A Using Permaculture to Enhance Urban Food Security:
An Abandoned Golf Course Case Study

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MLA Thesis
Virginia Polytechnic Institute and State University

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Landscape Architecture

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ABSTRACT

The Issue:

An increasing number of people in the United States are finding it difficult to access a safe, personally acceptable, nutritious diet. Urban agriculture is seen as an important avenue for increasing their food security. For better or worse, urban agriculture is subject to the urban setting, agriculture must complete with other socially and economically viable land uses.

Establishing and maintaining a robust system of urban agriculture will require a constant seeking out of urban open spaces that, at least for a time, are available for food production. This study focuses on golf courses as one such type of open space. Due to market saturation, a fairly significant number of golf courses are presently experiencing financial difficulty. Tone potential an emerging land use type catagor that is experiencing is increasing. Developing a robust and reliable system of urban agriculture is one strategy for improving food security. In the urban setting, agriculture must complete with other socially and economically viable land uses. Consequently, much of the research completed to date focuses on using abandoned lots as food growing sites. Fewer studies seek to identify the broad range of urban open spaces that might eventually contribute to a system of urban agriculture that is economically and socially viable. This thesis focuses on a newly emerging class of abandoned urban lands – golf courses. Countryside Golf Course located in Roanoke, Virginia is the case study site that is deeply investigate for its potentional of contributing to food security.

Research Question:

Main question:

How can urban food security be maximized by application of permaculture in urban environment?

Sub-questions:

How can food energy be maximized by application of permaculture in urban environment?

How can micronutrients and dietary fiber be maximized by application of permaculture in urban environment?

How can economic income be maximized by application of permaculture in urban environment?

How can food flow be maximized by application of permaculture in urban environment?

Methodology:

The study uses an abandoned urban golf course in the city of Roanoke as a case study to investigate the design strategies for maximizing contribution to food security by application of permaculture. Alternative designs are used to identify how the different design strategies can make the changes in the outcome of food security.

The design process consists of three parts. The first part presents analysis of background information on the study site, which include city context, regional context and existing site conditions. These analyses give an overview of the opportunities and constrains to the development of permaculture on the site. And the second part develops design principles and strategies of permaculture to promote food security based on three dimensions of sustainability, which are (1) economic sustainability, (2) environmental sustainability, and (3) social sustainability. A series of development suitability assessments for the potential farm site are developed for different goals of sustainability. Lastly, the third part provides three scenarios in terms of different goals of sustainability.

Based on these three alternative designs, four management design strategies are developed and input in order to test different outcomes of food energy, micronutrients, economic income and food flow.

CHAPTER ONE INTRODUCTION AND POSITION

Selling Vegetables (by Xueyu Wang)

“Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life.”

- Food and Agriculture Organization of the United Nations (Nations, 2005, 29)

INTRODUCTION

In the United States, about 80 percent of people live in urban areas. People move to the city searching for a better quality of life and more job opportunities. Compared with rural residents, people who live in cities have limited opportunity to cultivate land and typically rely on food transported from far away. Transportation increases food costs and reduces nutritional value. As a result, city residents - especially the poor – often find it difficult to obtain healthy and nutritious food. Awareness of these issues has given rise to the concept of “food security”. Numerous city governments and public organization have, or soon will, develop and implement action plans aimed at enhancing food security.

Over the past 100 years, much has been learned about urban agriculture and its potential contributions to the economic, social and environmental needs of city dwellers. We learned how to enable people who suffer food shortage caused by war and economic depression to gain access to sufficient food as well as money and work opportunities. These previous successes bolster confidence in the ability of urban agriculture to enhance food security. Yet, establishing and maintaining urban food production systems is a challenging task. To contribute positively to all dimensions of food security including food availability, food access, food utilization and stability, it is necessary to build an efficient local food production system that integrates food production, food preparation, food distribution and waste reuse.

Permaculture is increasingly being used in urban environments to create sustainable food production systems. Permaculture, in some important dimensions, mimicks natural ecosystems. What makes permaculture popular is the potential it offers to design and build more fully integrated and self-maintaining agricultural systems.

This study seeks to assess the ability of permaculture strategies to enhance food security. To accomplish this, it tests productivity in relation to distinct sets of environmental planning and design priorities. Especially in urban settings, the aptness of metrics for gauging productively are contingent on conditions in the surrounding community. The amount of food energy, micronutrient and dietary fiber, economic income and/or continuity of food flow may be considered a more important measure of success depending on local circumstances. And, in every case, it is necessary to weigh the value of food production against a host of competing economic, social and environmental considerations. Understanding to potentials of permaculture to increase food security, while attending to these dynamics of the urban circumstance, lies at the core of this research.

Any robust and sustainable urban agriculture system depends on the availability of land that – for a time – is not subject to development for a ‘higher value’ use. Consequently, research on urban agriculture typically focuses on vacant or abandoned sites. Since urban land values are dynamic today’s vacant lot may become tomorrow’s prime development site. Consequently, enduring urban agriculture requires an ongoing methodology for identifying the available land-base and planning for its successful integration into a dynamic and adaptable overarching system of production.

In this thesis, an abandoned golf course provides a suitable case study venue. Due to current economic circumstances and changes in people’s ideas about leisure time activities the popularity of golf is waning. With a decline of golf participation, the market for golf facilities is over-saturated and an increasing numbers of courses are being abandoned. Golf courses are large undeveloped open spaces that typically feature the infrastructure required to support intense vegetative growth. Many golf courses are located in close proximity to urban residents. When vacated, such sites may become highly desirable candidates for urban agricultural production – particularly if they are, for some reason, protected from competing land-uses.

Countryside Golf Course located in Roanoke, Virginia is the case study site selected for this thesis. Countryside is located in proximity to the Roanoke Regional Airport and, even though much of the site has already be purchased and developed, and a major section is located within a runway protection zone. Freed from competing land uses, and surrounded by infill development, this portion of the Countryside site provides an ideal test-bed for assessing the capacity of permaculture practices to improve food security.

Urban Food Insecurity

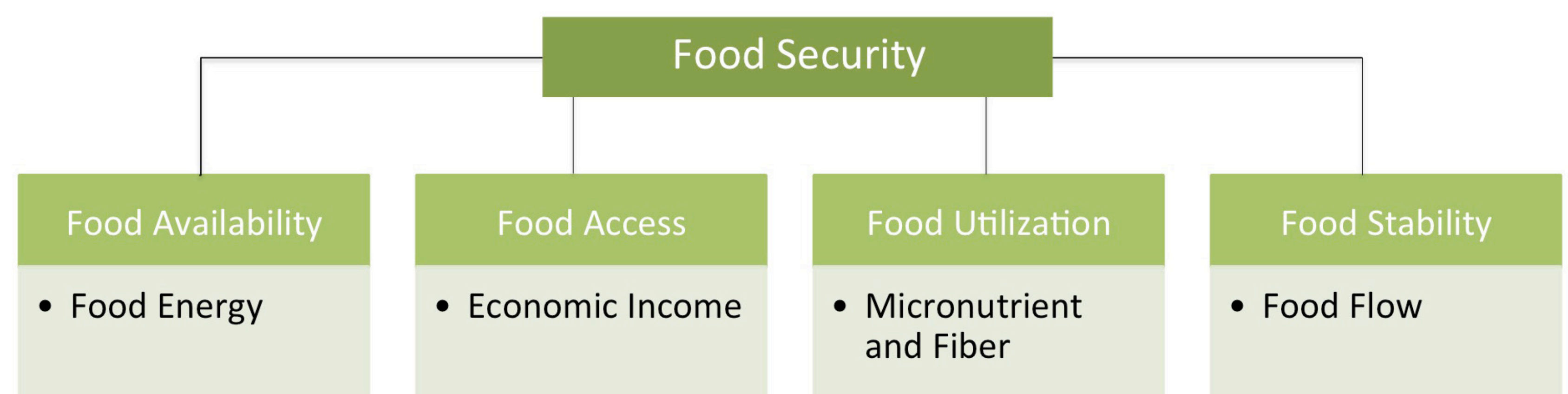
Urban food insecurity exists as a severe problem in many developed and developing countries. According to a conference report convened by Penn IUR, the amount of land in the U.S. converted to urbanized use increased by 2% annually between 1980-2000. Over half of this land (58%) was converted from agricultural uses. (Penn IUR, 2013, 14). While the agricultural land-base is shrinking a growing urban population increases the demand for food. The net result is a growing need to transport greater amounts of food over longer distances. Long-distance transportation sacrifices food freshness and increases its price in the market. Forces of urbanization also tend to increase poverty. Based on a survey by the American Community Survey, the number of people living under the poverty line has increased from 33.9 million to 44.9 million… 14.9% of the overall population (Bishaw, 2014,13). Simply put, growing numbers of people have less income available to buy increasingly expensive products. Poor diet has cascading implications for public health. Overnutrition and undernutrition both lead to serious health issues, such as diabetes, obesity and cardiovascular diseases. Based on the statistical data from Parece, Serrano, & Campbell, 27.2% of adults in Virginia suffer obesity (Parece, Serrano, & Campbell, 2016, 5).

Definition of Urban Food Security

Urban food security is a multi-dimensional concept composed of four components: food availability, food access, food utilization, and food stability. According to the Food and Agriculture Organization of the United Nations (FAO), food security is attained “when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (Nations, 2005, 29). According to this definition, food availability is identified as adequate supply of food to people; food access is recognized when all individuals especially the poor have economic and physical access to food; food utilization is considered when people are able to maintain a nutritious diet; and food stability is a concept that combines the ideas of food availability, food access and food utilization, which means to ensure all people can access adequate food at all times.

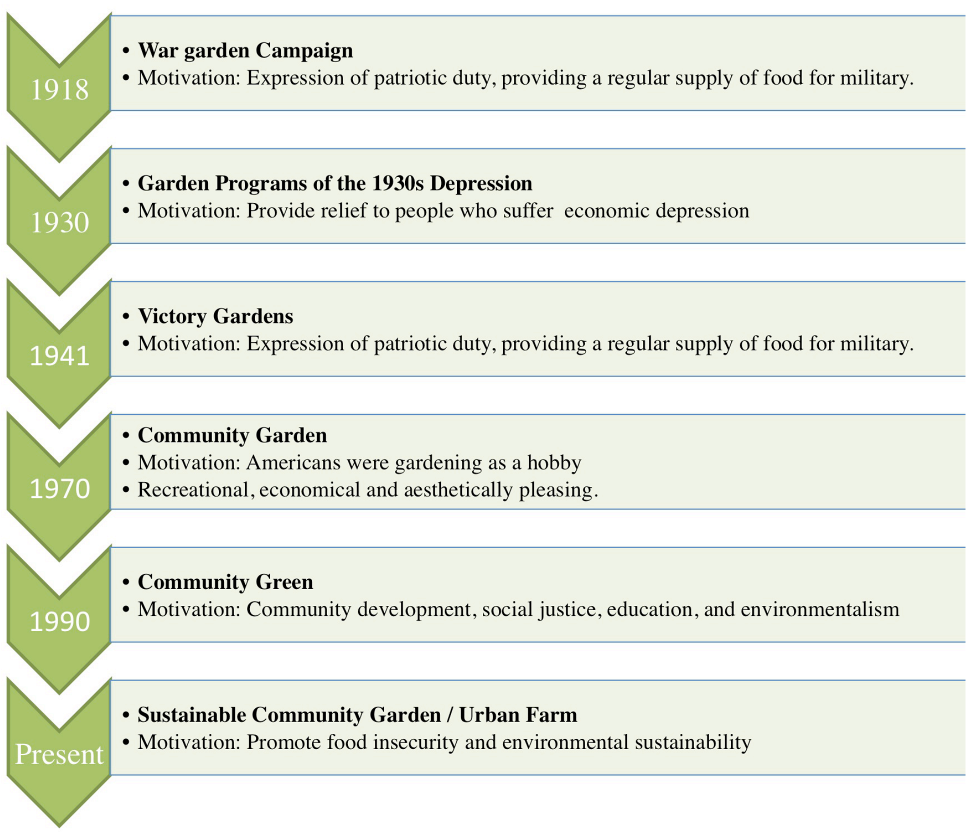
Food Energy, Micronutrient and Dietary Fiber, Economic Income and Food Flow

Food energy, micronutrient and dietary fiber, economic income, and food flow can contribute to these four dimensions of food security, respectively. Food energy refers to the calories contained in food. Total food energy can be determined for any discrete amount of food. But, a healthy diet requires more than energy. Eating the wrong balance of foods can lead to over nutrition or undernutrition. Both have implications for public health. For example, taking in too much of the wrong types of food is leading the United States into a national epidemic of obesity. For example statistical data indicates that 27.2% of adults in Virginia suffer from obesity (Parece, Serrano, & Campbell, 2016, 5). Rising rates of obesity are linked with increases in both cardiovascular diseases and diabetes. Micronutrients and fibers are important to food security because they assist human body to absorb advantageous nutrients and contribute to better health. Where food availablity exceeds consumption, the economic value of the surplus may be the most important metric of productivity. Maximizing economic income may help urban farmers to sustain a higher overall quality of diet over an extend portion of the year. Food flow is a way to describe how much locally produced food is available throughout the duration of a calendar year. It can be described as the available food energy per every month. Maximizing food flow ensures that people consistently get a more adequate diet comprised of an enhanced variety of foods.



Compositions of Food Security

A HISTORICAL VIEW OF URBAN AGRICULTURE



Motivations of Community Gardens in Different Period of United States

HISTORY OF URBAN AGRICULTURE

Urban agriculture refers to a type of agricultural activity that aims to reuse urban vacant lots for food production and provide benefits to urban residents. (Bailkey, & Nasr, 2000). Multiple agriculture practices are applied in the city environment to contribute to the food production. These include vegetable production, aquaculture, and livestock breeding. Urban farms and community gardens are both forms of urban agriculture but they tend to accommodate different kinds of practices. Community gardens are typically small-scale production and intended to mainly benefit residents of the local community. Community gardens often aspire to community empowerment through social interaction and education. Vegetable production is the predominate agricultural practice found in community gardens. By contrast, urban farms are based on large-scale production and may be capable of benefitting all residents of the city. Most urban farms are run on a commercial basis. Because of the increased emphasis of commerce, urban farms tend to incorporate a broader variety of agriculture practices (Hochberg, 2014, 11).

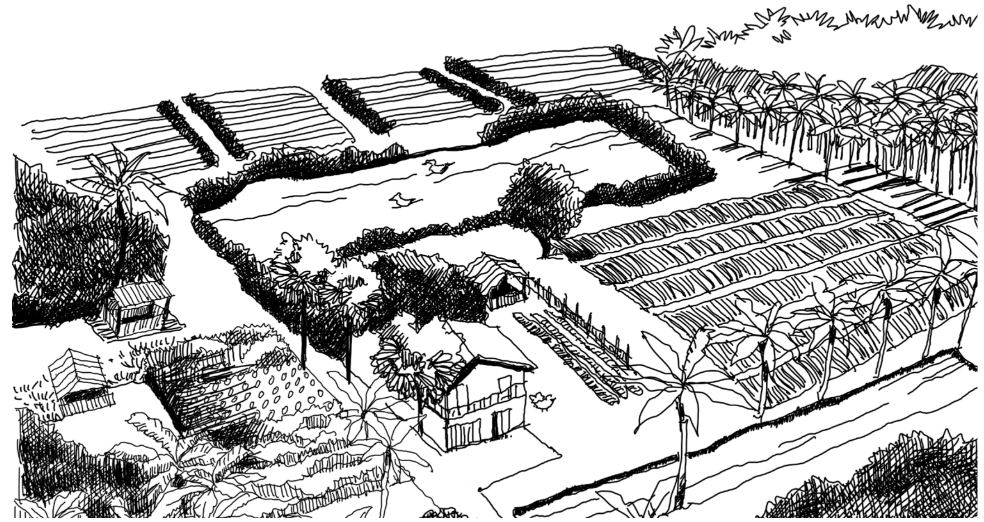
The history of community gardens in the United States can be divided into six periods. During the Great Depression, community gardens were developed to bring multiple benefits on an individual level and social level. These gardens contributed to psychological health, physical health, individual income, social capital and a unique environment aesthetic. They were cultivated in various city fabrics composed of vacant lots and large undisturbed parcels. Depression era gardens were outstanding in their ability to bring benefits to individuals and the whole society by serving as “farmyard enterprises” for producing food while also as social arenas for participants to build sustainable social relationships (Kurtz, 2001, 658). In the heyday of depression garden programs, two types of gardens emerged to implement relief efforts: the work-relief gardens and the subsistence gardens (Lawson, 2005). Due to distinct intentions, these two types of garden programs yield different results. The benefits in work-relief gardens were mainly associated with individual economy and mental health due to the creation of working opportunities and providing salary to the unemployed. Subsistence gardens had broader benefits related to mental and physical health, individual economy and environment health with the intention of supporting the unemployed to grow foods for their own consumption or distribution.

For their tremendous benefits, subsistence gardens remained a vital part as the history of urban agriculture in America progressed. During World War II the federal government and other public agencies promoted victory gardens to defend with crisis of rationing of food. By the 1970’s, many new community gardens boomed as result of urban renewal (Lawson, 2005).

The motivation for urban agriculture has changed in today’s society. In addition of food insecurity, urbanization is often associated with degradation and decline of natural habitats such as forest, wetlands, and wildlife. Sprawling development patterns fragment the landscape in ways that threaten biodiversity (Jaeger et al., 2016, 158). Increased impervious surface alters the hydrological cycle and causes degrading of water quality. Parking lots, roadways and building roofs prevent ground water infiltratng resulting in greater flow volumes, velocities and non-point source water pollution (Bhatta, 2010, 34). As cities grow and sprawl, the demand to promote food security arises simultaneously with our awareness of the need for environmental sustainability.

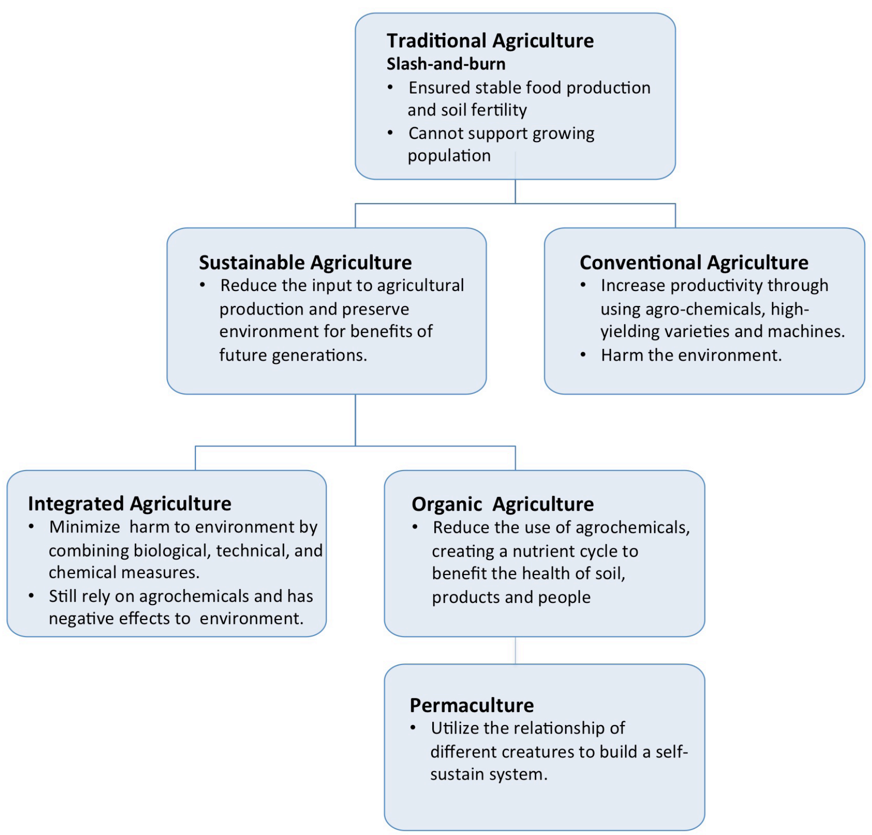
EVOLUTION OF AGRICULTURE PRACTICE:

PERMACULTURE



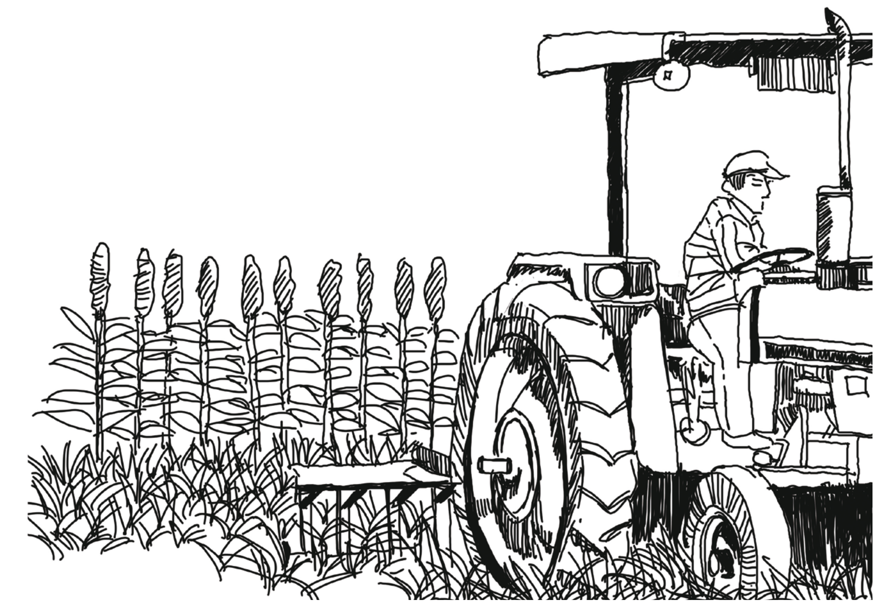
Permaculture

Slash-and-Burn



Evolution of Agriculture Practices and their Influence

Historically, agriculture has passed through various stages of development (Martin, & Sauerborn, 2013). For example, slash-and-burn is one example of traditional agricultural practice that allowed farmers to sustain their food supplies. Periodically relocating agricultural production ensured stable food production and persistent soil fertility as long as the demand for food, caused by growing population, did not exceed certain naturally imposed limits ("Traditional Agriculture", 2017). By contrast, modern conventional agriculture is a product of technological innovation. The invention of agrochemicals, high-yielding crop varieties and machines helped to increase productivity and contribute to a new era of agriculture. Although conventional agriculture brought tremendous benefits to human society, it results in substantial environmental impacts. More recent concerns about human health and the environment gave rise to sustainable agriculture. The goal of sustainable agriculture is to reduce the inputs to agricultural production and preserve environmental benefits of future generations. Integrated agriculture and organic agriculture are two families of practices to used accomplish the goals of sustainable agriculture (Martin, & Sauerborn, 2013).



Conventional Agriculture

Sustainable Agriculture

INTRODUCTION TO PERMACULTURE

Selling Apples (by Xueyu Wang)

"Cultures cannot survive without a sustainable agricultural base and land use ethic. Permaculture is about the relationships we can create between minerals, plants, animals and humans by the way we place them in the landscape. The aim is to create systems that are ecologically sound and economically viable, which provide for their own needs, do not exploit or pollute, and are therefore sustainable in the long term."

-Bil Mollison (Mollison, Jeeves, & Slay, 1988)

DEFINITION OF PERMACULTURE

Permaculture can be regarded as one form of organic farming. Like organic farming, permaculture aims create a nutrient cycle that benefits the health of soil, products and people (Martin, & Sauerborn, 2013). A distinguishing feature of permaculture is the use of a variety of flora and fauna species to build a production system that is self-sustaining to the greatest possible extent.

Proponents contend that permaculture should be defined as permanent culture rather than permanent agriculture. However, permanent agriculture is the most important component of permaculture and provides the theoretical basis for it. Permanent agriculture seeks to create an energy conservation system to obtain a high yield with low input and minimal waste. In order to achieve this goal, an open and complex system must be built to encourage exchange between organisms in the system. Aquaculture and holistic animal management are examples that provide evidence for developing self-regulating systems through exchanging extra energy between organisms. Perennial crops are an important component of permanent agriculture systems.

Looking beyond permanent agriculture to permaculture brings the environmental, economic and social dimensions of sustainability into clearer focus. (Mollison, Jeeves, & Slay, 1988). Beyond agriculture, permaculture is trying to build a comprehensive system for long-term healthy living. Within the frame of permaculture the need for a secure food supply must be balanced with a host of additional, and sometimes equally important, human needs. Designers of permaculture systems frequently considerations such as social inclusion, fair share economics, education models output and creative human interaction (Holmgren, 2002).

To summarize, the concept of permaculture can be exressed by three summary terms – "permanent" "culture" and "agriculture". These three terms reflect three ethics of permaculture, which are care for the earth, care for the people and setting limits on consumption and reproduction (Mollison, Jeeves, & Slay, 1988). Permaculture is an attempt to design human management systems that mimic relations of creatures and land found in natural systems (Holmgren, 2002). Different from the idea of permaculture developed by Bill Mollison that addressed on developing specific design strategies on different landforms, David Holmgren is more focused on the philosophy of permaculture and he proposed twelve principles that should be applied in permaculture (Table 1).

Table 1: Permaculture Principles[a]

1. Observe and interact
A design principle that emphasizes developing system thinking through observation and experience

2. Catch and store energy
A design principle that emphasizes capturing and transferring renewable resources through self-organizing system

3. Obtain a yield
A design principle that emphasizes designing a system that can maximizes the reserved and transferred energy to obtain great yields

4. Apply self-regulationand accept feedback
A design principle that emphasizes developing self-regulation mechanisms through holistic thinking

5. Use and value renewable resources
A design principle that emphasizes using renewable resources and services to obtain yields

6. Produce no waste
A design principle that emphasizes minimizing pollution and energy waste through a designed system

7. Design from patterns to details
A design principle that emphasizes recognizing spatial and temporal pattern in permaculture design

8. Integrate rather than segregate
A design principle that emphasizes investigating the relationship between each element and integrating them into a system that performs many functions

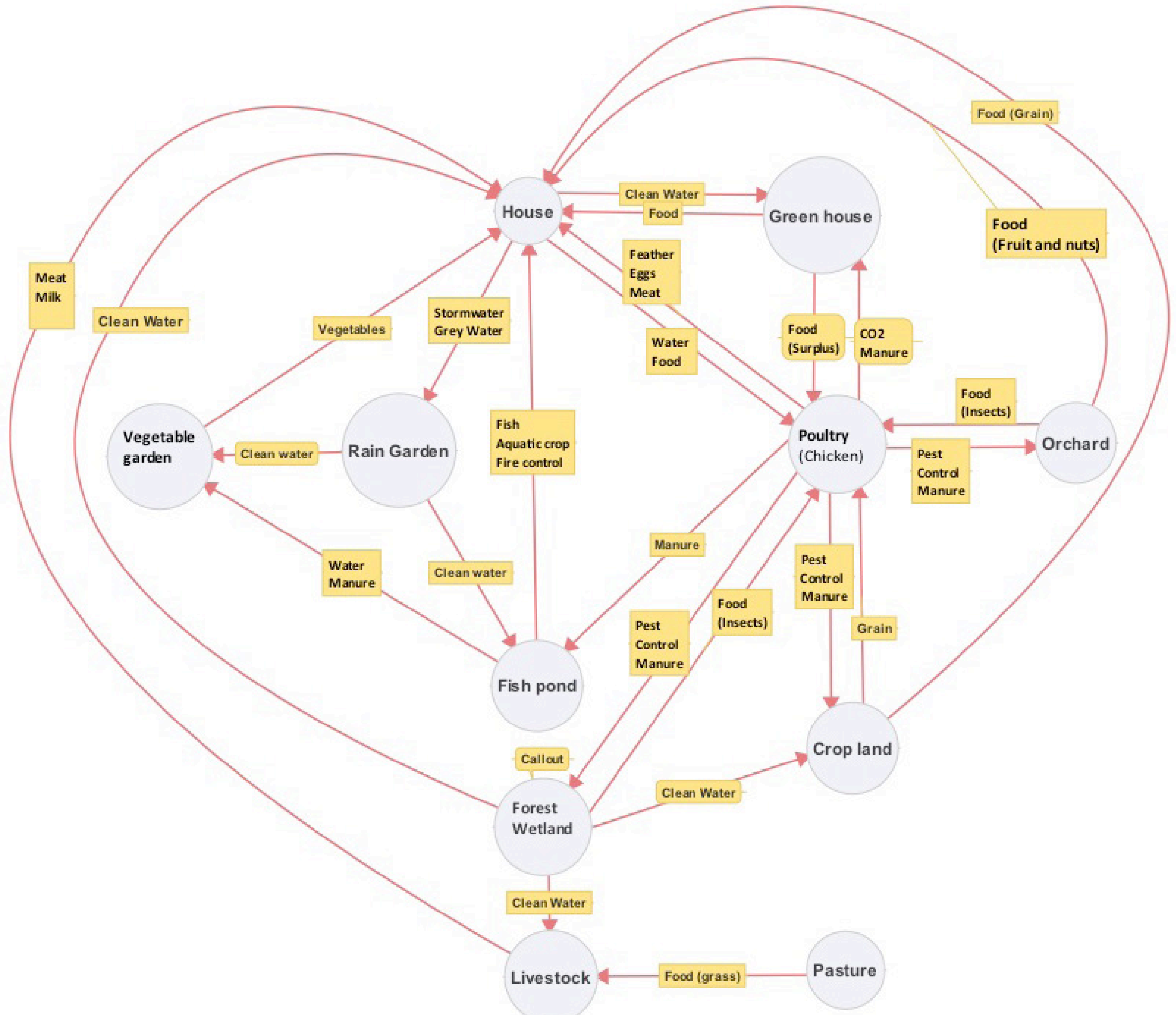
9. Use small and slow solutions
A design principle that emphasizes on designing a system at the smallest scale and lowest speed

10. Use and value diversity
A design principle that emphasizes building diversity of forms, functions, and interactions in nature and humanity

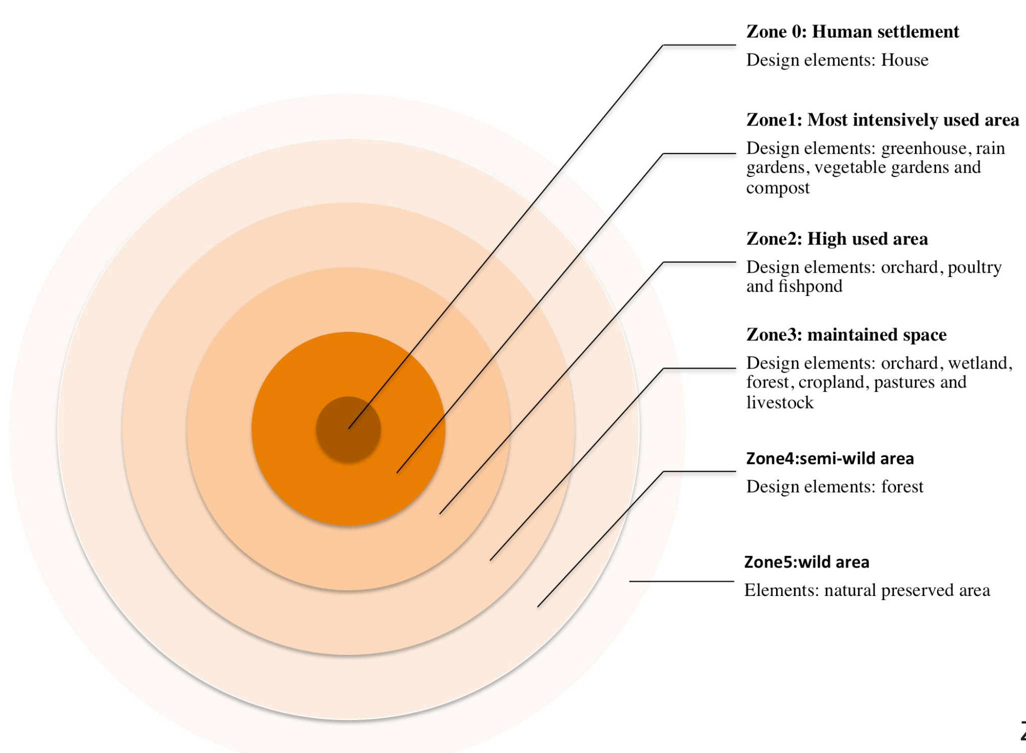
11. Use edges and value the marginal
A design principle that emphasizes considering edges as the most dynamic and productive part of natural system and plant

12. Creatively use and respond to change
A design principle that emphasizes developing ecological models in response to ecological succession within cultivated systems

[a]Principles derived from Holmgren, D. (2002, 1) with summarized description



Permaculture System



Zoning

PERMACULTURE DESIGN

The modern practice of permaculture is derived from a series of experimental studies on tree crops, water harvesting, no-till gardening and aquaculture. According to Bill Mollison's book, important elements in a permaculture farm includes a house, a greenhouse, a vegetable garden, chicken pens, a water storage tank, a compost pile, beehives, a nursery area, a potting shed, a woodlot, a dam, an aquaculture pond, windbreaks, a barn, a toolshed, a woodpile, pasture area, hedgerows, worm beds, and a guest house (Mollison, Slay, & Jeeves, 1991). Addressing the need for holistic on-site stormwater management, bioretention gardens and weltands were added to the compendium of permaculture design elements. Each of these different elements have a tight relationship with each other and should be carefully placed to maximize function and production. A schematic diagram is drawn to illustrate how each element connects and contributes to the function of the whole system.

