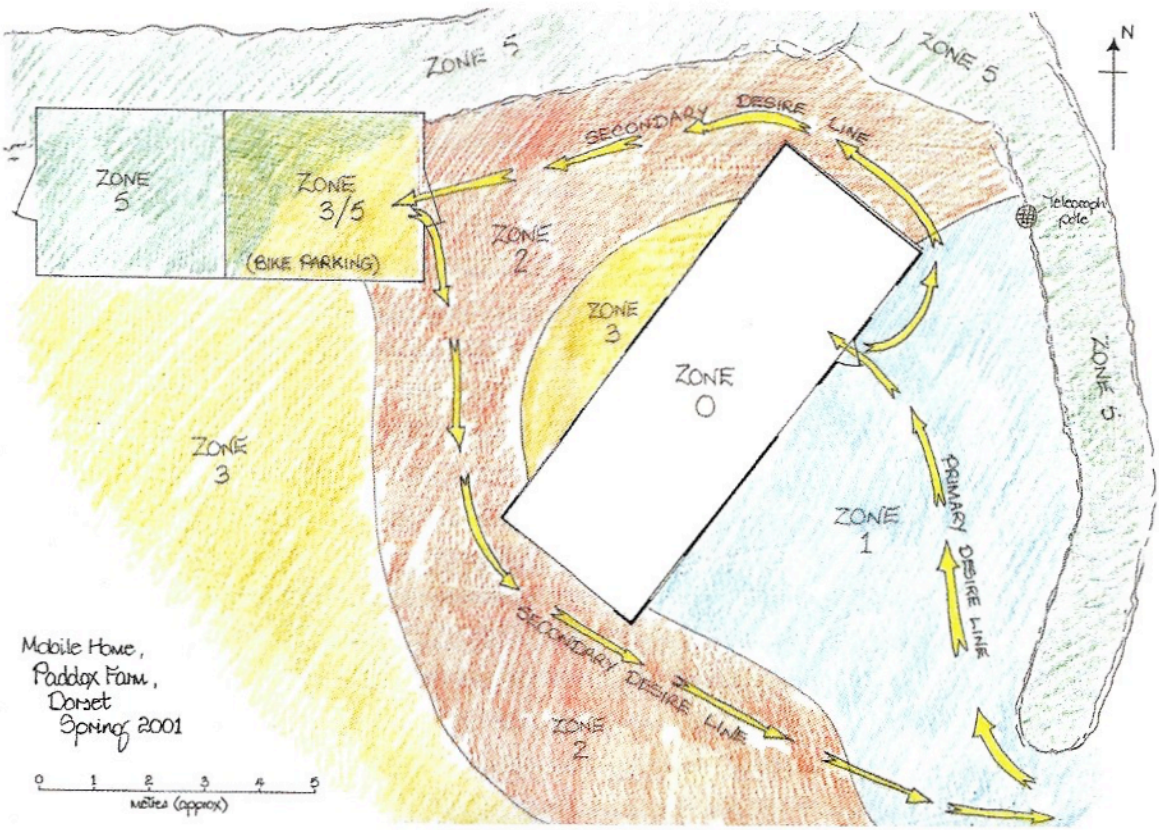
There are five common approaches to design, the first of which is to begin mapping the land. However, this is not as simple as drawing a rough sketch of the area and calling it done. The first step is to create a “base map.” This map “should be simple, mapping site boundaries and ‘fixed’ elements like buildings, roads, significant bodies of water, and large trees.” (Aranya, 2015, p. 34) Although this first map is extremely simple, it will serve as a basis for the rest of the design process, so it is important to take accurate measurements. The base map is then used to make overlay maps conveying this newly recorded information. Other information that is commonly recorded is climate, soil quality, water supply, contour, and access

The second approach is to take stock of and analyze the elements that already exist. A common acronym for this step is PASTE for plants, animals, structures, tools, and events. (Aranya, 2015, p. 58) A useful tool for analyzing elements in the system is a needs and yields analysis. This method looks at all of the inputs an element requires and all of the outputs it produces. By listing these out it can be easier to notice when one element is outputting a necessary input of another element. These connections can then inform what new elements are added and where they are placed.

The third design method, sector planning, is one of the most prominent methods. It includes zones, sectors, slope, and orientation. Zones are a useful way of planning a project based "on importance, priorities, and number of visits needed for each element." (Permaculture Institute, 4) These zones are sometimes conceptualized concentrically progressing out from the main center of activity, such as a home or main management building, but can be designed differently based on the individual. Five zones are defined in most permaculture literature, even if every site will not have all five zones.

- Zone 1 is the center of activity on the site. Elements placed here are likely the most energy intensive and therefore placed closest for ease of access.
- Zone 2 is the next logical step away from the center of activity. Elements here will likely still be pretty energy intensive, densely planted, and well maintained. Poultry, such as chickens, ducks, or quails are also often found in Zone 2.
- Zone 3 starts to become less intensive. Elements here are typically hardy trees, windbreaks, and other animals such as goats, sheep, or bees. This zone can also serve as a windbreak for some of the less hardy elements in the zones closer to the center.
- Zone 4 is typically reserved for long term development. Some large timber trees may be cultivated in this sector over a number of years, but this Zone will require minimal energy.
- Zone 5 is typically left uncultivated, allowing for natural regrowth. (Permaculture Institute, 4)

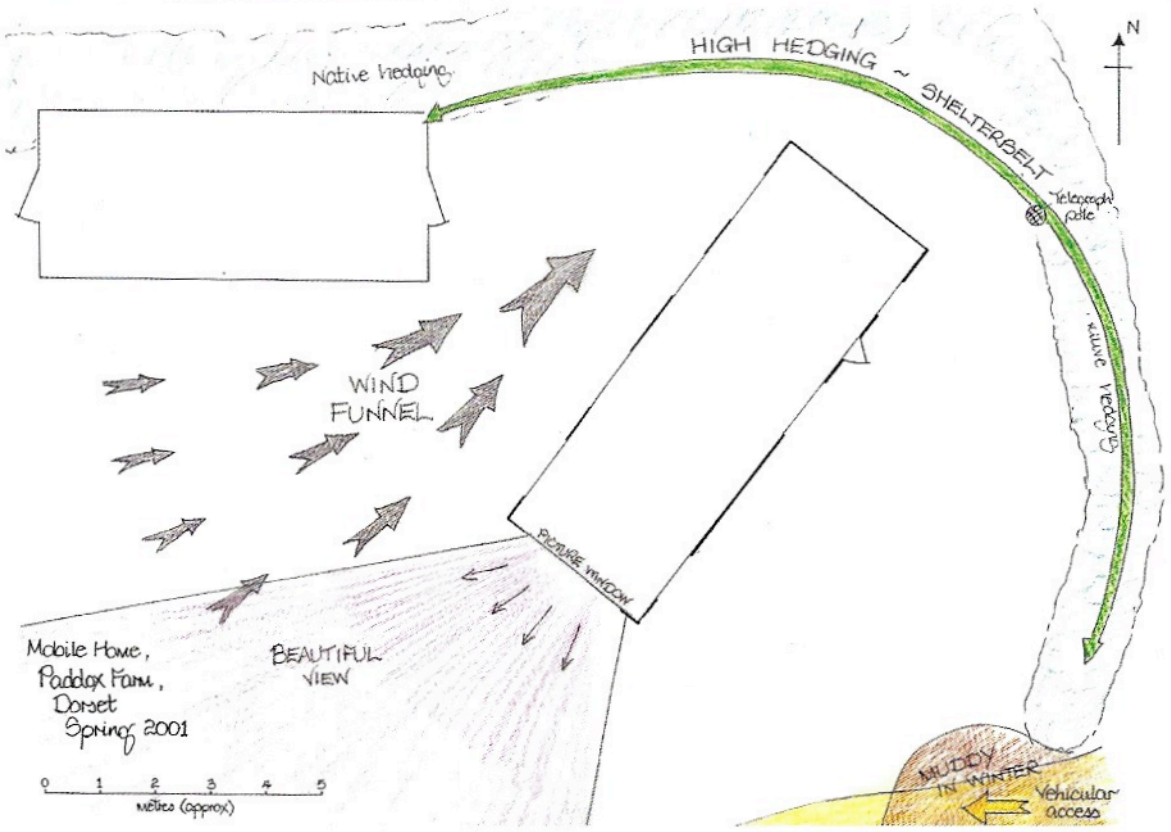
Figure 4, (Aranya, 2015, p. 60)



