Edible Forest Garden Permaculture

For the Great Lakes Bioregion

Background, Development and Future Plans for
The Michigan State University Student Organic Farm
Edible Forest Garden

Prepared by
Jay Tomczak

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Michigan State University
East Lansing, MI 48824

"We are not working with nature, we are nature working."

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Table of Contents

Preface

About the time I was working with students to develop the ideas and plans for the MSU Student Organic Farm, I was working with an off campus faith community to build a meditation and prayer labyrinth. When walking the completed labyrinth, it was obvious that I had a hard time slowing down – not unlike the challenge people have when it comes to slowing down for meals and to consider "where food comes from". Somewhere during the walking and meditating, the picture of a food labyrinth garden worked up to the surface - concentric circular paths with gardens in between for walkers to experience and savor the flavor.

The plot that eventually became the Student Organic Farm Edible Forest Garden was covered in straw and wood shaving bedding for sheet composting with a food labyrinth image in mind. I had watched the newly planted cherry trees that were part of the last experiment on that plot struggle in the heavy clay subsoil. I had also watched the rapid growth of my own newly planted fruit trees at home in the site I had prepared with sheet composting for two years prior to planting. The soil was fed first, and the quack grass was given the opportunity to become soil organic matter of a different kind.

The Edible Forest Garden that Jay Tomczak and helpers created on the site far exceeds any picture I ever conjured in my head. While the planting is just over a year old, it is an incredible collection of plant material with an inviting and creative layout. It is indeed an inviting food labyrinth. Not concentric rings, but paths and pockets, spaces and guilds that will take years to develop. It captures the imagination of most everyone that hears about it or walks through it.

If you need to see your food crops in straight lines and well protected from the competition of other plants, you probably won't readily understand or appreciate the Edible Forest Garden. There is going to be a lot of competition, likely too much for some crops. But the garden is an experiment. Not a traditional replicated and statistically valid experiment. It is however an experiment that hopefully will nurture more questions than it answers. What happens when the soil is not regularly tilled? Can apples or peaches on dwarfing root stocks produce fruit in this environment? Will the predators and the "pests" stay in balance? The SOF EFG is a chance to put many different ideas together and to see what happens over time.

Jay Tomczak came to the SOF as an undergraduate in Fisheries and Wildlife Management and equally importantly as one of many students in the RISE specialization (Residential Initiative for Study of the Environment). While knowledgeable and mostly self taught about survival skills, wild edible plants, and "peak oil" issues, Jay had not yet experienced much horticulture or permaculture. During his time at the SOF, his highly motivated self learning style, together with mentoring from Laurie, Michelle, Emily, Jeremy and Corie, he worked to understand the Student Organic Farm and help manage it. He also quickly became a wealth of information about permaculture and edible forest gardening. Through his effort, Mark Sheppard and David Jacke came to the SOF and became his mentors. He is now regarded as one of the key permaculture resource people in Michigan.

One of the goals of the SOF is to invite people to think more about the food they eat and the farmers who grow it. Another is to foster diversity. Jay has helped create a space that will serve those functions for many years to come. Enjoy his summary of edible forest gardening and the story of how it happened at the MSU-SOF.

John Biernbaum, Professor of Horticulture and SOF Co-Advisor July 2007

Introduction

This project began as more than just a Horticulture Masters of Science thesis project. In my earliest memories as a child I had a devoted interest in edible native plant species which was strongly encouraged by my parents. While many youth my age were focused on athletic pursuits, I began intensively studying the indigenous skills of hunter-gatherers and dreamed of being able to cut the umbilical cord of society and live free in my native ecosystem.

While studying Fisheries and Wildlife Management at Michigan State University I became interested in local and global community food security. I came to the realization that I was part of an ecological community that is in danger of becoming vanquished by improper earth stewardship and that humanity is a vital part of that community. Recognizing that with 6.6 billion people in the world we could not all be hunter-gatherers nor would that be desirable, I began a very personal search for humanity's ecologically sustainable niche within the biosphere. While working with an anthropologist named Kevin Finney I learned about the polyculture practices of indigenous peoples and felt that the answers lay somewhere within the realm of a sustainable agriculture.

It was near the end of my undergraduate studies that I joined the MSU Student Organic Farm (SOF) and instantly felt affirmation. Despite all of humanity's technological advances and disconnect from the earth, we are still an “agrarian” society completely dependent on agriculture. While working and studying with John Biernbaum and the SOF I began graduate studies focused on permaculture. It seemed like the perfect balance. Permaculture is based on the premise that a stable, sustainable culture cannot exist without an integrated relationship with a system of sustainable agriculture. “We are not working with nature, we *are* nature working.” This realization has become a guiding force on my path. The MSU Edible Forest Garden is the culmination of my last three years of studies and searching.

The report that follows is intended as a resource for students at the Student Organic Farm, for students at other college and university based food system projects, and for farmers and urban gardeners interested in pursuing permaculture and the edible forest garden as either a commercial production or personal use food production method. While the Section 1 Review of Literature provides the background information in agroecology and permaculture, it does not include information about two key factors that provide a motivation for the edible forest garden. Over the last three years I spent great effort learning about the issues of food security and fossil fuel depletion. Before addressing the edible forest garden, I would like to briefly address these very important motivations.

Food Security. For me, developing an understanding of permaculture started with attempting to understand the state of food security and the limiting factors regulating the current food system. All species on earth require energy (e.g. solar) and resources (e.g. renewable and non-renewable) to exist and thrive and it is the supply of vital limiting resources that regulate population growth.

The threat of hunger has been a persistent problem for humanity, and today with great surpluses of food being produced globally, it is the restricted access to this food that plagues many poor communities (Caraher *et al* 1998). More recently, some of the most well fed members of our society are waking up to the vulnerabilities of their fossil fuel dependent meals and realizing that they too, may soon face the realities of a food insecure world (Genauer 2006). After the inadequacy of the industrial food system in achieving food security amidst agricultural abundance, many community decision makers and informed citizens are realizing that a new holistic approach to food security must be implemented (Allen 1999). Giving people food does not make a food secure community. Creating appropriate social networks and empowering people economically is what makes a community food secure (Delind 1994, Wekerle 2004).

The modern industrial food system converts cheap, abundant fossil fuel energy into agricultural commodities (e.g. corn and soy). These commodities must then be heavily processed or converted into animal food products and distributed throughout the global market before eventually being consumed by people. This industrialized food system has traditionally focused on producing as much food as possible, as cheaply as possible (Pollen 2006). Under traditional economic doctrine it is believed that if massive amounts of cheap food are produced, hunger will disappear. Access to and consumption of this food has been dealt with as a separate issue (Allen 1999). Because this system inadequately provides access to nutritious food for low income communities, emergency food programs based on the charity model, such as food banks, soup kitchens, food stamps and Women Infant and Children programs (WIC) have proliferated. These charitable food organizations are essential for responding to actual short term food emergencies. This system is inadequate because these organizations (mainly private) are depended on to supply the long term food needs of people in chronic poverty. Demand for this emergency food has continued to grow rapidly since the 1980's. This rise in demand for emergency food programs is attributed to the impact of large federal cutbacks in food assistance programs and the assault on the welfare state by the Reagan and Bush administrations (Poppendieck 1994). These programs do not adequately provide food security, because the clients have no legal, enforceable rights to the food being provided, it is heavily dependent on volunteers and donations, there is no mechanism for determining the location and availability of such programs and the availability of quality food is very unreliable. Often, the disproportional ability of minority groups to access food is not appropriately addressed. These programs are being perpetuated due to the undermining of the welfare state (i.e. Society has become accustomed to discretionary giving as an acceptable way to combat hunger) and the diverting of energy of food advocacy organizations away from more considerable advances in combating hunger and poverty (Poppendieck 1994).