Zone planning, a core idea of permaculture, is used to organize the spatial relationship between different site elements. An "ideal" site has a gentle south-facing slope with few confounding variables. In reality, however, there will always be other factors that influence planning, such as proximity to market, site access, varying slopes, local climatic quirks, areas of special interest, and soil conditions.

Zones are distinguished by their frequency of use. Zone 0, the center is defined as human settlement and intersects with each of the other zones. Zone 1, located closest to the center, contains the most intensely used elements: the greenhouse, rain gardens, vegetable gardens, and compost beds. Zone 2, also intensely used, includes important elements such as poultry production, fishpond, and the orchard. Zone 3, which has some overlap with Zone 2 is a maintained space, containing the orchard, wetlands, forests, cropland, pastures and livestock. Zone 4 is a semi-wild forest area which produces timber for people and provides habitat for wildlife. Zone 5 is a barely managed natural area linking the permaculture farm with preserved natural spaces. It has the ability to support wildlife and recreational activities (Mollison, Slay, & Jeeves, 1991).

BENEFITS OF APPLYING PERMACULTURE IN URBAN ENVIRONMENT

Declan Kennedy, a professor of urban infrastructure at Technical University Berlin, suggested sustainable planning can be achieved by integrating permaculture into the urban fabric (Kennedy, 1991). Through permaculture, cities can build resilient local food systems and improve their ability to resist natural disasters such as flooding, storm surges and landslides.

The most obvious benefits of permaculture are associated with food production. Because residents lose opportunities to cultivate land in urban areas, where density and land use patterns impose constraints, most people purchase groceries in the supermarket, where vegetables and produce are transported from farms in rural areas. This traditional food system is largely dependent on transporting food long distances resulting in food insecurities and environmental problems. Not only does food lose freshness with long transit times but the risk of contamination also increases. The traditional food system's extensive use of transport is energy consumptive and creates greenhouse gas emissions, which contributes leads to climate change.

Urban permaculture gardens can provide people with an opportunity to plant their own food and a path to a healthy die. Working together, all participants could have daily access to fresh, inexpensive produce instead of the alternative, where lack of choice or opportunities forces people to buy low-cost, high-calorie food from the grocery store(Thompson, Corkery, & Judd, 2007). Garden-fresh vegetablesare high in nutritional value and contribute to maintaining a healthy weight. The process of food production can also help teach children and adults about plants and important agricultural skills.

The physicality of gardening activities helps to build a strong, healthy body. Many gardening tasks such as digging or mixing soil helps to stretch the body, increases physical energy, burns calories and helps in reducing body weight (Park et al., 2008). Local food production minimizes the energy expenditures of transportation, packaging, processing and production inputs (Lovell, 2010). Surplus food could then be sold for profit in local markets, which can alleviate financial pressuresfor low-income people.

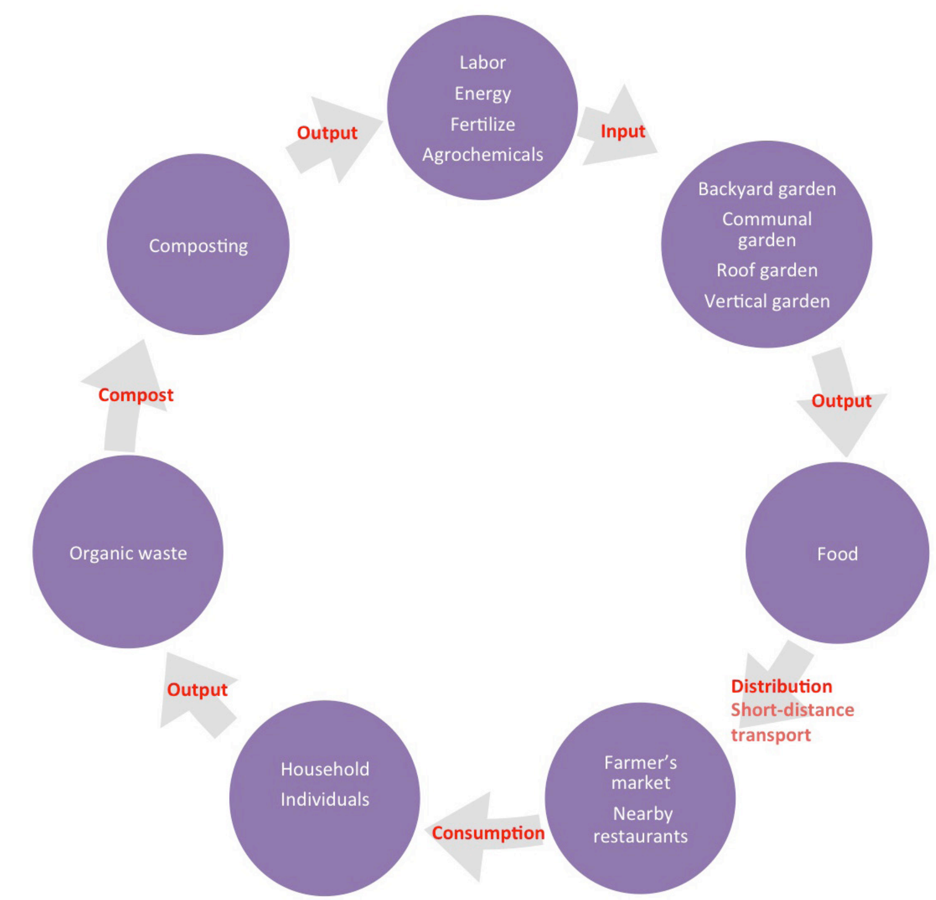
Other benefits of permaculture include promoting the health of the urban environment through improved aesthetics and ecological rehabilitation. Buildings, roads and other characteristic urban constructions create a "grey world" through their consumption of large amounts of green land (e.g., forest and pasture).Permaculture fills the world with plants, making the world more beautiful. Enhanced with plants, flowers, and vegetables, these green spaces serve as habitat for various birds and insects while also createing beautiful landscapes for local residents and visitors. Permaculture contributes to biodiversity and conservation especially when native species are integrated into the system. These green spaces contribute to other benefits in the urban landscape. They act on the urban microclimate, adjusting humidity, reducing wind and providing shade (Lovell, 2010, 2503).

Density is a major factor that influences temperature and urban ventilation conditions. Having a high building density contributes to poor ventilation and strengthens the"heat island" effect (Hui, 2001, 630). Unlike conventional food systems, permaculture can reduce greenhouse gas emissions and reduce agriculture's impacts on global warming.

The use of renewable energy contributes to permaculture's environmental sustainability. Utilizing solar energy, plants photosynthesize, converting water and carbon dioxide into sugar, thus allowing them to grow (University of California, 2017). Growing plants can contribute to temperature reduction in the city through several ways: through the process of evapotranspiration, through the production of shade, and by acting as a heat-sink in general for nearby impervious surfaces. Permaculture gardens complete the carbon cycle by fertilizing urban soils through composting plant wastes and other organic garden byproducts. The reuse of wastes minimizes land use for disposal and pressures from transportation for long-term management in municipal dumps, thus closing the loop in the cycle of waste resources (Lovell, 2010).

Permaculture also influences hydrological processes using preserved woodlots, wetlands, and rain gardens. Preserved woodlots and wetlands aid in managing stormwater runoff, allowing for groundwater infiltration and flow regulation. Rain gardens can be constructed as wastewater treatment facilities to catch polluted runoff. Rain gardens can also be used to shift polluted runoff to water treatment plants (UNEP, 2014). They also help to mitigate climatic pressures from flood and drought. In times of flood, they provide opportunities for stormwater storage in the ground and in surface waters. In times of drought, this stored water is released for consumption.

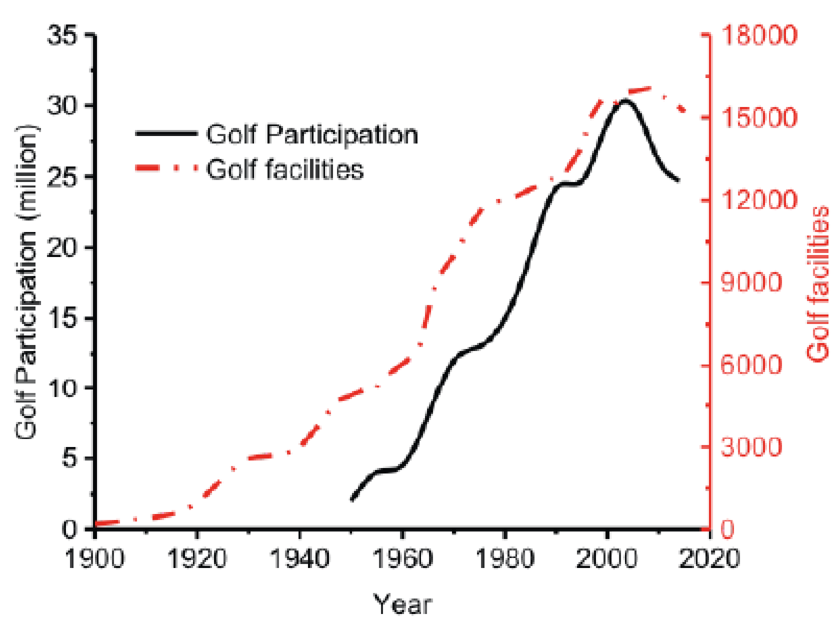
Traditional Food System



Sustainable Local Production Food System in Permaculture

GOLF COURSE DEVELOPMENT

Table2:Trend of Golf Course Development



Source: The data are adapted from "A Strategic Perspective on the Future of Golf," by J. Beditz and J. Kass, 2007. Copyright 2007 by National Golf Foundation. Retrieved from www.ngf.org

Although the true origin of the first golf course is still under debate, it is commonly believed that its birthplace is in early 15th century Scotland. It became a popular game before war broke out between England and Scotland and the people were forced to give it up. In the 16th century, golf became a favorite royal pastime, and golf courses, along with the game, spread across Europe.

Britain was an early leader in golf course development and was responsible for the spread of golf courses to countries all around the world ("A History of Golf since 1497 part 1", 2017). At the end of the 18th century, golf courses were first introduced to eastern shore of United States. In the beginning, golf faced stiff competition with horse-racing, prize fighting and baseball for viewership. People were critical of golf, seeing it as a sport for the fat, aged and idle rich, and preferred to watch the more physically demanding games. As golf began to gain acceptance as a sport, the Civil War broke out, becoming its biggest obstacle to development (Grimsley, 1966). After the fighting was done, golf courses finally had the chance to spread across the United States.

The first record of a golf course in United States was built by John Reid in Yonkers, New York, where he put a 3-hole course on a private cow pasture in 1888 ("America's first golf club marks a major anniversary", n.d.). In addition to the course, Reid established St. Andrews Club to regulate course activities. Although popular, this first course was limited in size and so St. Andrews made many moves, occupying several parcels of land on its way to its final location in Mt. Hope.

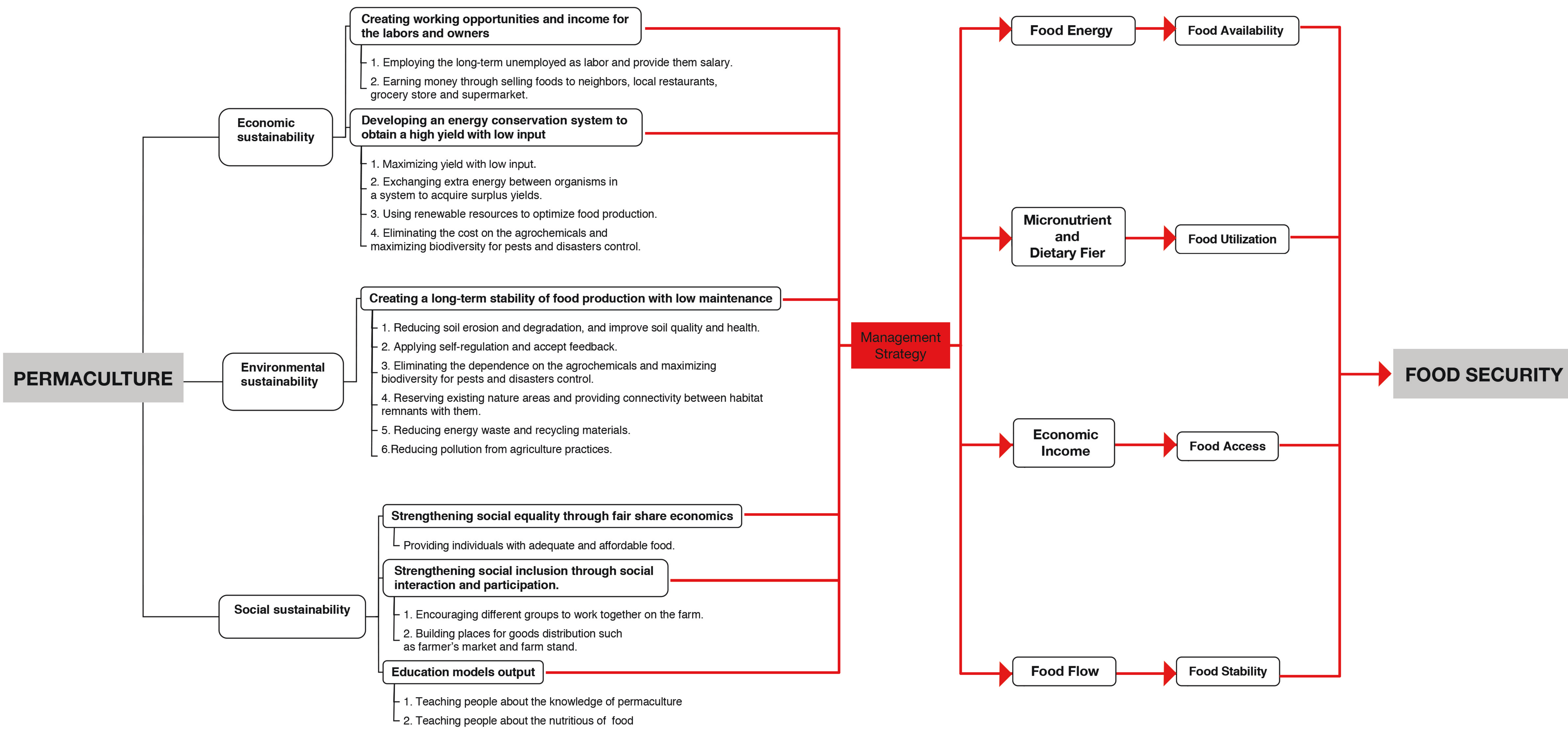
The first move was to a larger, 30-acre parcel on North Broadway and Shonnard Place and developed into a rolling 6-hole course. Yet, there were critics who argued the land was wasted space and would be better used for residential development. At request of the city government, a planned road was built and the golf course was divided. St. Andrews moved to Sawmill River Road, building a 9-hole course on a 34-acre orchard named Great Oaks. Their final move to Mt. Hope came later, where they built an 18-hole course. At the same time St. Andrews developed, many 6- and 9-hole courses sprung up across the United States, ranging from New York to Chicago. The first 18-hole course in the United States emerged in Chicago in 1893 and would eventually become one of America's great championship courses. Golf courses were even adopted into residential communities. Florence Boit, one of the game's early driving forces, transformed several neighbors' lawns into a 7-hole course on the weekends. (Grimsley, 1966).

During the Great Depression, golf courses saw difficulties and opportunities for development. Depression brought destructive impacts on private golf course's survival. Membership slipped 65 percent due to unaffordable membership fees. Yet, golf courses prevailed, becoming an antidote to living in such desperate times. In the 1930's, with the support of WPA, hundreds of municipal golf course programs were developed to provide people with exercise opportunities. This encouraged people to join the sport and gave them relief from their negative emotions. Bobby Jones, a golf market leader, saw the commercial potential in popularizing this game. With his effort, golf course membership became affordable for most people. Even local governments expressed great interest in these developments and supported a series of similar programs. It became so popular that golf lessons were being taught in schools, community centers, department stores and industrial plants. According to Golfdom magazine, the number of golf participants nearly tripled in just two years during the Depression (Kenny, 2014).

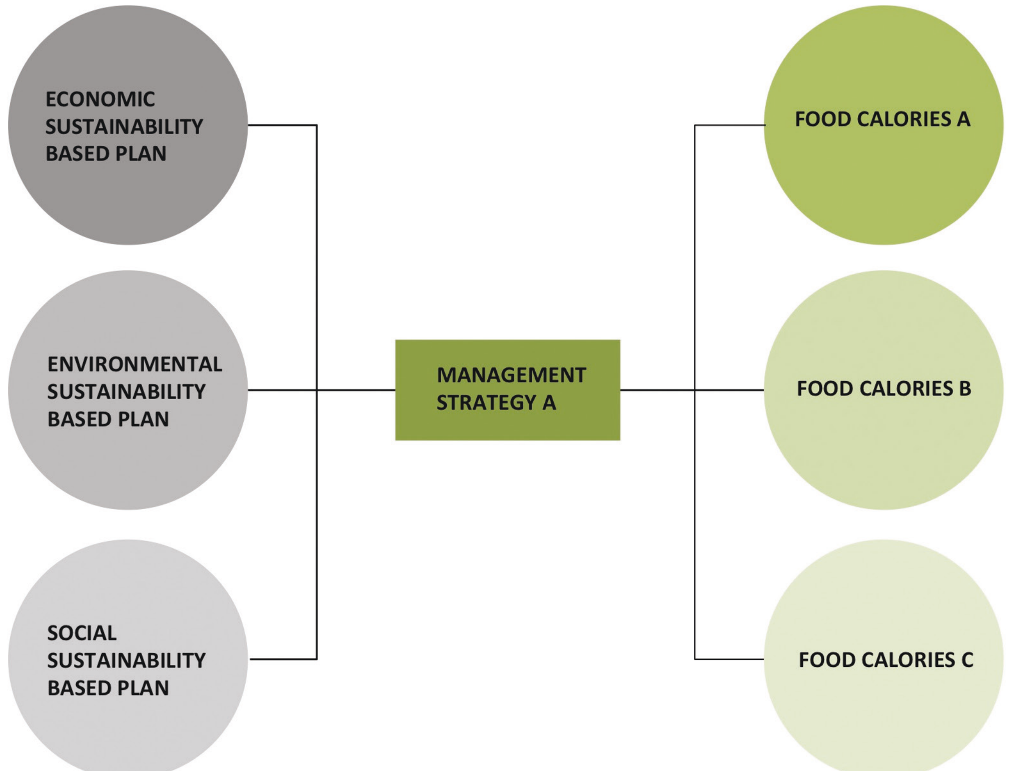
By the end of 2005, the number of golf facilities has seen stunning growth. Data retrieved from National Golf Foundation (NGF) shows that there was a positive correlation between the increase in golf participation and increase in golf facilities. There were three obvious booms in golf participation during the 1920s, 1960s and 1990s. Golf courses have become viewed as a lure for residential real estate .

Now, in the 21st century, golf courses are facing challenges once again. Some are critical of golf courses and question whether they are economically viable. According to data from NGF, about 848 golf courses have closed in United States in the last several decades. The decline of golf courses has a direct relationship with decreases in golf participation (Figure 7). Fewer golf participants has resulted in decreases in revenues, which forced owners to close down their courses. Koppenhaver points out that the number of golf course participants had reduced 9% in the United States since 2000 (Koppenhaver, 2006). One of the reasons for this recession is excess consumption of leisure time. A player needs four or five hours to finish a full competitive 18-hole game. On the contrary, other recreational activities, such as fitness training, needs less time and becomes a preferred choice for people who want to exercise for shorter amounts of time (Narain, 2009). Other reasons include the recent economic crisis and increasing difficulty of the game. Facing the economic crisis that led to belt-tightening in wages, middle and low-income golfers had to leave the game due to expensive membership fees. Even more challenges emerged in the game in general which confused golfers and thus reduced their enthusiasm and potential desire to pick up the sport ("Why golf is in decline in America", 2015).

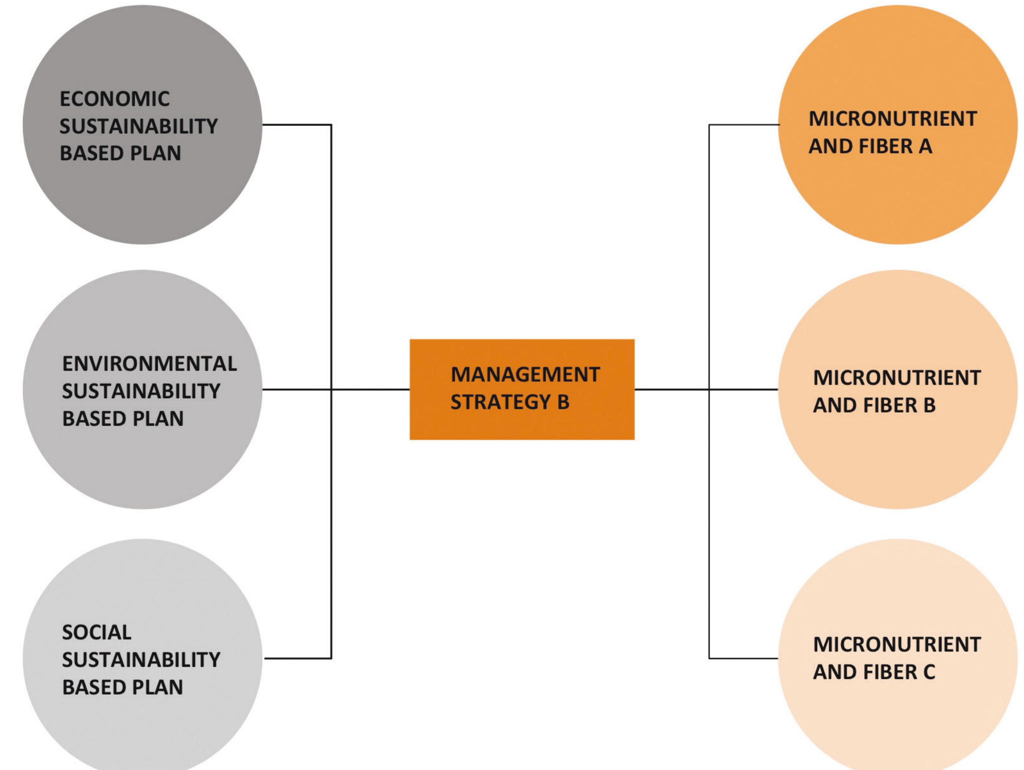
THEORETICAL FRAMEWORK



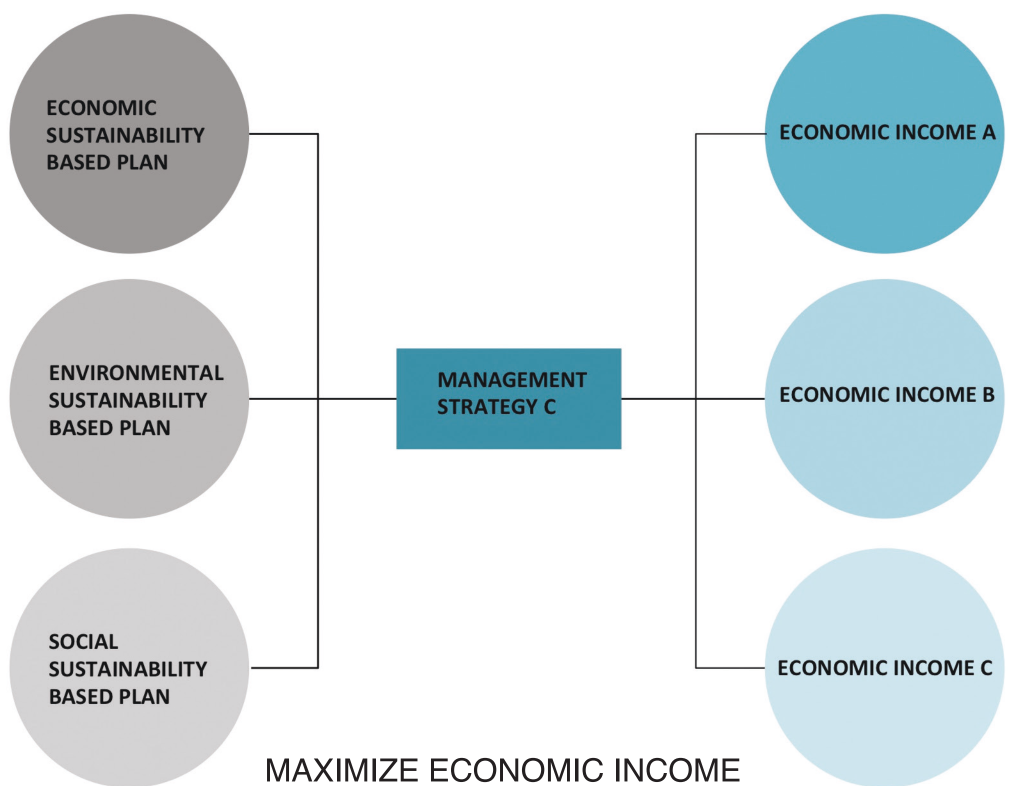
THEORETICAL FRAMEWORK



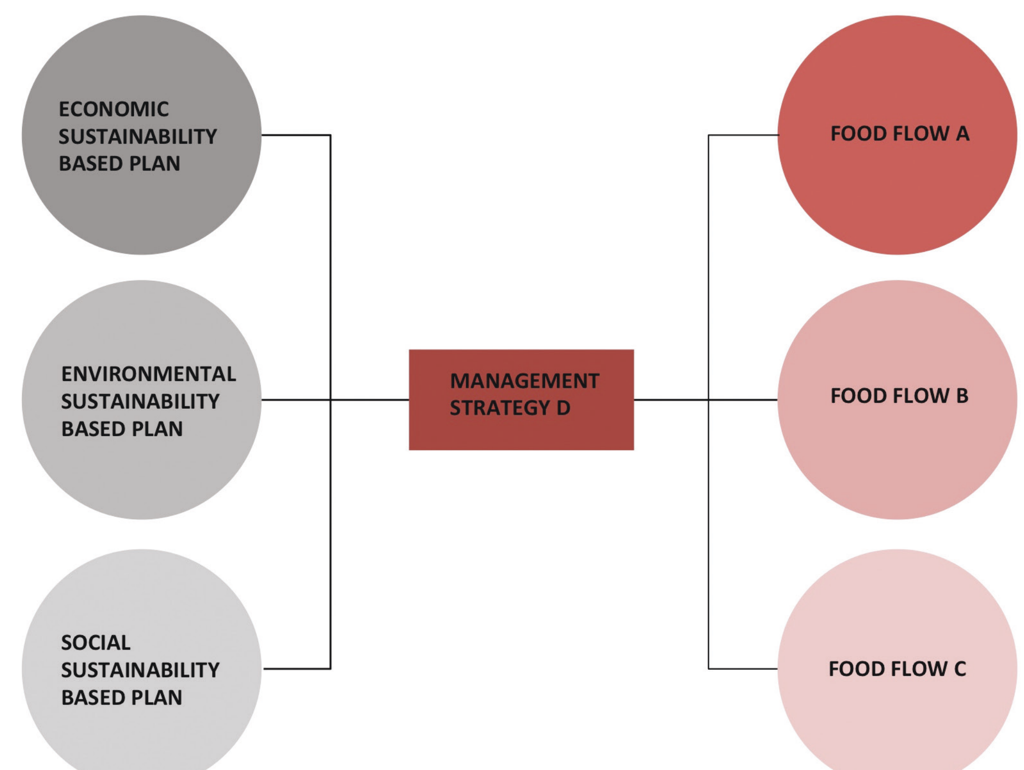
MAXIMIZE FOOD ENERGY



MAXIMIZE MICRONUTRIENT AND DIATERY FIBER



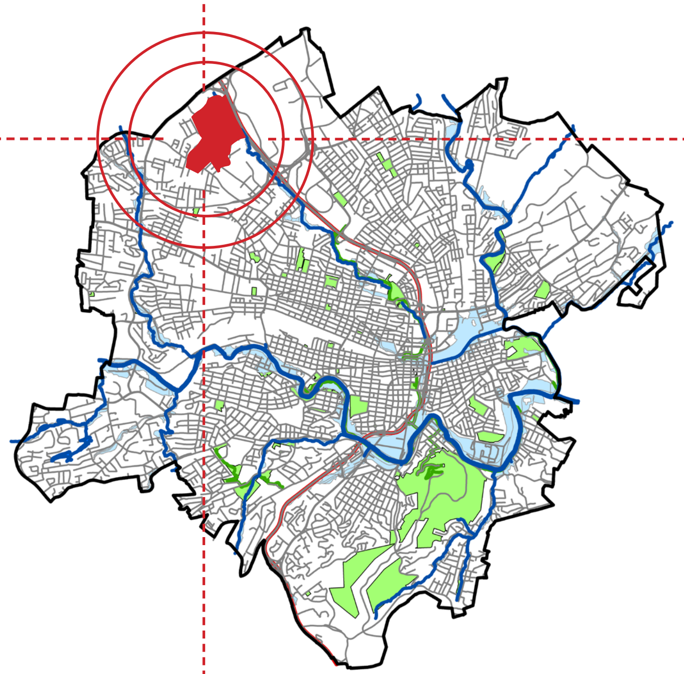
MAXIMIZE ECONOMIC INCOME



MAXIMIZE FOOD FLOW

CHAPTER TWO DESIGN

ROANOKE CITY + STUDY SITE



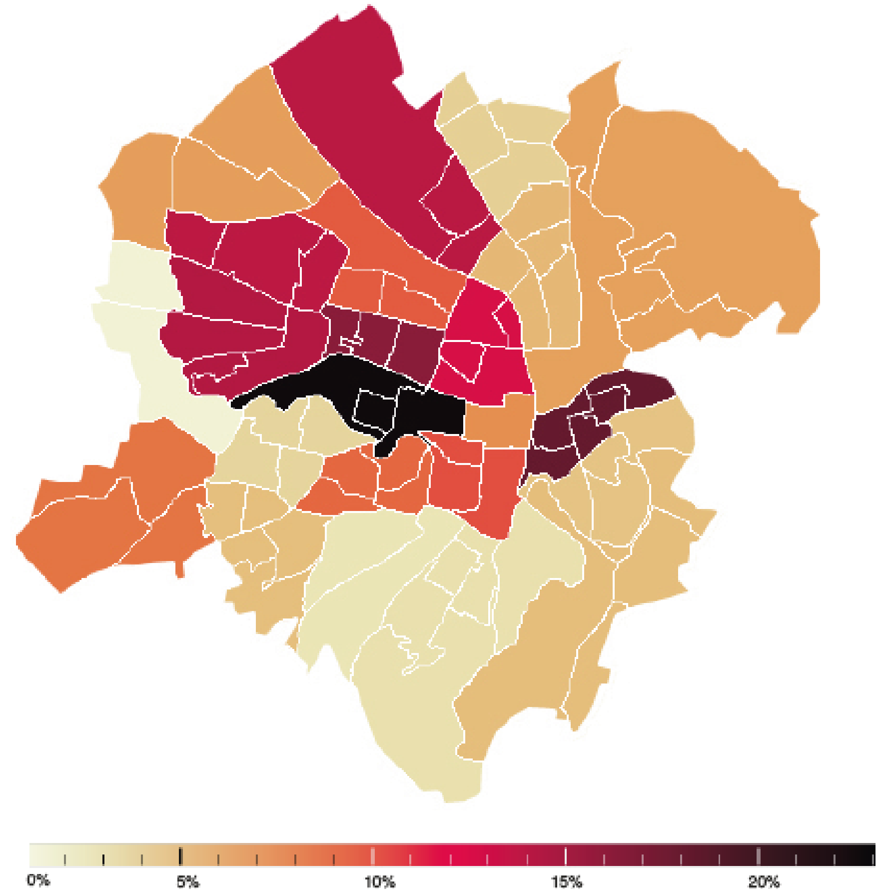
Specifying the Location of Golf Course in the Roanoke City

Aerial View of The Countryside Golf Course

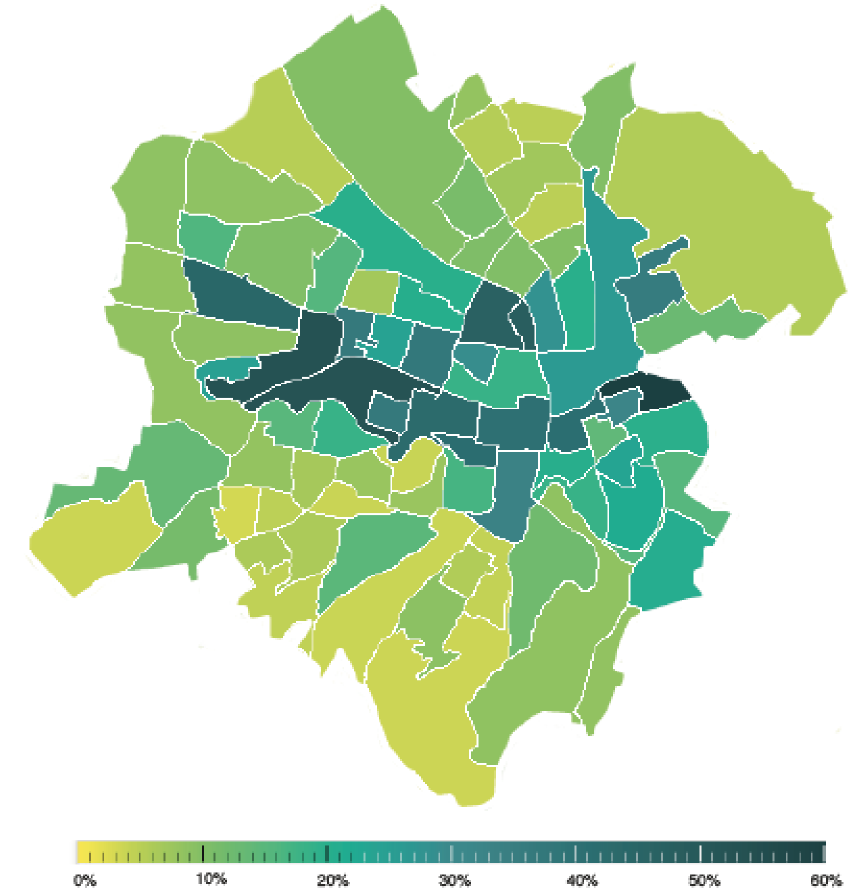
CITY CONTEXT

Roanoke is the largest city in northern Virginia with a population of 99,320 people living across 43 acres. Roanoke city possesses plentiful natural resources and superior geographical conditions. Northern Roanoke connects with the branch of Appalachian Mountains called the Blue Ridge Mountains. This is the origin of the Roanoke River that passes through the center of the city ("Roanoke Government Documentation", 2017). Fertile lands and abundant water sources attracted people to live here; agriculture and business developed under these superb conditions.