The desire lines around my mobile home shaped my zoning of the space

Sectors on the other hand attempt to capture data that has not yet been captured in any of the base or overlay maps. Sectors are typically directional, topographical, or some combination of the two. Directional sectors are typically sun sectors or prevailing winter/summer winds. While these factors can be difficult to visualize, they have a tangible effect on the site and therefore must be considered in the planning process. A topographical sector is typically a low point on the site that is prone to flooding, or an area that frosts especially badly. Combinational sectors often combine elements of the other two sectors. For example, a combinational sector could be a wind funnel created by structures on the site, sun and rain shadows, nighttime light pollution, or even areas of privacy on the site. (Aranya, 2015, p. 62-65)

Figure 5, (Aranya, 2015, p. 65)



Combination sectors that were affecting my mobile home garden design

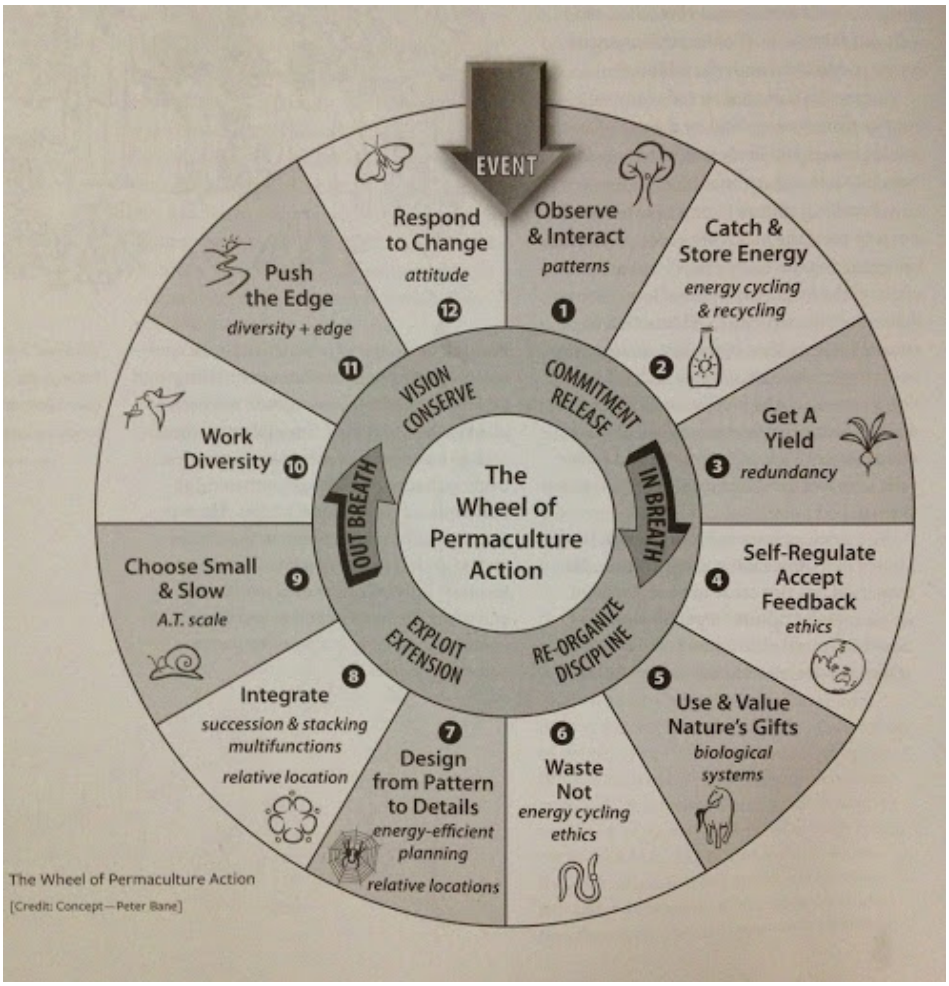
The final two approaches are somewhat more nebulous. An observational approach is simply free of thematic thinking. This approach merely suggests that you make note of unexplained phenomena, investigate, and devise a plan to address them. The experiential approach is even more loose. This approach involves simply becoming aware of oneself, feelings, and environment.

All of these approaches are bound together by three attributes of natural systems: "Everything is connected to everything else, every function is supported by many elements, and every element should serve many functions." (Permaculture Institute, 2) Although not explicitly stated above, the presence of these guiding principles should already be evident. For example, the needs and yields analysis looks at the functions of each element, and Zone 3 is designed to

serve as a windbreak outside of its function as a production area. A functional design succeeds when it is “Sustainable, or provides for its own needs, and provides good product yield, or even surplus yield. This happens when elements have no product unused by other elements, and they have their own needs supplied by other elements in the system.” (Permaculture Institute, 2) When a functional design is not successful, pollution and excess work are the result. “Pollution is a product not used by something else; it is an overabundance of a resource. Work results when there is a deficiency of resources and when an element in the system does not aid another element.” (Permaculture Institute, 2)

In his work *The Permaculture Handbook*, Peter Bane attempts to break this process into a wheel of twelve principles. These principles are noticeably and intentionally not presented as a list, but rather as a cyclic wheel. While Holmgren and Mollison presented these principles, Bane’s primary contribution is his restructuring of them into a wheel. This presentation represents the cyclic nature of permaculture design and reminds practitioners that these are not necessarily steps that need to be executed in order but guiding principles. These principles also serve as the inspiration and structure base of the educational course provided by the application example.

Figure 6, (Bane, 2012, p. 28)



These twelve principles are an excellent way of framing the course designed for the application, but this work will focus on just a few. These few principles in particular are the ones that were the most important to me in the design and implementation of this project. This project collectively is not only about permaculture but is also a representation of permaculture in and of itself. The application is designed to teach others about the broad concepts of permaculture and provide a tool for them to design their own local solutions. However, it was also designed using permaculture theory and systems thinking.