The community food security and food justice movements are developing in response to the insensibility of perpetuating emergency food programs that are responding to a never ending emergency (Poppendieck 1994). This justice model is developing as a social movement that is relocalizing food systems and disconnecting them from corporate control (Wekerle 2004). This is being done buy addressing the issues from a holistic perspective on multiple scales. Advocates are paying greater attention to regulations and policies at the federal and state level as well as the local ordinances. Food security is being re-framed as part of a democratic and just society. Grassroots organizations are working together with communities to reconnect them mentally, physically and politically with their food system and their food culture. These movements are focusing on civil society as a space for organizing policy and practices (Delind 1994, Wekerle 2004). Some important elements are programs that allow:

- Low-income family's access to fresh, quality food (e.g. project fresh)
- Rezoning neighborhoods for community gardens which provide space for food procurement and social networking around food culture
- Facilitating the creation of new farmers markets
- Connecting communities with small farmers and CSA's (community supported agriculture)

Placing food procurement and the sharing of local resources at the center of community life builds and empowers communities. This will not replace emergency food programs, but rather allow them to be used for emergencies, not long term food procurement. This frees up the energy of many food advocacy organizations to work toward a more sustainable food system (Delind 1994).

The principles of the permaculture philosophy can be used as a framework for developing social, economic and ecological sustainability in a food insecure community. From its conception, permaculture has had a strong emphasis on developing relationships between communities and agriculture for the purpose of creating a stable, secure, localized food system. Permaculture systems seek to amend the vulnerability and destructiveness of the modern industrial food system (Holmgren 2002). Permaculture food systems make efficient use of energy, labor and material resources and maximize synergistic relationships and yield. Establishing increased food security in a community requires a holistic approach. A food system can not be sustained in isolation and needs to be integrated with a network of social, economic and environmentally sustainable practices.

Fossil Fuel Dependence. Aside from issues of food access affecting low income communities, some food system vulnerabilities that affect food security for global society are fossil fuel dependences. The major limiting resources regulating the current food system are non-renewable fossil fuels which will soon become increasingly scarce and expensive. This dependence is a threat to food security and future food supply. For most of the last 10,000 years, agriculture has had balanced energy and nutrient cycles, which appropriated the solar energy harnessed by photosynthesis (Chancellor and Goss 1976, Smil 1991). Taking advantage of cultural practices such as crop rotations, green manures and draft animals allowed for humanity to live within the regenerative capacity of the biosphere (Bender 2001, Wackernagel *et al* 2002). The current food system can be viewed as a system that converts non-renewable fossil fuel energy into food (Heller and Keoleian 2000, Pimentel and Giampletro 1994). Currently about 10 to 15 calories of fossil fuel energy are used to create 1 calorie of food and although it only uses about 17% of the U.S. annual energy budget it is the single largest consumer of petroleum products when compared to any other industry. It requires about 1,500 liters of oil equivalents to feed each American per year (Hendrickson 1996). As long as the energy resources are cheap and abundant the inefficiencies are unimportant, however *dependence on* finite resources is quite a vulnerability when those resources become scarce (Gever *et al* 1991).

The U.S. food system has had three main periods of change which have brought it to the current condition of fossil fuel dependence (Gever *et al* 1991). The first was the *expansionist* period occurring between around 1900 and 1920. In this period, increases in food production were a factor of putting more land into production, with no real breakthroughs in technology. The second was the *intensification* period, also called the "green revolution" which occurred between around 1920 and 1970. In this period technological advances allowed for the exploitation of cheap abundant fossil fuel energy resulting in a seven fold increase in productivity (output per worker hour). Farm machinery, pesticides, herbicides, irrigation, new hybrid crops and synthetic fertilizers allowed for the doubling and tripling of crop production and the corresponding growth of the human population (Gever *et al* 1991, Ruttan 1999). We are currently in the *saturation* period of agriculture characterized by greater amounts of energy required to produce smaller increases in crop yield (i.e. the ratio of crop output to energy input is diminishing). An ever growing amount of energy is expended just to maintain the productivity of the current system; for example about 10% of the energy in agriculture is used just to offset the negative effects of soil erosion and increasing amounts of pesticides must be sprayed each year as pests develop resistance to them (Gever *et al* 1991, Pimentel and Giampletro 1994).

Aside from being dependent on non-renewable resources, agriculture is also rapidly diminishing the ability of vital "renewable" resources to regenerate (Pimentel and Giampletro 1994, Wackernagel *et al* 2002). Of these resources water and topsoil (humus) are most limiting. Water scarcity associated with agriculture is typically a regional issue. In the western U.S. the Colorado River has had so much water diverted from it that it no longer reaches the ocean and the great Ogallala aquifer is being overdrawn at 130 to 160% its recharge rate (Pimentel and Giampletro 1994). Other problems are the vast amount of pollution associated with agricultural runoff, which degrade aquatic ecosystems and create dead zones in the ocean (Matthews and Hammond 1999).

Approximately 90% of U.S. agricultural lands are losing topsoil above sustainable rates (1t/ha/yr) due to erosion and the application of synthetic fertilizers actively promotes soil degradation (Gever *et al* 1991, Pimentel and Giampletro 1994). Other considerations are the loss of biodiversity due to clearing land for large monocrops as well as agricultures contribution to global climate change by way of its CO2 and methane by products (Pirog *et al* 2001, Wackernagel *et al* 2002).

The food system is currently dependent on fossil fuels for powering irrigation pumps, petroleum based pesticides and herbicides, mechanization for both crop production and food processing, fertilizer production, maintenance of animal operations, crop storage and drying and for the transportation of farm inputs and outputs. Of these fossil fuel dependences, some are more easily overcome than others (Ruttan 1999). It has been estimated that 95% of all food products require the use of oil at some point in the production process. For example, just to farm a single cow and deliver it to market requires the equivalent of 6 barrels of oil (Lucas *et al* 2006). Due to their current necessity, dependence on synthetic nitrogen fertilizer and the long distance transport of farm inputs and outputs are two outlying limiting factors that exemplify the vulnerability of the current food system and therefore require further analysis (Smil 1991, Pirog *et al* 2001).

In terms of its necessity for the existence of a large portion of the global population, the most important invention of the 20th century is the Haber-Bosch process for the synthesis of nitrogen fertilizer. Nitrogen accounts for 80% of volume of atmospheric gas but it is in a non-reactive form that is not readily available to plants, making it the main limiting factor for global crop production and human growth. It is a vital component of chlorophyll, amino acids, nucleic acids, proteins and enzymes. Synthetic N is responsible for raising crop yields approximately 35 to 50% over the last half century accounting for 80% of the increase in cereal crops, without which much of the population would not exist (Smil 1991).

For most of human existence N fixation (i.e. the splitting of N_2 to form Ammonia) was limited to bacteria (primarily *Rhizobium).* With the invention of the Haber-Bosch process in 1913 humans began domination of the N cycle (Smil 1991). This process is extremely energy intensive requiring the reaction of 1 mole of nitrogen gas with 3 moles of hydrogen gas under temperatures of approximately 400°C and pressures of approximately 200 atmospheres (Marx 1974). This accounts for 30% of the energy expenditures in agriculture. The hydrogen gas for this process comes almost exclusively from natural gas which is considered as a feedstock and not factored in as part of the energy expenditure (Hendrickson 1996). It is also possible to get the required hydrogen from the electrolysis of water but this requires more energy, making it an unfavorable alternative at this time (Gilland 1983). Natural gas currently accounts for 90% of the monetary cost of N fertilizer (Wenzel 2004).

Other obstacles associated with N fertilizer are production capacity, transport, storage, application and N saturation. Crops only absorb about half of the nitrogen they are exposed to, much of the rest runs off the fields with water flow, saturating the environment and polluting aquatic ecosystems (Matthews and Hammond 1999, Smil 1991). Between 1950 and 1989 fertilizer use increased by a factor of 10 and it has since had continued growth. In developed nations much of that use produces animal feed which is converted into more animal product consumption. However, in lesser developed parts of the world such as Asia which currently accounts for 50% of fertilizer use, crop yield for direct human consumption has been increased (Matthews and Hammond 1999). In many developing countries access to fertilizer and proper application are still often a limit to crop production (Hardy and Havelka 1975).