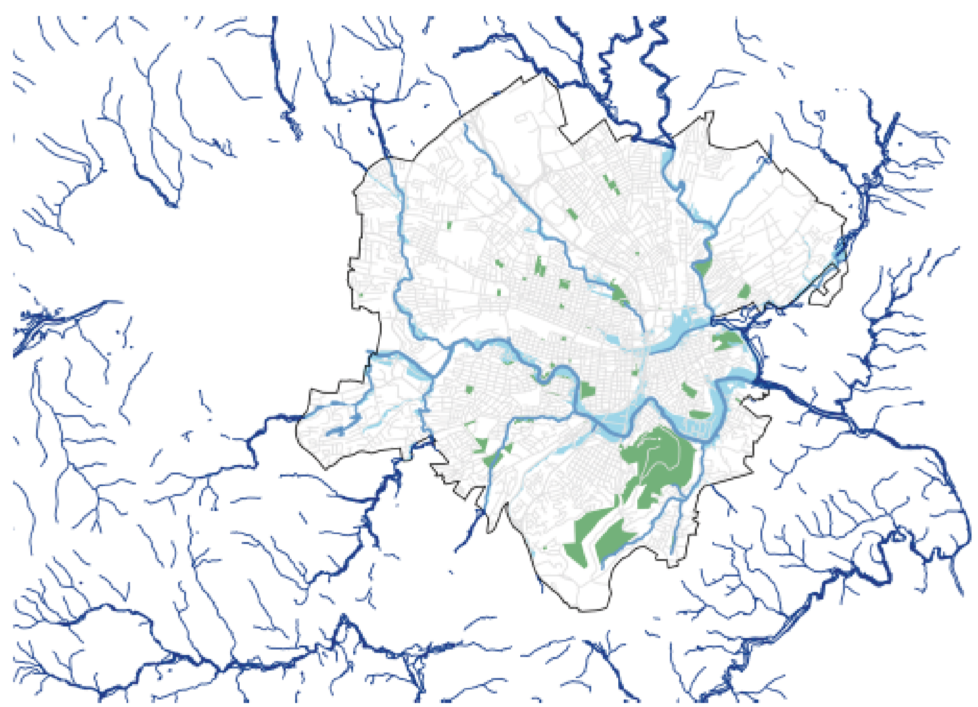
Nevertheless, the rapid urban growth brought with it societal problems such as resource shortages and lost job opportunities, leading an increase in the poverty rate. In Roanoke, roughly 12.9% people live below the poverty line, and 5.8% are unemployed (Etienne, 2006). Compared to other cities and counties, Roanoke has a relatively high poverty rate and high rate of food insecurity. In addition, Roanoke's citizens face grave health problems including obesity, diabetes, and physical inactivity (Parece, Serrano, & Campbell, 2016, 5). These social and economic factors point to systemic problems with how we design our cities and provides a basis for the development of permaculture the urban environment.



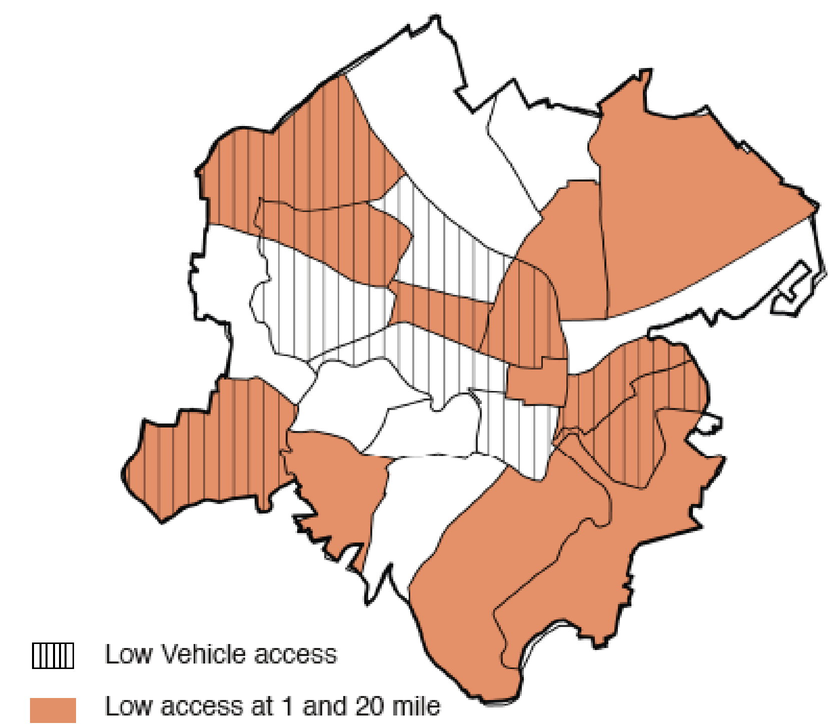
Unemployment Rate



Residents with Income below the Poverty Level



Water System and Green Open Space



Food Desert Area

NEIGHBORHOOD CONTEXT

OPPORTUNITIES AND RESTRICTIONS

OPPORTUNITIES

- **Convenient Transportation System**

The golf course connects Peters Creek Road on its north boundary and is bounded by Frontage Road NW. Both roads connect with Interstate 581, which provides convenience vehicular circulation for food transportation.

- **Market Vicinity**

There are many businesses on both sides of Peters Creek Road, there is an Asian supermarket, a grocery store, and five restaurants. Located on the south end of the golf course are a hotel, a retail store, and four restaurants.

- **Education Opportunity**

Southview Preschool and William Fleming High School are located on the north and south of the golf course, respectively. If an education center were built on the course it would be an ideal place to teach students about permaculture and the importance of maintaining a healthy diet.

- **Available Nature Resources**

The existing natural areas: floodplain, riparian buffer, pond, and wetland provide opportunities for developing a water harvesting system and aquaculture. Some existing trees such as pine trees, oak trees, and birch trees build the base for a food forest.

RESTRICTIONS

- **RPZ (Runway Protection Zone)**

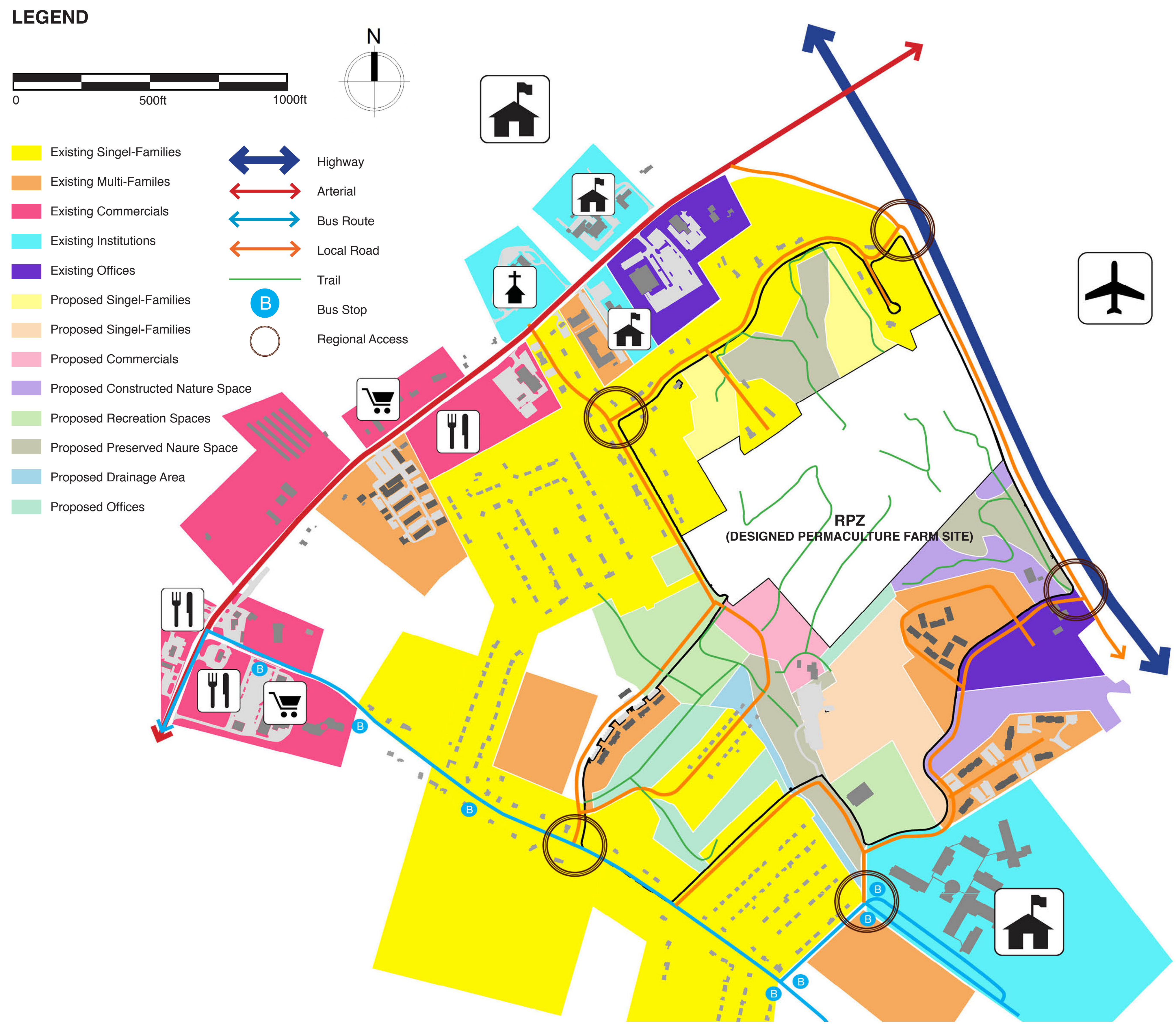
RPZ possesses the potential for permaculture development, but it does have limits. It cannot support space for activities of large groups of people and needs bird control to ensure the safety of airplanes going and coming to the nearby airport.

- **Low Walkability**

The east and west sides of the golf course are roads designed for cars and trucks alsond lack trails for pedestrians. A trail system would a need to be built to enhance walkability.

- **Changed Topography**

The topography varies over the whole site and some areas are very steep.



Analysis Diagram of Neighborhood

EXISTING SITE CONDITION

Located in the countryside northwest of Roanoke, is an abandoned 18-hole 209-acre course owned by the government. After its financial collapse and subsequent 2010 abandonment, the golf course was considered for various other functions. The current land use of this golf course primarily composed of grassland, forest, multi-family and single family homes. One 137-acre parcel was already planned to be a multifunctional development for business, education and office facilities, accommodations, and places to relax. The remaining 72 acres, at the center of the course, is limited in potential uses because it is part of the Runway Protection Zone (RPZ). Appropriate land use in the RPZ includes agriculture, golf course and other land uses that exclude intense human activities and construction ("Airport Planning - Federal Aviation Administration", n.d.). Therefore, the RPZ constraints on the golf course presents itself as an opportunity for permaculture. There will still be challenges as it is necessary to carefully consider how to manage the vegetation in order to reduce hazards from birds around the airport.

View from Tuckawana Cir NW looking west showing existing land cover of northern golf course site (by Xueyu Wang)

View at Northern entrance of golf course site showing trees and shrubs that obscure vision from inside to outside (by Xueyu Wang)

View at fairway of golf course site showing relatively flat grassland bounded by pine tress, oak trees, birch trees and forest (by Xueyu Wang)

Site Sketch (by Xueyu Wang)

View from central area to eastern area of golf course site showing steep slopes of the hill and a stream bank covered by forest (by Xueyu Wang)

Birds Control

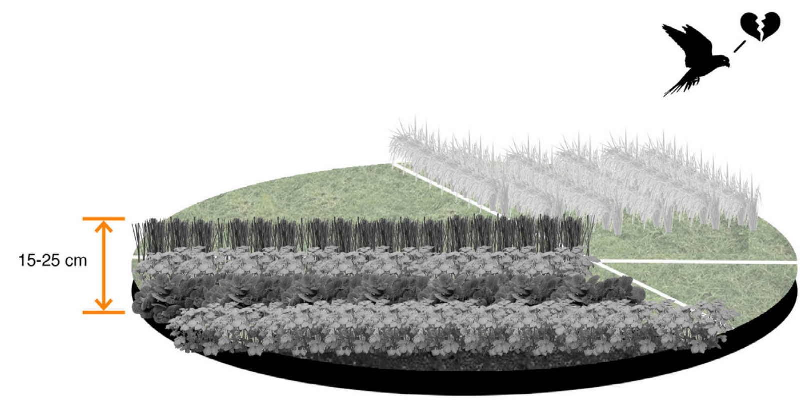
Managing for bird strikes in close proximity of an airport is crucial for the safety of the planes as well as people on the ground. In the golf course RPZ, vegetation management is a vital factor to consider when designing permaculture since some plants may attract birds, which hinders flight security.

Based upon research by Washburn and Seamans, several approaches are effective at reducing potential bird hazards (Washburn and Seamans, 2004). One method is to control plant height. The recommended plant height, which varies between 15 and 25 cm prevents birds from nesting and prevents the PRZ plain from becoming a feeding ground for small insectivorous birds.

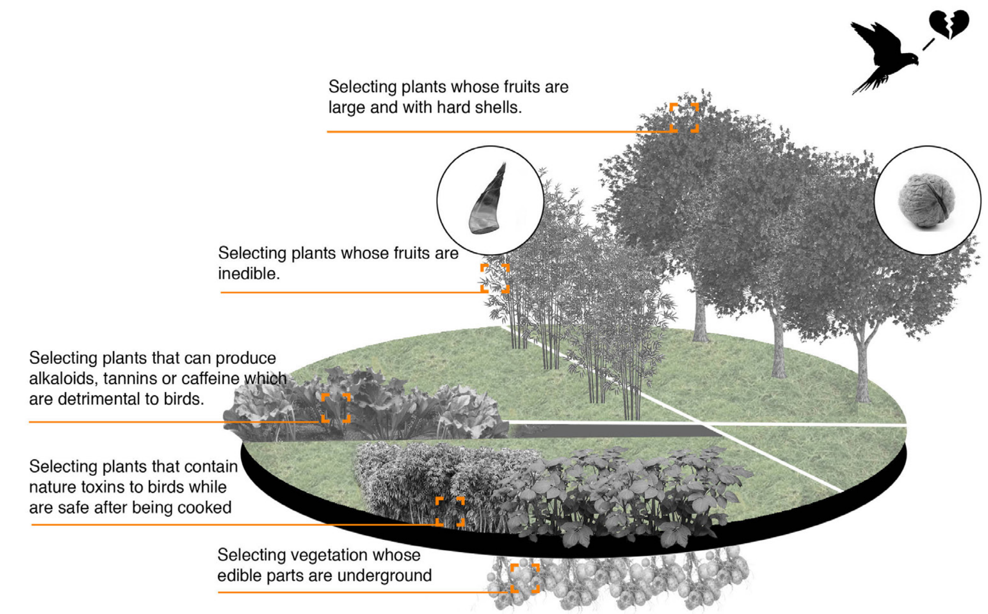
Another approach, managing vegetative species composition, works well because some plants attract birds more than others. Berries and apple trees, for example, attract birds easily, as they are a food source. Planting vegetation favored by birds in the surrounding environment will attract birds to those areas and keep them away from the PRZ.

Vegetation that will not attract birds and can be planted on subtropical areas include:
1. Alkaloid, tannin or caffeine-producing plants, which are detrimental to birds. Examples include oak, rhubarb, tobacco, lettuce, carrots, spinach, onions, cocoa, coffee, and tea ("Safe, Toxic, and Unsafe Foods", 2017).
2. Bamboo shoots and cassava, which are toxic to birds, are safe after being cooked. ("Dangerous human foods", 2017).
3. Plants with underground edible parts, such as root vegetables, include radish, sweet potato, potato, peanut, carrot, beet, burdock, parsley root and native ginger.
4. Plants with fruits that are large or have hard shells, like lemon, squash, walnut, and hickory.
5. Useful plants with inedible fruits, such as cotton and bamboo.

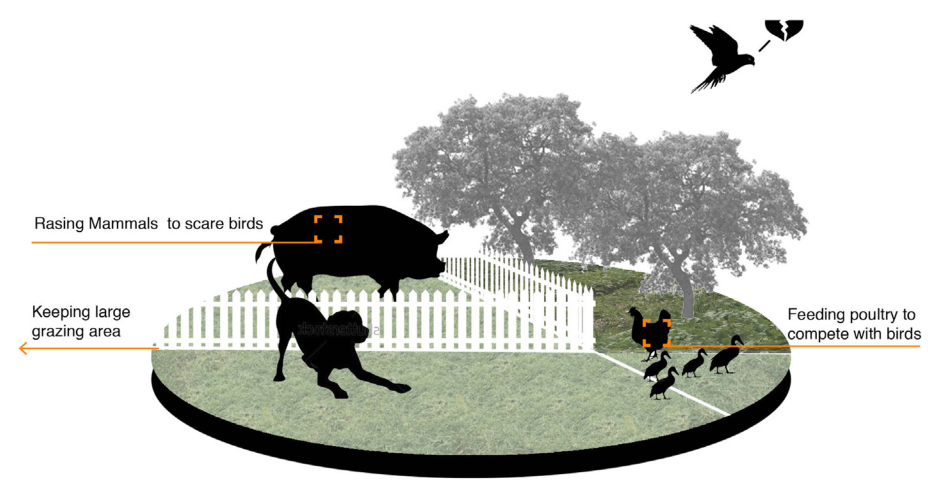
Another strategy is to place animals on site that will compete with birds and deter their presence. For instance, chickens and ducks eat worms and other insects that birds like. Some mammals, such as dogs and pigs, have been shown to successfully drive birds away ("Airports get creative to combat threat of bird strikes", 2017). Thus, keeping poultry on large grazing areas can effectively reduce the



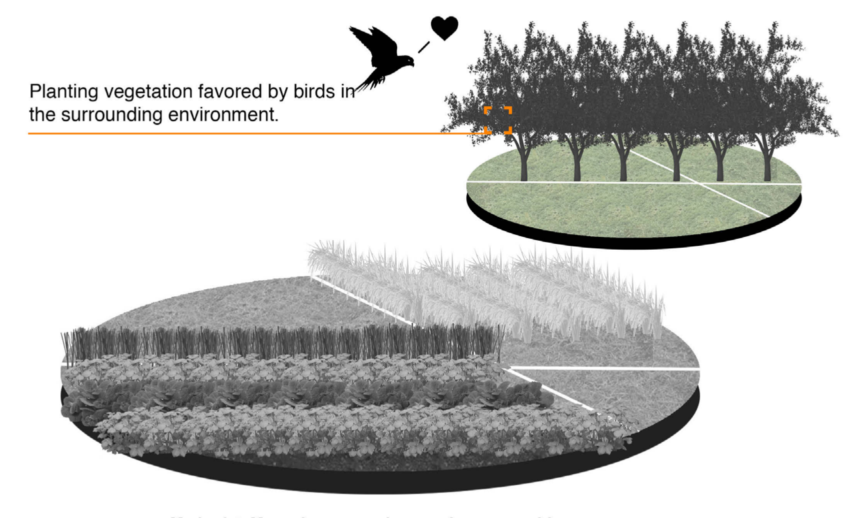
Method 1: Control height of vegetation



Method 2: Manage vegetative species composition



Method 3: Raising animals that will keep birds off



Method 4: Planting vegetation favored by birds in the surrounding environment

DESIGN PRINCIPLES

ECONOMIC SUSTAINBIITY-BASED PLAN
Sustainability Features:
- Maximize food yield through local climate analysis and site development suitability assessment.
- Increase food diversity by using polyculture strategy.
- Build places for goods distribution such as a farmer's market and farm stands.
- Sell products to local restaurants, grocery stores and supermarkets.

Required Analysis:
- **Climate Analysis**

Use official data and reports to acknowledge local climate information for plant choice and design, including hardiness zone, annual precipitation, wind orientation and solar path.
- **Aspect Analysis**

Use Graphic Information System (GIS) map to analyze site aspect to maximize production by determining which areas are best for sun-loving and shade-loving plants.
- **Slope analysis**

Use GIS maps to analyze site slopes: moderate slopes are beneficial for many permaculture activities while steeper slopes limit agricultural activities.
- **Soil analysis**

Use GIS maps to analyze site soils to determine which areas are prime for farmland and which areas are not.
- **Vegetation analysis**

Use GIS maps to analyze site vegetation to determine what existing vegetation needs to be reserved.

ENVIRONMENTAL SUSTAINBIITY-BASED PLAN
Sustainability Features:
- Appropriate water use and management. Utilize stormwater management to reduce water pollution, promote water quality and prevent flooding. Create a rainwater harvesting system according to hydrology analysis.
- Recycle waste materials. Collect compost in a concentrated area for use in soil improvement, fuel and animal feed.
- Manage trees and forest to acquire biomass for fuel and construction materials.
- Use conservative practices such as no-till instead of agro-chemistry.
- Planning and design based on the positive and negative effects of each permaculture design element.

Required Analysis:
- Water system analysis. Use GIS map to determine the floodplain and use a grading map to analyze water flow.
- Analyze the positive and negative effects of each permaculture design element.

SOCIAL SUSTAINBIITY-BASED PLAN
Sustainability Features:
- Pattern thinking on the spatial distribution of each permaculture design element.
- Enhance community participation in the permaculture farm.
- Build a permaculture education center to teach neighbors about the principles of permaculture and permaculture knowledge in general.
- Create an aesthetic environment for the neighborhood.

Required Analysis:
- Analysis of existing and proposed neighborhood plan.
- Analysis of potential intensive working areas.
- Analysis of potential social connections between permaculture site and neighbors.
- Analysis of circulation

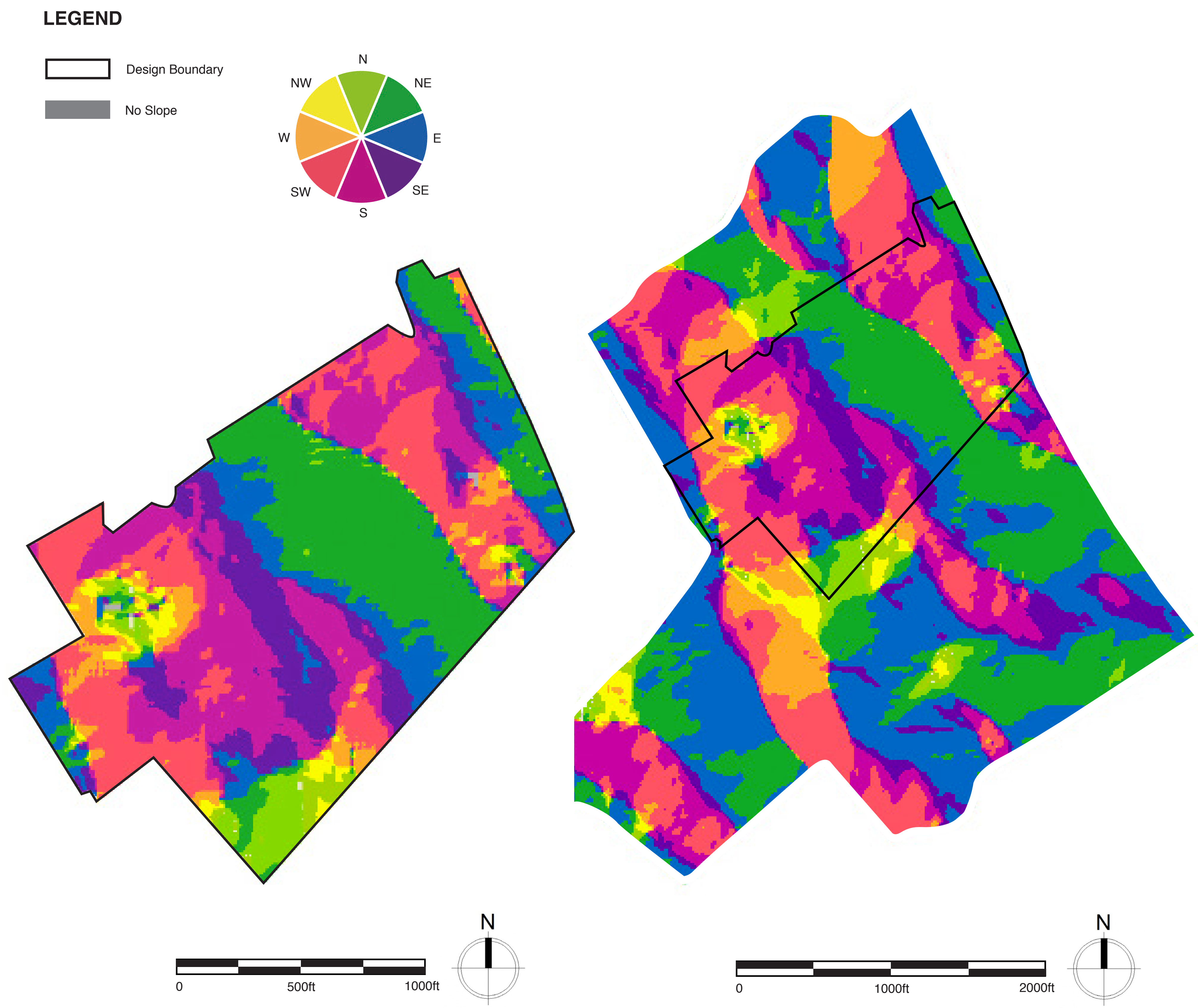
DEVELOPMENT SUITABILITY ASSESSMENT

ECONOMIC SUSTAINABILITY

Aspect Analysis

Aspect refers to the direction slopes face, which has an important effect on food production. In the northern hemisphere, slopes facing south receive maximum sun, are hot and prone to drought. North-facing slopes receive minimum sun and are cool and wet. Thus, south-facing slopes are suitable for sun-loving crops and north-facing slopes suitable for shade-friendly plants. Considering these advantages and disadvantages of sun and slope will lead to increased success in food production (Mollison, Slay, & Jeeves, 1991).

The countryside golf course site is located on a hillside connecting with Blue Ridge Mountains. Here, the landforms vary, containing plains, ridges and valleys. Influenced by the dynamic terrain, site aspect is diverse. The floodplain areas, centrally located on site, face north and are suitable for growing shade-friendly plants. The plains, which flank the floodplain on both sides face south and are suitable for growing crops that need a lot of sunlight.

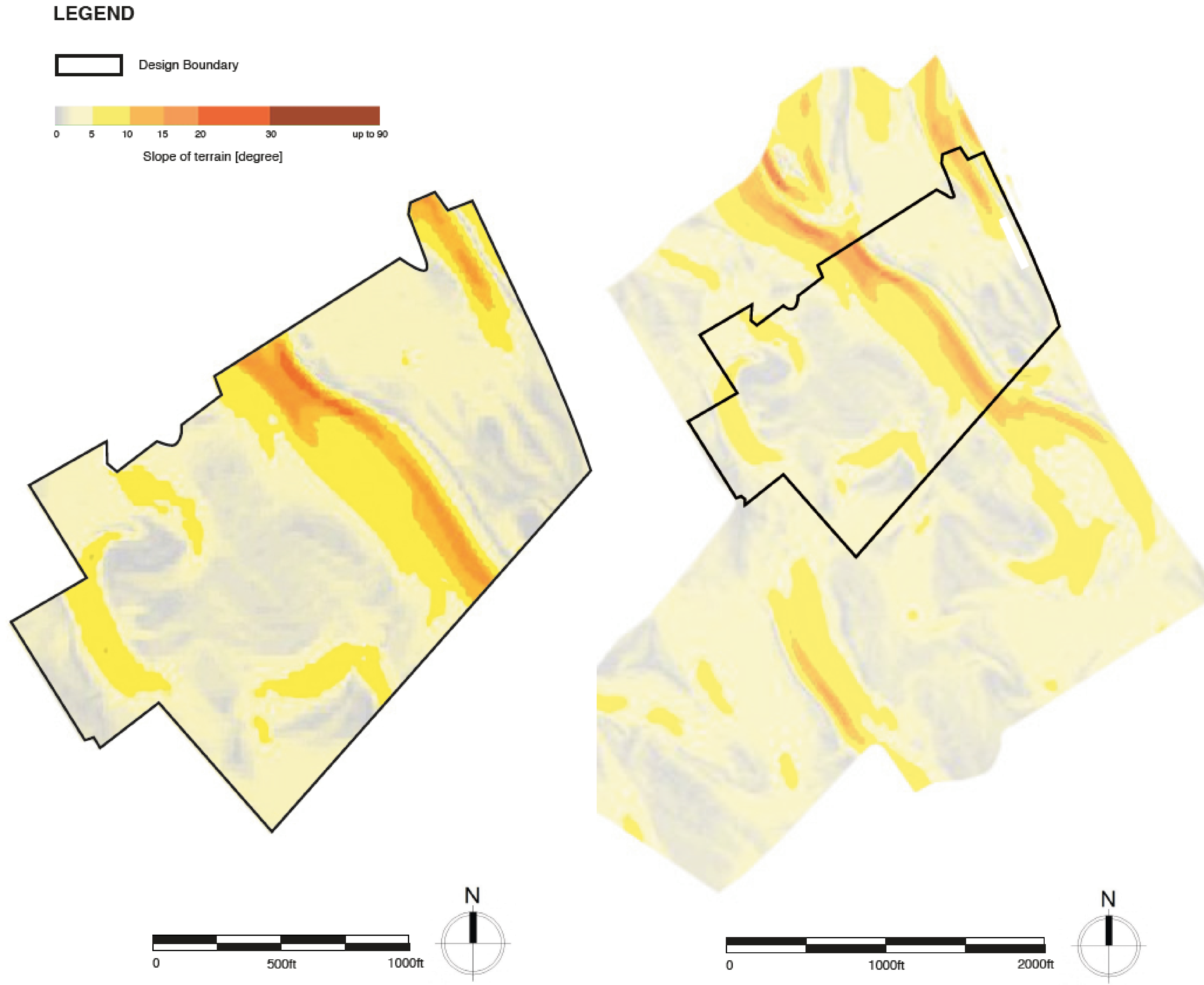


Aspect Analysis Diagram

Slope Analysis

Slope analysis is important in determining the applicability of the different agricultural land uses. While most of the areas across this development site are flat, there are few that are steep. Steep areas on the ridges are between 5%-30% slopes and represent agricultural development limitations. In these areas, it is not suitable to develop cropland and vegetable gardens because of potential erosion issues. One possible solution to these issues is taking conservation practices in these areas. Combining different conservation practices, such as contour orchard farming, hillside ditches and live stakes, can help to conserve water and increase food yields (USDA NRCS, n.d.).