The first principle that was vital to me is also Bane's first principle: "Observe and Interact." In the context of physical permaculture, this refers to the mapping and land observation

mentioned above. However, in the context of the design of this project and application, it was a process that extended over the entirety of my academic career. In my experience as both a computer scientist and permaculturist, I have found that the two very rarely overlap. Many prominent permaculture authors call for the scaling back of technology. Both Berry and Bane expound upon the wonders of using horses for labor on the farm. While computer scientists are more likely to look to technology as the end all be all solution to all problems. There is a sense that there is no problem that cannot be reduced to ones and zeros in the community. However, there is very little discussion about a middle ground between the two. It is the observed lack of interaction between these two that was the seed for this project.

The next principle that was a driving factor for this project is "Integrate, Don't Segregate." Although this is Bane's eighth principle, it took a main focus in the design of this work. As the main issue observed was the lack of connection between two systems, integrating those systems is a key goal in the production of this project. Although at first glance software engineering and permaculture may seem like oil and water, when combined, they in fact form a powerful tool for changing system structures. Not only is this thesis and accompanying application designed to inform the reader, or user respectively, about permaculture, but they are in and of themselves a demonstration of permaculture design. Permaculture design calls for us to find connections between elements and find ways to see problems as solutions. The love of and practice of both permaculture and software engineering are integral elements of who I am. In designing and implementing this project I have sought to find connections between them and to see a solution where others may see a problem.

One of the greatest points of integration between the two is Bane's seventh principle, "Design from Patterns to Details." This principle refers to the "recognition of pattern, which is a

kind of language of form that enables us to see trends and influences from the past as they recur." (Bane 30) Pattern observation and implementation has two main parts: "1) the perception of the patterns that already exist (and how these function), and 2) the imposition of pattern on sites in order to achieve specific needs." (PDC 5) We have already seen how the pattern of a spiral can exist in a negative way through climate and industrial agribusiness. However, these patterns that exist in both natural and man-made systems can also be positive and serve a number of different functions. Some of the most common are waves, spirals, branching, honeycomb, and net. These patterns have developed over millennia of evolution and are the markers of a balanced natural ecosystem. When we attempt to imitate these patterns in our man-made systems, it is known as biomimicry. (McNamara, 2014, p. 14-15)

Alternately, in software design we also design from patterns to details. The MongoDB, Nest, Angular, Node.js stack framework was carefully selected to be most adherent to the principles of permaculture and provide the greatest access for the greatest number of people. Traditionally, websites are hosted on a LAMP (Linux, Apache2, MySQL, Php) stack. This form of website design has been the standard for a number of years, but in recent years this has begun to change. A LAMP stack is bound to its operating system, most commonly Linux, while this stack can be built and deployed in any environment. Additionally, backend server code for a LAMP stack is written in php and requires a full reload in order to access the MySQL database. However, MongoDB is written in JavaScript Object Notation, or JSON and Nest, Angular, and Node are all written in JavaScript. By standardizing everything to object oriented JavaScript it makes communication between backend and front-end developers much easier. Angular is driven by recent AJAX innovations that have completely dispelled with the requirement for a full

reload. This stack architecture essentially provides a faster user experience, and an easier development environment without losing functionality.

However, this application is built inside of a larger framework. Nx by Nrwl is a framework pioneering at leading tech agencies such as Google, and Facebook. This extensible framework allows multiple applications to be built in a single monorepo, allowing data to be shared between applications. Building a project of scale in a monorepo without a tool like Nx is cumbersome because it requires a full build and test of the repo. However, Nx is capable of detecting what applications are affected by changes to different files. This allows it to only build and test what it needs to. It will also generate a dependency graph of all resources in the repo with a simple command, allowing a developer to easily visualize large and complex projects.

These frameworks and architectural styles do not call for the designer to begin by thinking about what specific details will be needed, but rather what the broader structure will look like. Like permaculture, it also works to set things up at the beginning for the least amount of work down the line. Through the use of shared data and dependency testing, developers are able to minimize the amount of time and effort needed to both deploy and maintain an application. In recognizing where functionality can most efficiently be placed in a file structure, the overall success of the project is improved.

The final principle that provided inspiring motives in the design of this project is "Cultivate Vision and Respond to Change." Throughout the process of building this project, the application took three different forms. It began as an android application integrated with a Google Firebase Database. However, as I came to learn more about issues with proprietary software I chose to move away from this approach. The Software Freedom School is an organization based in Denver, that is dedicated to the production and propagation of free

software. “Free” here does not refer to financially free, but rather intellectually free. While Android and Google Firebase are proprietary software that prevent the community from learning from and improving upon them. Alternatively, Linux is one of the oldest and most widely used free software. As a result, I shifted my approach to that of a LAMP stack. However, as I dove deeper into web development, I discovered the more modern tools of MongoDB, Angular, and Nest. As such the final implementation was the result of a continual response to change.

Localized Instances of Permaculture:

Given the scope of what permaculture has come to encompass, it can be difficult to visualize exactly what it might look like within its implementation. Even more so, it can be difficult to accept that these guiding principles can work for different ecosystems. In order to demonstrate the broad applicability, we will examine two case studies: Sister Gardens managed by Frontline Farming and the University of South Carolina garden implemented by Mark Finley. In particular these farms were chosen because they represent permaculture in an urban setting in two vastly different climates.

Finley’s garden was also implemented as part of a thesis program at the university. Finley begins by constructing the beds he will need for the project, and then begins the process of placing different elements in the site. Finley notes that “We planned the locations of each plant based on its need for water, as the area has a wetland nearby, and its ability to grow in shade, as the area has trees nearby, so the area is often shady during various parts of the day. The 6 raspberry bushes, along with the two apple trees were planted the closest to the wetland area. The blueberry bushes made up the next row out and the Pawpaw trees and blackberry bushes made up the final row. The trees were separated by the multiple rows to account for the resources they require and the sizes that they will be once the trees become full grown.” (Finley, 2018, p. 8-9)

His planning represents an explicit connection with his local environment, while still utilizing permaculture principles. He also explicitly attempts to create microclimates and microhabitats within the system. Through observing the needs and yields of the different needs and yields of elements in the system, he was able to reduce the total number of inputs for the system. Finley "intentionally planned for fruits, vegetables and flowers of all different sizes to provide habitats and resources for the other species that may be in the area. The trees once they are full grown will provide safety and a home for birds and squirrels and insects and many other species of organisms as well as providing shade to create another microhabitat within which various other species can prosper...The flowers were planted as a method of helping bring in pollinators to help ensure the successful reproduction of each species and to bear fruit. The pawpaw trees particularly require pollination from beetles and flies in order to reproduce and bear their fruit." (Finley, 2018, p. 10) Not only is this an excellent example of making use of the different functions of elements but is again a reminder of anchoring in the local ecosystem.

However, Finley's garden was not without its challenges. He was also forced to creatively respond to change. In the design and implementation of his garden, he was bound by the larger system of the university. As a result, his plans were put off indefinitely until the maintenance crew marked where power and water lines were. When the lines were finally drawn, Finley was forced to change his initial plan. Finley had recognized the sidewalk as a transitional space into the broader community. To both beautify, draw people into the space, and provide for pollinators he had intended to plant a row of flowers along the sidewalk. However, "this plan was forced to change when the maintenance staff marked the power lines in the area and the area in which we were planning on planting the rows of flowers, there was a power line." (Finley, 2018, p. 12) In response, he chose to construct beds from unused wood available on the site.

Site Photos:

Small boxes are flowers for pollinators, big boxes are veggies, background is apple, pawpaw trees, bushes are blueberries, blackberries, raspberries.