Although synthetic nitrogen fertilizer and its dependence on natural gas is a major limiting factor of the industrialized food system, perhaps the greatest vulnerability is the dependence on the transportation system for farm inputs and outputs; for example fertilizer is of little value if it can not be effectively delivered to where it is needed (Hardy and Havelka 1975, Heller and Keoleian 2000, Pirog et al 2001). In the U.S. long distance food transportation is often a luxury, providing us with "fresh" produce and seafood from exotic places at any time of year (Gever *et al* 1991). The mean distance U.S. food travels is now estimated at 1,546 miles but this distance varies greatly depending on the food item (Pirog et al 2001). One of the primary reasons for this, is that 90% of the fresh vegetables consumed in the U.S. are grown in the San Juaquin Valley, California (Heller and Keoleian 2000).

Although the transport of food uses a relatively small amount of the U.S. energy budget, it is important to realize that it is a vulnerability for food security (i.e. many communities do not have the infrastructure to produce even non-luxury food items). Currently 6 to 12% of the food dollar is spent to account for transportation costs, however U.S. tax dollars heavily subsidize highway maintenance and the oil industry so the true cost is much greater (Hendrickson 1996). Considering the importance of long distance transportation to our food supply, the cost of food and the security of our food supply is very dependent on the cost and availability of oil (Gever *et al* 1991, Lucas et al 2006).

Fossil Fuel Depletion. The fossil fuels which are most important to the food system are oil and natural gas. Both of these are finite resources and therefore began being depleted the moment humans started using them. When graphed over time, production (synonymous with extraction) of these resources follows a bell shaped curve. The high quality easily produced (cheap) resource is produced first (on the up slope), followed by a peak or plateau in production, then the progressively harder to extract lower quality (expensive) resource is produced on the down slope of the curve (Bently 2002, Campbell 2004, Gever *et al* 1991). When peak production occurs we know that roughly half of the resource remains, however much of it will never be produced because it becomes to energy intensive (expensive) to do so (i.e. it takes increasingly more energy to produce increasingly less energy and when that ratio (energy profit ratio) reaches 1, it is no longer an energy source, it is an energy sink). This model for resource depletion is what is known as Hubberts peak (Gever *et al* 1991). The production of all conventional hydrocarbons will soon begin to decline and supply shortages will be inevitable (Bentley 2002, Campbell 2004).

Global natural gas reserves are difficult to assess relative to that of oil due to lack of reliable data, however we do know that the majority of gas left to extract is in the middle east and Russia (Bentley 2002). Global gas reserves are also somewhat less of a viable supply than regional reserves because of the cost and limited capacity to transport gas by ship. To transport gas over the ocean it must first be liquefied and shipped in tankers designed especially for this purpose, and then brought to regasification facilities of which there is limited capacity. All of these steps lower the energy profit ratio. All of the worlds 156 gas tankers are currently under long term contract. World ship building capacity is 20 ships/year and the U.S. has ordered 18 ships for delivery by 2008 (Duffin 2004).

Understanding the regional gas supply is important because gas is most easily transported by pipeline. U.S. gas production peaked in 1973 and production has remained relatively constant for the last two decades (Paris 2004). More recently new wells have been progressively smaller and now average 56% depletion in the first year. Over the last few years drilling has increased while production has declined. The demand for gas is projected to increase 50% by 2020 and the U.S. known reserves are expected to last less than 8 years (Duffin 2004). Global natural gas production is expected to peak within the next 20 years and with a 2% decline in North American gas production, supply is expected to fall short of projected demand by around 2008 (Bentley 2002, Duffin 2004).

U.S. oil production peaked in 1971, however unlike natural gas, oil is more easily transported, which makes understanding global production important (Bentley 2002). The peak of onventional global oil production is expected to occur sometime this decade and many experts believe we may have already reached a production plateau (Bentley 2002, Gever *et al* 1991, Pirog et al 2001). Part of how peak oil production is estimated is by knowing the peak of oil discovery, since more oil can not be produced than is discovered (Ivanhoe 1997).

Global oil discoveries peaked back in 1962 and have declined steadily ever since (Bentley 2002). We now consume approximately 5 barrels of oil for every new barrel discovered each year, using increasingly more of our reserves from past discoveries (Ivanhoe 1997). The trend that is perhaps most discouraging is the dramatic drop and progressive decline in the energy profit ratio since the 1970's (Gever *et al* 1991). Demand for oil is growing at 2-3% per year, while production is declining at an average of 4-6% per year (Lucas *et al* 2006). These trends indicate that if we continue on our current consumption path we will soon experience fossil fuel supply shortages.

It is time that we leave behind the saturation period of agriculture and develop a new more efficient and ecologically sustainable food system. Permaculture provides a potential framework for developing this food system.

This publication has been organized and prepared with the intent of providing a valuable resource for the continued development and implementation of the SOF EFG as well as for future farmers and urban gardeners seeking to apply the concepts of temperate edible forest garden permaculture. There is still so much to learn, but following is a short summary of several years effort. Please refer to the Table of Contents for a summary of the topics and organization.

I want to thank my parents and all those wonderful souls that helped guide me during those pivotal junctions of this path.

namaste

Jay Tomczak
July, 2007

Introduction Literature Cited

Allen, P. 1999. Reweaving the food security safety net: mediating entitlement and entrepreneurship. Agriculture and Human Values. 16:117-129.

Bender, M. 2001. Energy in agriculture and society: insights from sunshine farm. The Land Institute. http://www.landinstitute.org/vnews/display.v/ART/2001/03/28/3accb0712

Bentley, R.W. 2002. Global oil and gas depletion: an overview. Energy Policy. 30:189-205.

Campbell, C.J. 2004. Oil and gas production profiles. Association for the Study of Peak Oil and Gas. http://www.aspo-global.org

Caraher, M. et al. 1998. Access to healthy foods: part I. Barriors to accessing healthy foods: differentials by gender, social class, income and mode of transport. Health Education Journal. 57:191-201.

Chancellor, W.J. and J.R. Gross. 1976. Balancing energy and food production, 1975- 2000. Science, New Series. 192:213-218.

Delind, L.B. 1994. Celebrating hunger in Michigan: a critique of an emergency food program and an alternative for the future. Agriculture and Human Values. 11:58-68.

Duffin, M. 2004. The energy challenge 2004: natural gas. Energy Pulse. http://www.energypulse.net/centers/article/article_display.cfm?a_id=828

Genauer, E. 2006. Peak oil and community food security. Communities: Journal of Cooperative Living. Issue 130.

Gever, J., et al. 1991. Beyond oil: the threat to food and fuel in the coming decades, third edition. University Press Colorado. Denver. p.351

Gilland, B. 1983. Considerations on world population and food supply. Population and Development Review. 9:203-211.

Hardy, R.W.F. and U.D. Havelka.1975. Nitrogen fixation research: a key to world food? Science. 188:633-643.

Heller, M.C. and G. A. Keoleian. 2000. Life cycle-based sustainability indicators for assessment of the U.S. food system. Center for Sustainable Systems: University of Michigan. Report No. CSS00-04.

Hendrickson, J. 1996. Energy use in the U.S. food system: a summary of existing research and analysis. Center for Integrated Agricultural Systems, UW-Madison. http://www.cias.wisc.edu/pdf/energyuse2.pdf

Holmgren, D. 2002. Permaculture: principles and pathways beyond sustainability. Holmgren Design Services. Victoria. p.286.