The central floodplain area is relatively flat very fertile, and is the best growing location for certain flood-tolerant crop varieties such as rice, wheat, oat, barley, soybean and maize (Verhoeven, & Setter, 2017). The remaining lands are mostly flat and offer great opportunities for many permaculture activities, including the orchard, cereal crop plantings, vegetable gardens, aquaculture and animal husbandry.



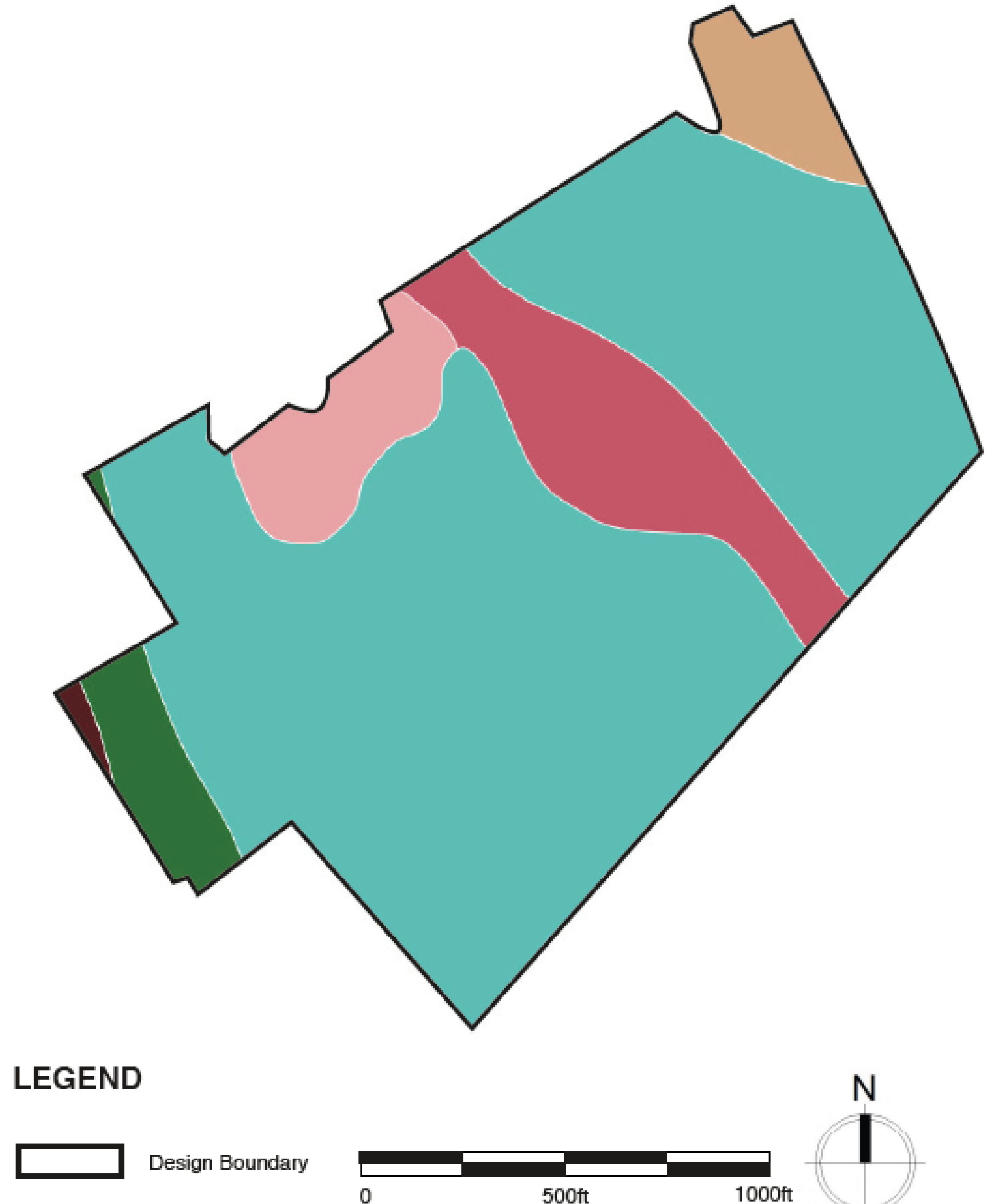
Slope Analysis Diagram

Soil Analysis

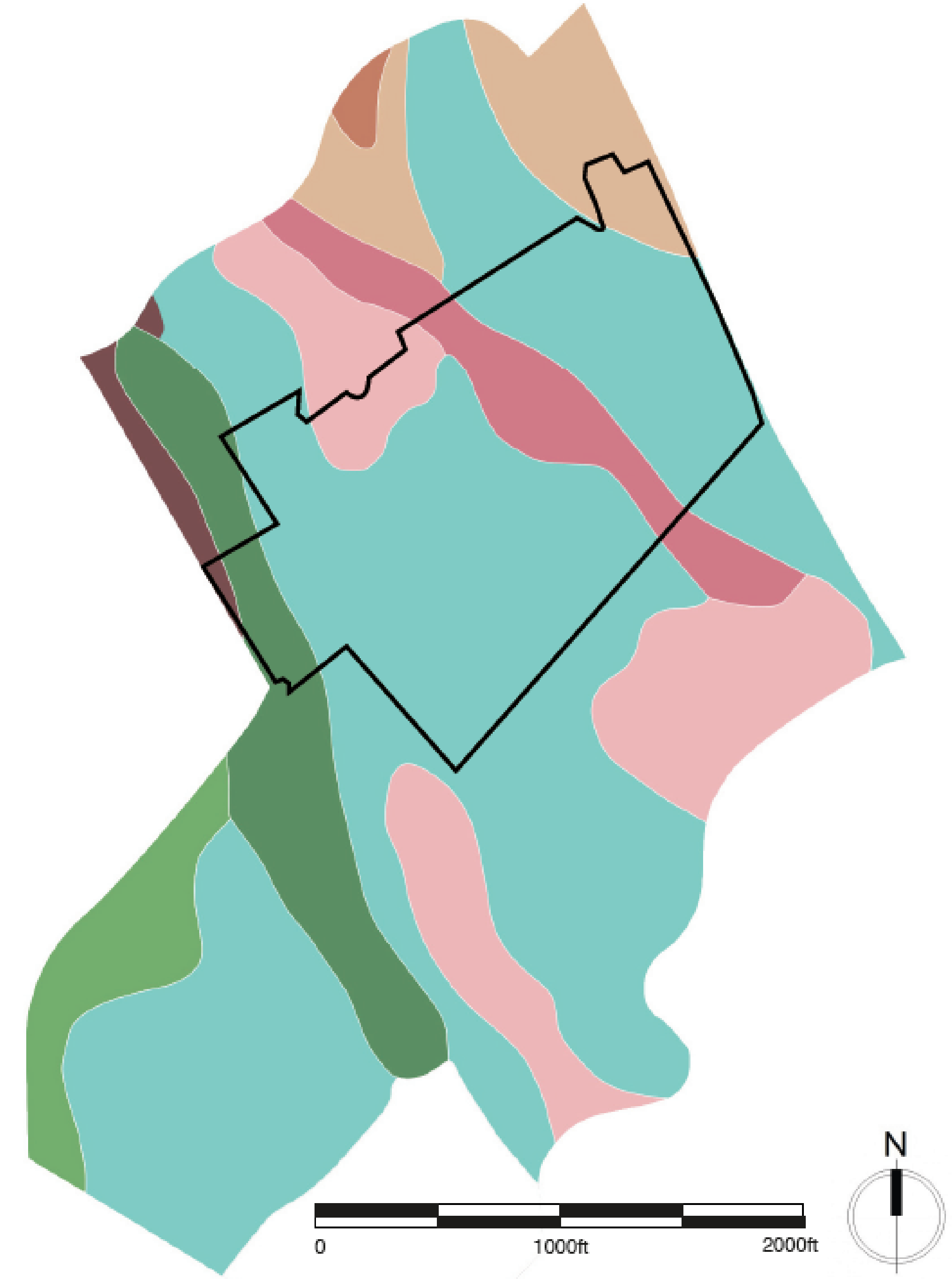
Soil is categorized into different groups, referred to as the soil series, based on their chemical and physical properties. Soil series, together with exterior physical factors such as slope, determines the development suitability of agricultural lands. Conditions at the golf course reveal the soil is classified into eight categories, three of which are primary farmlands and are best suited for food, animal feed, fiber, forage and oilseed crops. These three soils are Combs loam with 0-2% slope, Frederick silt loam with 2-8% slope, and Frederick silt loam with 8-15% slope, altogether totaling 160.5 acres and occupying 69.9% of the whole course.

Combs loam is a well-drained and nutritious soil type, which can tolerate a wide range of moisture conditions and can still produce food. It is suitable for various crops including corn, small grains, tobacco and garden or truck crops. It is also suitable as pastureland and hay production. Native species on this soil includes some mesophytic hardwood forest interspersed with cane breaks ("COMBS SERIES", n.d,).

Frederick silt loam is a deep and well-drained soil with intermediate permeability and slopes ranging from 2-35%, which is suitable for crops, hay or pasture. Oaks, hickory, ash, elm, maple, black walnut and flowering dogwood are native to this soil type ("FRANKSTOWN SERIES", n.d.).



SYMBOL	MAP UNIT NAME	ACRES	PERCENT	RATING
8 A	Combs loam, 0-2% slopes	2.1	3%	All areas are prime farmland
18 C	Frederick silt loam, 8-15% slopes	49.3	71.2%	Farmland of statewide importance
19 E	Frederick very gravelly silt loam, 25 to 40%	7.8	11.3%	Not prime farmland
21 C	Frederick-Urban land complex, 2 to 15%	0.1	0.2%	Not prime farmland
37 D	Sequoia silt loam, 15 to 25% slopes	4.5	6.4%	Not prime farmland
52	Udorthents-Urban land complex	5.5	7.9%	Not prime farmland

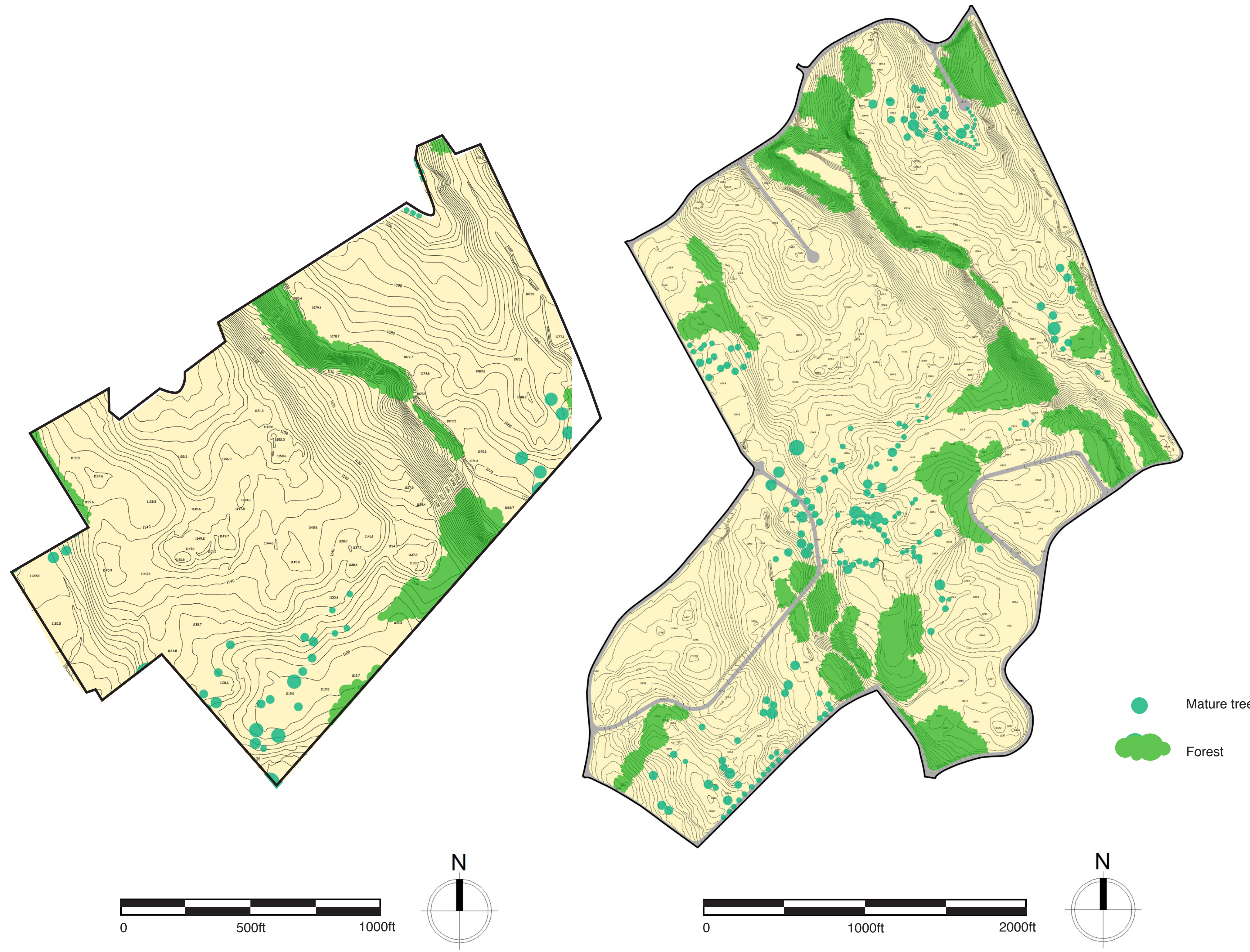


SYMBOL	MAP UNIT NAME	ACRES	PERCENT	RATING
8 A	Combs loam, 0-2% slopes occasionally flooded	19.8	8.4%	All areas are prime
18 B	Frederick silt loam, 2-8% slopes	10.2	4.3%	All areas are prime farmland
18 C	Frederick silt loam, 8-15% slopes	135.5	57.2%	Farmland of statewide importance
19 E	Frederick very gravelly silt loam, 25 to 40%	14.0	5.9%	Not prime farmland
21 C	Frederick-Urban land complex, 2 to 15%	4.1	1.7%	Not prime farmland
37 C	Sequoia silt loam, 7 to 15% slopes	1.5	0.6%	Not prime farmland
37 D	Sequoia silt loam, 15 to 25% slopes	16.4	6.9%	Not prime farmland
52	Udorthents-Urban land complex	35.5	15.0%	Not prime farmland

Soil Analysis Diagram

Vegetation Analysis

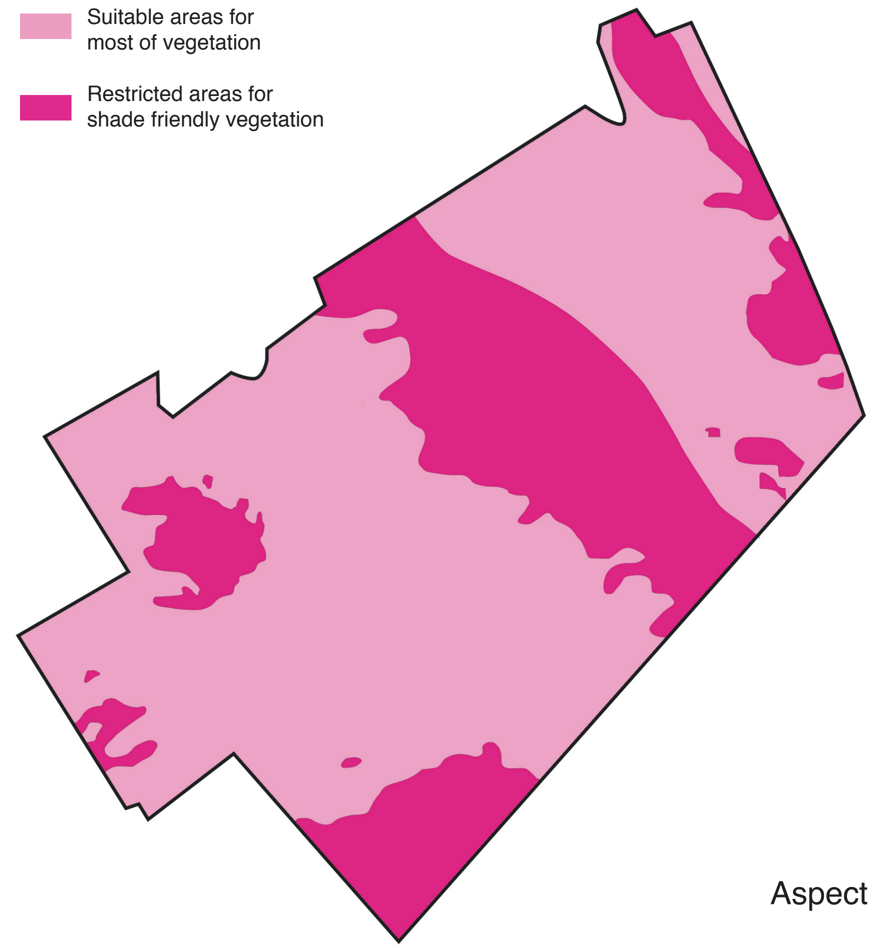
Vegetation series on the site represents the effects of water on the distribution of vegetation. Around 20% of the course is forested in the low, wet areas where rain collects. The remaining 80% is dry and dominated by grasses. In transition areas between wet and dry soils are pine, oak, and birch trees. Proportions of forest and grass are similar in the RPZ zone as well. 90% of the RPZ zone is covered by grass. The remaining 10% of the RPZ area is located in the center of the alluvial plain and is covered by forest. South of this area are pine trees, oak trees, and birch trees. Conservation of the existing trees and forest provides ecosystem services, especially regulating and provisioning services. Floodplain trees are also important to preserve because they can reduce stormwater runoff and flooding, as well as reduce stream channel erosion. The grass-covered areas are appropriate for multiple permaculture activities including grazing animals, composting, aquaculture, vegetable and orchard farming.



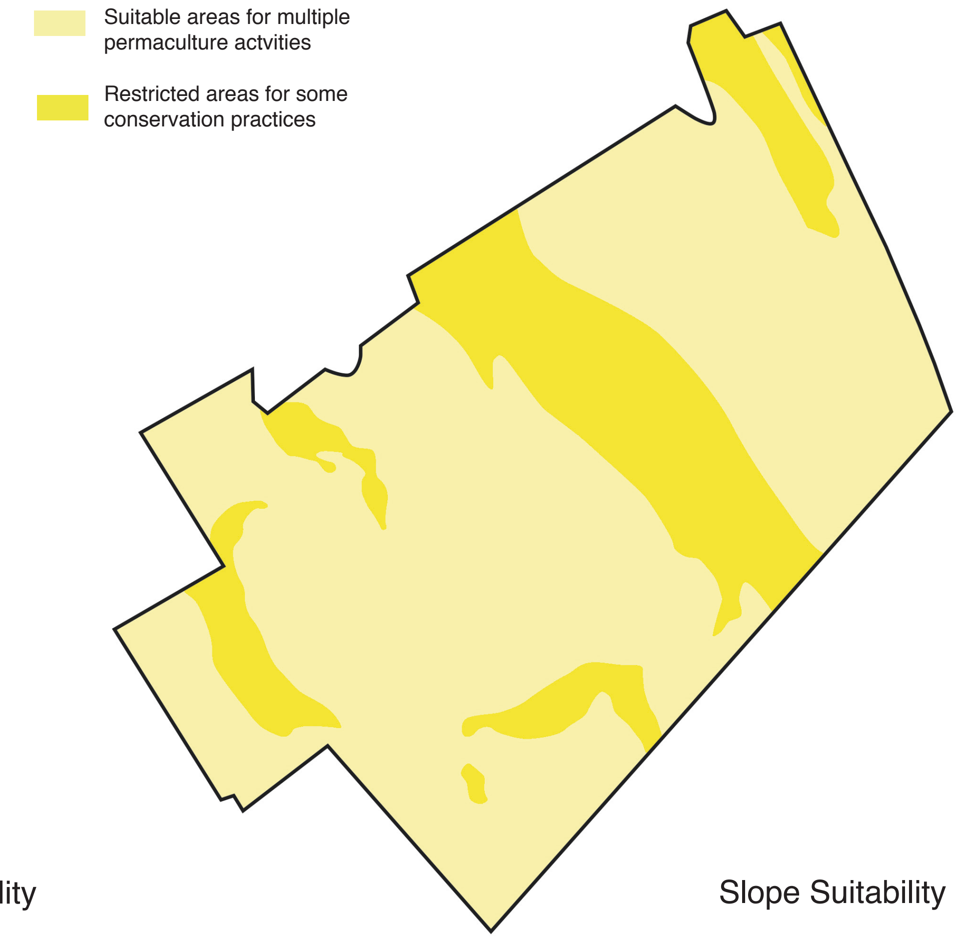
Vegetation Analysis Diagram

Analysis of Individual Elements Effects

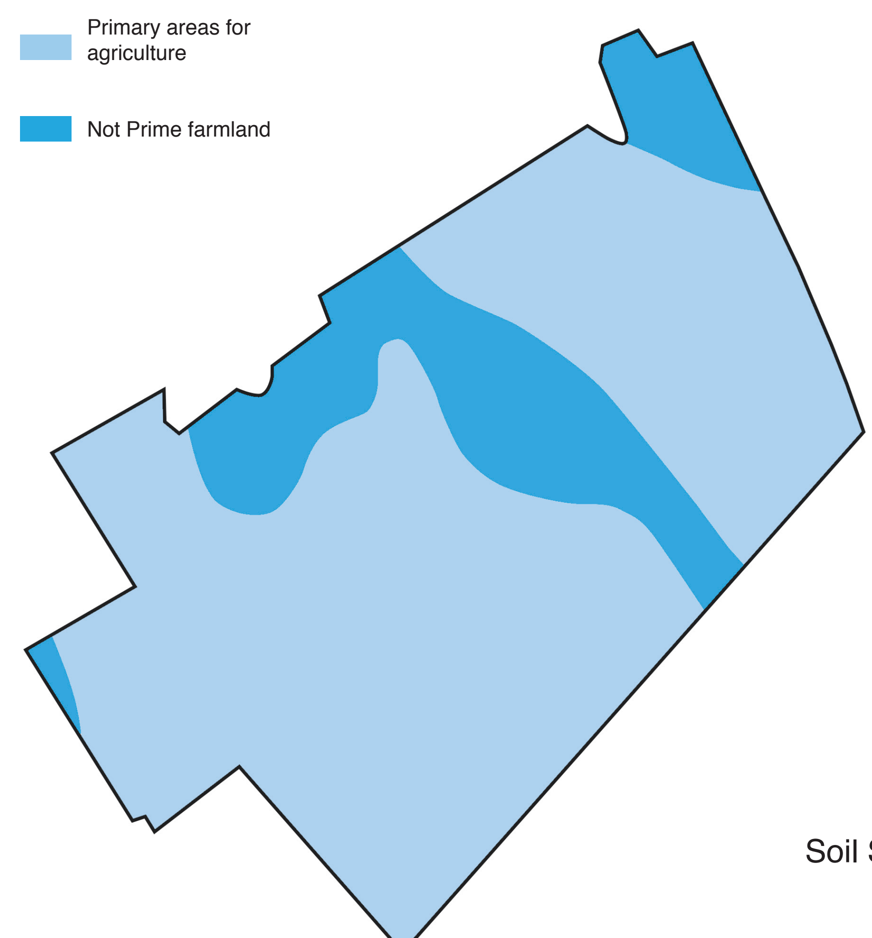
In planning for maximum food production, GIS and USDA maps were used to analyze site aspect, slopes, soils and vegetation. Based on the results, four analytical diagrams were developed, which represent the suitable areas and restricted areas for agricultural development. In the aspect analysis, slopes facing west, southwest, south, southeast and east are considered as appropriate areas for most vegetables. Slopes facing northwest, north and northeast are restricted to shade-friendly vegetables. 0-5% slopes are good for many permaculture activities and areas with slopes over 5% are in need of conservation practices. In the soil analysis, lands covered by Combs loam with 0-2% slopes and Frederick silt loam with slopes of 8-15% are the prime farmlands. Land covered by very gravelly Frederick silt loam with slopes of 25% to 40%, Frederick-urban land complex with slopes of 2 to 15%, Sequoia silt loam with slopes of 7-25% and the Udorthents-Urban land complex are not prime farmland. In the vegetation analysis, land covered by forest and trees cannot be developed into agriculture land.



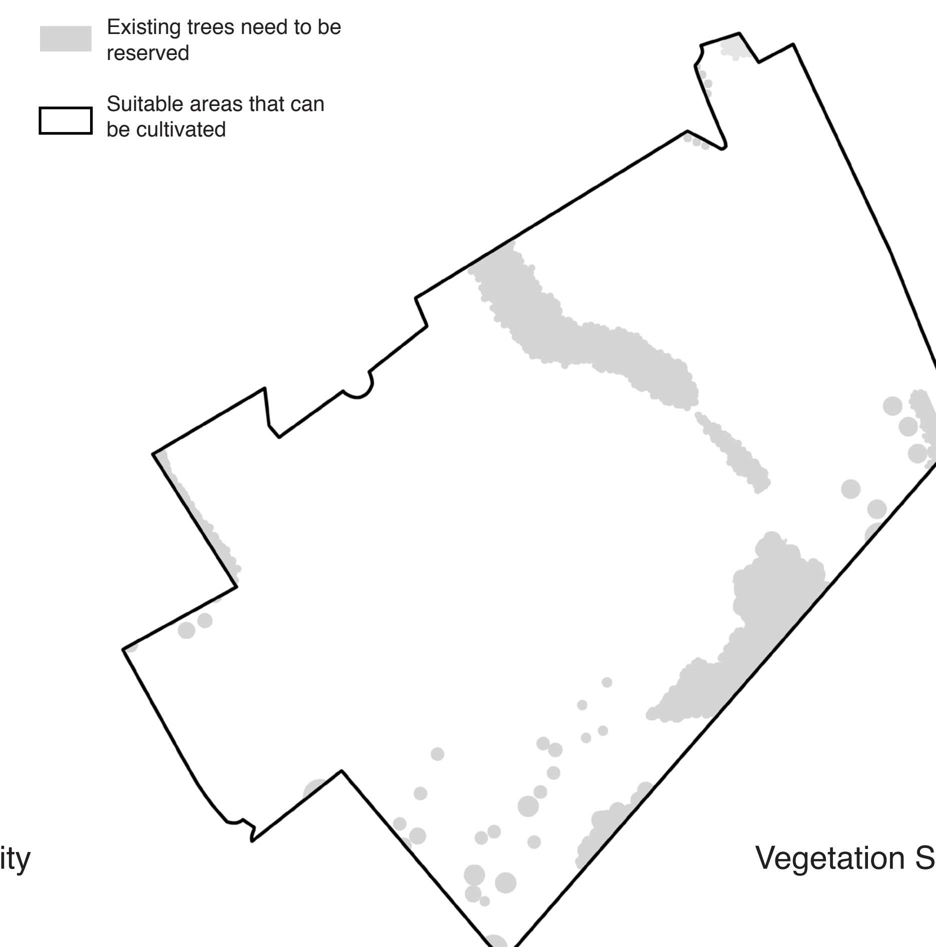
Aspect Suitability



Slope Suitability



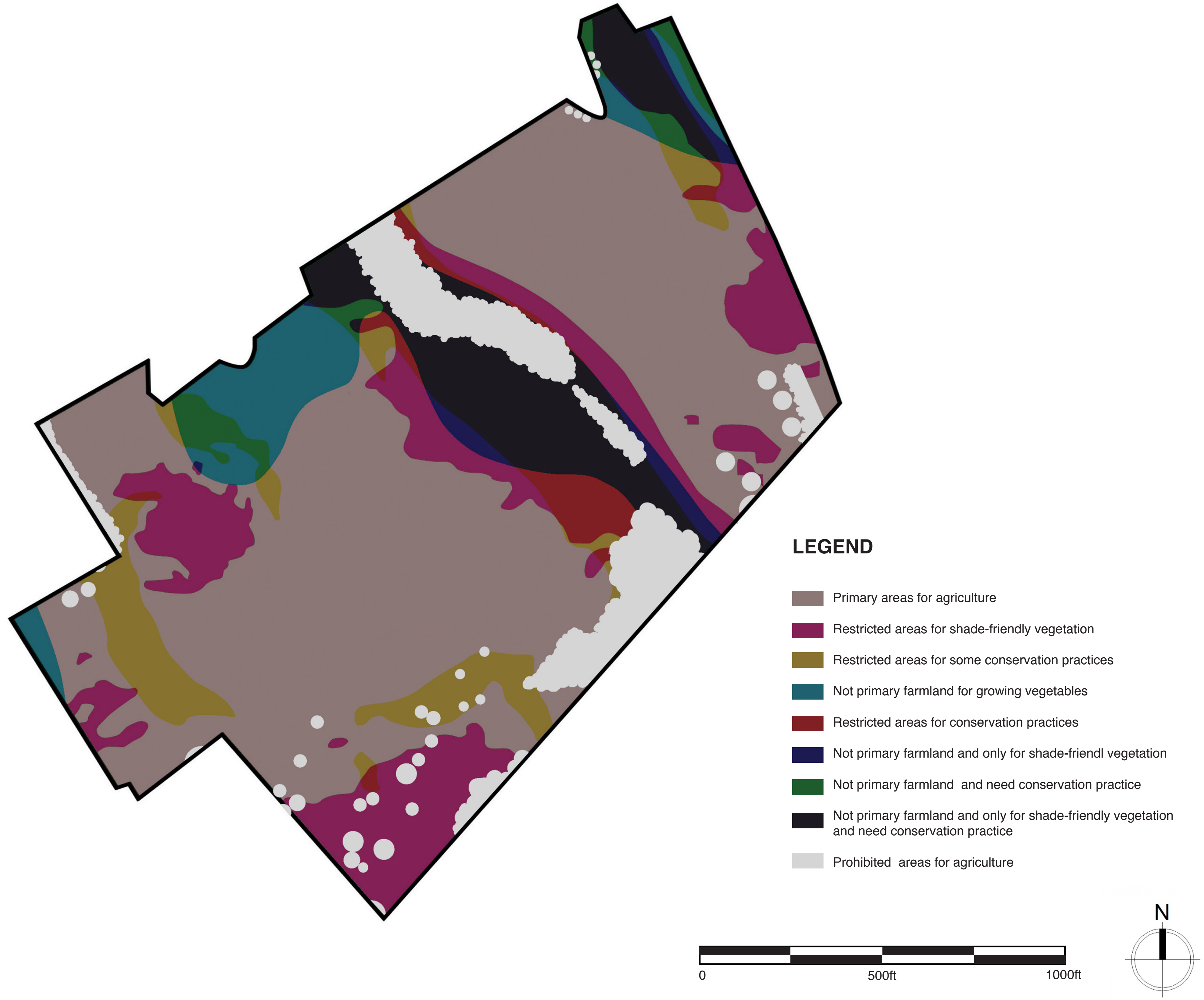
Soil Suitability



Vegetation Suitability

Synthesis Analysis

The four analytical diagrams are overlaid and are integrated into a synthetic map for a comprehensive understanding of on-site development suitability. By mixing the primary colors of the three analytical diagrams and adding white color to the vegetation analysis diagram, nine distinct colors appear, representing different areas with potential for permaculture development. The nine types are: areas prime agriculture activities, areas for shade-friendly vegetation, areas restricted to conservation practices, non-primary farmland for growing vegetables, non-primary farmland for shade-friendly vegetation, non-primary farmland in need of conservation, non-primary farmland only for shade-friendly vegetation with conservation needs, and areas where agriculture is prohibited.