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11

A more intensive and established project is Sister Gardens in Denver, Colorado. Although formerly under the management of Groundwork Denver, it is now managed by Frontline Farming. Frontline is "a community engaged in food production and education along the Front Range." (Frontline Website) It was co-founded by Fatuma Emmad, the executive director, and Damien Thompson, the director of Center for Food Justice and Healthy Communities (Damien Thompson is also an advisor on this work). This site was allowed to develop slightly more organically. Although the physical permaculture implementation was carried out in a similar manner, aligning the beds in a specific way and terracing a large portion of the land, this site is heavily focused on social engagement. As a space, it is specifically implemented as a space for education, and therefore that was a major aspect of its design. However, they knew it was important to engage with the community as educators, while still respecting their local knowledge. In this pursuit Sister Gardens has partnered with both the co-housing unit it is adjacent to and Regis University.

As a place of education, plant selection at Sister Gardens was also a slightly different process than that of Finley's. Although they also chose to plant fruit trees for longevity, they also chose to plant a bed celebrating African foodways. This consideration serves as a reminder the local environment consists of both the natural environment, and the social environment. However, just like Finley, they also faced unexpected challenges. Their initial plan for a labyrinth element involved different colored flowers forming the petals of a pattern laid out. However, they came to realize that the location of the labyrinth did not hold enough water and they were forced to adapt their plant selection to that reality.

Sister Gardens Site Photos:

Figure 12, Sister Gardens Upper Growing Site

Figure 13, Sister Gardens Terraced Growing Site (The Wedges)

Figure 14, Sister Garden's Labyrinth

Figure 15, Sister Gardens Labyrinth

Figure 16, Regis University Community Food Systems Class at Sister Gardens Greenhouse

Figure 17, Assorted Harvest from Sister Gardens

Although these permaculturists had different focuses on different sides of the country and faced different problems, they were both able to apply the permaculture framework successfully. These vastly different but ultimately successful sites are an excellent demonstration of the viability of permaculture in a variety of different circumstances.

Mobile Technology as a Localized Delivery Mechanism:

From both the physical and the social side of permaculture, the importance of smaller, community-based solutions becomes apparent. But how is it possible to provide a single solution to a problem that has to be solved uniquely on the individual level? By changing "the structure of information flows" and "creating the power to self-organize system structure" (Meadows, 1999, p.3). In an increasingly digital world, the best way to implement that change and provide that power is through the use of mobile technology.

Given the negative repercussions of agricultural technology rising out of the industrial age, it would be easy to dismiss technology as altogether incompatible with this form of agriculture. The clearest criticisms are to say that technology dismisses the traditional, indigenous knowledge that is the foundation of modern permaculture and that assuming access to technology is elitist. However, in 2004, Sylvia Owiny conducted a study focused on the nations of Kenya, Uganda, Tanzania, Rwanda, and Burundi addressing these very concerns. Despite the rate of illiteracy in these nations, Owiny proposes "the use of social media and mobile technologies (cell phones) in the creation, preservation, and dissemination of indigenous knowledge and discusses the role of libraries in the integration of social media technologies with older media that employ audio and audiovisual equipment to reach a wider audience." (Owiny, 2014, p. 235)

This proposal includes a careful evaluation of the potential difficulties in actually implementing a solution based around mobile technology. She notes that "efforts at technology transfer that 'ignore local circumstances, local technologies, and local systems of knowledge are often doomed to waste enormous amounts of time and resources.'" (Owiny, 2014, p. 236) This waste is because the dynamic and people-based traditional knowledge that is central to indigenous agriculture cannot be pigeonholed into predefined categories. Owiny reinforces the idea that it can't be imposed on people from a broad context because the knowledge and skills involved are unique to their area.

However, what may be initially perceived as a problem, ends up being part of the solution. While localized Internet availability is still certainly a point of concern, even in "developed" nations, the reality is that there are more than four billion internet users in 2019. More than half of those users access the internet via mobile technology, a number that is only projected to increase. This expansion "enables local communities to access relevant local content." (Owiny, 2004, p. 240) It is this specific ability that makes the internet and mobile technology uniquely powerful tools for the spread of permaculture. These tools have the ability not only to cohabitate with traditional knowledge, but to provide a platform for sharing traditional knowledge.

The platform that is provided however, is not a solution. This methodology uses the framework of "reflexive justice" to enact change, rather than providing a universal solution based on some universal set of values. In response to the question "Is the creation of a single set of universal values intrinsically nonegalitarian, creating a situation where some determine a singular set of ideals not necessarily shared by others, values that others resist as a violation of their freedom?" (Depuis et al., 2011, p. 285) the answer is simply yes. Because of these pitfalls,

mobile technology has been selected to provide a reflexive framework for justice. “Reflexivity is not a set of values, but a process, by which people pursue goals while acknowledging the imperfection of their actions. It is also not a particular, fixed process, but one that responds to changing circumstances.” (Depuis et al., 2011, p. 297) Mobile technology is uniquely capable of providing a platform that is compatible with this framework.

Internet and mobile applications also promise to only increase in efficacy. Christina Zhang and her team did a study evaluating the importance of electronic word of mouth (eWOM). Although the paper is structured around customer behavior in markets, its conclusions have important implications about the current and continuing influence of eWOM on Generation Y. In a summative statement for the work of her team Zhang states that “the communication patterns Generation Y members have embraced already through their use of social networking technology and mobile apps and devices will continue, as they move up the economic ladder, such that, even as they mature, have families and assume increasing significant responsibilities, their enthusiasm for widespread information sharing, including eWOM, is predicted to continue.” (Zhang, 2017, p.733) Not only will mobile technology be a prominent form of communication but “because of their facility with technology, Generation Y holds positive views about its influence on their lifestyles and accepts it as a key partner in nearly all of their activities, whether at home, in the workplace or at leisure.” (Zhang, 2017, p. 733)

Electronic word of mouth is a common marketing strategy that employs social media and mobile technologies and is “defined as the process that allows consumers to share their views online and directs consumers to favor and go against specific products.” (Zhang, 2017, p. 734) However, this definition seems limited to a very specific system and way of thinking. eWOM as a basic concept can easily be adapted to apply to the spread of permaculture in the food system.

In this different context we can rethink this definition as "the process that allows **people** to share their views online and **opens a discussion about the benefits and detriments of specific ideas**."

One of the reasons this tactic is so effective is that Generation Y, defined by Zhang as "who were born between 1981 and 1994" (Zhang, 2017, p. 735), value the opinions of their peers. They are "less responsive to the marketing instruments provided directly by companies and instead tend to collect opinions from the people around them and make their choices based on the assessment of those opinions." (Zhang, 2017, p. 735)

This method of crowdsourcing, in our modern world, is inevitably carried out through technology. In particular, the majority of this communication is in fact carried out over mobile technology. Zhang tells us that "Nearly two-thirds of Generation Y respondents in the USA keep or regularly update their social networking profiles through their smartphones. Approximately 90 percent of Generation Y in the USA communicates via emails, whereas 85 per cent of this cohort sends or receives text messages every month, and 72 percent of Generation Y consumers in the USA own smartphones compared with the 50 percent of Americans who do nationwide." (Zhang, 2017, p. 737) This further indicates that the most effective way of reaching Generation Y and future generations will be through the use of mobile technology.