Ivanhoe, L.F. 1997. Get ready for another oil shock. The Futurist. http://www.allbusiness.com/professional-scientific/scientific-research/601959-1.html

Lucas, C., A, Jones and C. Hines. 2006. Fueling a food crisis: the impact of peak oil on food security. The Greens, European Free Alliance in the European Parliament. http://www.carolinelucasmep.org.uk/news/PeakOilFood_191206.htm

Marx, J.L. 1974. Nitrogen fixation: research efforts intensify. Science. 185:132-136.

Matthews, E. and A. Hammond. 1999. Critical consumption trends and implications degrading earths ecosystems. World Resources Institute. http://business.wri.org/pubs_description.cfm?PubID=2997

Paris, J. 2005. Natural gas depletion and what it will mean this winter. Daily Kos. http://www.dailykos.com/

Pimentel, D. and M. Giampletro. 1994. Food, land, population and the U.S. economy. Carrying Capacity Network. http://dieoff.org/page55.htm

Pirog, R., et al. 2001. Food, fuel, and freeways: an Iowa perspective on how far food travels, fuel usage, and greenhouse gas emissions. Leopold Center. http://www.leopold.iastate.edu/pubs/staff/ppp/index.htm

Pollen, M. 2006. The Omnivores dilemma: a natural history of four meals. The Penguin Press. New York. p. 464.

Poppendieck, J. 1994. Dilemmas of emergency food: a guide for the perplexed. Agriculture and Human Values. 11:69-76.

Ruttan, V.W. 1999. The transition to agricultural sustainability. Proceedings from the National Academy of Sciences of the U.S.A. 96:5960-5967.

Smil, V. 1991. Population growth and nitrogen: an exploration of a critical existential link. Population and Development Review. 17:569-601.

Wackernagel, M., et al. 2002. Tracking the ecological overshoot of the human economy. Proceedings of the National Academy of Sciences of the U.S.A. 99:9266-9271.

Wekerle, G.R. 2004. Food justice movements: policy, planning, and networks. Journal of Planning Education and Research. 23:378-386.

Wenzel, W. 2004. U.S. farm bureau sounds alarm on natural gas. Farm Industry News. http://farmindustrynews.com/news/Farm-Bureau-natural-gas-092204/

Section 1
Background Information and Literature Review

Introduction

The Michigan State University Student Organic Farm Edible Forest Garden (MSU EFG) project is based on the literature and practices of agroforestry and permaculture. The garden is an *integrated perennial polyculture* system that incorporates perennial and annual plants for agricultural production. The term *polyculture* refers to the practice of growing a number of crop species on the same land at the same time. The term *perennial* refers to a plant species which lives for more than two years (Whitefield 2004). The term *integrated* refers to the varied combination of factors and relationships that make up such systems. The objective of this literature review is to provide background information on the disciplines of agroforestry and permaculture and detail about the horticultural principles of these disciplines applied to the MSU EFG.

Agroforestry

Agroforestry is a multiple land use strategy, which as a system attempts to overcome social and environmental problems (Budd et al 1990). It requires two or more crops (at least one being a tree), has two or more outputs and has a production cycle of more than one year (Elevitch and Wilkinson 2001). Besides providing useful products for people, many of the practices restore degraded lands, make more efficient use of natural resources, are culturally compatible, more economically profitable and enhance long term ecological sustainability, when compared with conventional monoculture systems (Elevitch and Wilkinson 2001, Sanchez *et al* 1997, Singh *et al* 1995). Some agroforestry systems focus on producing outputs (e.g. food), while others focus more on reducing inputs (e.g. fertilizer) (Elevitch and Wilkinson 2001). They tend to follow a continuum of low intensity management (often larger scale) with fewer outputs such as *forest farming* and *buffer strips*, to mid-scale management intensity (often mechanized) such as *alley cropping* and *silvopasture*, to higher intensity management systems such as *homegardens* (often smaller scale) which have high diversity and outputs. These are generalizations and it is common for multiple methods to be integrated on the same parcel of land (Elevitch and Wilkinson 2001, Nautiyal *et al* 1998, Sharashkin *et al* 2005). Tree based agriculture has been practiced for hundreds and in some places thousands of years (Alavalpati and Mercer 2004, Elevitch and Wilkinson 2001). Indigenous peoples have traditionally practiced agroforestry techniques in almost any region on earth where trees can grow, from India to Russia to the Amazon (Miller and Nair 2006, Nautiyal *et al* 1998, Sharashkin *et al* 2005). The current modern understanding of agroforestry practices and the state of agroforesty today are a culmination, continuation and modification of past indigenous knowledge.

Tropical Agroforestry. Tropical agroforestry is diverse and can be extremely complex (Thevadthasan and Gordon 2004). It is a holistic approach to tropical land management that has had great contributions to food production and is making strides to help save the rainforests. In tropical systems agroforestry is as important to forest preservation as it is to agriculture and it is no longer appropriate to think of the two as separate (Combe 1982, Von Maydell 1991). Sustainable agroforestry practices are the best protection against deforestation in tropical systems because they provide for the economic needs of the people while maintaining much of the integrity of the indigenous forests (Combe 1982).

Anthropological studies in South America indicate that Amazonian cultures practiced pre-colonial agroforestry techniques such as the deliberate cultivation and domestication of fruit trees and the management of wild species to provide fruits, oils, resins, essences and many other useful products (Miller and Nair 2006). Because of the tremendous biodiversity of the Amazon, researchers are currently working with these indigenous farmers to develop and understand these complex systems. So far work has been focused on species in homegardens and swidden-fallow systems (Miller and Nair 2006).

In tropical regions integrated multistory fruit trees are planted in plantation-crop combinations to grow crops such as coffee, cacao and rubber (Alavalapati and Mercer 2004). Alley cropping is often done with woody leguminous species used for crop manures and animal fodder (Alavalapati and Mercer 2004). Multistory homegardens are typically intensively planted combinations of mixed trees and other crops. These homestead gardens are among the oldest and most diversified form of agroforestry (Elevitch and Wilkinson 2001, Miller and Nair 2006).

Alavalapati and Nair (2001) classify Tropical Agroforestry Systems as follows:

- Taungya – Agricultural crops grown during the early stages of forest plantation establishment.
- Homegardens – Intimate, multistory combinations of a variety of trees and crops in homestead gardens; livestock may be present.
- Improved fallow – Fast-growing, preferably leguminous woody species planted during the fallow phase of shifting cultivation; the woody species improve soil fertility and may yield economic products.
- Multipurpose trees – Fruit and other trees randomly or systematically planted in cropland or pasture for the purpose of providing fruit, fuel wood, fodder, and timber, among other services, on farms and rangelands.
- Plantation-crop combinations – Integrated multistory mixtures of tree crops (e.g. coffee, cacao, coconut, and rubber), shade trees, and/or herbaceous crops.
- Silvopasture – Combining trees with forage and livestock production, such as grazing in existing forests; using trees to create live fences around pasture; or to provide shade and erosion control.
- Shelterbelts and windbreaks – Rows of trees around farms and fields planted and managed as part of crop or livestock operations to protect crops, animals, and soil from natural hazards including wind, excessive rain, seawater or floods.
- Alley cropping – Fast-growing, preferably leguminous woody species in single or grouped rows in agricultural fields. Prunings from the woody species are applied as mulch into the agricultural production alleys to increase organic matter and nutrients and/or are removed from the field for animal fodder.

Temperate Agroforestry. Temperate agroforestry systems are generally less diversified than agroforestry of tropical climates. Its modern form started to gain significant interest in the early seventies due to concerns of fossil fuel shortages (Gold and Hanover 1987, Thevathasan and Gordon 2004, Williams and Gordon 1992). Agroforestry is being practiced in temperate climates across the earth. In the temperate climate of Garhwal Himalaya in India, indigenous peoples traditionally maintained agroforestry systems by selective protection and natural regeneration (Nautiyal *et al* 1998). The traditional peasant agricultural system of Russia has shaped the more modern agroforestry movements such as the *Ringing Cedars* movement which focuses on the economic, environmental and spiritual role of trees (Sharashkin *et al* 2005). In North America the traditional forest management practices of indigenous peoples have largely disappeared but are influencing a resurgence of modern agroforestry practices (Lassoie and Buck 1999).