DEVELOPMENT SUITABILITY ASSESSMENT

ENVIRONMENT SUSTAINABILITY

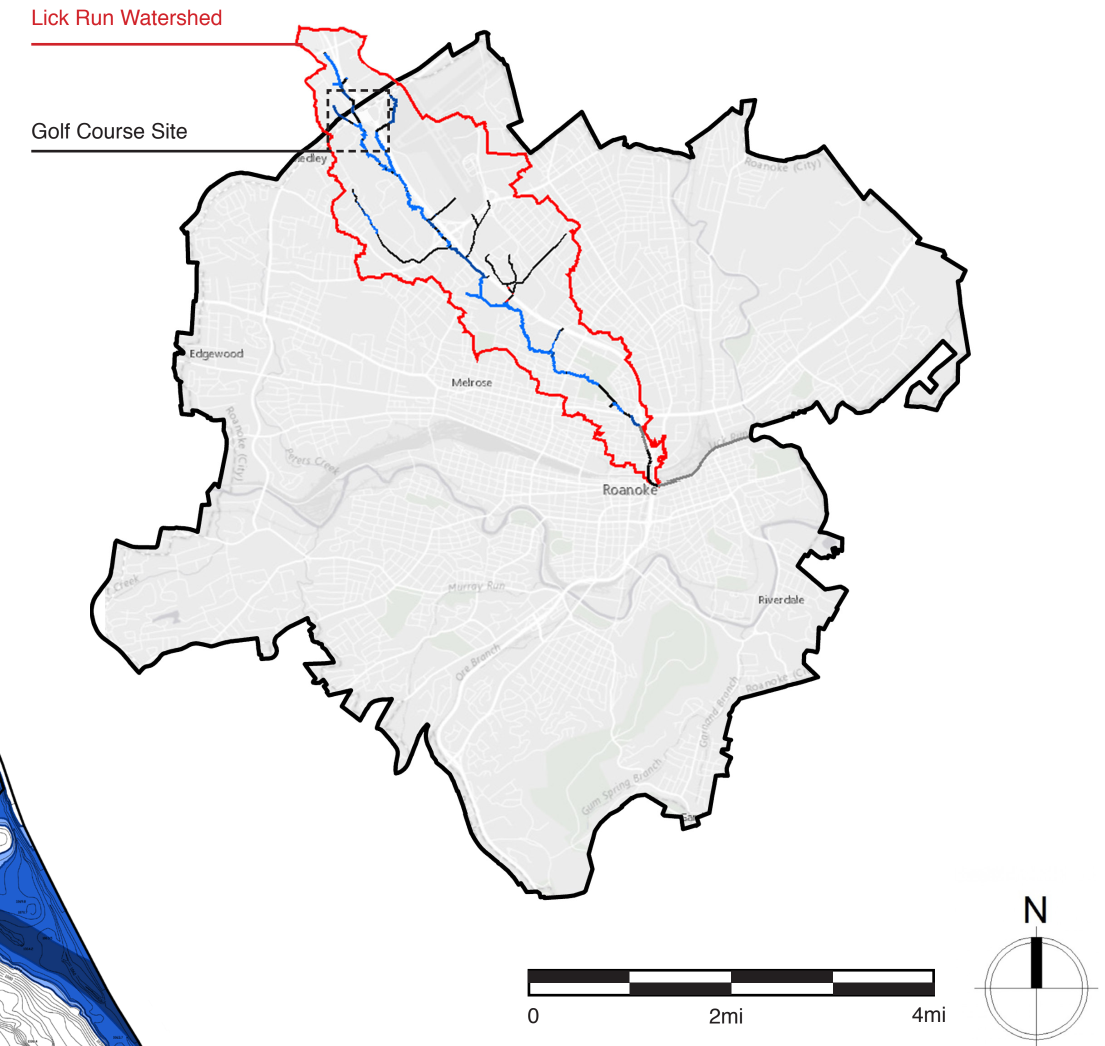
Hydrology Analysis

Water is the key of permaculture design, and plays an important role in building a sustainable environment. Appropriate water use is important to protecting urban ecosystems and making efficient use of site energy. In a natural environment, the hydrologic cycle maintains balance between water in the air, on the ground and in the ground ("Flood and Floodplain Management", n.d.). However, some human activities have destroyed this ecological balance, resulting in the deterioration of water quality and exacerbation of natural disasters such as flooding and problems with erosion. In response to these problems, Best Management Practices (BMP) have become the standard tools used in the urban environment.

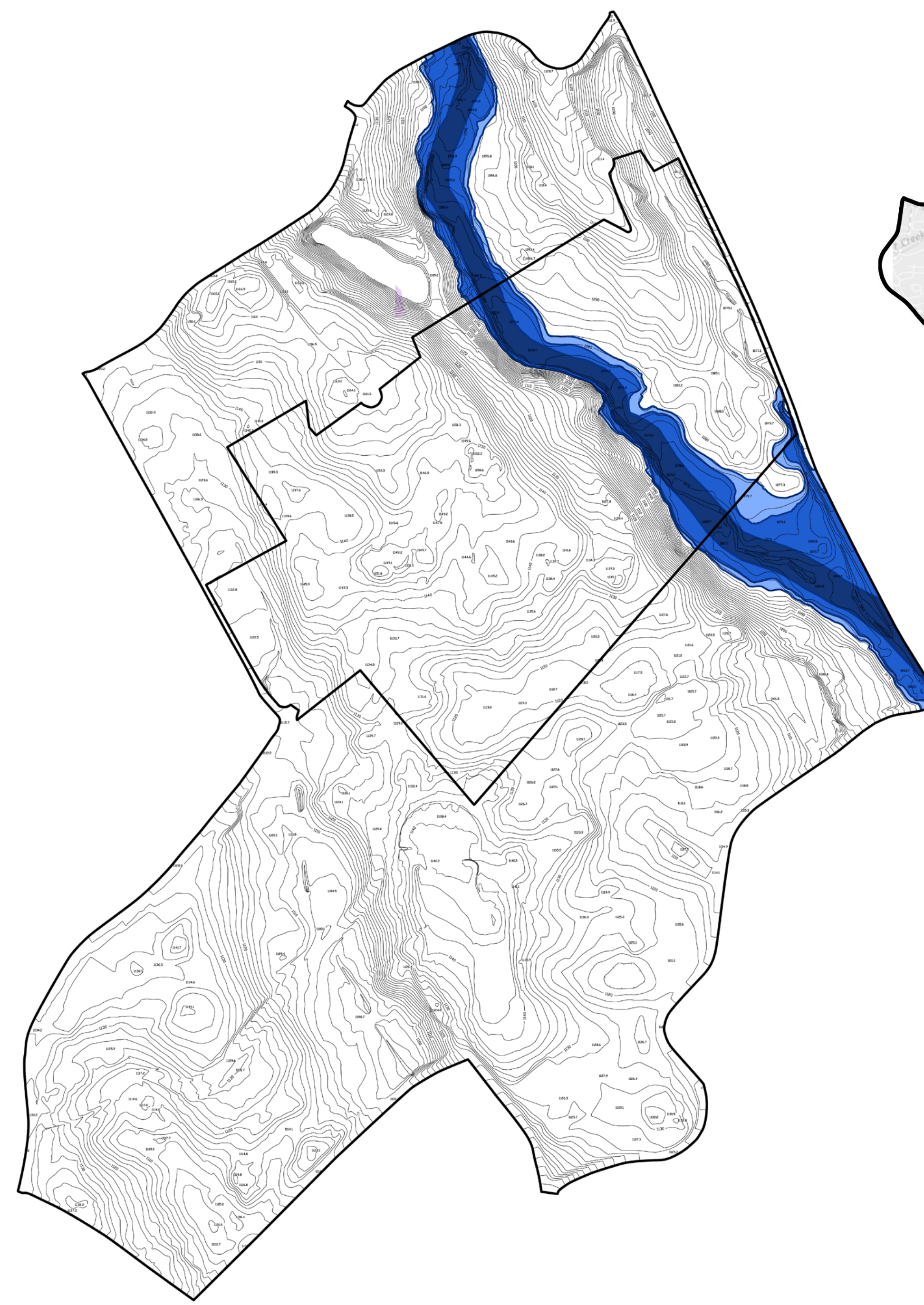
It is important to consider the watershed when deciding how to improve the local ecosystem. Watercourses, including streams, rivers and creeks are important components of the watershed, having a great impact on the regional environment and quality of life.

Lick Run watershed covers most central areas of the northern part of Roanoke City and 98.5% of land is developed ("Roanoke River Clean-up Plan", 2014). It includes Fairland Court neighborhood, Gainsboro Southwest neighborhood, portions of east Melrose Rugby and N.N.I.C. It is bounded by Hershberger Road to the north, Williamson road to the east, Nortfolk Avenue to the south and Cove Road to the west. The golf course is part of Lick Run watershed and located in highland areas. An upland tributary stream crosses the site and has a significant impact on water quality to downstream. And as the floodplain area includes Frontage Road NW, there is an increased risk of flooding in certain places. BMPs include constructing a riparian buffer along the watercourse and building fences beside the stream to reduce impacts from the surrounding environment, promoting water quality and preventing some issues from flooding and erosion.

Although the permaculture practice of no-till agriculture and prohibition of agrochemicals, there is still nitrogen and phosphorous pollution from animal waste. Nutrient-loaded sediments run into the stream and accelerate eutrophication. The riparian buffer will help to absorb some of these nutrients. The riparian buffer slows down flowing water velocity and retains large volumes of runoff because the vegetation aids in infiltration. Because roots fasten soil under the riverbank and counteract forces from water flow (Hawes and Smith, 2005) vegetation can also minimize the impacts from erosion due to flooding.



Lick Run Watershed Diagram



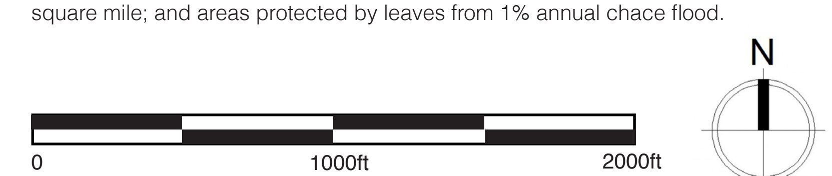
Floodplain Areas

LEGEND

Floodway Areas A
The Channel of the stream that must be kept free of enroachment so that the 1% annual chace flood can be carried without substantial increases in flood heights.

Floodway Areas B
Adjacent floodplain areas that must be kept free of enroachment so that the 1% annual chace flood can be carried without substantial increases in flood heights.

Other Flood Areas
Areas of 0.2% annual chance flood; areas of 1% annual chance flood with acerage depths of less than 1 foot or with drainage areas less than1 square mile; and areas protected by leaves from 1% annual chace flood.

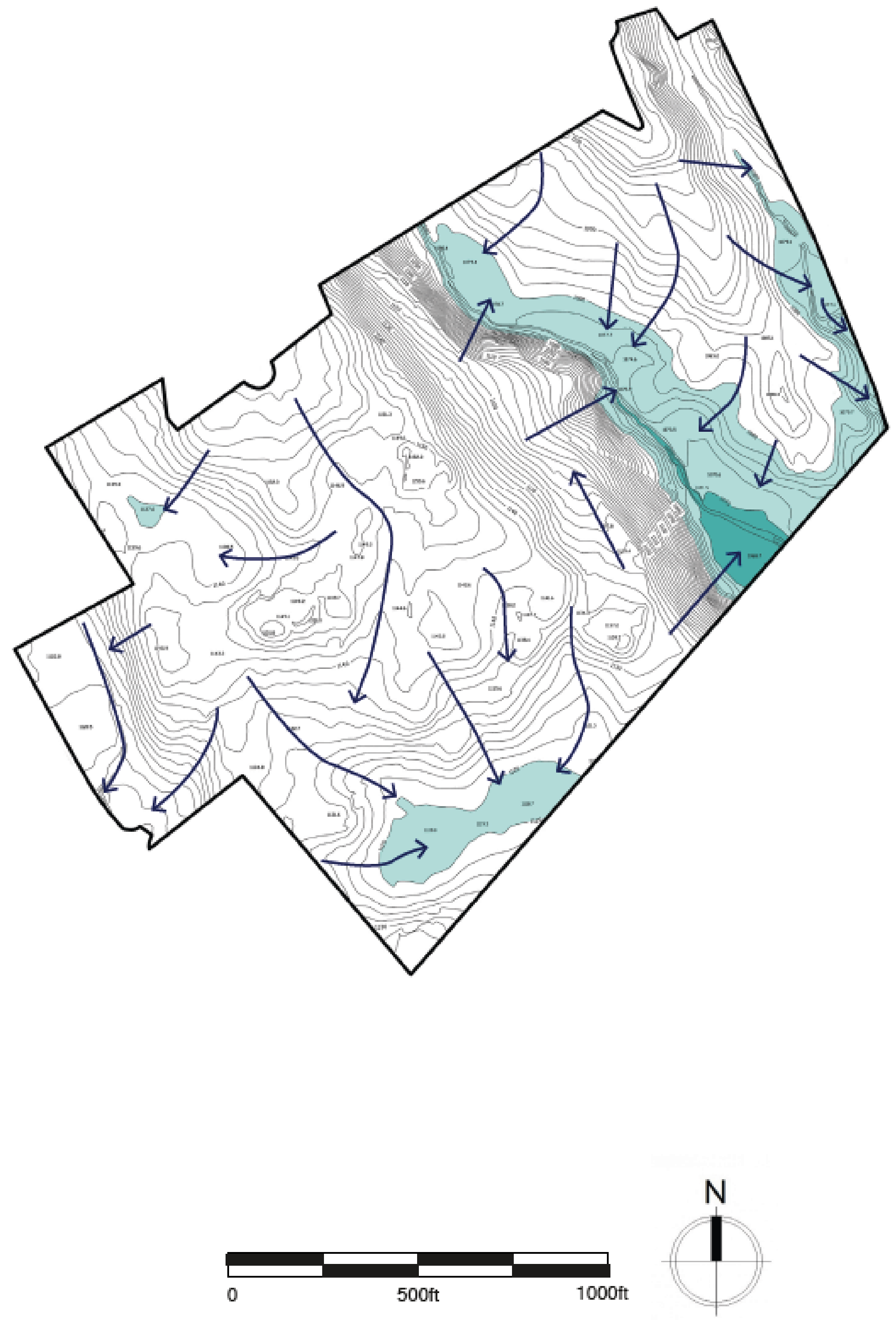


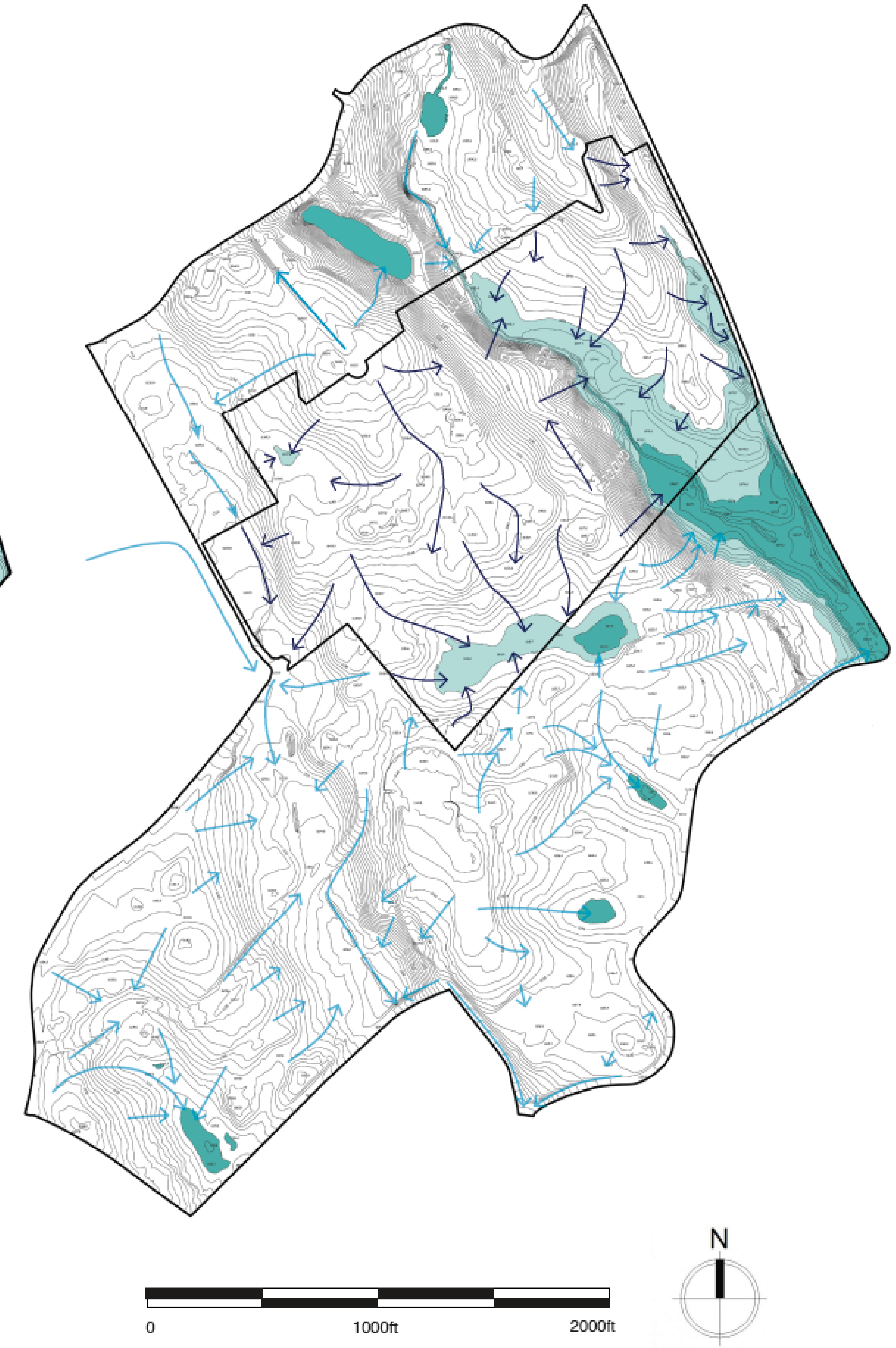
DEVELOPMENT SUITABILITY ASSESSMENT

ENVIRONMENT SUSTAINABILITY

Hydrology Analysis

Analysis of hydrology path inner site can provide a guide for developing rainwater harvesting system. The diagram reveals that the south of the site is the lowest point of. Therefore, it has potential to be transformed into a fish pond or wetland. Following the hydrology path, a series of swale can be built to store water and the water will be provided to crops and animals.





DEVELOPMENT SUITABILITY ASSESSMENT

SOCIAL SUSTAINABILITY

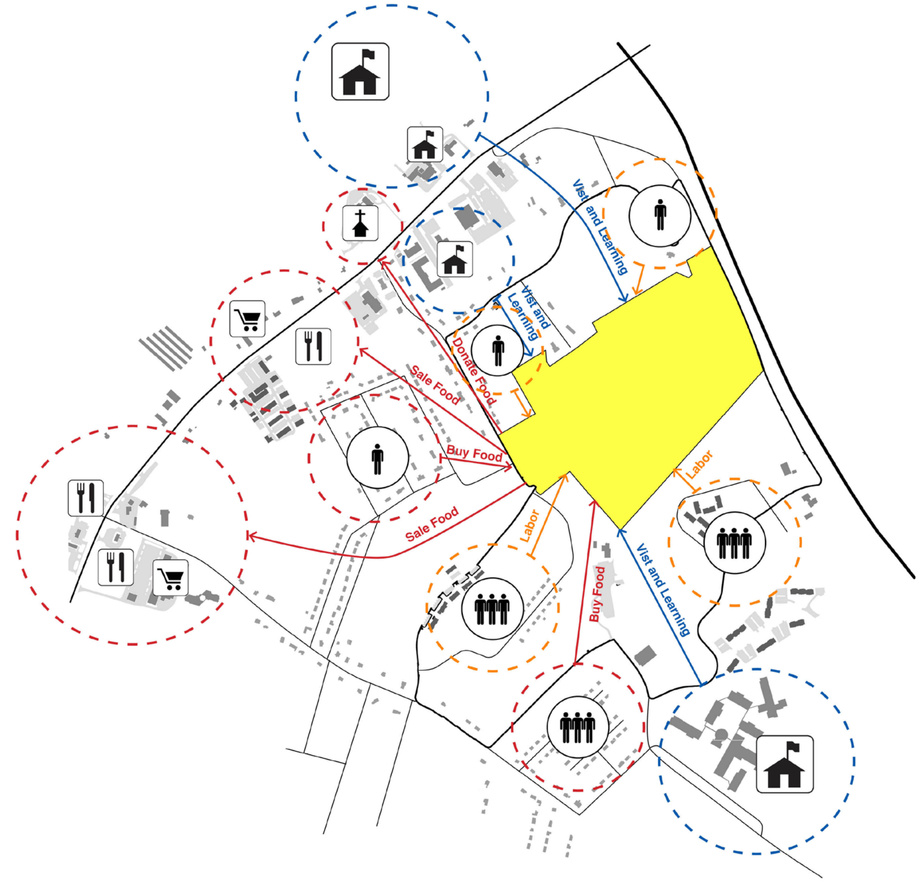
Neighborhood Analysis

The key to improving food access and food utilization is to construct a permaculture farm focusing on social sustainability. This will bring social justice as well, as sustainable permaculture imparts equal opportunities for diverse groups, especially the poor, in gaining access to local food and enhanced health benefits. Therefore, four strategies have been identified to enhance the social sustainability of the area.

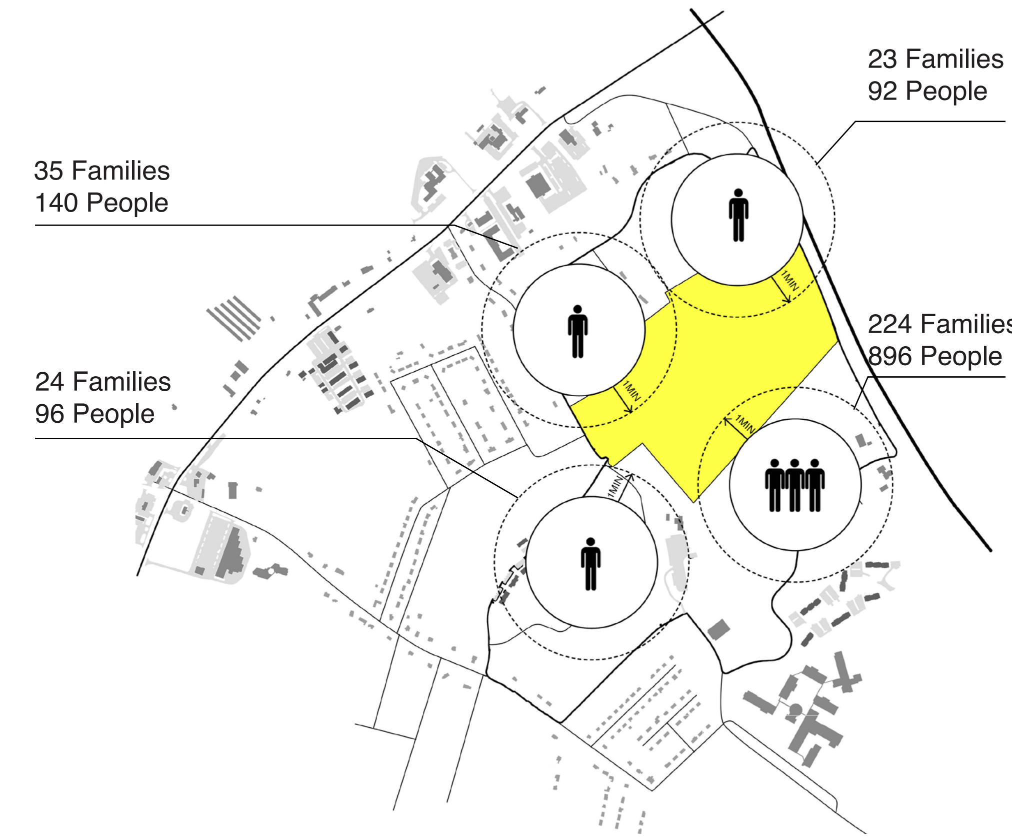
1. Increase walkability by building an inner “green street” road system to connect the golf course with neighbors.
2. Found an education center where faculty, students and neighbors can practice permaculture and learn the importance of maintaining a healthy diet.
3. Build a farmer’s market to provide public space for selling farm products and social interaction. To attract visitors, the farmer’s market should be situated close to the main street and commercial areas.
4. Design the permaculture program based on the different proposed land uses. Correspond site elements with appropriate soils, slopes and aspect. Create equitable space between different neighbors supporting diversity around the RPZ.

The education center should be sited on disturbed land located on the north side of the course. Sited here at the highest point on the site, it would make a good location with attractive views of the permaculture farm. As the new hub of activity, it would tie together existing circulation with the north road and offers convenience for proposed on-site circulation.

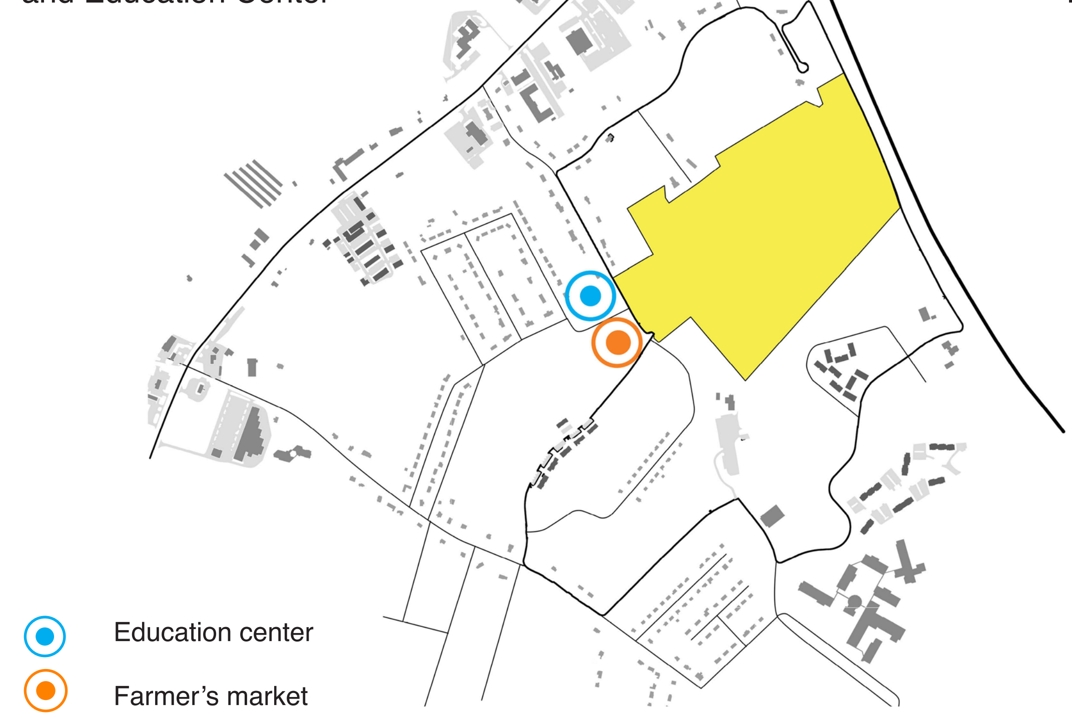
Potential Social Connection between Permaculture Site and Neighbors



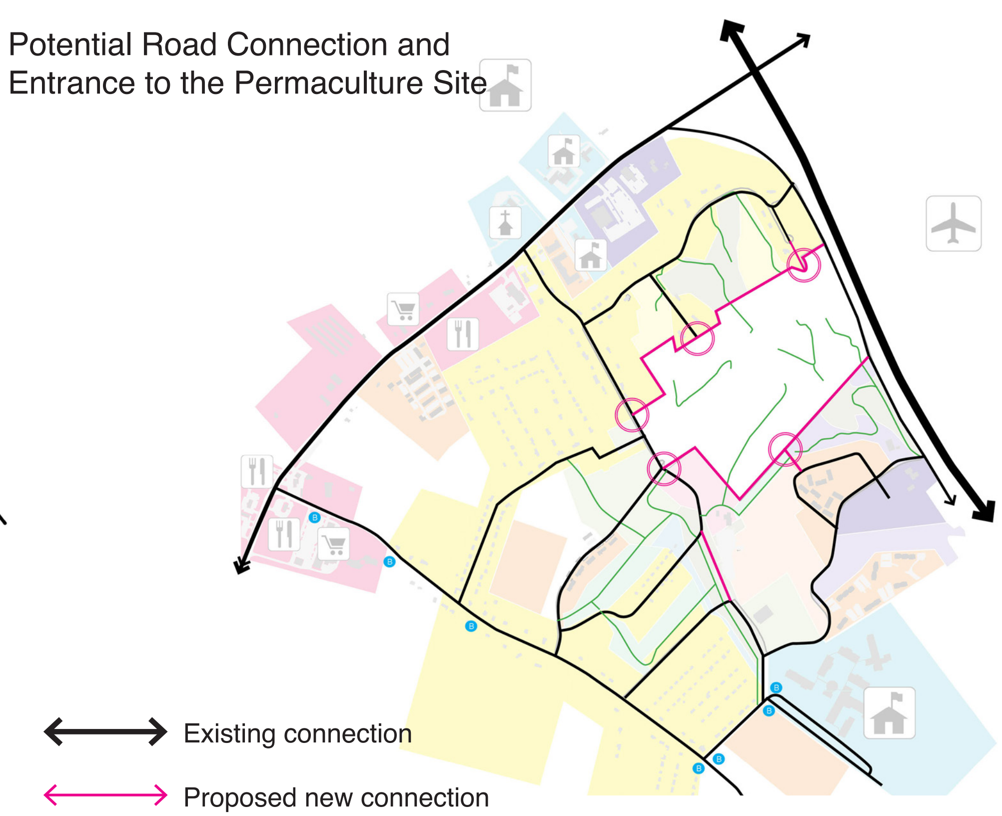
Potential Intensively Working Areas and Estimated Population



Potential Site for Farmer’s Market and Education Center



Potential Road Connection and Entrance to the Permaculture Site

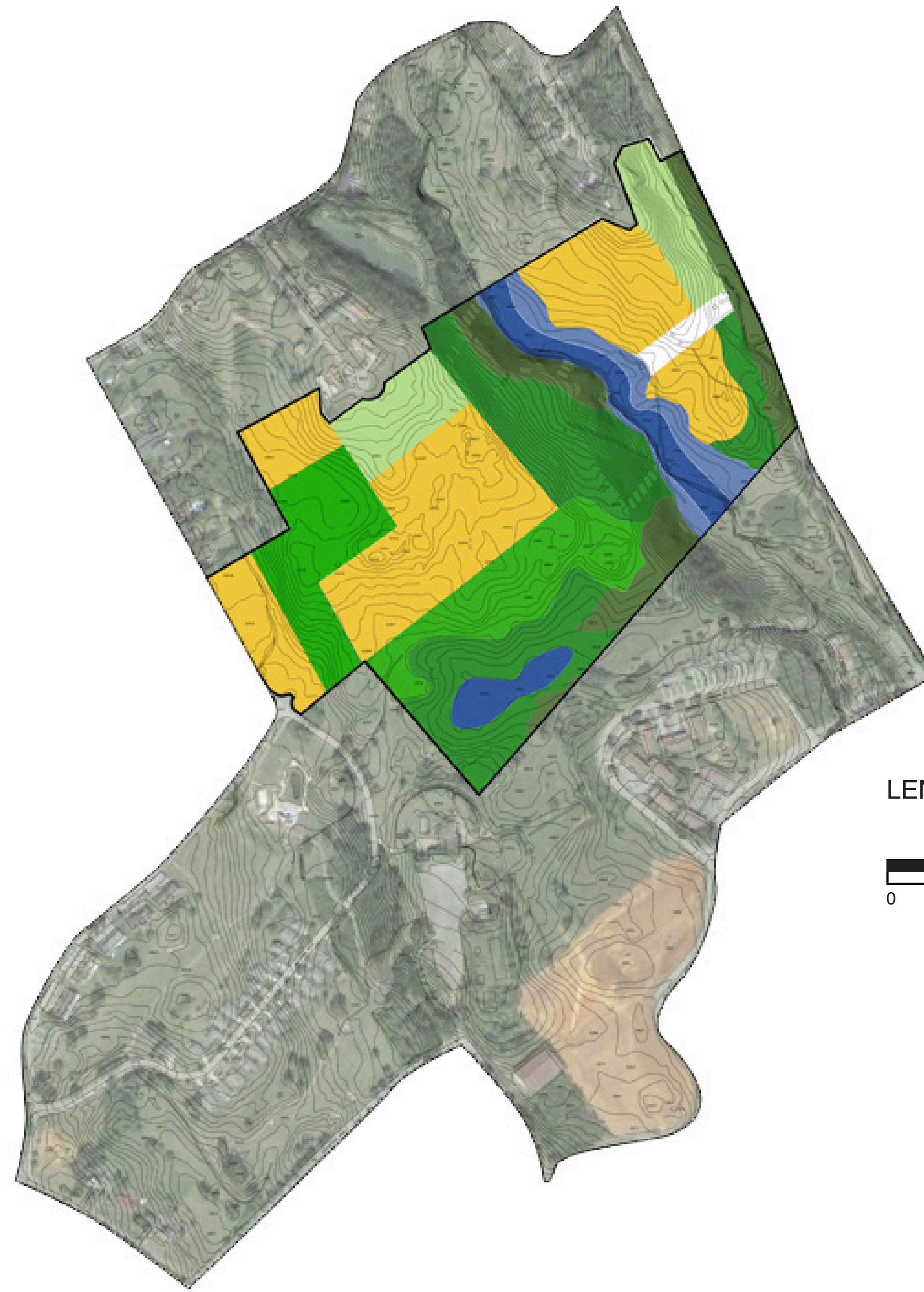


ALTERNATIVE DESIGN 1

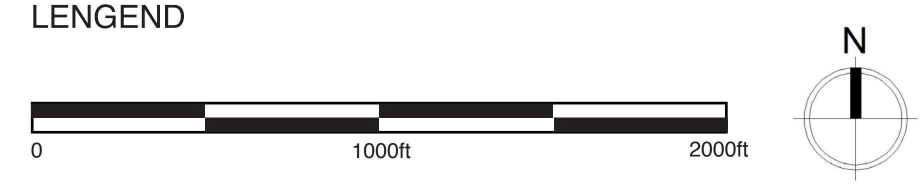
ECONOMIC SUSTAINABILITY-BASED PLAN

The first scenario focuses on economic sustainability. It is designed based on a synthesis of the analysis that produces the highest economic value for the course. Two goals were set for this scenario. The first, to create job opportunities and income for the laborers and owner of the farm. The second goal was to develop an energy conservation system to obtain high yields with low inputs. Practices of polyculture, aquaculture, holistic animal management, no-till farming, and water harvesting system, are applied to the course to optimize food production and support economic sustainability.