Zhang then discusses the degree to which members of Generation Y are impacted by their peers through social media Zhang states "it is more likely that this generation will follow and seek its peers' norms and acceptance actively. Because communication and dissemination of knowledge are quicker and easier with advanced technologies, consumers are able to seek and share information with anyone in the world. As a result, the probability of being influenced by mass opinion is significantly greater at present." (Zhang 2017, p. 738) Again, while this holds

true in a model that attempts to sell a product, it also holds true of general practices and choices. People are influenced by the opinions of their peers not just in their purchases, but in the choices they make in their life. These choices are then broadcast to the broader society. Through the use of "social currency" such as "likes, follows, friends, and retweets" (Zhang, 2017, p. 738) people are able to essentially vote on what is cool and what is not. This social currency can be leveraged to enact a shift in the food industry toward permaculture by generating positive eWOM.

The final key aspect of mobile technology that makes it a key delivery mechanism for spreading permaculture is the ability to interact with it. Denise Stockley's work focuses on the use of interactive technology to disseminate information. Her work is based on the theoretical framework that "focuses on the community and the relationships between group members and contexts, which include the social and material contexts in which members find themselves. The learning community is formed through members working collaboratively on shared situations. Individual members contribute personal expertise, experience, and skills that develop an individual's understanding and also construct new knowledge as a community. Thus, social participation leads to the acquisition of knowledge." (Stockley, 2009, p. 3) This directly states that social participation in an activity is a methodology for learning new skills. Fortunately, permaculture actively encourages practitioners to engage with the surrounding community and other local permaculturists. The web application developed as part of this thesis actively addresses this aspect of both learning and permaculture by offering a platform for social participation.

Application Planning:

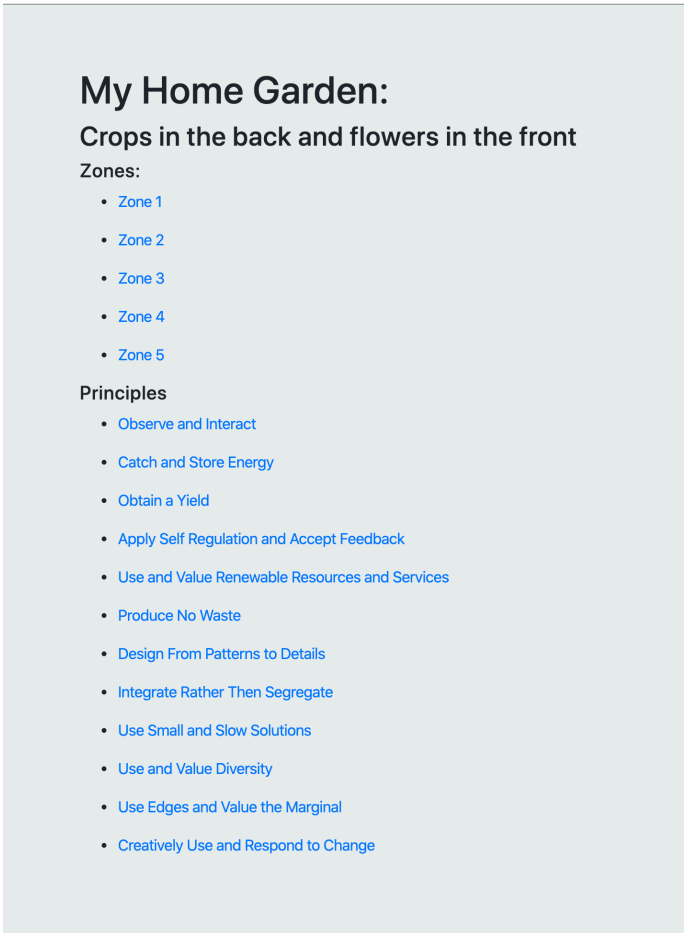
In further support of the potential of mobile technology to spread permaculture, I have designed and implemented a web-based application with three primary functions. It provides a

project management software for the user to manage their own permaculture garden, an interactive course in social and physical permaculture, and an integration with popular social media to allow for the creation of new social structures. Although the moral implications of popular social media are currently very much up for debate, these technologies can once again be viewed as tools. While these tools can and are commonly used for hostile purposes, this application uses them as a means to create community around a positive force.

At the top layer of the software each user is able to manage any number of different projects. Once a user has loaded a project, they will be presented with the main dashboard and can select to either enter the project management module or the educational course module.

User Interface Image:

Figure 18, Project Level User Interface View



Although it is a simplification of permaculture, the structure of the project management module is designed to mirror the structure of a permaculture garden. The top layer of this module is a garden component. This view presents the user with the five zones of permaculture and a brief description of each. The user can choose to dive deeper and view the contents of a specific zone. Inside each zone component the user is able to view all of the garden beds that are contained within that zone and a brief description the user provides. Each garden bed contains components that show all of the crops in that bed and all of the tasks associated with those crops. The user is able to give each crop a name, description, the date it was planted, and any number of tasks that need to be completed for that crop. Each task can be given a name, description, due date, and status of completion. The user is then able to track their progress on each garden bed or on each crop.

User Interface Images:

Figure 19, Zone Level User Interface View

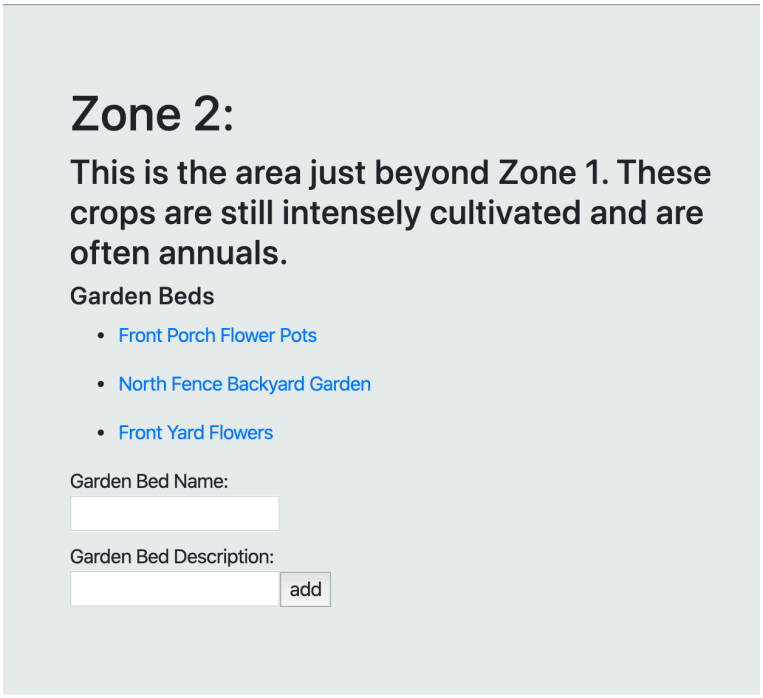


Figure 20, Garden Bed Level User Interface View

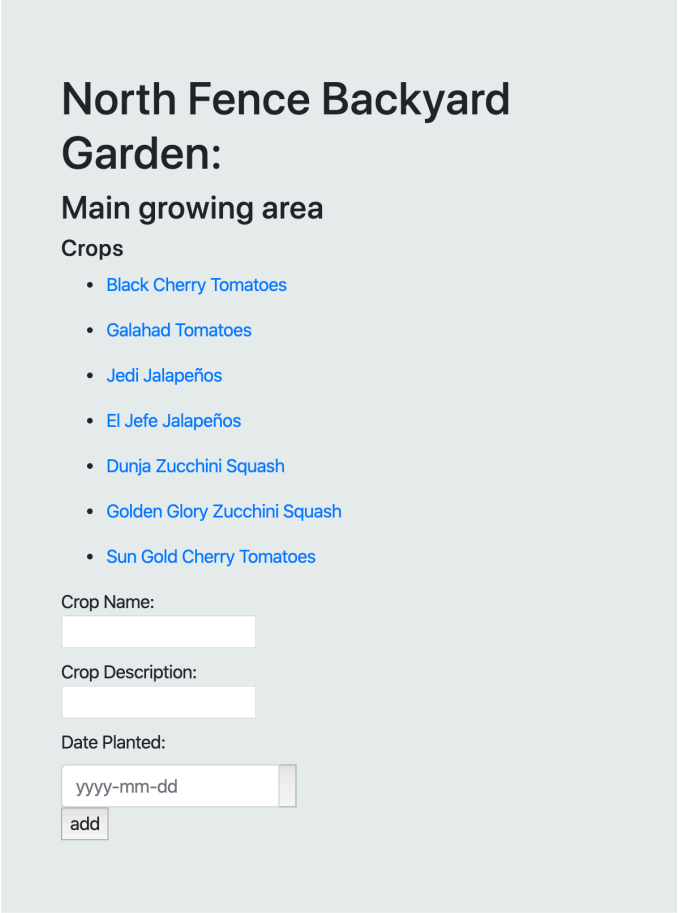


Figure 21, Crop Level User Interface View

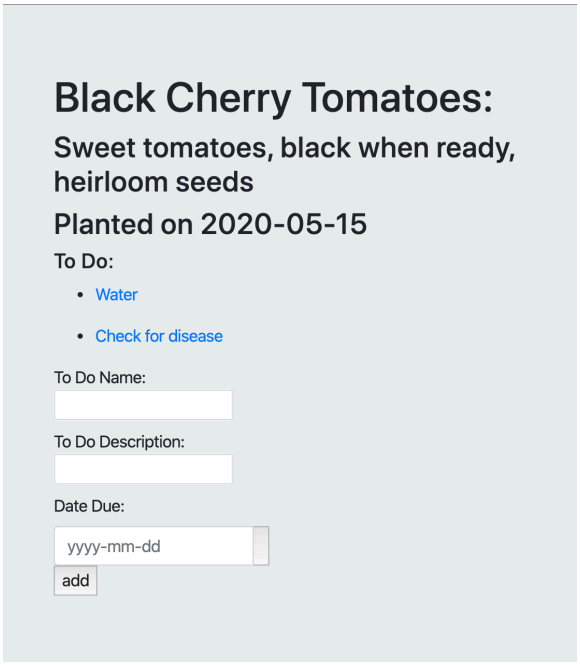
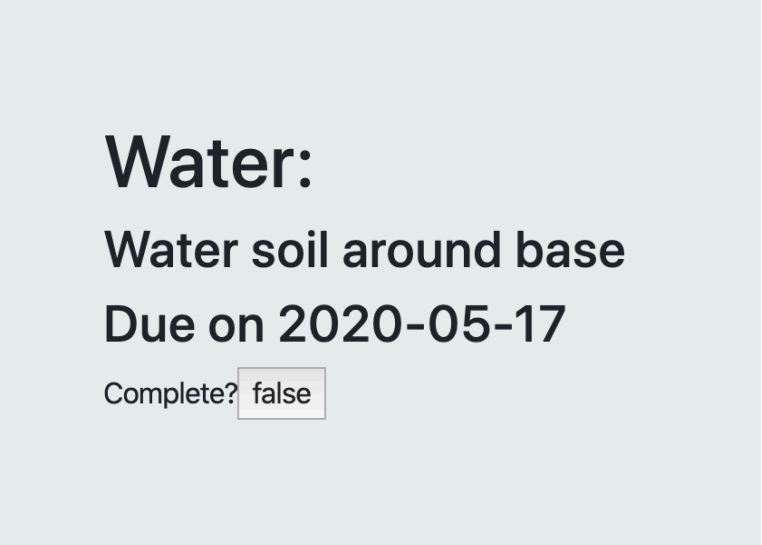


Figure 22, To Do Level User Interface View



The educational course module is designed to teach the user not only what permaculture is and how to do it physically, but also how to integrate social permaculture and provide the user with a number of tools for planning and design in all aspects of their lives. The educational course is broken down into the permaculture principles. Although these principles should be viewed cyclically, the flow of this course is designed for users to progress through the principles from 1 to 12. Each of the principles contains 3 or more activities with at least one in each pertaining to physical, social, and personal aspects of permaculture. Although not discussed at length, introspection is a vital part of designing a permaculture system and is therefore afforded that importance in the application design. As the user progresses through the principles, some of these activities are designed to build on one another. The user will be able to track their progress from the view of the course as a whole, and from within each principle.

User Interface Images:

Figure 23, Principle Level User Interface View

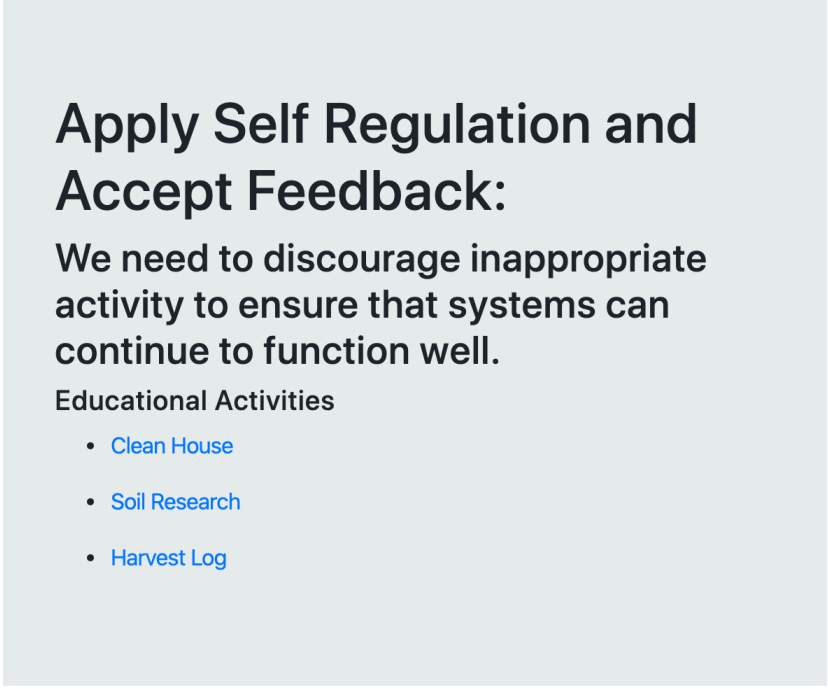
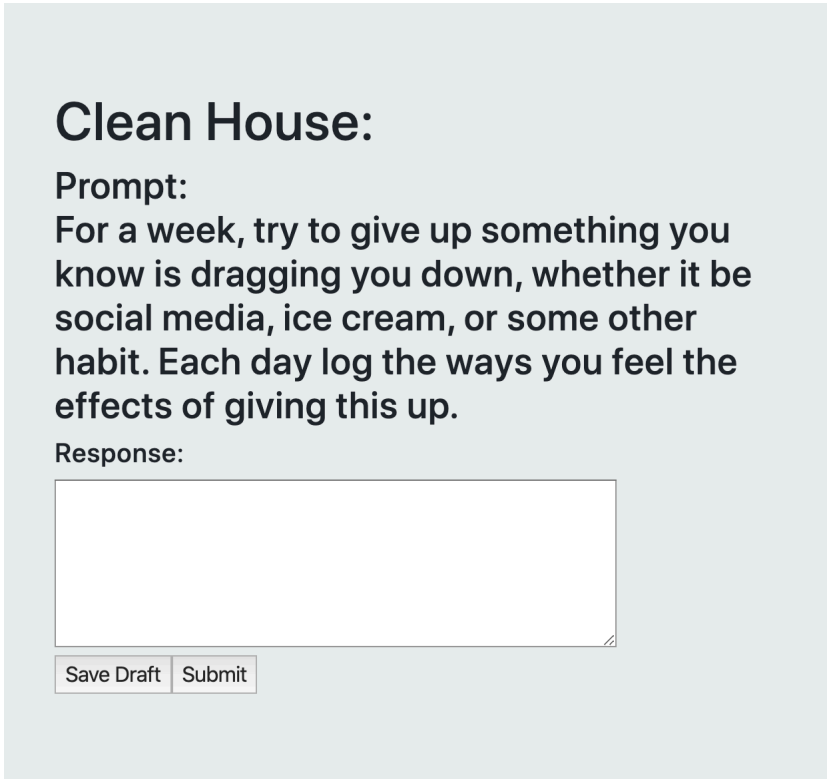