Alley cropping is a more modern adaptation of agroforestry principles in temperate climates commonly done on larger scales, often with the use of mechanization. Alley cropping is the planting of useful tree species in single or grouped rows with another crop planted between the rows (Alavalapati and Mercer 2004). In Ontario, Canada intercropping in row fruit and nut orchards is done to increase profitability in non-bearing orchard years. These orchards are planted like conventional orchard systems with row spacing appropriate for tractors. Once the orchard begins bearing at a profitable level (6-10 years) the intercropping ceases and conventional orchard management begins. The crops planted in these non-bearing years are diverse and include, strawberries, pumpkins, potatoes, cut flowers, landscape plants and many more (Leuty 2001).

Another example of temperate agroforestry can be seen at New Forest Farm in Wisconsin (USA) where alley cropping and plantation-crop combinations are used to create a system that mimics the successional brushland native to that region (Figure 1.1). This system has a diverse planting of fruits and nuts of both trees and shrubs with annual crops planted within alleys during some years for increased profitability (Shepard 2005). This system can be used on a large scale to produce commodity crops conducive to mechanization while mitigating the effects of deforestation and soil erosion (Shepard 2003). There is currently research being done to evaluate these types of multilayered polyculture systems at Ohio State University. These trials are being used to evaluate the efficiency, economics and pest density in such systems for peri-urban polyculture gardens in temperate regions (Kovach 2005).

Figure 1.1 Early successional chestnut/hazelnut polyculture at New Forest Farm in Wisconsin with monoculture corn in the background (summer 2005).

The Association for Temperate Agroforestry (1997) classifies Temperate Agroforestry Systems as follows:

- Alley cropping – Trees planted in single or grouped rows within agricultural or horticultural fields with crops grown in the wide alleys between the tree rows.
- Forest farming- Forested areas used for the production or harvest of natural standing specialty crops for medicinal, ornamental, or culinary uses (e.g. ginseng, ferns, shiitake mushrooms).
- Shelterbelts and windbreaks – Rows of trees around farms and fields planted and managed as part of crop or livestock operations to protect crops, animals, and soil from natural hazards including wind, excessive rain, seawater or floods.
- Riparian buffer strips – Strips of perennial vegetation (trees/shrubs/grass) planted between cropland/pastures and water sources such as streams, lakes, wetlands, and ponds to protect water quality.
- Silvopasture – Combining trees with forage and livestock production, such as growing trees on ranchlands; grazing in existing forests; providing shade and erosion control or environmental services.

Permaculture

The term permaculture is less well known than the term agroforestry and is often used synonymously with the term agroforestry. The two terms are not mutually exclusive and can sometimes be used to describe the same system. The main difference is that permaculture is a philosophy that acts within a specific set of ethics incorporating all aspects of the human experience, going well beyond just agricultural production (Holmgren 2002). Permaculture was developed in the early 1970's by Australian ecologists Bill Mollison and David Holmgren as a positive response to the energy crisis of the time and to ensuing environmental degradation and resource depletion. Permaculture was founded on the following assumptions: 1) the environmental crisis is real and of a magnitude that will transform industrial society and threaten its existence, 2) humans are subject to the same natural laws that govern the rest of the universe, 3) the industrial era and corresponding population explosion were made possible by exploiting cheap abundant fossil fuel energy, 4) this energy is a finite resource which will eventually become depleted returning human society to patterns found in nature and pre-industrial societies (Holmgren 2002). The term itself, is derived from the words **perm**anent, agri**culture** and **culture**. It comes from the principle that a stable, sustainable culture cannot exist without an integrated relationship with a system of sustainable agriculture (Holmgren 2002, Whitefield 2004). From its conception, permaculture has had a strong emphasis on developing relationships between communities and agriculture for the purpose of creating a stable, secure, localized food system. Permaculture systems seek to amend the vulnerability and destructiveness of the modern industrial food system which is heavily dependent on massive amounts of fossil fuel inputs (e.g. petroleum based pesticides and herbicides, fertilizer production and transportation) (Gever *et al* 1991, Holmgren 2002). Permaculture food systems make efficient use of energy, labor and material resources and maximize synergistic relationships and yield. Along with this food system focus and partly because of it, the other principles of permaculture developed to facilitate the creation of sustainable communities.

Part of the success of the permaculture movement has been its ability to evolve and adapt to various locations over time without the support of large institutions (Holmgren 2002). The permaculture movement began spreading out globally from the Australian roots with the development of the standard permaculture designers training course, first taught in 1981 and the subsequent publications of permaculture texts. Since this time thousands of people globally have taken the course and millions of people have been affected by the influence of permaculture (Holmgren 2002, Mollison 1988). The movement started out primarily in warmer climates similar to that of Australia where polyculture garden practices were already established and where developing nations needed such practices the most. The practices and knowledge then began to spread in cooler climates, such as Northern Europe (mainly Britain) and North America. Temperate climate permaculture texts have since had increased publication (Genauer 2006, Hemenway 2000, Whitefield 2004). More recently in the United States, a growing network of people with knowledge of permaculture has elevated the exposure of the concept to a larger audience. Permaculture organizations (often called guilds) in the U.S. are growing in number (mainly near urban centers) and disseminating knowledge and information (Genauer 2006). Spurred on by a critical mass of permaculture educated individuals and the publication of David Holmgren's work, "Permaculture: principles and pathways beyond sustainability," (2002) the stage is now set for a resurgence of the permaculture concept to a new audience of activists and sustainable development advocates. It is the maturation of the permaculture movement and new wave of environmentalism that is enabling this current resurgence in permaculture (Genauer 2006, Holmgren 2002).

Permaculture Ethics and Design Principles. Permaculture is a philosophy, a practice and a social movement, based on the ethics of a) care for the earth, b) care for people and c) setting limits to consumption. Care for the earth implies that all of the life systems on the planet are respected and provision is made for them to thrive. Central to this is proper stewardship and care for the soil. Care for people implies that all people are treated with respect and provision is made for them to have the resources needed to exist with integrity. This starts with accepting personal responsibility for ourselves in our situation and expands outward to our family, friends, community and future generations. Setting limits to consumption is about governing our own needs so that a surplus can be shared and distributed in order to care for the earth as well as people. In permaculture there is no separation between humans and nature, therefore caring for the earth also fulfills the objective of caring for people (Holmgren 2002, Mollison 1988). These ethics have been adopted from cooperative indigenous cultures in recognition that many of these cultures were able to survive for centuries in relative balance with their environment (Holmgren 2002). These ethics serve as the foundation for all the permaculture design principles (Shepard and Weiseman 2006).

David Holmgren (2002) captures the essence of permaculture as a practical and applicable philosophy with his descriptions of what he considers the 12 major permaculture design principles. Each of the principles has a corresponding phrase which is found in traditional popular culture, indicating that this wisdom is nothing new.

Permaculture design principles described by Holmgren (2002).

- **Observe and interact:** Beauty is in the eye of the beholder (i.e. systems thinking).
- **Catch and store energy:** Make hay while the sun shines.
- **Obtain a yield:** You can't work on an empty stomach.
- **Apply self-regulation and accept feedback:** The sins of the fathers are visited on the children unto the seventh generation.
- **Use and value renewable resources and services:** Let nature take its course.
- **Produce no waste:** Waste not, want not.
- **Design from patterns to details:** Can't see the wood for the trees.
- **Integrate rather than segregate:** Many hands make light work.
- **Use small and slow solutions:** The bigger they are, the harder they fall. Slow and steady wins the race.
- **Use and value diversity:** Don't put all your eggs in one basket.