Functional areas of the permaculture farm include an intensely managed vegetable garden, food forest, grazing area, fish farming, woodlots, and floodplain. In this design, most of the prime agriculture lands are converted into the intensively managed vegetable garden to cultivate cash crops, such as bell pepper, tomato, celery, leaf lettuce, carrot, broccoli, cauliflower, onion, cabbage, and watermelon. A chicken pen is located in the vegetable garden for pest control purposes. At the same time, the chicken manure fertilizes the crops. Irrigation cost is reduced with the application of a water harvesting system. The vegetable garden, which surrounds the fish pond, helps clean the pond. An island built for ducks in the pond hosts a shelter where they can nest and be fed. The duck manure serves as fish food, and the ducks contribute to pest management around the pond.



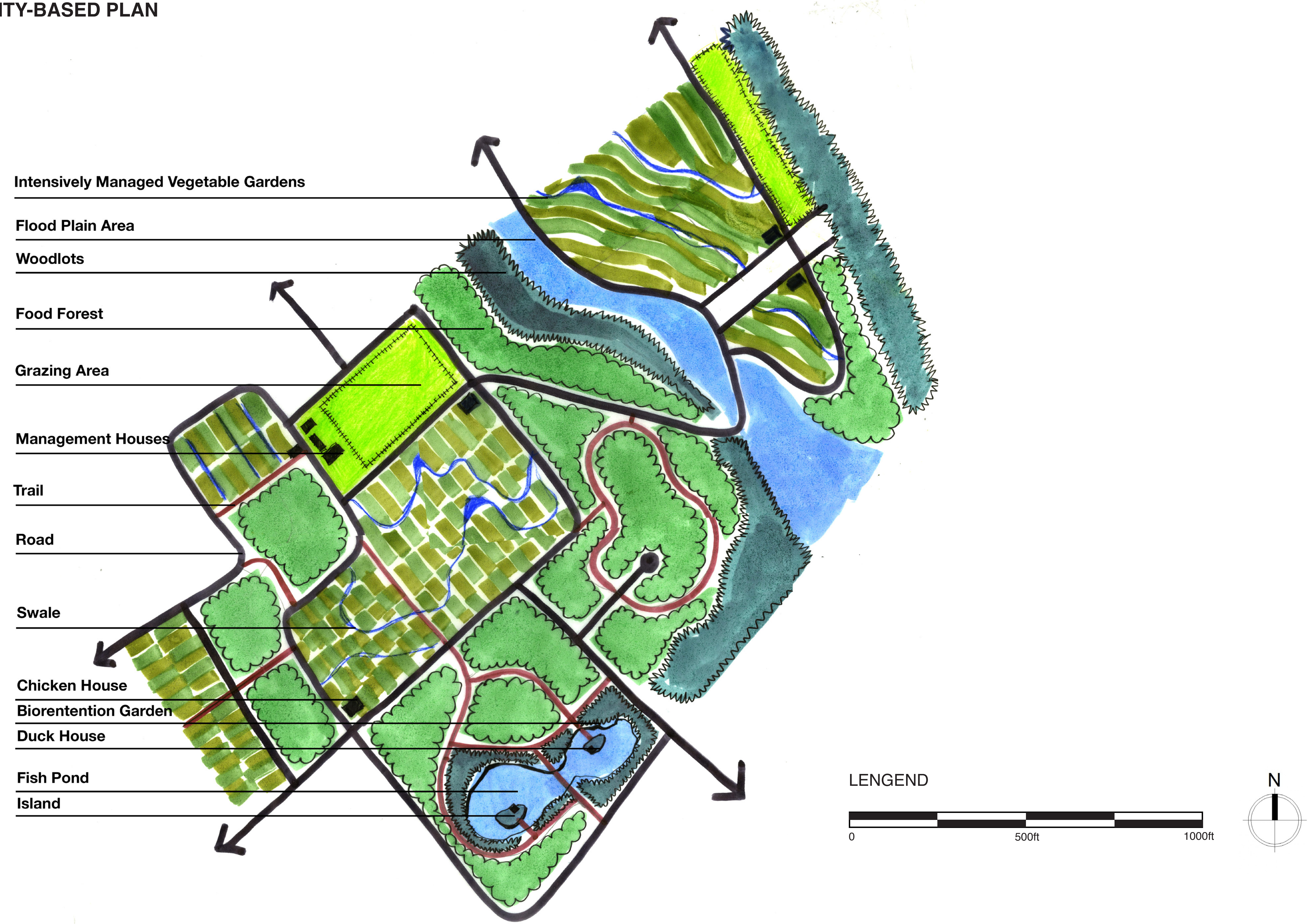
LENGEND



MAP UNIT NAME	ACRES
Intensively Managed Vegetable Garden	24.14
Food Forest	29.28
Grazing Area	6
Fish Farming	5
Woodlots	7.6
Flood Plain Area	6

ALTERNATIVE DESIGN 1

ECONOMIC SUSTAINABILITY-BASED PLAN



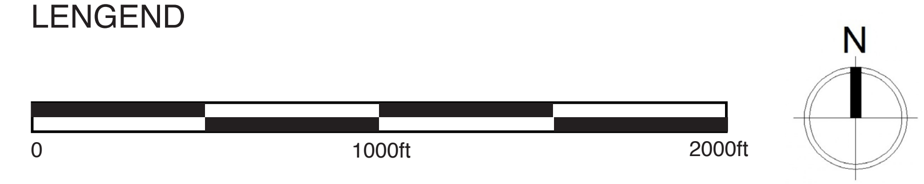
ALTERNATIVE DESIGN 2

ENVIRONMENTAL SUSTAINABILITY-BASED PLAN

Scenario two is designed with a focus on environmental sustainability, developed on the basis of hydrology and slope analyses. The objective is to achieve a balance between agricultural development and environmental protection, to create long-term stability in food production with low overall disturbance. Permaculture practices of stormwater management, agroforestry, and no-till farming are utilized to provide regulatory services and optimize environmental benefits.

The functional areas of the course are the intensively managed vegetable garden, food forest, grazing area, compost area, wetlands, woodlots, and floodplain. Intensively managed vegetable gardens are located on two fringe spots to the north of the community, because vegetable gardening easily disturbs the environment. The main agricultural programming in this scenario is the orchard and it occupies the majority of the prime farmland. A circle-shaped grazing area connects to the orchard, where the livestock manure is used as fertilizer for the trees as well as on field crops, where the latter are planted in the center of the circle-shaped grazing area. Simultaneously, products from the field crops provide forage for the livestock. The disturbed land in the north part of the course are used for infrastructure. Buildings, including the barn and power station, as well as the composting area are sited here. On either side of the floodplain where the land is steep are two woodlots. The woodlots, one 200 ft and the other 100 ft long, play a major role in protecting the soil from erosion and pollution.

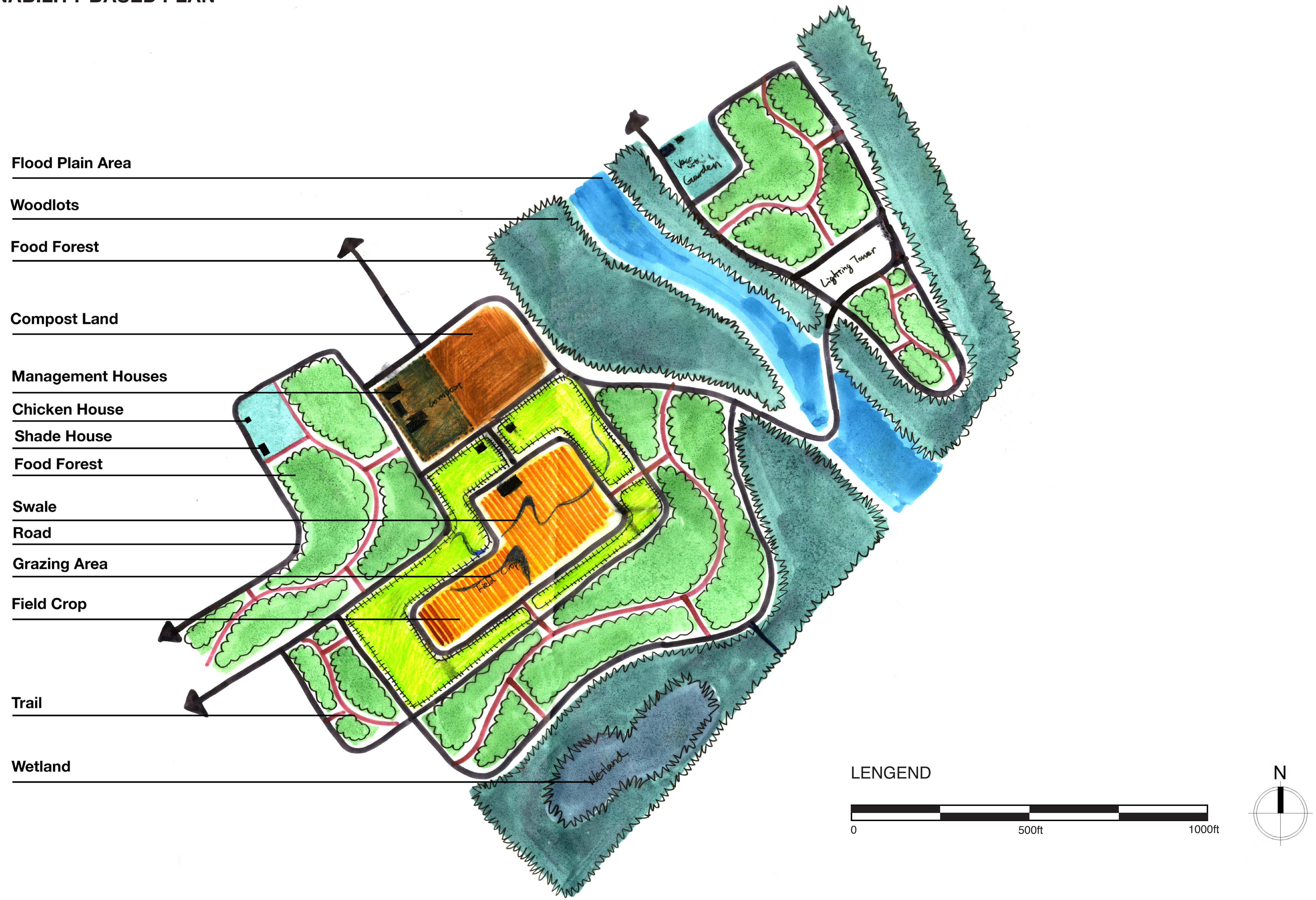
LENGEND



MAP UNIT NAME	ACRES
Intensively Managed Vegetable Garden	1.92
Food Forest	20.73
Grazing Area	5.8
Field Crop	4
Woodlots	30.61
Flood Plain Area	6

ALTERNATIVE DESIGN 2

ENVIRONMENTAL SUSTAINABILITY-BASED PLAN



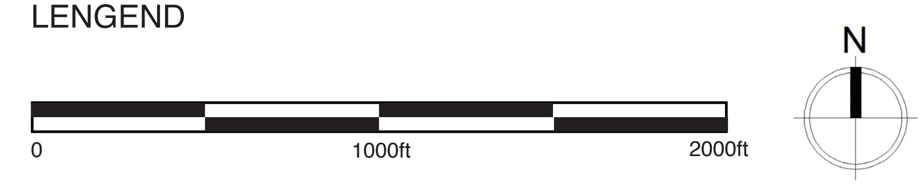
ALTERNATIVE DESIGN 3

SOCIAL SUSTAINABILITY-BASED PLAN

Developing from neighborhood analysis and circulation analysis, the third scenario focuses on social sustainability, aiming to construct a relationship that connects the course, its neighbors, and the forest in order to improve social quality of life. The goals are to strengthen social equality through a fair share economy, to strengthen social inclusion through social interaction and participation, and to produce an education model. The cornerstone of the permanent culture is the construction of the education learning center and farmer's market.

The functional areas are composed of intensively managed vegetable gardens, food forest, a grazing area, an education center, a farmer's market, some woodlots and floodplain. The intensively managed vegetable gardens are located on the north and south of the course, close to the neighboring communities, and their sizes are proportional to the populations they serve. The food forest and grazing area are sited outside the vegetable gardens and far away from the community due to their low-cost maintenance. Near the crossing of the South Main Street and Lewiston Street NW sits the farmer's market, which connects the school, community and nearby restaurants. The disturbed land, which connects the community on the north end of the course, is used for infrastructure buildings such as the barn and power station, and education center.

LENGEND



MAP UNIT NAME	ACRES
Intensively Managed Vegetable Gardens	11.04
Food Forest	28.26
Grazing Area	13.2
Farmer's market	1.2
Education Center	4
Woodlots	14
Flood Plain Area	6

ALTERNATIVE DESIGN 3

SOCIAL SUSTAINABILITY BASED PLAN

CHAPTER FOUR DATA COLLECTION AND ANALYSIS

Table 3: Composition and Rank of Food Energy in Available Food Resources[a]

	Calories	Total Fat		Saturated Fat		Sodium		Cholesterol		Carbohydrate		Sugar	Dietary Fiber		Protein		Vitamin A	Vitamin C	Calcium	Iron	Yield	Calories	
Field Crop	Cal/100g	g	% Daily Value	g	% Daily Value	mg	% Daily Value	mg	% Daily Value	g	% Daily Value	g	g	% Daily Value	g	% Daily Value	% Daily Value				LBS/Acre	Cal/Acre	Rank
Corn for grain	365	4.7	7%	0.7	4%	35	2%	0	0%	74	25%	0.6	7.3	29%	9.4	19%	4%	0%	1%	15%	11270	9329400	1
Wheat	340	2	3%	0.4	2%	2	0%	0	0%	75	25%	0.4	13	52%	11	22%	0%	0%	3%	30%	3960	6107080	2
Barley	352	1.2	2%	0.2	1%	0%	0%	0	0%	78	26%	0.8	16	64%	9.9	20%	0%	0%	3%	14%	3600	5747924	3
Oat	389	6.9	11%	1.2	6%	2	0%	0	0%	66	22%	0	11	44%	17	34%	0%	0%	5%	26%	2432	4291059	4
Rye	338	1.6	2%	0.2	1%	2	0%	0	0%	76	25%	1	15	60%	10	20%	0%	0%	2%	15%	2049	3142325	5
Soybean	147	6.8	10%	0.8	4%	15	1%	0	0%	11	4%	0	4.2	17%	13	26%	4%	48%	20%	20%	2070	1380236	6
Vegetables																							
Sweet potato	86	0.1	0%	0	0%	55	2%	0	0%	9.3	3%	4.2	1.7	7%	1.1	2%	0%	12%	2%	1%	56336	10221400	1
Carrot	41	0.2	0%	0	0%	69	3%	0	0%	9.6	3%	4.7	2.8	11%	0.9	2%	334%	10%	3%	2%	38640	7185988	2
Spinach	23	0.4	1%	0.1	0%	79	3%	0	0%	18	6%	0.6	1.3	5%	2.1	4%	0%	10%	1%	5%	24640	8829435	3
Pumpkin	26	0.1	0%	0.1	0%	1	0%	0	0%	20	7	4.2	3	12%	1.6	3%	284%	4%	3%	3%	13440	5242801	4
Broccoli	34	0.4	1%	0	0%	33	1%	0	0%	3	1%	1.3	1.6	6%	0.7	1%	9%	5%	4%	1%	69216	5023328	5
Leaf Lettuce	15	0.2	0%	0	0%	28	1%	0	0%	5.8	2%	3.2	2.5	10%	1.3	3%	2%	61%	4%	3%	40432	4584900	6
Bell pepper	20	0.2	0%	0	0%	3	0%	0	0%	7.6	3%	6.2	0.4	2%	0.6	1%	11%	14%	1%	1%	28000	3810180	7
Cauliflower	25	0.3	0%	0.1	0%	30	1%	0	0%	4.6	2%	2.4	1.7	7%	0.9	2%	7%	134%	1%	2%	41552	3759520	8
Cabbage	25	0.1	0%	0	0%	18	1%	0	0%	19	6%	3.2	2.7	11%	3.2	6%	0%	11%	0%	3%	9072	3538900	9
Tomato	16	0.2	0%	0	0%	42	2%	0	0%	6.6	2%	1.7	2.6	10%	2.8	6%	12%	149%	5%	4%	19712	3040008	10
Snap Bean	31	0.2	0%	0.1	0%	6	0%	0	0%	6.5	2%	2.8	0.5	2%	1	2%	170%	15%	2%	4%	20608	2430376	11
Squash	16	0.2	0%	0	0%	2	0%	0	0%	3.2	1%	0	0.9	4%	1.2	2%	30%	27%	0%	3%	33040	2397856	12
Watermelon	30	0.2	0%	0	0%	1	0%	0	0%	5	2%	1.9	2	8%	1.9	4%	0%	80%	2%	2%	19712	2235300	13
Celery	16	0.2	0%	0	0%	80	3%	0	0%	2.9	1%	0.8	1.3	5%	1.4	3%	148%	15%	4%	5%	28896	1966050	14
Onions	40	0.1	0%	0	0%	4	0%	0	0%	3.6	1%	0.4	2.2	9%	2.9	6%	188%	47%	10%	15%	16576	1729312	15
Potato	79	0.1	0%	0	0%	5	0%	0	0%	3.4	1%	2.2	1.1	4%	1.2	2%	4%	28%	2%	2%	17360	1259888	16
Sweet Corn	86	1.2	2%	0.2	1%	15	1%	0	0%	2.2	1%	1.4	0.7	3%	0.6	1%	1%	5%	1%	1%	11200	609624	17
Cucumber	12	0.2	0%	0	0%	2	0%	0	0%	7	2%	3.3	2.7	11%	1.8	4%	14%	20%	4%	6%	3808	535432	18
Fruit Tree																							
Apple	52	0.2	0%	0	0%	1	0%	0	0%	15	5%	9.8	3.1	12%	0.4	1%	0%	7%	1%	1%	40785	9619870	1
Plum	46	0.3	0%	0	0%	0	0%	0	0%	9.5	3%	8.4	1.5	6%	0.9	2%	7%	11%	1%	1%	18908	3945198	2
Nectarines	44	0.3	0%	0	0%	1	0%	0	0%	14	5%	10	2.4	10%	0.3	1%	1%	8%	1%	1%	18645	3721178	3
Peaches	39	0.3	0%	0	0%	0	0%	0	0%	11	4%	9.9	1.4	6%	0.7	1%	7%	16%	1%	1%	19000	3361117	4
Pear	57	0.1	0%	0	0%	1	0%	0	0%	14	5%	10	2.4	10%	0.7	1%	1%	16%	1%	2%	8833	2283749	5
Blueberry	57	0.3	0%	0	0%	0	0%	0	0%	11	4%	7.9	1.7	7%	1.1	2%	7%	9%	1%	2%	2420	625685	6
Cherry	63	0.2	0%	0	0%	0	0%	0	0%	16	5%	13	2.1	8%	1.1	2%	1%	12%	1%	2%	1700	485797	7
Nut Tree																							
Walnut	654	65	100%	6.1	30%	2	0%	0	0%	14	5%	2.6	6.7	27%	15	30%	0%	2%	10%	16%	5350	15870730	1
Almonds	579	50	77%	3.8	19%	1	0%	0	0%	22	7%	4.4	0	0%	21	42%	0%	0%	27%	21%	1166	3062263	2
Hazelnut	628	61	94%	4.5	22%	0	0%	0	0%	17	6%	4.3	9.7	39%	15	30%	0%	10%	11%	26%	1033	2942560	3
Pecans	691	72	111%	6.2	31%	0	0%	0	0%	14	5%	4	9.6	38%	9.2	18%	1%	2%	7%	14%	344	1078206	4
Livestock prod																							
Milk	120	5	8%	3	15%	120	5%	20	7%	11	4%	11	0	0%	9	17%	10%	4%	30%	0%	16450	8953906	1
Pork	518	53	82%	19	95%	32	1%	72	24%	0	0%	0	0	0%	9.3	19%	0%	0%	0%	3%	2850	6696378	2
Beef	198	13	20%	5.3	26%	68	3%	62	21%	0	0%	0	0	0%	19	38%	0%	0%	1%	11%	594	533478	3
Lamb	282	23	35%	10	50%	59	3%	73	24%	0	0%	0	0	0%	17	34%	0%	0%	2%	9%	125	159891	4
Aquaculture																							
Tilapia	96	1.7	3%	0.6	3%	52	2%	50	17%	0	0%	0	0	0%	19	38%	1%	2%	8%	7%	2711	1180500	1
Trout	119	3.5	5%	0.7	4%	31	1%	59	20%	0	0%	0	0	0%	20	40%	0%	0%	1%	3%	1125	607246	2
Catfish	119	5.9	9%	1.3	6%	98	4%	55	18%	0	0%	0	0	0%	20	40%	1%	4%	7%	4%	1000	539774	3
Sunfish	89	0.7	1%	0.1	0%	80	3%	67	22%	0	0%	0	0	0%	15	30%	0%	0%	1%	1%	127	51269	4

Source: [a]The data are adapted from "Nutrition Value" by V. Vanovschi, n.d. Retrieved from https://www.nutritionvalue.org/

MICRONUTRIENT AND DIATERY FIBER

Table 4: Composition and Rank of Micronutrient and Dietary fiber in Available Food Resources[a]

Field Crop	Dietary Fiber		Vitamin A	Vitamin C	Calcium	Iron	+	Yield	% Daily Value	Rank
	g	% Daily Value	% Daily Value					(100g/acre)		
Corn for grain	7.3	29%	4%	0%	1%	15%	49%	48742.75	2388395%	1
Wheat	13	52%	0%	0%	3%	30%	85%	17127	1455795%	2
Barley	16	64%	0%	0%	3%	14%	81%	15570	1261170%	3
Soybean	4.2	17%	4%	48%	20%	20%	109%	8952.75	975850%	4
Oat	11	44%	0%	0%	5%	26%	75%	10518.4	788880%	5
Rye	15	60%	0%	0%	2%	15%	77%	8861.925	682368%	6
Vegetables										
Sweet potato	3	12%	284%	4%	3%	3%	306%	243653.2	74557879%	1
Carrot	2.8	11%	334%	10%	3%	2%	360%	167118	60162480%	2
Broccoli	2.6	10%	12%	149%	5%	4%	180%	299359.2	53884656%	3
Leaf Lettuce	1.3	5%	148%	15%	4%	5%	177%	174868.4	30951707%	4
Spinach	2.2	9%	188%	47%	10%	15%	269%	106568	28666792%	5
Bell pepper	1.7	7%	7%	134%	1%	2%	151%	121100	18286100%	6
Cauliflower	2	8%	0%	80%	2%	2%	92%	179712.4	16533541%	7
Pumpkin	0.5	2%	170%	15%	2%	4%	193%	58128	11218704%	8
Squash	1.1	4%	4%	28%	2%	2%	40%	142898	5715920%	9
Tomato	0.9	4%	30%	27%	0%	3%	64%	85254.4	5456282%	10
Snap Bean	2.7	11%	14%	20%	4%	6%	55%	89129.6	4902128%	11
Cabbage	2.5	10%	2%	61%	4%	3%	80%	39236.4	3138912%	12
Celery	1.6	6%	9%	5%	4%	1%	25%	124975.2	3124380%	13
Watermelon	0.4	2%	11%	14%	1%	1%	29%	85254.4	2472378%	14
Onions	1.7	7%	0%	12%	2%	1%	22%	71691.2	1577206%	15
Potato	1.3	5%	0%	10%	1%	5%	21%	75082	1576722%	16
Sweet Corn	2.7	11%	0%	11%	0%	3%	25%	48440	1211000%	17
Cucumber	0.7	3%	1%	5%	1%	1%	11%	16469.6	181166%	18
Fruit Tree										
Apple	3.1	12%	0%	7%	1%	1%	21%	176395.125	3704298%	1
Peaches	1.4	6%	7%	16%	1%	1%	31%	82175	2547425%	2
Plum	1.5	6%	7%	11%	1%	1%	26%	81777.1	2126205%	3
Pear	2.4	10%	1%	16%	1%	2%	30%	38202.725	1146082%	4
Nectarines	2.4	10%	1%	8%	1%	1%	21%	38202.725	802257%	5
Blueberry	1.7	7%	7%	9%	1%	2%	26%	10466.5	272129%	6
Cherry	2.1	8%	1%	12%	1%	2%	24%	7352.5	176460%	7
Nut Tree										
Walnut	6.7	27%	0%	2%	10%	16%	55%	23138.75	1272631%	1
Hazelnut	9.7	39%	0%	10%	11%	26%	86%	4467.725	384224%	2
Walnut	6.7	27%	0%	2%	10%	16%	55%	23138.75	1272631%	1
Hazelnut	9.7	39%	0%	10%	11%	26%	86%	4467.725	384224%	2
Almonds	0	0%	0%	0%	27%	21%	48%	5042.95	242062%	3
Pecans	9.6	38%	1%	2%	7%	14%	62%	1487.8	92244%	4
Livestock Prod										
Milk	0	0%	10%	4%	30%	0%	44%	71146.25	3130435%	1
Pork	0	0%	0%	0%	0%	3%	3%	12326.25	36979%	2
Beef	0	0%	0%	0%	1%	11%	12%	2569.05	30829%	3
Lamb	0	0%	0%	0%	2%	9%	11%	540.625	5947%	4
Aquaculture										
Tilapia	0		1%	2%	8%	7%	18%	11725.075	211051%	1
Catfish	0	0%	1%	4%	7%	4%	16%	4865.625	77850%	2
Trout	0	0%	0%	0%	1%	3%	4%	4325	17300%	3
Sunfish	0		0%	0%	1%	1%	2%	549.275	1099%	4

Source: [a]The data are adapted from “Nutrition Value” by V. Vanovschi, n.d.
Retrieved from https://www.nutritionvalue.org/

ECONOMIC INCOME

Table 5: Profits of Available Food Resources

Field crops	Yield [a]	Price[a]	Value	Cultural Cost	Profit	Rank
	BU/Acre	$/BU	$/Acre			
Corn, for Grain	161	4.05	652	331[b]	321	2
Wheat, Winter	66	5.45	360	113[b]	247	3
Soybeans	34.5	8.8	304	169[b]	135	4
Oat	76	2.4	182	103[b]	79	5
Barley, Fall	75	3.2	240	162[b]	78	6
Rye	36.6	6.01	220	160[c1]	60	7
	LBS/Acre	$/LBS	$/Acre			
Cotton	817	0.583	476	495[b]	-19	8
Tobacco	2415	2.028	4897	2608[d]	2289	1
Vegetables	CWT/Acre	$/CWT	$/Acre			**Rank**
Bell Pepper	371	48.3	17919	1889[e]	16030	1
Tomato	295	55	16225	1964[e]	14261	2
Celery	618	24.8	15326	1428[f1]	13898	3
Leaf Lettuce	258	59.7	15403	2557[f2]	12846	4
Carrot	345	26.68	9205	520[c2]	8685	5
Broccoli	176	48.4	8518	1448[e]	7070	6
Cauliflower	176	61.3	10789	4553[c3]	6236	7
Onions	503	15.4	7746	1679[f3]	6067	8
Cabbage	361	19.3	6967	1528[e]	5439	9
Watermelon	250	22	5500	1439[e]	4061	10
Spinach	148	56.5	8362	4336[f4]	4026	11
Squash	155	29	4495	1092[e]	3403	12
Cucumber	100	40	4000	1345[e]	2655	13
Potato	220	14.9	3278	1141[e]	2137	14
Sweet Corn	81	31	2511	730[e]	1781	15
Pumpkin	184	12	2208	711[e]	1497	16
Snap Bean	34	65	2210	1844[c4]	366	17
Sweet potato	120	12.5	1500	1663[e]	-163	18

	Profit = Income - Cultural Cost													Price	
	$/Acre													$/LBS	Rank
Fruit trees	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year	11th year	12th year	Average		
Apple[g]	-3234	-738	5472	4242	7987	15748	15748	15748	15748	15748	15748	15748	10330	0.367	1
Cherry[h]	-2898	-791	266	3321	8779	8779	8779	8779	8779	8779	8779	8779	5844	0.31	2
Nectarines[i]	-4389	-1021	904.5	5345	8087	8087	8087	8087	8087	8087	8087	8087	5461	0.27	3
Peaches[j]	-3572	-643	2643	6905	6905	6905	6905	6905	6905	6905	6905	6905	5048	0.367	4
Plum[k]	-6022	-998	885	2453	4416	4416	4416	4416	4416	4416	4416	4416	2637	1.125	5
Blueberry[l]	-9997	1227	1249	1249	1249	1249	1249	1249	1249	1249	1249	1249	310	0.342	6
Pear[m]	-5378	-801	-1227	-1658	-117	1823	1823	1823	1823	1823	1823	1823	298	0.434	7
Nut trees	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year	11th year	12th year	Average		**Rank**
Almond[n]	-4272	-585	-1109	491	1759	4713	4713	4713	4713	4713	4713	4713	29275	4	1
Hazelnuts[o]	-1353.3	-365.53	-256.63	142.64	436.40	640.82	1579.55	1641.51	2450.83	3150.85	3526.92	4401.95	15996	1.8	2
Walnut[p]	-5263	-518	-760	-633	-243	579	2743	2743	2743	2743	2743	2743	9620	0.81	3
Pecan[q]	-1635	-403	-246	-246	-246	-246	-246	216	383	549	715	881	-524	1.96	4

Livestock		Average Weight[r]	Meat Price[r]	Value	Numbers	Operating Cost	Growth Time	Profits		Rank
		LBS/Head	$/100LBS	$/Head	Head/Acre	$/Head/Year	Year	$/Acre/Year		
	Beef Cow	1432	153	2191		633.96[s]	2	550.61		
		Average Weight	**Meat Price**	**Value**		**Operating Cost**				
		1432	100.39	1437		638.96[s]				
		Milk production	**Milk price**	**Value**		**Operating Cost**				
Cow	Milk Cow	19820	27	5351	0.83	2100[t]	4	3450	2000	1
		Average Weight	**Meat Price**	**Value**	**Numbers**	**Operating Cost**	**Growth Time**	**Profits**		
Pig & Hog		285	76	218	20	1205[u]	2	1950		2
		Average Weight	**Meat Price**	**Value**	**Numbers**	**Operating Cost**	**Growth Time**	**Profits**		
		94	144	135						
		Wool Production	**Wool Price**	**Value**						
Sheep		5.6	0.775	4.34	2	95.88[v]	1.5	134.86		3

Aquaculture	Profits = Income- Cultural Costs													Price	Rank
	$/Acre													$/LBS	
	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year	11th year	12th year	Average		
Tilapia[w]	-2500	0	0	3615	3615	3615	3615	3615	3615	3615	3615	3615	2544	1.5	1
Trout[x]	-2500	0	0	1800	1800	1800	1800	1800	1800	1800	1800	1800	1420	1.2	2
Catfish[y]	-2500	0	0	1250	1250	1250	1250	1250	1250	1250	1250	1250	962	1.25	3

Source:

[a]The data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf

[b]The data are adapted from "Commodity Costs and Returns"(n.d.). Retrieved from http://www.ers.usda.gov/data-products/commodity-costs-and-returns.aspx