Figure 24, Activity Level User Interface View



This application seeks to specifically address the leverage points of "the structure of information flows" and "creating the power to self-organize system structure" (Meadows, 1999, p.3) The structure of information flows is changed both through the educational course provided and the social media interface. The educational course provides new information to members of a community, and the social media aspect allows them to share their knowledge with one another and create new knowledge. The social media interface and the project management software, on the other hand, help create the power to self-organize system structure. Through the project management software, users are provided with a tool to regain their own food sovereignty while the social media interface provides these users a tool to organize a new system structure based on their sovereignty.

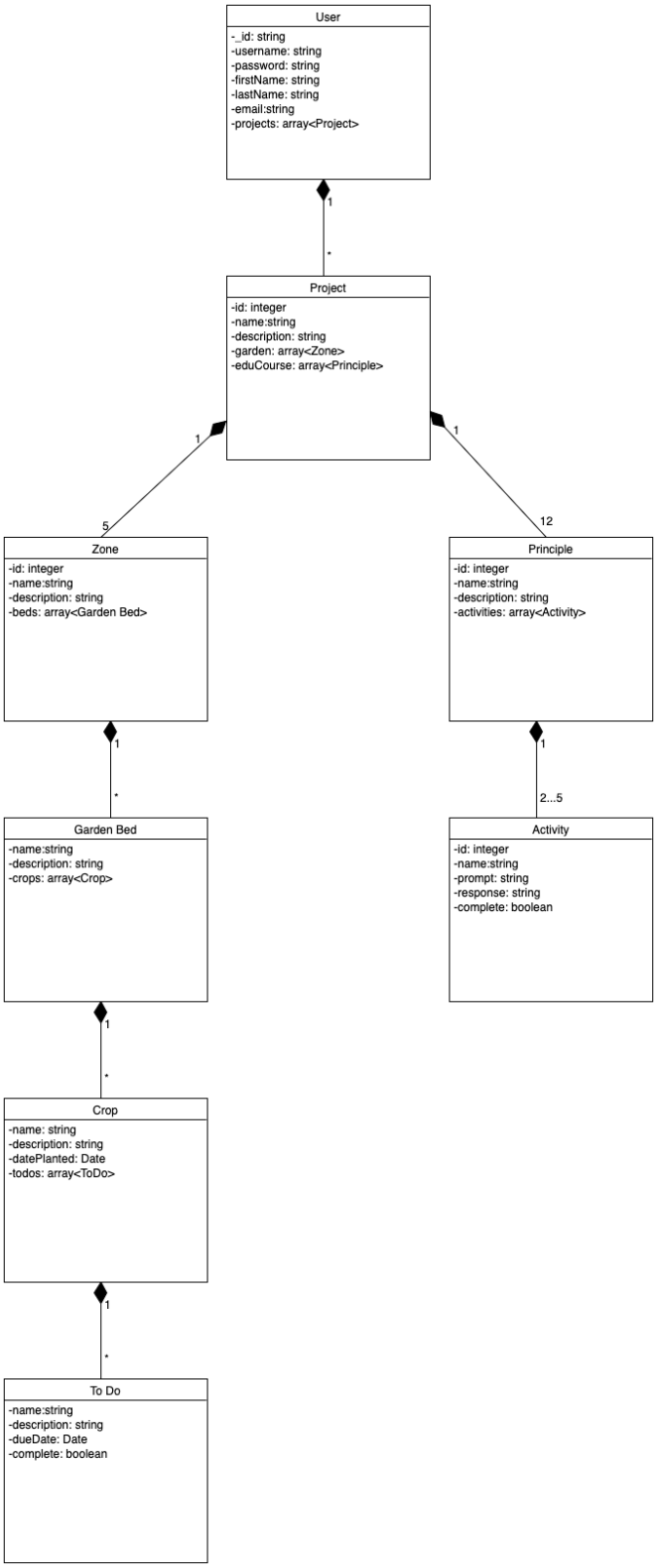
Conclusion:

The issue of climate change will be one of the defining battles the world faces in the coming years and agriculture must be one of the main fronts on which that battle is fought. The current system cannot be allowed to continue and those on the margins are already starting to see the effects of why. Permaculture is a viable agricultural alternative that allows local communities to solve local agricultural issues. However, without an efficient delivery mechanism, the data tells us that we will reach a crisis before permaculture can begin to take effect at a global scale. Mobile technology serves as the perfect delivery system for permaculture not only for its efficiency but for its coherence with permaculture design. Mobile technology fits permaculture principles both from a deployment perspective and from the perspective of the design of the application itself.