- **Use edges and value the marginal:** Don't think you are on the right path just because it is well traveled.
- **Creatively use and respond to change:** Vision is not seeing things as they are but as they will be.

To apply these principles in the real world requires understanding them in the context of all the elements in the system that is being manipulated. These elements fall into the categories of, site components (e.g. water, earth, landscape, climate, organisms), energy components (e.g. technologies, structures, sources, connections), social components (e.g. legal aids, people, culture, trade and finance), and abstract components (e.g. timing, data, ethics) (Mollison 1988).

Perhaps the most commonly understood and applied design tools in permaculture are those of zone and sector analysis (i.e. Design from patterns to details) (Hemenway 2000, Holmgren 2002, Mollison 1988, Whitefield 2004). There are 6 zones in permaculture and the components of each can be applied at different scales, both physically and conceptually. For example, on a homestead scale, zone 0 would be the inside of the home, zone 1 intensively managed gardens and landscapes immediately surrounding the home, zone 2 less intensively managed orchards and ranging domestic livestock, zone 3 field crops, zone 4 very low management grazing and woodland, and zone 5 would be considered wilderness (Whitefield 2004). When applying this at a larger more conceptual scale, zone 0 is the permaculture design principles, zone 1 is personal and household, zone 2 is business and community, zone 3 is bioregional, zone 4 is national/continental and zone 5 is global . All of these elements are arranged for maximum energy efficiency. At least conceptually, these zones form concentric rings from 0 to 5, with increasing scale and distance and decreasing power of influence. Sectors are made up of external, ecological, cultural and economic forces and flows acting upon the zones. These forces and flows can be either beneficial or destructive (Holmgren 2002).

Permaculturalist Bart Anderson (2006) has redefined zone and sector analysis so that it can be more readily applied to urban communities. His system is based on zones of fossil fuel usage and transportation, zone 0 is the home, zone 1 is anything within walking distance (pedosphere), zone 2 is within cycling distance (cyclosphere), zone 3 reachable by public transit, zone 4 driving distance, zone 5 long distance, plane travel. Anderson's methods are perhaps the best way to apply a zone and sector analysis to a low income urban community for the purpose of defining the elements acting on the food system. Once the sector energies (e.g. influence of mega-corporations) acting upon the different zones are understood, it is necessary to define whether they are positive or negative. These energies must then be encouraged or discouraged, using shields, deflectors and collectors (Anderson 2006). For example, collecting positive energy might mean encouraging the development of a community garden and deflecting negative energy might mean having a zoning policy that prevents the invasion of a corporate chain store that uses unsustainable practices. A framework for an urban zone and sector analysis can be seen in Figure 1.2 (Anderson 2006).

Figure 1.2 Getting ideas from zones and sectors (Anderson 2006).

Permaculture systems are the result of using design methods to determine how to manipulate or influence the elements in the system based on the permaculture ethics and design principles. This is a constantly evolving process that can be applied to a myriad of circumstances and scales as depicted in the permaculture flower (Figure 1.3). The permaculture flower depicts how the ethics and principles can be used to weave beneficial relationships among the various domains of sustainable human culture. Around the outside of the flower are various systems associated with and consistent with the permaculture philosophy. In permaculture design, all things are connected and energy wasted in one area is a missed opportunity to use it in another area (e.g. fuel used inefficiently in transportation, is fuel that could have been used in agriculture). Permaculture design emphasizes a bottom-up approach to change (i.e. grassroots), it focuses on pre-industrial sustainable societies and natural systems as models and prioritizes existing pools of wealth as sources for restoring natural capitol (Holmgren 2002).

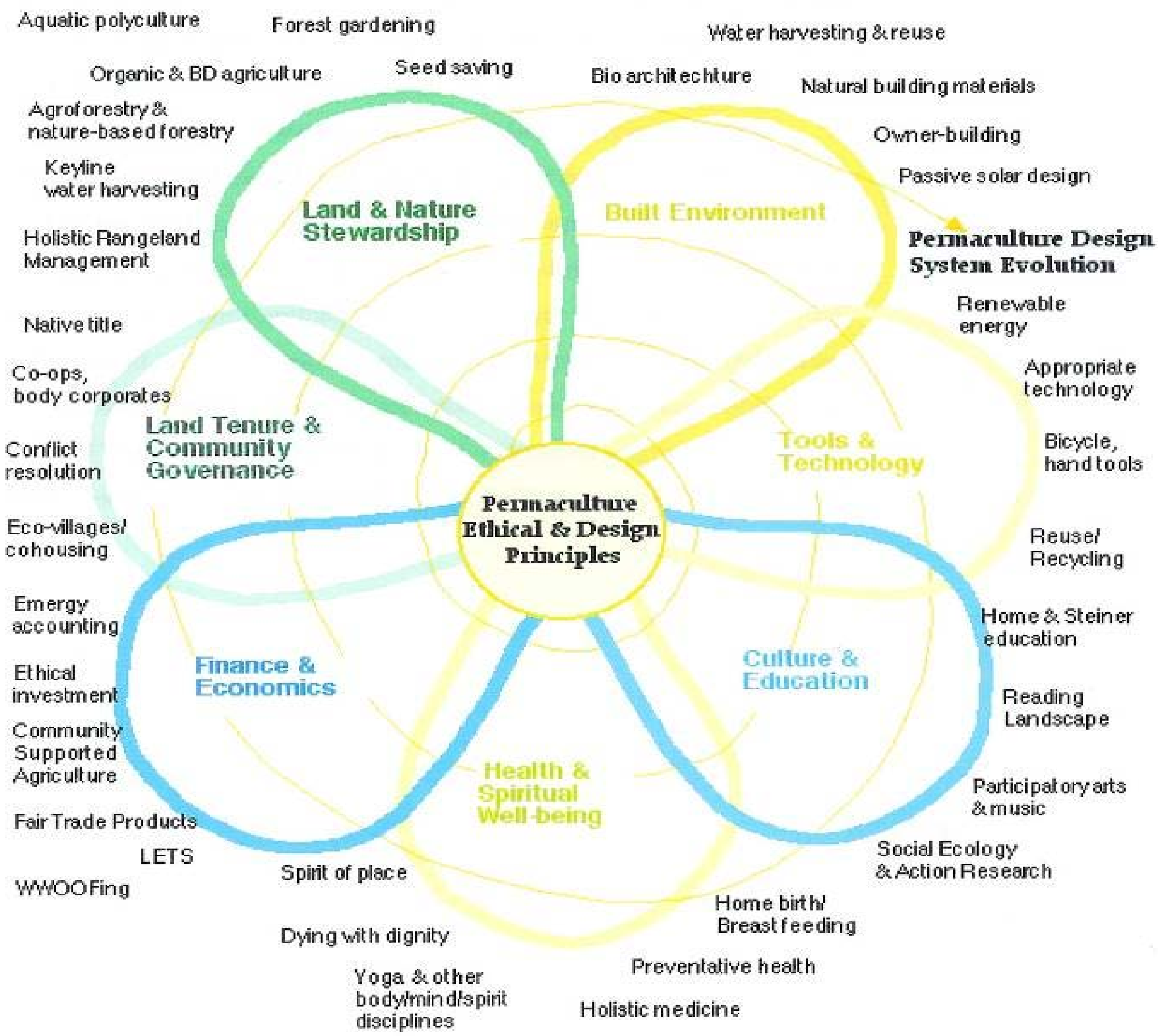


Figure 1.3 The permaculture flower (Holmgren 2002).

Although permaculture is more than a horticultural practice, the remaining focus is on the principles of permaculture that are most relevant to horticulture. The land and nature stewardship petal of the permaculture flower (Figure 1.3).