[c1]The data are adapted from "Rye Budget for Wisconsin for 2014," by K. Barnett, 2014, University of Wisconsin Center for Dairy Profitability. Retrieved from http://fyi.uwex.edu/farmteam/field-crop/

[c2]The data are adapted from "Carrot processed irrigated budget for Wisconsin for 2014," by K. Barnett, 2014, University of Wisconsin Center for Dairy Profitability. Retrieved from http://fyi.uwex.edu/farmteam/commercial-vegetables/

[c3]The data are adapted from "Cauliflower market non-irrigated budget for Wisconsin for 2014," by K. Barnett, 2014, University of Wisconsin Center for Dairy Profitability. Retrieved from http://fyi.uwex.edu/farmteam/fresh-market-vegetables/

[c4]The data are adapted from "Snap bean market non-irrigated budget for Wisconsin for 2014," by K. Barnett, 2014, University of Wisconsin Center for Dairy Profitability. Retrieved from http://fyi.uwex.edu/farmteam/fresh-market-vegetables/

[d]The data are adapted from "Tobacco Management: Optimizing Profits"(n.d.). Retrieved from http://www2.ca.uky.edu/agcomm/pubs/agr/agr157/agr157.htm

[e]The data are adapted from "2013 Vegetable and Melon Budgets," by M. Ernst, T. Woods, T. Coolong, & J. Strang, 2013. Retrieved from http://www.uky.edu/Ag/CCD/vegbudgets13.html

[f1]The data are adapted from "Costs and Profitability Analysis for Celery Production In the Oxnard Plain, Ventura County, 2012-2013," by E.Takele, O. Daugovish, & M. Vue, 2013. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/3c/da/3cda417c-e970-4882-be23-f97b785acb3d/costs-and-profitability-analysis-for-celery-production-in-the-oxnard-plain-ventura-county-2012-13.pdf

[f2]The data are adapted from "Sample Cost to Produce Organic Leaf Lettuce," by L. Tourte, R. Smith, K. Klonsky, & R. Moura, 2009. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/7d/96/7d96db67-49ca-442f-9543-4482187c9cd1/lettuceleaforganiccc09.pdf

[f3]The data are adapted from "Sample Costs to Produce Onions For Dehydrating," by R. Wilson, D. Sumner, K. Klonsky, & D. Stewart, 2016. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/a7/1e/a71ed327-7d6c-4ae5-92a2-52854cb4195c/16_onionshydrostulelakefinaldraftmar22.pdf

[f4]The data are adapted from "Sample Costs to Produce and Harvest Organic Spinach," by L. Tourte, R. Smith, K. Klonsky, D. Sumner, K. Tumber, & D. Stewart, 2015. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/79/02/79023ea8-80a8-4fba-b69e-5d60225dbf8b/2015_organicspinach-finaldraftjan29.pdf

[g]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish an Apple Orchard and Produce Apples," by J. Caprile, J. Grant, B. Holtz, K. Kelley, E. Mitcham, K. Klonsky, & R. Moura, 2001.Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/6e/24/6e24cf05-727f-4eb0-952c-1ed-0da7bb256/applesjv2001.pdf

[h]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish an Orchard and Produce Sweet Cherries," by J. Grant, J. Caprile, W. Coates, K. Anderson, K. Klonsky, & R. Moura, 2011. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/6f/9b/6f9b0a93-163b-4060-ba94-8a3fc689e97d/cherryvn2011.pdf

[i]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish an Orchard and Produce Nectarines," by K. Day, K. Klonsky, & R. Moura, 2009. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/39/b6/39b6cb12-0c79-4b66-bb92-b1012bdbbfd2/nectarinevs09.pdf

[j]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish an Orchard and Processing Peaches," by M. Norton, J. Hasey, R. Duncan, K. Klonsky, & R. Moura, 2011. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/67/04/6704c84a-02fa-45a4-8026-508bd019a35f/peacheslatesv2011.pdf

[k]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish an Orchard and Processing Plums," by K. Day, K. Klonsky, D. Summer, & D. Stewart, 2016. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/05/1e/051eabc3-9bdd-45cc-9c85-f122f8f275f0/2016plumssjvfinaldraft112316.pdf

[l]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish and Produce Fresh Market Blueberries," by M. Jimenez, K. Klonsky, & R. Moura, 2016. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/79/77/7977d8f7-9f4e-4858-abc8-74c81163b3a5/blueberryvs2009.pdf

[m]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish and Produce Pear," by R. Elkins, K. Klonsky, R.Tumber, 2012. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/f9/c1/f9c1777a-1c0e-4231-9d59-15e5aa3da588/pearsnc2012.pdf

[n]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish and Produce Almonds," by R. Duncan, B. Holtz, D. Doll, K. Klonsky, D. Summer, C. Gutierrez, & D. Stewart, 2016. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/27/59/27599258-3e53-4e5f-aefb-08d12f5b0cb9/16almondssjvnorthfinaldraft81116.pdf

[o]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "The Costs and Returns of Establishing and Producing Hazelnuts in the Willamette Valley," by M. Miller, C. Seavert, & J. Olsen, 2013. Retrieved from http://arec.oregonstate.edu/oaeb/files/pdf/AEB0043.pdf

[p]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish a Walnut Orchard and Produce Walnuts," by J. Grant, J. Caprile, D. Doll, K. Anderson, K. Klonsky, & R. Moura, 2013. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/6d/d5/6dd51838-68ce-4294-83a5-1eeb460baeda/walnutvn2013.pdf

[q]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf. The cultural cost data are adapted from "Sample Cost to Establish and Produce Pecans," by M. Freeman, G. Sibbett, K. Klonsky, & R. Moura, 2005. Retrieved from https://coststudyfiles.ucdavis.edu/uploads/cs_public/f6/c7/f6c7d8c2-d02a-4c61-a364-6d3b08a5428b/pecansjv2005.pdf

[r]The income data are adapted from "Vegetables 2016 Summary"(2017). Retrieved from http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-02-22-2017_revision.pdf

[s]The data are adapted from "2015 Cow-Calf Budget," by A. Griffith, & B. Bowling, 2015. Retrieved from http://economics.ag.utk.edu/budgets/2015/Beef/CowCalf2015.pdf

[t]The data are adapted from "Guidelines for Estimating Dairy Cow Production Costs 2015 in Manitoba"(2015). Retrieved from https://www.gov.mb.ca/agriculture/business-and-economics/financial-management/pubs/cop_dairy_cow.pdf

[u]The data are adapted from "Feeder Pigs, Projected Budget for 2014 Per Sow Per Year," by P. Ron, 2014. Retrieved from http://agebb.missouri.edu/mgt/budget/swine14.pdf

[v]The data are adapted from "Sheep 201: Enterprise budgeting"(n.d.). Retrieved from http://www.sheep101.info/201/budget.html

[w]The data are adapted from "Growth Performance, Yields and Economic Benefits Of Nile Tilapia Oreochromis Niloticus and Kales Brassica Oleracea Cultured Under Vegetable-Fish Culture Integration," by A. Shoko, A. Getabu, G. Mwayuli, & Y. Mgaya, 2011,Tanzania Journal of Science, 37, 37-48. Retrieved from https://www.ajol.info/index.php/tjs/article/view/73613.

[x]The data are adapted from "Rainbow Trout Input, Output and Economics"(n.d.). Retrieved from http://www.ncagr.gov/markets/aquaculture/Trout01.pdf

[y]The data are adapted from "Catfish Inputs, Outputs and Economics"(n.d.). Retrieved from http://www.ncagr.gov/markets/aquaculture/Catfish01.pdf

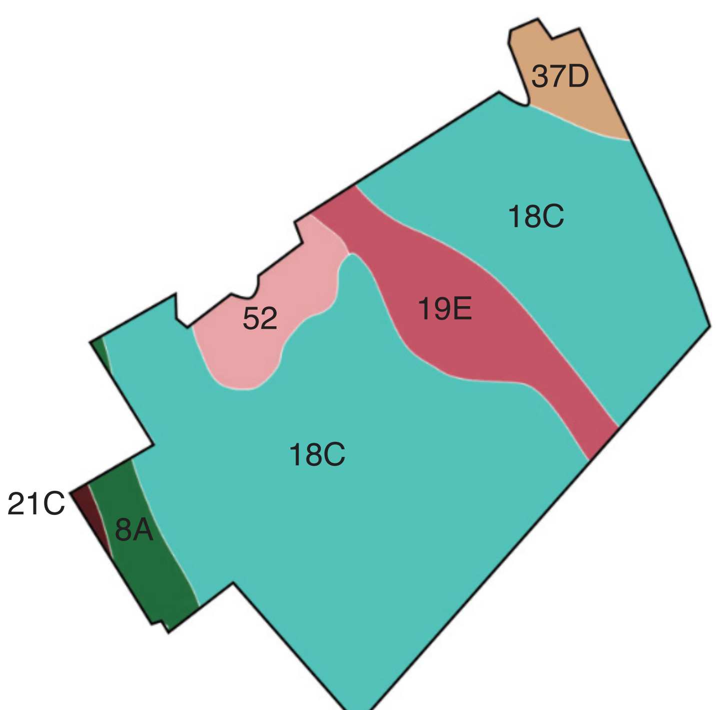
Table 6: Food Flow of Available Food Resources

	Growing Seasons											
Field Crops[a]	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Corn, for Grain								■	■	■	■	
Wheat, Winter						■	■					
Soybeans										■	■	
Oat							■	■				
Barley, Fall					■							
Rye						■	■					
Vegetables												
Bell Pepper[b]							■	■	■			
Tomato[b]							■	■	■	■		
Celery[c]								■	■			
Leaf Lettuce[b]			■	■	■				■	■		
Carrot[d]					■	■			■	■		
Broccoli[b]			■	■					■	■	■	
Cauliflower[d]				■	■					■	■	
Onions[d]							■	■				
Cabbage[b]									■	■	■	
Watermelon[b]								■	■	■		
Spinach[c]				■						■		
Squash[b]						■	■	■	■	■		
Cucumber[b]					■	■	■	■				
Potato[b]					■	■	■					
Sweet Corn[b]								■	■			
Pumpkin[b]									■	■		
Snap Bean[b]						■	■	■	■	■		
Sweet potato[b]									■	■		
Fruit trees												
Peaches[b]								■	■			
Pear[e]								■	■			
Plum[f]									■	■		
Blueberry[b]									■	■	■	
Cherry[e]								■	■			
Apple[b]								■	■	■		
Nectarines[b]							■	■				
Nut trees												
Almond[g]								■	■			
Hazelnuts[h]									■	■		
Walnut[g]									■	■	■	
Pecan[g]									■	■	■	
Livestock												
Beef Cow	■											
Milk Cow	■	■	■	■	■	■	■	■	■	■	■	■
Pig	■	■	■									
Sheep	■											
Aquaculture[i]												
Tilapia									■	■		
Trout			■	■								
Catfish									■	■		

Source:
[a]The data are adapted from "Usual planting and harvesting dates for U.S. field crops"(2010). Retrieved from http://usda.mannlib.cornell.edu/usda/current/planting/planting-10-29-2010.pdf
[b]The data are adapted from "Virginia Harvest Calendar"(n.d.). Retrieved from http://www.pickyourown.org/VA-calendar.htm
[c]The data are adapted from "Veggie Harvest"(n.d.). Retrieved from http://veggieharvest.com/calendars/zone-7.html
[d]The data are adapted from "Zone 7 - Vegetable Planting Calendar Guide"(n.d.). Retrieved from http://www.ufseeds.com/Zone-7-Planting-Calendar.htm
[e]The data are adapted from "West Virginia"(n.d.). Retrieved from http://www.pickyourown.org/WVharvestcalendar.htm
[f]The data are adapted from "What's In Season"(n.d.). Retrieved from https://www.suzannesfruitfarm.com/HarvestCalendar.htm
[g]The data are adapted from "Harvesting and Storing Your Home Orchard's Nut Crop: Almonds, Walnuts, Pecans, Pistachios, and Chestnuts"(n.d.). Retrieved from http://homeorchard.ucdavis.edu/8005.pdf
[h]The data are adapted from "Nut Growers Handbook"(n.d.). Retrieved from http://oregonhazelnuts.org/growers-corner/resources/nut-growers-handbook/
[i]The data are adapted from "Cage Culture Harvesting and Economics," by M. Masser, 1988. Retrieved from http://www.aces.edu/dept/fisheries/aquaculture/pdf/166fs.pdf

■ Harvest Date

OPTIONAL FOOD RESOURCES



8A: Combs Loam

Field Crops

Corn	Wheat	Soybean	Rye

Vegetables

Legume	Root	Fruit	Leaves
Snap Bean	Carrot	Tomato	Lettuce
Potato	Onion	Cucumber	Spinach
	Sweet Potato	Watermelon	Sweet Corn
	Celery	Pepper	Cauliflower
		Squash	Cabbage
			Broccoli

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Peach	Chestnut
Cherry	Apple	Pecan
	Plum	Walnut
	Nectarine	Hazelnut
	Pear	

18C: Frederick Silt Loam, 8 to15 Percent Slopes

Field Crops

Corn	Wheat	Soybean	Rye

Vegetables

Legume	Root	Fruit	Leaves
Snap Bean	Onion	Cucumber	Lettuce
Potato	Sweet Potato	Watermelon	Spinach
			Sweet Corn
			Cauliflower
			Cabbage
			Broccoli

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Walnut
		Hazelnut

19E: Frederick very gravelly Silt Loam, 25 to40 Percent Slopes

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

21C: Frederick Uran Land Complex, 2 to 15 Percent Slopes

Field Crops

Rye

Vegetables

Legume	Root
Potato	Sweet Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

37D: Sequoia Silt Loam, 8 to 15 Percent Slopes

Field Crops

Rye

Vegetables

Legume	Root
Potato	Sweet Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

52: Udorthents-Urban Land Complex

None

MANAGEMENT STRATEGY A:

MAXIMIZING FOOD ENERGY

8A: Combs Loam

Field Crops

Corn

Vegetables — 4 Crops Rotation

Legume	Root	Fruit	Leaves
Snap Bean	Sweet potato	Belll Peppers	Spinach

Snap Bean	Sweet potato	Belll Peppers	Spinach
Spinach	Snap Bean	Sweet potato	Belll Peppers
Belll Peppers	Spinach	Snap Bean	Sweet potato
Sweet potato	Belll Peppers	Spinach	Snap Bean

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Walnut

18C: Frederick Silt Loam, 8 to15 Percent Slopes

Field Crops

Corn	Wheat	Soybean	Rye

Vegetables — 4 Crops Rotation

Legume	Root	Fruit	Leaves
Snap Bean	Sweet potato	Watermelon	Spinach

Snap Bean	Sweet potato	Watermelon	Spinach
Spinach	Snap Bean	Sweet potato	Watermelon
Watermelon	Spinach	Snap Bean	Sweet potato
Sweet potato	Watermelon	Spinach	Snap Bean

Legume	Root	Fruit	Leaves
Potato	Onions	Cucumbers	Broccoli

Potato	Onions	Cucumbers	Broccoli
Broccoli	Potato	Onions	Cucumbers
Cucumbers	Broccoli	Potato	Onions
Onions	Cucumbers	Broccoli	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Walnut

19E: Frederick very gravelly Silt Loam, 25 to40 Percent Slopes

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

21C: Frederick Uran Land Complex, 2 to 15 Percent Slopes

Vegetables — 3 Crops Rotation

Legume	Root	Field Crop
Potato	Sweet potato	Rye

Potato	Sweet potato	Rye
Rye	Potato	Sweet potato
Sweet potato	Rye	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

37D: Sequoia Silt Loam, 8 to 15 Percent Slopes

Vegetables — 3 Crops Rotation

Legume	Root	Field Crop
Potato	Sweet potato	Rye

Potato	Sweet potato	Rye
Rye	Potato	Sweet potato
Sweet potato	Rye	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

52: Udorthents-Urban Land Complex

None

MANAGEMENT STRATEGY B:

MAXIMIZING MICRONUTRITION AND DIATERY FIBER

8A: Combs Loam

Field Crops

Corn

Vegetables — 4 Crops Rotation

Legume	Root	Fruit	Leaves
Snap Bean	Carrot	Squash	Broccoli

Snap Bean	Carrot	Squash	Broccoli
Broccoli	Snap Bean	Carrot	Squash
Squash	Broccoli	Snap Bean	Carrot
Carrot	Squash	Broccoli	Snap Bean

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Walnut

18C: Frederick Silt Loam, 8 to15 Percent Slopes

Field Crops

Corn	Wheat	Soybean	Rye

Vegetables — 4 Crops Rotation

Legume	Root	Fruit	Leaves
Snap Bean	Sweet potato	Watermelon	Broccoli

Snap Bean	Sweet potato	Watermelon	Broccoli
Broccoli	Snap Bean	Sweet potato	Watermelon
Watermelon	Broccoli	Snap Bean	Sweet potato
Sweet potato	Watermelon	Broccoli	Snap Bean

Legume	Root	Fruit	Leaves
Potato	Onions	Cucumbers	Leaf Lettuce

Potato	Onions	Cucumbers	Leaf Lettuce
Leaf Lettuce	Potato	Onions	Cucumbers
Cucumbers	Leaf Lettuce	Potato	Onions
Onions	Cucumbers	Leaf Lettuce	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Walnut

19E: Frederick very gravelly Silt Loam, 25 to40 Percent Slopes

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

21C: Frederick Uran Land Complex, 2 to 15 Percent Slopes

Vegetables — 3 Crops Rotation

Legume	Root	Field Crop
Potato	Sweet potato	Rye

Potato	Sweet potato	Rye
Rye	Potato	Sweet potato
Sweet potato	Rye	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

37D: Sequoia Silt Loam, 8 to 15 Percent Slopes

Vegetables — 3 Crops Rotation

Legume	Root	Field Crop
Potato	Sweet potato	Rye

Potato	Sweet potato	Rye
Rye	Potato	Sweet potato
Sweet potato	Rye	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

52: Udorthents-Urban Land Complex

None

MANAGEMENT STRATEGY C:

FOCUSING ON MAXIMIZING ECONOMIC INCOME

8A: Combs Loam

Field Crops

Corn

Vegetables — **4 Crops Rotation**

Legume	Root	Fruit	Leaves
Potato	Celery	Belll Peppers	Leaf Lettuce

Potato	Celery	Belll Peppers	Leaf Lettuce
Leaf Lettuce	Potato	Celery	Belll Peppers
Belll Peppers	Leaf Lettuce	Potato	Celery
Celery	Belll Peppers	Leaf Lettuce	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

18C: Frederick Silt Loam, 8 to15 Percent Slopes

Field Crops

Corn	Wheat	Soybean	Rye

Vegetables — **4 Crops Rotation**

Legume	Root	Fruit	Leaves
Potato	Onion	Watermelon	Leaf Lettuce

Potato	Onion	Watermelon	Leaf Lettuce
Leaf Lettuce	Potato	Onion	Watermelon
Watermelon	Leaf Lettuce	Potato	Onion
Onion	Watermelon	Leaf Lettuce	Potato

Legume	Root	Fruit	Leaves
Snap Bean	Onion	Cucumber	Broccoli

Snap Bean	Onion	Cucumber	Broccoli
Broccoli	Snap Bean	Onion	Cucumber
Cucumber	Broccoli	Snap Bean	Onion
Onion	Cucumber	Broccoli	Snap Bean

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

19E: Frederick very gravelly Silt Loam, 25 to40 Percent Slopes

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

21C: Frederick Uran Land Complex, 2 to 15 Percent Slopes

Vegetables — **2 Crops Rotation**

Legume	Field Crop
Potato	Rye

Potato	Rye
Rye	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

37D: Sequoia Silt Loam, 8 to 15 Percent Slopes

Vegetables — **3 Crops Rotation**

Legume	Field Crop
Potato	Rye

Potato	Rye
Rye	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

52: Udorthents-Urban Land Complex

None

MANAGEMENT STRATEGY D:

MAXIMIZING FOOD FLOW

8A: Combs Loam

Field Crops

Corn

Vegetables — **4 Crops Rotation**

Legume	Root	Fruit	Leaves
Snap Bean	Carrot	Cucumber	Spinach

Spinach	Snap Bean	Carrot	Cucumber
Cucumber	Spinach	Snap Bean	Carrot
Carrot	Cucumber	Spinach	Snap Bean
Snap Bean	Carrot	Cucumber	Spinach

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Walnut

18C: Frederick Silt Loam, 8 to15 Percent Slopes

Field Crops

Corn	Wheat	Soybean	Rye

Vegetables — **4 Crops Rotation**

Legume	Root	Fruit	Leaves
Snap Bean	Sweet Potato	Cucumber	Spinach

Snap Bean	Sweet Potato	Cucumber	Spinach
Spinach	Snap Bean	Sweet Potato	Cucumber
Cucumber	Spinach	Snap Bean	Sweet Potato
Sweet Potato	Cucumber	Spinach	Snap Bean

Legume	Root	Fruit	Leaves
Potato	Onion	Watermelon	Cabbage

Potato	Onion	Watermelon	Cabbage
Onion	Watermelon	Cabbage	Potato
Potato	Onion	Watermelon	Cabbage
Onion	Watermelon	Cabbage	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Walnut

19E: Frederick very gravelly Silt Loam, 25 to40 Percent Slopes

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

21C: Frederick Uran Land Complex, 2 to 15 Percent Slopes

Vegetables — **3 Crops Rotation**

Legume	Root	Field Crop
Potato	Sweet potato	Rye

Potato	Sweet potato	Rye
Rye	Potato	Sweet potato
Sweet potato	Rye	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

37D: Sequoia Silt Loam, 8 to 15 Percent Slopes

Vegetables — **3 Crops Rotation**

Legume	Root	Field Crop
Potato	Sweet potato	Rye

Potato	Sweet potato	Rye
Rye	Potato	Sweet potato
Sweet potato	Rye	Potato

Food Forest

Fruit Shrub	Fruit Tree	Nut Tree
Blueberry	Apple	Hazelnut

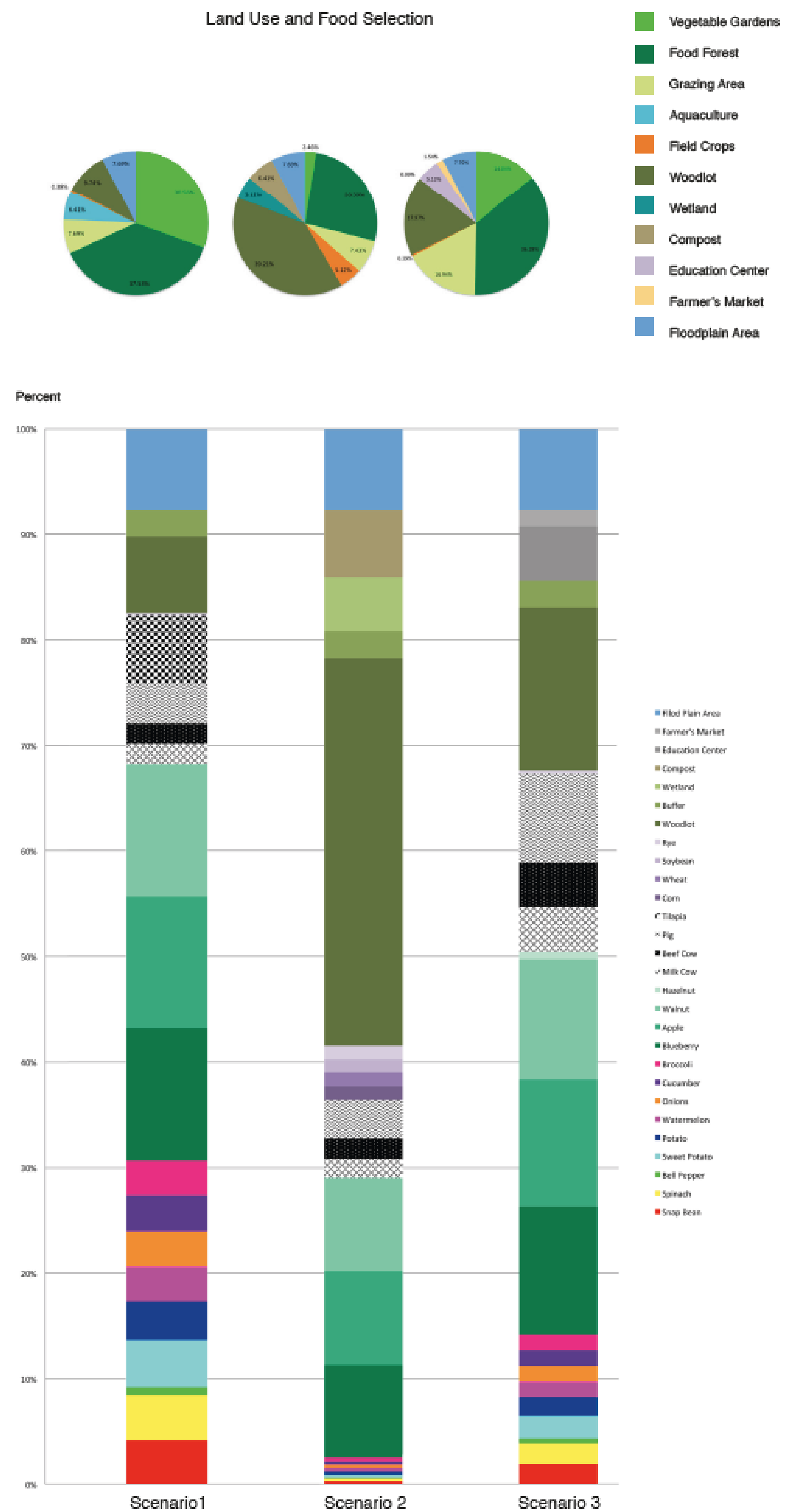
52: Udorthents-Urban Land Complex

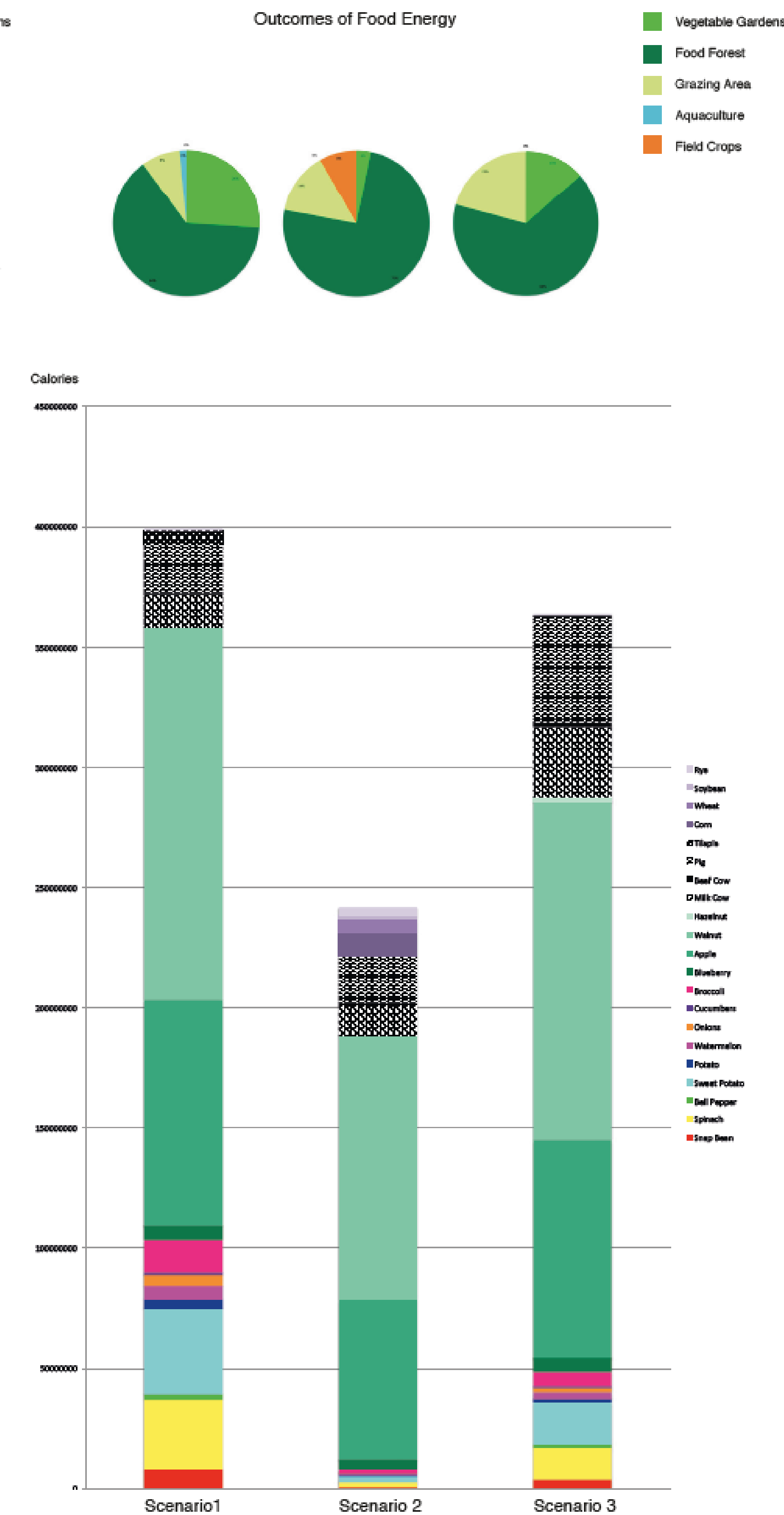
None

OUTCOMES IN ALTERNATIVE DESIGNS: FOOD ENERGY

Comparing the outcomes of food calories in three design scenarios, we can find that scenario one, which focuses on economic sustainability, produces the most calories. Scenario three, which focuses on social sustainability, produces 4% fewer calories than scenario one. Scenario two, which emphasizes environmental sustainability, generated the least amount of calories, at a rate of 13% less than scenario one. There is a positive correlation between the land use and outcomes of food energy as seen in these three scenarios. In scenario one, economic sustainability, preserved areas only occupied 17% and productive space occupied 83% of the available land. In scenario two, environmental sustainability, preserved areas and productive space occupied 58% and 42% of the available land, respectively. In scenario three, social sustainability, preserved areas and built areas together occupied 33%, and productive space occupied 67% of the available land.

Upon comparison of the productive programming elements, we find that the food forest occupies the most space and produces the most calories. In all three scenarios, the food forest occupies the most available land area because it is much less constrained by slope than other land uses and can be planted on the steeper slopes found on the course. Using an analysis of unit outcome (calories/acre) and soil adaptability of various food trees, blueberry, apple, walnut and hazelnut were chosen as food resources and applied in the three scenarios. Among these fruit trees, blueberry, apple and walnut were mixed and planted in equal-size areas. Hazelnut, as the walnut substitute, was planted in a small-size area in scenario three. From this analysis, it is apparent that walnuts contribute to the most food calories and blueberries contribute the least. In the countryside golf course, the selection of orchard species was influenced by soil characteristics and limited to blueberry, apple, walnut and hazelnut in most places. There are opportunities to find other species for use in the farm if programming on site is changed. Different species will yield different energy outputs, as well as different nutrition and economic values. For instance, almonds could produce more profits than other types of nut trees, if the soil were suitable. The proportion of calories generated from vegetable gardens, animal products, field crops are similar to the proportion in size of each respective land use.