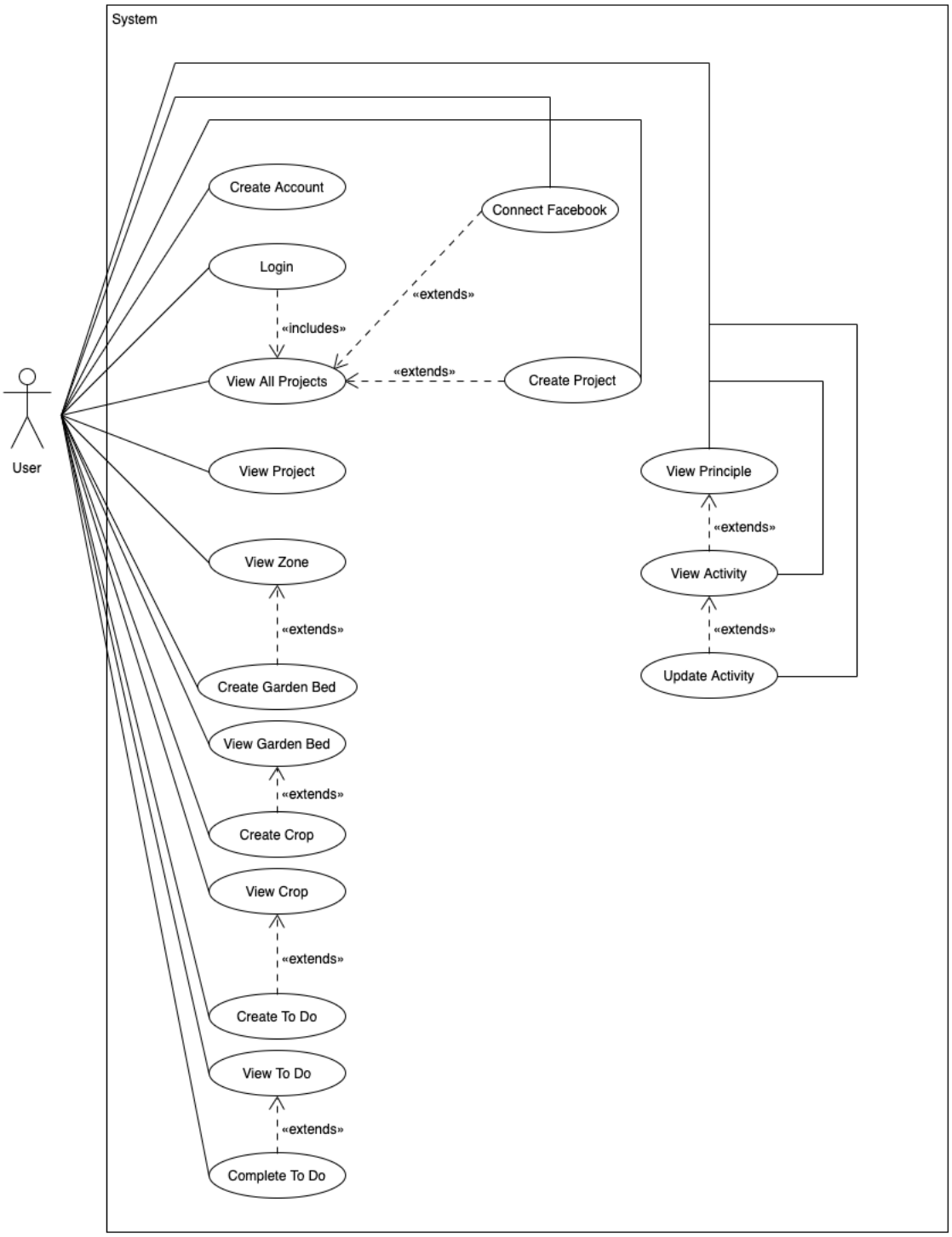
A 2014 assessment of the food system in Denver found that our experience of the existing food systems, shapes our perception of what is possible. For example, they found that

"surveys did not indicate significant resident interest in shopping at local corner stores for fresh fruits and vegetables, yet from a proximity standpoint, corner stores offer an important form of convenience. But in focus groups and semi-structured community dialogues, participants showed great interest in shopping at corner stores for fresh fruits and vegetables once it was explained that corner stores could be enhanced, from their current state, to carry a greater variety of fruits and vegetables and other healthy foods." (Share Network, 2014, p. 21) This same principle holds true for our perception of what technology in the agriculture industry looks like. We envision enormous tractors and sterile GMO seeds as agricultural technology, rather than a website that helps anyone be a producer. In order to move forward in the food system we have to re-envision how technology and agriculture interact.

Appendix A: Domain Model



Appendix B: Use Case Diagram



Bibliography:

Aranya. *Permaculture Design: a Step-by-Step Guide*. Permanent Publications, 2015.

Bane, Peter, and David Holmgren. *The Permaculture Handbook*. New Society Publishers, 2012.

Berry, Wendell. *The Unsettling of America: Culture & Agriculture*. Counterpoint, 2015.

"Course Outline." In Permaculture Design Certificate Course, Permaculture Institute

Dupuis, Melanie, et al. "Just Food?" Cultivating Food Justice, edited by Julian Agyeman and Alison Hope. Alkon, MIT Press, 2011, pp. 283–307.

FAO, IFAD, UNICEF, WFP and WHO. 2018. The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Rome, FAO.

Finley, Daniel, and Damien Thompson. "Permaculture at Sister Gardens." 3 Dec. 2019.

Finley, Mark, and Jake Scott. "Permaculture Gardening on Green Quad." *University of South Carolina*, 2018.

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Macnamara, Looby, and Rebecca Storch. *People & Permaculture: Caring and Designing for Ourselves, Each Other and the Planet*. Permanent Publications, 2014.

Meadows, Donella. "Leverage Points: Places to Intervene in a System." *The Academy for Systems Change*, donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/.

Mollison, Bill, and David Holmgren. *Permaculture One: A Perennial Agricultural System for Human Settlements*. Eco-Logic Books / Worldly Goods, 1990.

Mollison, Bill. *Permaculture: A Designers' Manual*. Tagari Publications, 2014.

Moyers, Bill, and Wendell Berry. "Wendell Berry: Poet and Prophet." *Moyers & Company*, 4 Oct. 2013, billmoyers.com/api/ajax/?template=ajax-transcript&post=44152. Accessed 21 Feb. 2019.

"Northeast Denver Food Systems Assessment Report and Findings." *Community Initiatives*, Share Network and Partners, 2014, communityinitiatives.com/wp-content/uploads/2015/07/CommunityReport-Final.pdf.

Owiny, Sylvia A., et al. "The Use of Social Media Technologies to Create, Preserve, and Disseminate Indigenous Knowledge and Skills to Communities in East Africa." *International Journal of Communication (19328036)*, vol. 8, Jan. 2014, pp. 234–247. *EBSCOhost*

"Permaculture Principles - Creative Commons." Permaculture Principles - Creative Commons, permaculturepriniciples.com/downloads/Principle_Wheel_with_type.jpg.

Shiva, Vandana. *Stolen Harvest: The Hijacking of the Global Food Supply*. Zed Books, 2001.

Stockley, Denise, et al. "Using Interactive Technology to Disseminate Research Findings to a Diverse Population." *Canadian Journal of Learning and Technology / La Revue Canadienne De l'Apprentissage Et De La Technologie*, vol. 35, no. 1, 2009, doi:10.21432/t20k5r.

Thompson, Damien, and Fatuma Emmad. "FrontLine Farming: Beyond Organic: Colorado." *Frontline Farming*, www.frontlinefarming.org/

Zhang, Tingting (Christina), et al. "Generation Y's Positive and Negative EWOM: Use of Social Media and Mobile Technology." *International Journal of Contemporary Hospitality Management*, vol. 29, no. 2, 2017, pp. 732–761. *EBSCOhost*, doi:10.1108/IJCHM-10-2015-0611.

Rosado, Javier I., et al. "Obesity among Latino Children within a Migrant Farmworker Community." *American Journal of Preventive Medicine*, vol. 44, no. 3, Suppl 3, Mar. 2013, pp. S274–S281. *EBSCOhost*, doi:10.1016/j.amepre.2012.11.019.