Edible Forest Gardens and Multistrata Homegardens

The MSU EFG is based on the framework of edible forest gardens and multistrata homegardens. Both of these systems are very similar, even though the terms come from different disciplines; permaculture and agroforestry respectively. These systems take ecosystem mimicry to the highest level and are some of the oldest forms of integrated perennial polyculture. To the untrained eye it can be difficult to distinguish these gardens from the surrounding native forest. Nair

(2001) said that understanding the complexity of these systems currently eludes conventional ecologists and economists. As a result, scientific studies of these systems are disproportionately lower than other agricultural systems when considering their social, ecological and economic benefits (Nair 2001).

The modern forms of agroforestry and permaculture were developed in the 1970's as a response to energy supply scares and environmental degradation, and both of these disciplines claim indigenous multistrata homegardens as a primary source of their inspiration (Holmgren 2002, Jacke and Toensmeier 2005, Shepard and Weiseman 2006, Wiersum 2004, Williams and Gordon 1992). Due to this common origin of thought the conceptual characteristics of multistrata homegardens and edible forest gardens are essentially the same. Multistrata home gardens are almost always associated with a home or group of homes. Edible forest gardens are often, but not always associated with a home. The terms mainly diverge due to the general geographic location of the systems being described. The term multistrata homegarden or homegarden is generally associated with tropical climates and the term edible forest garden or forest garden is generally associated with temperate climates. This can be viewed as somewhat of a convergent evolution of the concepts to adapt to both tropical and temperate climates. Although it is useful to try and describe multistrata homegardens and edible forest gardens for the purpose of providing background for this paper, it is important to recognize that there are many terms used across the globe to describe agricultural systems that mimic the structure and function of natural forest ecosystems and therefore we should not be inhibited by trying to categorize each term (DeClerck and Negreros-Castillo 2000, Nair 2001, Soemarwoto *et al* 1985).

Multistrata Homegardens. Multistrata homegardens (MH) are generally in moist tropical climates and have existed for centuries. These systems are usually found in developing countries where there is a shortage of land (Mergen 1987). These systems have been used in countries such as Java, Tanzania, West Africa, Thailand, Brazil, Papua New Guinea, Nepal, Chile, Mexico, India and Indonesia (DeClerck and Negreros-Castillo 2000, Kehlenbeck and Maass 2004, Mergen 1987, Nair and Sreedharan 1986).

MH are systems that incorporate many multipurpose trees, shrubs, food crops and often livestock on the same parcel of land at the same time. These MH often have an intimate association with a home (Mergen 1987, Nair and Sreedharan 1986). These systems mimic local ecosystems indigenous to the region and function to provide for human needs and protect native forests, reduce erosion and conserve biodiversity (DeClerck and Negreros-Castillo 2000, Kehlenbeck and Maass 2004, Mergen 1987). Because MH mimic natural systems, the structural integrity and ecosystem functions of a natural forest are preserved (Wiersum 2004). There is a large diversity of useful species grown in tropical MH such as; banana, cassava, coconut, citrus, pineapple, coffee, pepper, clove, cacao, plantains, yams, groundnuts, maize, pumpkins, sesame, rubber, eucalyptus, ginger, bamboo and taro (Mergen 1987). These plant species provide fruit, herbs, vegetables, medicines, mulch, animal fodder, fiber, ornamentals, fuel, building materials, and other food plants (Mergen 1987, Nair and Sreedharan 1986). MH are considered an ecologically sustainable production system (Kehlenbeck and Maass 2004).

Edible Forest Gardens. The edible forest garden (EFG) is essentially the temperate analog of the tropical MH. The EFG is a perennial polyculture of multipurpose species that mimic the structure and function of a natural forest ecosystem (Jacke and Toensmeier 2005). Unlike in tropical climates, these systems were not traditionally practiced on this scale of intensity and therefore intensive EFGs in temperate climates are a relatively new concept. In the past, traditional temperate homegardens were diverse but did not mimic natural ecosystems in the same way as was common in tropical regions (Williams and Gordon 1992). This is likely because many indigenous temperate cultures were more nomadic with seasonal village sites and less likely to have permanent home sites which require more intensive management.

The temperate EFG is a multistrata system that incorporates species that attempt to fill all ecosystem niches and have mutually beneficial relationships that form an ecologically sustainable community of organisms. Some of the species that are found in EFG of the Great Lakes bioregion are; Chinese chestnut, Carpathian walnut, northern pecan, pawpaw, Amercian persimmon, apple, European pear, Asian pear, plum, peach, apricot, Korean stone pine, mulberry, amelancher, Siberian pea shrub, nanking cherry, beach plum, hazelnut, blueberry, currents, gooseberry, raspberry spp, strawberries, grapes, hardy kiwi, hops, sunchokes, asparagus, rhubarb, sage, mint, white clover, multiplier onion, ramps, sorrel, skirret, comfrey, giant solomon's seal, groundnut, Chinese artichoke, good king henry, wild ginger, corn, beans, squash, shiitake and oyster mushrooms (Jacke and Toensmeier 2005). It is common for livestock such as chickens, hogs and cattle to be incorporated into such systems to efficiently trap and cycle nutrients and solar energy (Mollison 1988).

Edible Landscaping. Edible landscaping is the practice of planting food producing plant species in place of ornamental species in the landscape, typically in residential areas. Edible landscaping around residential areas provides an ascetically pleasing landscape while producing food. This is far more than just a way to garden. In low-income communities edible landscapes provide food security by insuring access to healthy food in times of scarcity. Edible landscaping is not the same as gardening. In edible landscapes plants are placed amidst living spaces in a similar manner as conventional ornamental landscapes (Creasy 1982, Kourik 1986, Salcone 2005).

Companion Planting. Companion plants are plants that benefit from being planted near each other. Indigenous people have practiced companion planting in their gardens for thousands of years (e.g. three sisters gardens of North America) to create multifunctional relationships among crops (Kuepper and Dodson 2001). In addition to producing food, many of these plants fix nitrogen, aggregate nutrients, suppress undesired species, facilitate trap cropping, facilitate nurse cropping, provide security through biodiversity, have physical interactions (partition resources), attract beneficial insects and wildlife, mitigate pest pressure, enhance soil structure and enhance the health of the soil food web (Jacke and Toensmeier 2005, Kuepper and Dodson 2001).

Common Design Principles for Temperate Climates

The forest ecosystem is the model for the edible forest garden because of its stability and resilience and mimicking this ecosystem is the primary design principle for creating these systems (Hart 1980, Jacke and Toensmeier 2005). Only by understanding the structure and function of forest ecosystems through time and space is it possible to design and manage an edible forest garden. Therefore two vital concepts to apply are those of forest succession and ecosystem disturbance.

Succession. Typically in a bioregion where forests are indigenous, when an agricultural field is abandoned it will follow a successional trajectory back toward a forest. Often, but certainly not always these systems will be initially dominated by shade intolerant pioneering annuals, followed by the increased presence of herbaceous perennials, small and large shrubs, small and large trees and finally shade tolerant understory species of both woody and herbaceous varieties. The development of these different layers over time is what creates the architecture of these systems (DeClerck and Negreros-Castillo 2000, Hart 1980, Jacke and Toensmeier 2005).

Ecosystem succession is the natural flow and going against this flow is like swimming up stream. Working with rather than against natural forest succession is very energy and resource efficient (Shepard 2003). Fighting against natural forest succession, as is common practice in traditional annual agriculture with cultivating machinery and often herbicides, requires massive amounts of energy in the form of labor and fossil fuels. Creating appropriate polycultures for EFG requires plant species that fit together through time and space, form symbiotic, reinforcing relationships and produce high, diverse yields (Jacke and Toensmeier 2005).

In an EFG the plant species are planted spatially and sequentially to fulfill their respective successional roles. The goal is to direct and constructively manipulate succession to create the desired design and subsequent yields. This requires a detailed understanding of the life histories and niches of the species being utilized in the EFG. Mimicking a mid-successional woodland ecosystem (i.e. not a mature forest) in temperate climates is desired to produce maximum yields (Jacke and Toensmeier 2005). These mid-successional forest systems have the highest net primary production and potential for high yield. They also provide space for high species niche diversity.