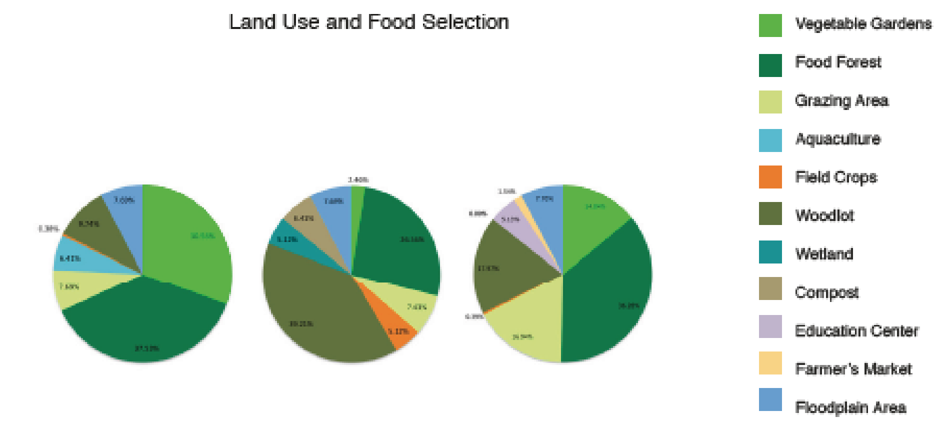


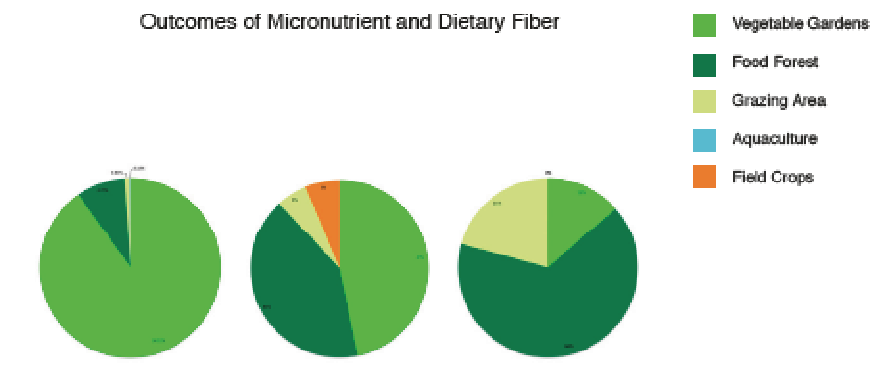


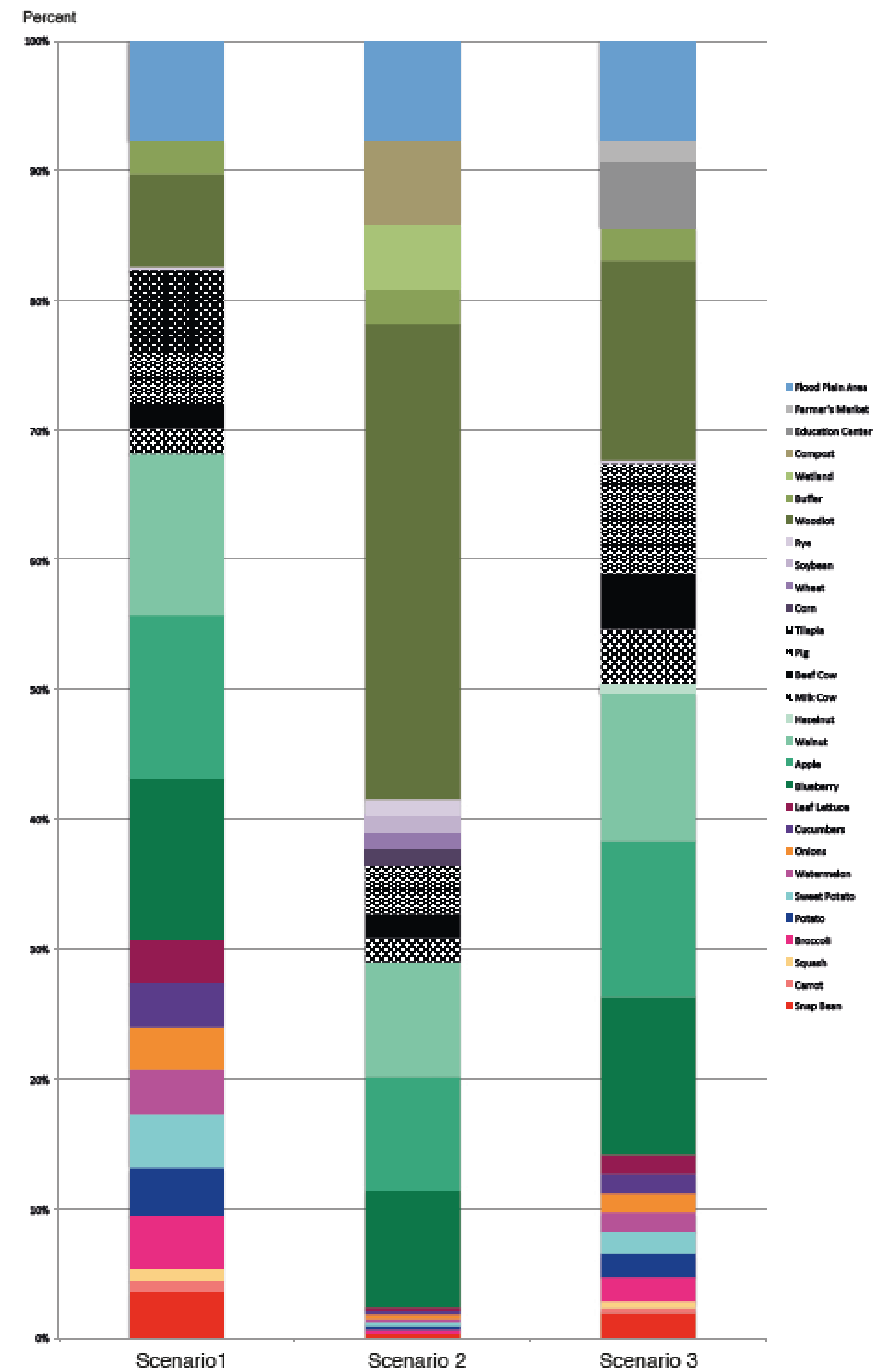
OUTCOMES IN ALTERNATIVE DESIGNS: MICRONUTRIENT AND DIETARY FIBER

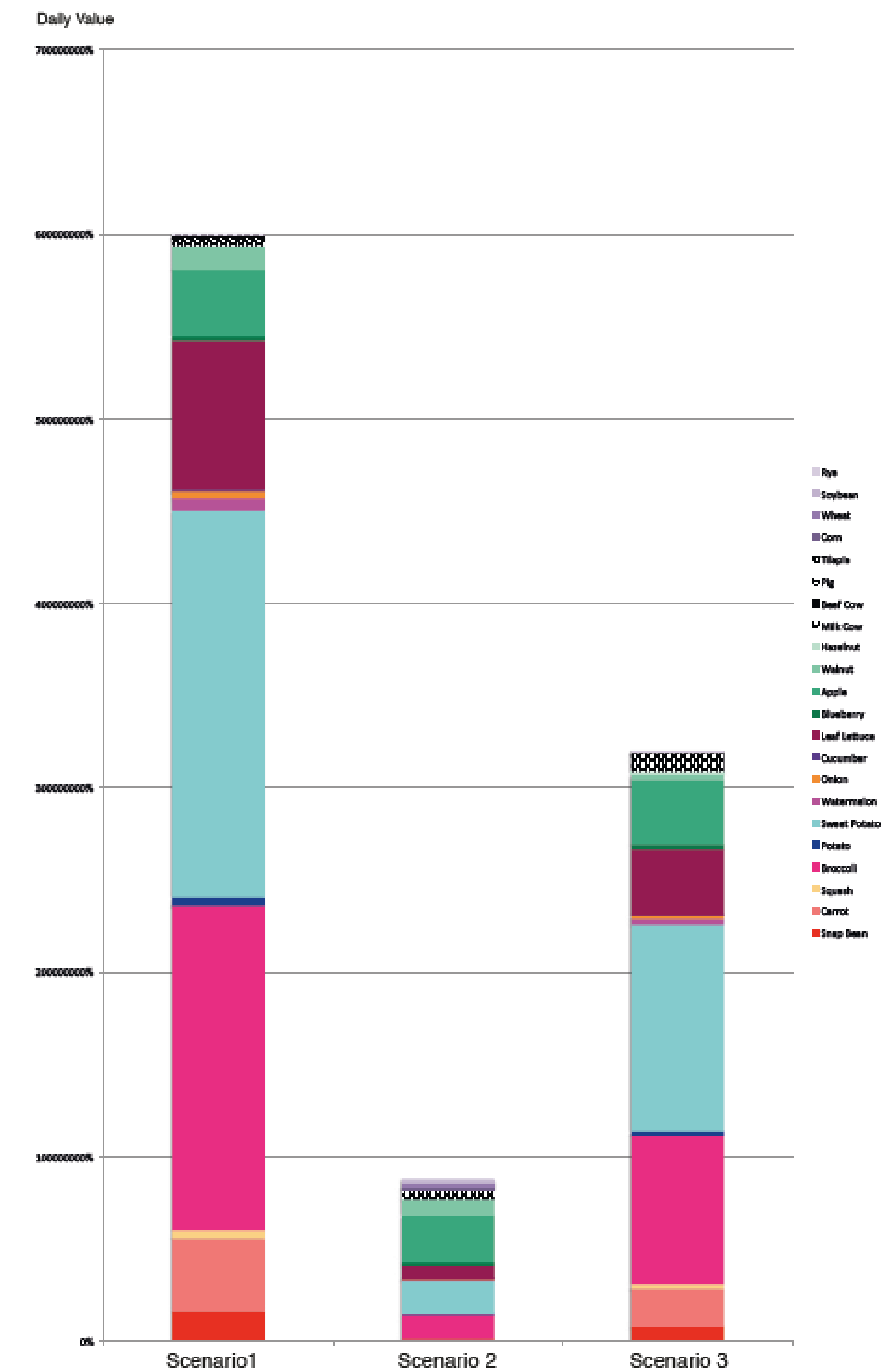
Micronutrients and dietary fiber are important compositions of food nutrition and play an important role in protecting humans against diseases. Scenario one produced enough micronutrients and dietary fiber to meet the annual consumption of 16,011 people. Scenario three's production of micronutrients and dietary fiber per acre per year was only half that of scenario one, meeting the needs of 8,736 people. Scenario two yielded the fewest micronutrients and dietary fiber production per year per acre, meeting the needs of just 2,396 people.

Different from its role in food energy (calories), the food forest created fewer micronutrients and dietary fiber, although it occupied the most land use. In contrast, vegetable gardens are the most active in producing micronutrients and dietary fiber. Among the vegetables, sweet potato and broccoli contribute over 50% of needed nutrition. Although carrots only occupy a very low percentage of land use, it also provides a lot of micronutrients and dietary fiber. Similar to the food forest, animal products and field crops have little contribution to micronutrients and dietary fiber.



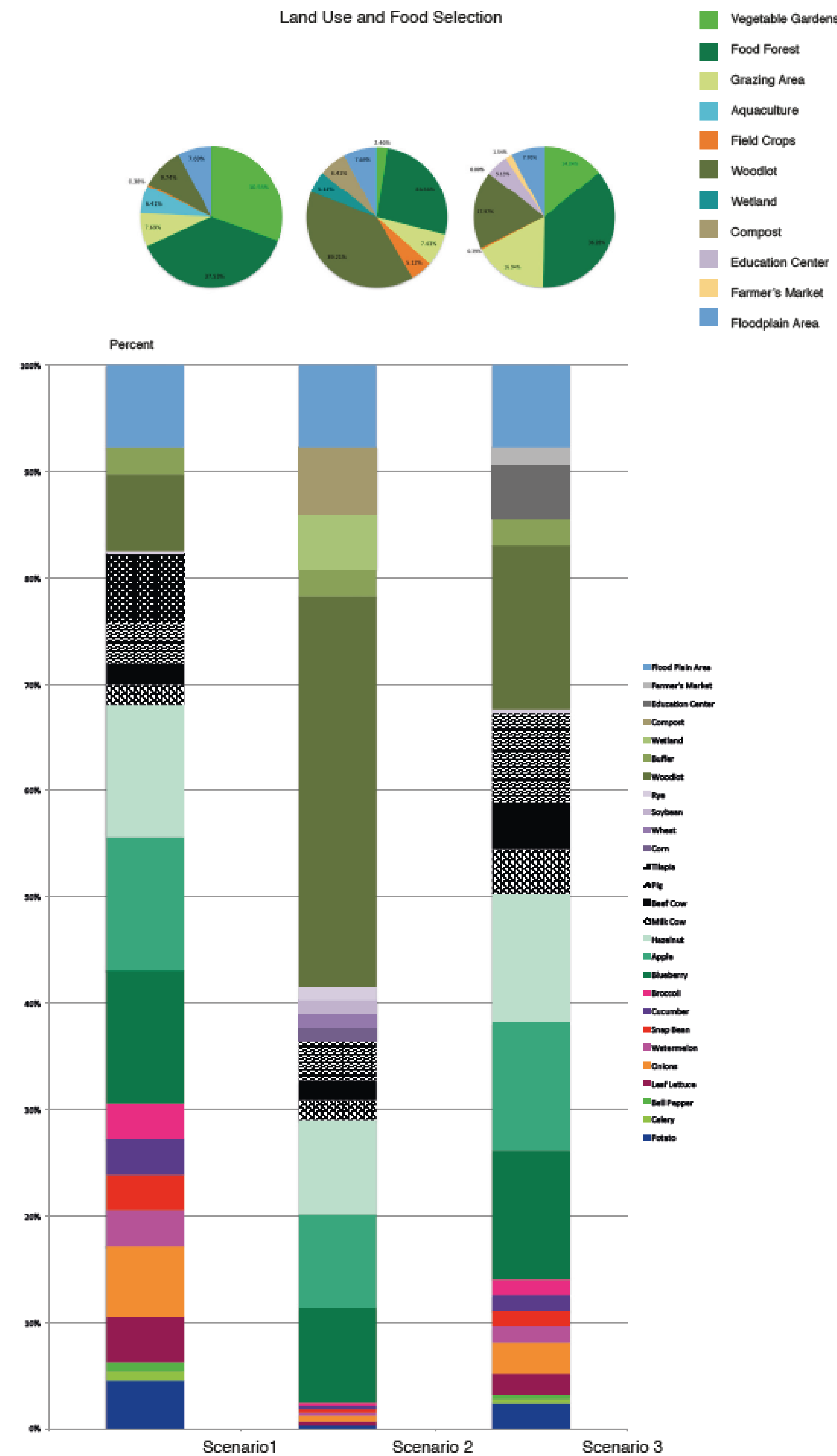


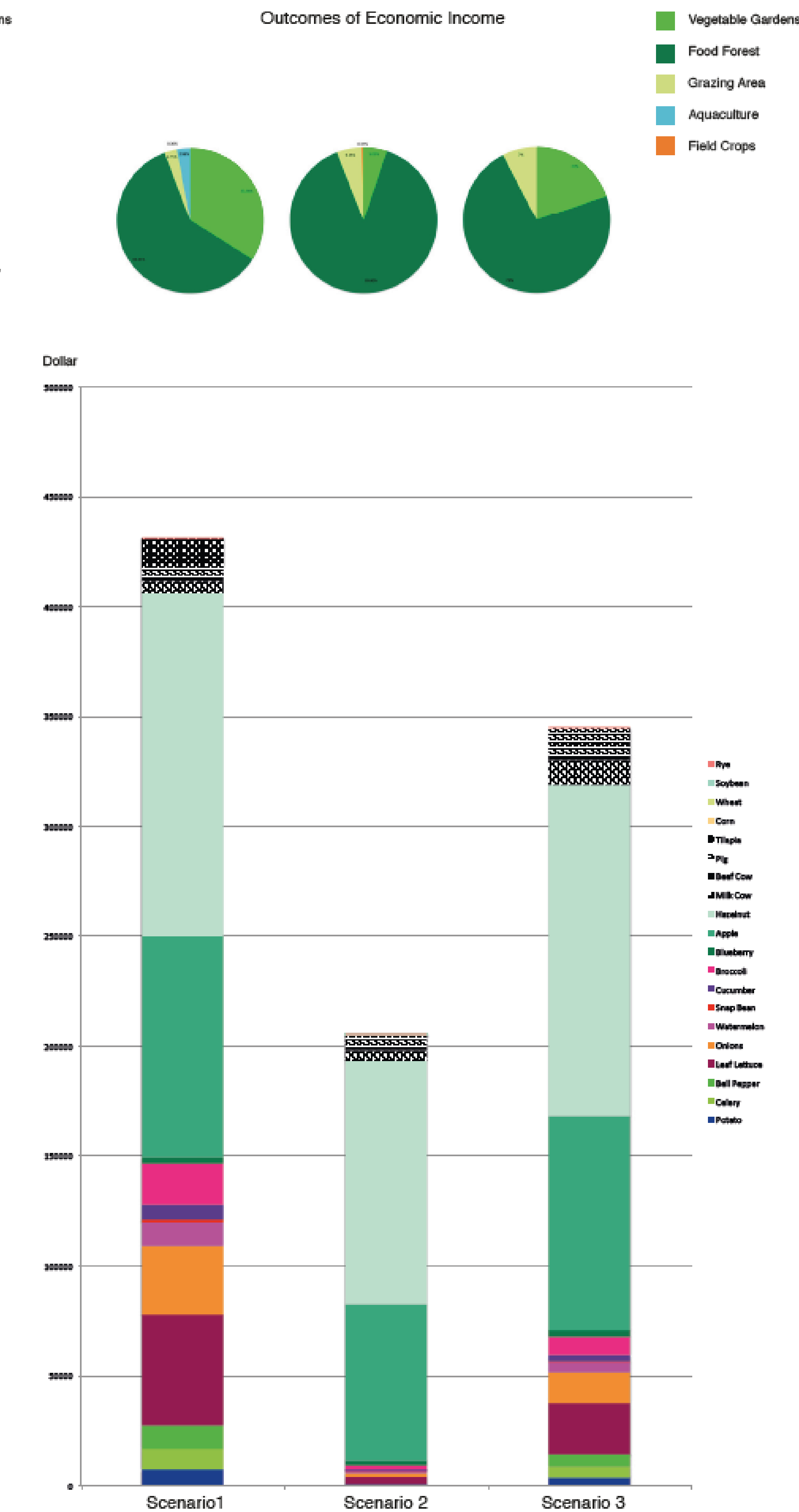




OUTCOMES IN ALTERNATIVE DESIGNS: ECONOMIC INCOME

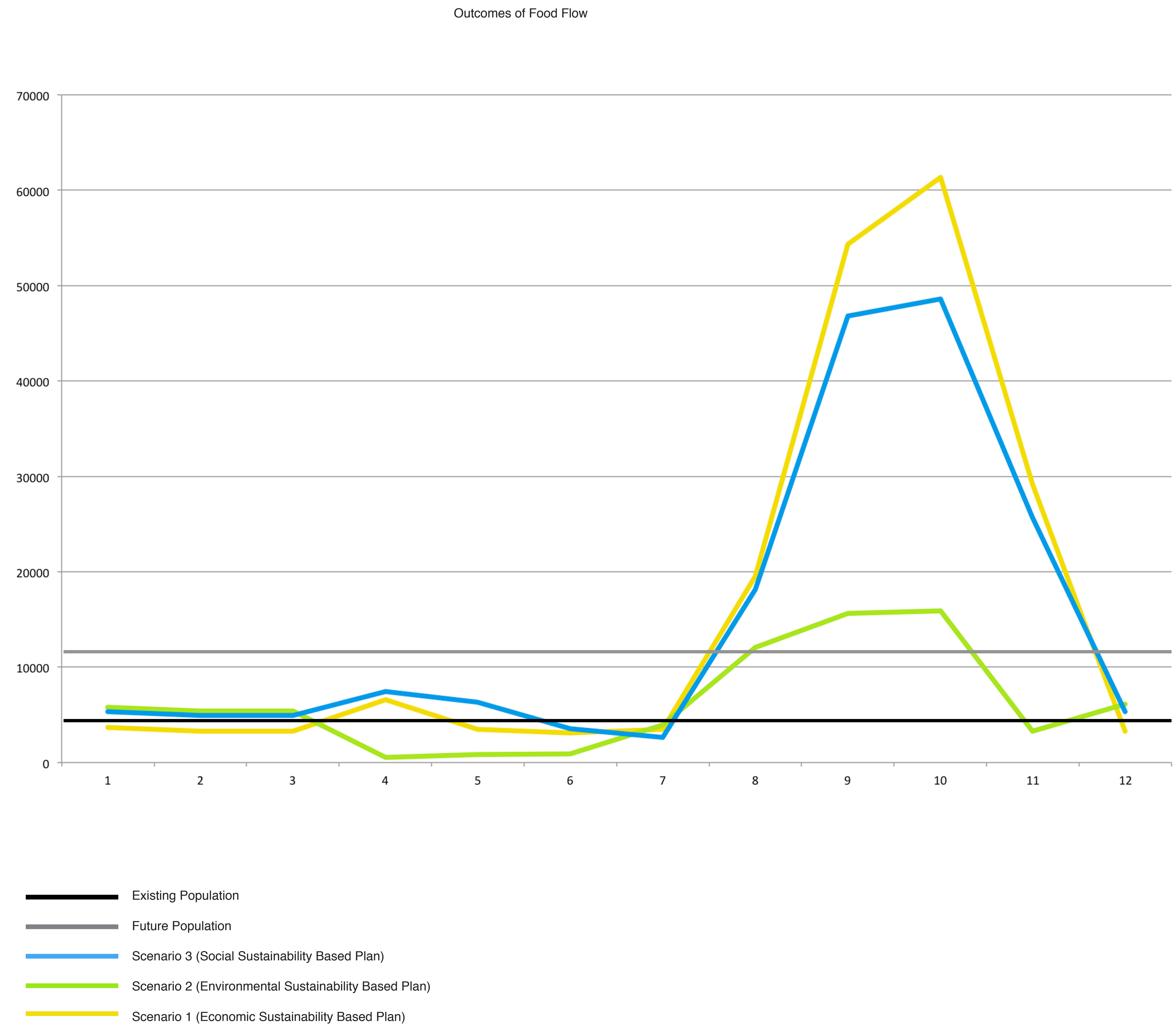
Maximizing economic income through selling surplus crops can help the poor citizens earn money to purchase food during winter time when food is scarce. Scenario one, with the highest value in economic income, is followed by scenario three and scenario two, whose economic incomes are 9% and 23% less, respectively. The food forest contributes the most to economic income, in which hazelnuts and apples, as highly profitable produce, contribute the most, with some contributions from blueberry. Animal products and field crops contribute very little to economic income, while the extent of contributions from vegetable gardens was the same as their percentage of size in land use. Among the vegetables, leaf lettuce and onions yielded the most economic income.





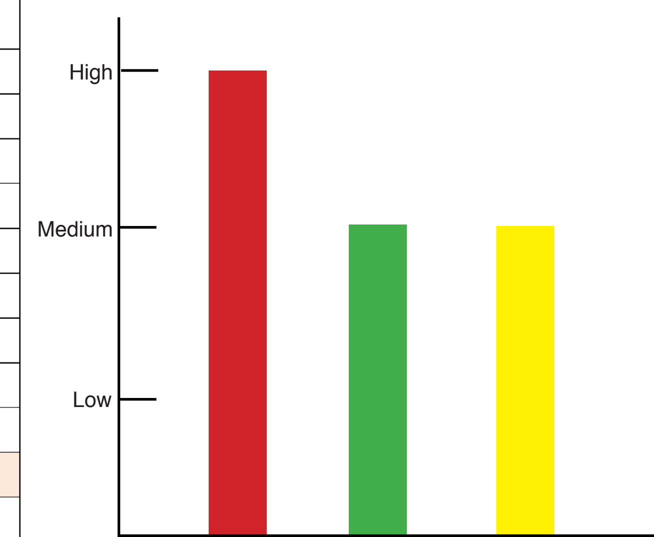
OUTCOMES IN ALTERNATIVE DESIGNS:
FOOD FLOW

Food flow is defined as food energy change per time unit during a set period. The figure illustrates the human life-supporting energies generated per period in a year for each of these three scenarios. It is apparent that the peak of food energy generation is between July and November with the peak-of-peak arriving in October. Nonpeak time is from November to the following July. During the peak time of food generation, scenario one produces the most food energy, with the more energy than scenario three in the October peak, which has the ability to support 1000 more people. Both scenario one and three yield far more food energy than produced in scenario two, which can support 4500 and 5500 more people, respectively, during the October energy peak. It should be noted that during the nonpeak period, scenario three performs the best, generating food energy continuously and stably, with the ability to produce meat and dairy products in winter. In addition, all the scenarios can support a self-sustained life by generating adequate food in one time period, allowing people to sell or preserve the surplus food produced during peak times, suggesting a necessity to build small-scale factories for canning or packaging surplus food.

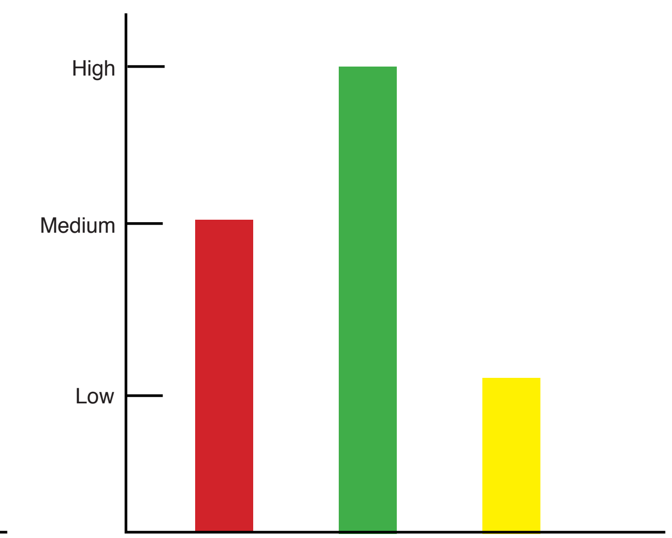


CREDITS OF SUSTAINABILITY IN ALTERNATIVE DESIGNS:

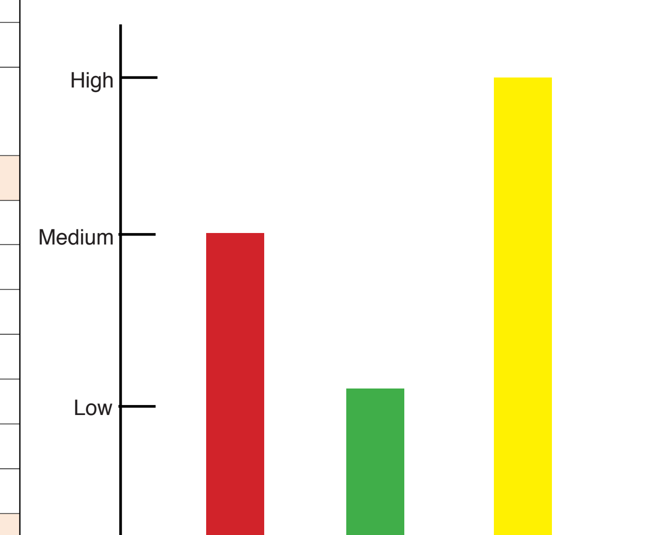
CRETERIA		CREDITS		
		Scenario 1 (Economic)	Scenario 2 (Environmental)	Scenario 3 (Social)
Economic Sustainability	**Creating working opportunities and income for the labors and owner.**			
	1.Employing the long-term unemployed as labor and provide them salary.	✓	✓	✓
	2.Earning money through selling foods to neighbors, local restaurants, grocery store and supermarket.	✓	✓	✓
	Developing an energy conservation system to obtain a high yield with low input.			
	1. Maximizing yield with low input.	✓	✓	×
	2. Exchanging extra energy between organisms in a system to acquire surplus yields.	✓	✓	✓
	3. Using renewable resources to optimize food production.	✓	✓	✓
	4. Eliminating the cost on the agrochemicals and maximizing biodiversity for pests and disasters control.	✓	✓	✓
	Maximizing areas for planting cash crops	✓	×	×
		High	**Medium**	**Medium**
Environmental Sustainability	**Creating a long-term stability of food production with low disturbance.**			
	1. Reducing soil erosion and degradation, and improve soil quality and health.	✓	✓	×
	2. Applying self-regulation and accept feedback.	×	✓	×
	3. Eliminating the dependence on the agrochemicals and maximizing biodiversity for pests and disasters control.	✓	✓	✓
	4. Reserving existing nature areas and providing connectivity between habitat remnants with them.	✓	✓	×
	5. Reducing energy waste and recycling materials.	✓	✓	✓
	6.Reducing pollution from agriculture practices.	✓	✓	×
	Selecting perennial crops as primary food resource to create a resilient system to withstand climate change and natural disaster.	×	✓	✓
	Total	**Medium**	**High**	**Low**
Social Sustainability	**Strengthening social equality through fair share economics.**			
	Providing individuals with adequate and affordable food.	✓	✓	✓
	Strengthening social inclusion through social interaction and participation.			
	Encouraging different groups to work together on the farm.	✓	×	✓
	Building places for goods distribution such as farmer's market and farm stand.	×	×	✓
	Education models output			✓
	Teaching people about the knowledge of permaculture and the nutritious of food.	×	×	✓
	Total	**Medium**	**Low**	**High**



ECONOMIC SUSTAINABILITY-BASED PLAN



ENVIRONMENTAL SUSTAINABILITY-BASED PLAN



SOCIAL SUSTAINABILITY-BASED PLAN

ECONOMIC SUSTAINABILITY

ENVIRONMENTAL SUSTAINABILITY

SOCIAL SUSTAINABILITY

CHAPTER FIVE IMPLICATION AND DISCUSSION

DESIGN IMPLICATION

CONCLUSION

The findings from the permaculture design on the countryside golf course is explained by the design methods and management strategies in relation to overall production and food security outcomes. The countryside golf course study is a good example for the application of permaculture designs in the urban environment. For each of the following three scenarios, four management strategies were applied and the outputs were evaluated. Figure 1 summarizes the results.

	Food Energy	Micro-nutrient And Fiber	Economic Income	Food Flow
Scenario 1 (Economic Sustainability)	High	High	High	High
Scenario 2 (Environmental Sustainability)	Medium	Low	Medium	Low
Scenario 3 (Social Sustainability)	High	Medium	High	Medium

LANDSCAPE ARCHITECTURE DESIGN

Landscape architecture design is key to creating a meaningful urban permaculture farm that can fulfill the diverse requirements of different stakeholders. Based on different degrees of economic, environmental and social inputs, the permaculture scenarios present distinct design patterns and outputs, offering different results for each set of criteria. The food flow diagram gives an interpretation of how design influences production.

The plan focusing on environment sustainability guarantees the food supply of the surrounding residents and creates a model for a better way to make environmentally friendly lifestyles. This tree-based farming system offers a low maintenance, reliable food resource while protecting the local ecosystem. With the purpose of building a self-sustaining community and nonprofit farm, designers should utilize an environmental sustainability-based plan to minimize tradeoffs between the environment and agricultural development.

Conversely, when considering expanding the beneficiaries of a permaculture farm to the city scale and regional scale, the economic sustainability-based plan and social sustainability-based plan become better options since they demonstrate advantages in gross food production. During the high peak period of food production, the outcome of food energy far exceeds the needs of the golf course's neighbors and those surplus foods can be sold at market to support the local food supply. These scenarios have the greatest potential to strengthen a sustainable local food production system.

Different from economic sustainability-based plan which focuses on maximizing agricultural production and economic benefits, the social sustainability based plan emphasizes social interaction. A series of public spaces, farmer's market and education center, are designed to connect different groups with the farm and forest, creating an equitable life. This scenario provides people with many different kinds of opportunities: social gatherings and meeting places and an atmosphere for selling and sharing fresh produce. In addition, this scenario provides opportunities for teaching, learning and sharing agricultural knowledge, while providing opportunities to promote food access and educate people on how to maintain a nutritious diet.

After all comparisons are made, the economic sustainability-based plan is the best option. If the permaculture farm is privately owned property and targeted as a commercial business, it has the zpotential to contribute the most food and results in the most nutrients produced and high overall economic value. But, if the permaculture farm is managed by the community and the goals are to enhance empowerment of the local community and construct a local food system, the social sustainability-based plan is the better choice, since it focuses on social and cultural life in addition to providing high quality food from the food forest.

As urban permaculture farm is applied in other sites, it may face different challenges and opportunities in terms of climate, hydrology, soil type, topography and existing natural resources. In addition to design, a good management strategy will have a great impact on the outcome of food production and contributes to the success of the farm. In this case, large woodlots are planted around the floodplain and trade food production for water protection. In other places that do not involve the stream, it is possible to expand the food forest areas to yield more fruits and nuts.

This study investigates the design and function of an urban permaculture farm and its potential contribution to local food security; however, there are still questions to be explored in the future. A permaculture farm combined with different environmental, economic and social goals will result different design ideas. These new designs may compete with each other. Is it possible to develop a plan that can balance each these imperatives in order to achieve mutual benefits and win-win situation for all parties?

DISSCUSSION

Taking both landscape architecture and urban planning into account, the urban planner should pay attention to the spatial distribution of the permaculture farm in the city and the type of earth that the different farm elements can potentially utilize.

Take Roanoke as an example: the poor district was more distributed in the middle which is crowded with buildings and occupied by many construction sites. In contrast, some smaller vacant lots could be the ideal place to develop permaculture within the city. Some unmanaged parks scattered in the south part of the city could also potentially be transformed into urban permaculture farms. A major constraint is that design and management strategies are limited by the size of land use and available labor. For instance, small vacant lots can be developed into vegetable garden-based permaculture because they are can be supported by local labor from the poor and unemployed. On the other hand, the southern unmanaged park, which was surrounded by a population with a higher socio-economic status, has greater potential when developed as tree-based permaculture. The abandoned golf course, located in the northern part of Roanoke, has the greatest potential to be transformed into mixed-use permaculture, due to the diverse opportunities provided by the mix of low and middle class neighborhoods surrounding the site.

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