Spacing. Achieving maximum yield requires appropriate plant spacing during EFG establishment. To accurately predict the future succession of the system, mature plant size (e.g. canopy width) and plant dispersal strategies (e.g. vegetative reproduction) must be understood (Jacke and Toensmeier 2005). This also allows for the creation of a multistrata architecture that does not produce stress on plant species from over-competition for resources. Plant species with aggressive dispersal strategies can smother out (i.e. become invasive) less aggressive species if they are not spaced appropriately in the garden. Plants spaced too close together create high competition for sunlight, water and soil nutrients (Jacke and Toensmeier 2005).

Strata. The architecture of a temperate EFG typically has between 3 and 7 layers including a combination of a tall tree (e.g. walnut) and short tree (e.g. pear) layer, a tall shrub (e.g. hazelnut) and short shrub or cane (e.g. raspberry) layer, a herbaceous perennial layer (e.g. comfrey), a groundcover (e.g. strawberry) and a vine layer (e.g. hardy kiwi). Consideration of the below ground layer, the rhizosphere is also extremely important. Whenever possible, plants with complimentary root morphology should be spaced so that they partition water and nutrients. Planting patterns are generally arranged from tallest plants to shortest to partition sunlight (Mollison 1988, Jacke and Toensmeier 2005).

Species Selection. Planting according to morphology is only the first step in creating truly dynamic, productive plant communities in EFG. The first step is to determine species that are appropriate for the climate and bioregion. To advance further, it is useful to perform a detailed niche analysis of all plant species being considered for the system. Functional attributes derived from a species niche analysis that need to be considered are:

ability to produce mulch and organic matter
aggregate and partition nutrients
attraction of beneficial insects (i.e. insectary) and wildlife
nitrogen fixation
suppression of undesired species
ability to build soil structure
enhancement of the soil food web
produce useful products, such as food, medicine, fiber, fuel and livestock fodder.

Other important attributes are shade tolerance, drought tolerance, flood tolerance, soil and nutrient requirements, pest and disease resistance, timing and requirements for pollination, plant growth and crop yield regime (Mollison 1988, Jacke and Toensmeier 2005, Shepard 2005, Toensmeier 2007).

Integrating Succession, Spacing, Strata, Species and Services. The next step in creating EFG is to assemble diverse species from a variety of ecosystem niches that perform multiple functions (e.g. edible, medicinal, mulch producing, insectary, shade tolerant, tap rooted, herbaceous perennial). It is also necessary to consider these attributes over time; for example spring ephemerals are only above the ground for a short part of the growing season and insectary species that provide bloom throughout the growing season are needed to allow for a healthy beneficial insect population (Jacke and Toensmeier 2005). By choosing useful plant species from a variety of ecosystem niches, the potential for invasion and subsequent competition from undesired species (i.e. weeds) is reduced significantly, reducing the time and energy required to remove them. An assemblage of these multifunctional plants spaced to form dynamic beneficial relationships is called a guild (Hemenway 2000, Whitefield 2004).

Guilds. The best way to select appropriate species for a guild is to observe indigenous species growing together in an unmanaged system and use them if possible (Shepard 2003, Shepard 2005). If the indigenous species are not appropriate, useful species that are closely related or an improved variety of a species (e.g. a hybrid variety of hazelnut to replace the native variety) should be used. The most important consideration is that the plant chosen has the same ecosystem niche as the native analog (Hart 1980, Shepard 2003, Shepard 2005).

An example of the type of guild found in the MSU EFG, centers on a fruit or nut tree (e.g. apple) with a nutrient aggregating, mulch producing herbaceous perennial (e.g. comfrey) planted under the canopy to build soil and suppress weeds. Surrounding the outside of the mature canopy width of the fruit tree could be found a nut bearing shrub (e.g. hazelnut) a fruit bearing shrub (e.g. beach plum) and a nitrogen fixing shrub (e.g. siberian pea shrub). On the shadier north side of the guild could be found a shade tolerant fruit bearing shrub (e.g. *ribes* or *amelancher*). Beyond and between the growing space of the shrubs could be found a variety of herbaceous perennials that produce food, medicine and attract beneficial insects (e.g. rhubarb, sage, daylily, cow parsnip). These plants should be spaced to partition sunlight, water and soil nutrients. In the shady spaces between these plants could be a shade tolerant, culinary ground cover (e.g. wild ginger). Any space left is filled with a nitrogen fixing, insectary groundcover (e.g. white clover).

Planned Patterned Guilds. These guilds should then be connected to each other to create a structurally, compositionally and functionally diverse landscape. Guilds are arranged according to the needs of future management practices and needs of the dominant species in the guild so they are in the best location for pollination (i.e. typically within 50ft of another of the same species), pest mitigation (i.e. typically not directly adjacent to another of the same family), resource partitioning and management. The use of natural patterns should also be emphasized when arranging these guilds. The planting patterns should flow and contour over the landscape and should maximize the use of edges. Useful natural patterns to imitate are those of fractal forms, spirals, funnels, dendritic branching and flow forms (Mollison 1988, Shepard and Weiseman 2006).

Hart (1980) prescribes the use of 3 main classes of information for designing these types of cropping systems; species to be used, arrangement of the components through time and space and the quantity and nature of inputs and outputs. The main components of the system have been divided further by Jacke and Toensmeier (2006), using design elements to create ecosystem dynamics that yield the desired conditions of maximum diverse yields, maximum self maintenance and maximum ecological health (Figure 1.4). Creating these overyielding polycultures requires maximizing the synergistic relationships of the components in the ecosystem (Jacke and Toensmeier 2006).

One method used to create guilds that is less systematic and more intuitive, is called “freestyle permaculture.” This involves empathizing with the life requirements of an individual plant in light of its life history and ecosystem niche and placing it the in the garden accordingly. This does not mean personifying the plant but rather envisioning yourself as the plant (i.e. empathizing) and considering where you would want to live and what you would want in a neighbor if you were that plant. This method is only effective with an understanding of the life requirments of the plant.

Certainly, meticulous attention to detail and careful planning is the preferred method of creating guilds, however an alternative method sometimes prescribed by permaculturalist Mark Shepard is the 'get it in the ground' method. This is a viable method when there are time constraints, plant material is readily available and space is readily available. The concept is that if you haphazardly arrange a group of perennials together they will compete with each other for growing space and thin themselves out (i.e. let nature design the guild). There are costs and benefits to this method. Some of the costs are a possible waste of plant material and possible stressful growing conditions for the surviving plants. Some of the benefits are that the strongest and best suited plants will survive and this can provide valuable information for designing future plantings. Since many perennials do not start producing high yields until after a few years, this method also allows you to get plants in the ground sooner so that they yield sooner (Shepard 2005). Shepard says, “the best time to plant a tree is 10 years ago.”

Ecosystem Benefits

Edible Forest Gardens provide many ecosystem services that benefit the surrounding biotic and abiotic environment. They create sanctuary for threatened and endangered species of both rare domesticated cultivars and native species, and are repositories for biodiversity and species richness. They enhance soil structure and the health of the soil food web. They help mitigate the negative effects of erosion, pest pressure, drought, deforestation and sequester carbon dioxide (a greenhouse gas) (Elevitch and Wilkinson 2001).

Soil Health. Healthy soil is the essence of a productive ecosystem. Much of the world's formerly forested lands have been cleared for annual agricultural crops, exposing them to erosion of the sensitive biological soil food web which provides fertility. Following deforestation, many of these lands follow a pattern of annual agriculture, livestock grazing and eventually desertification as the soil loses its ability to support life (if degradation continues). Adopting tree-based agriculture has been hailed as a way to mitigate annual agriculture's devastating impacts on soil degradation (Smith 1929).

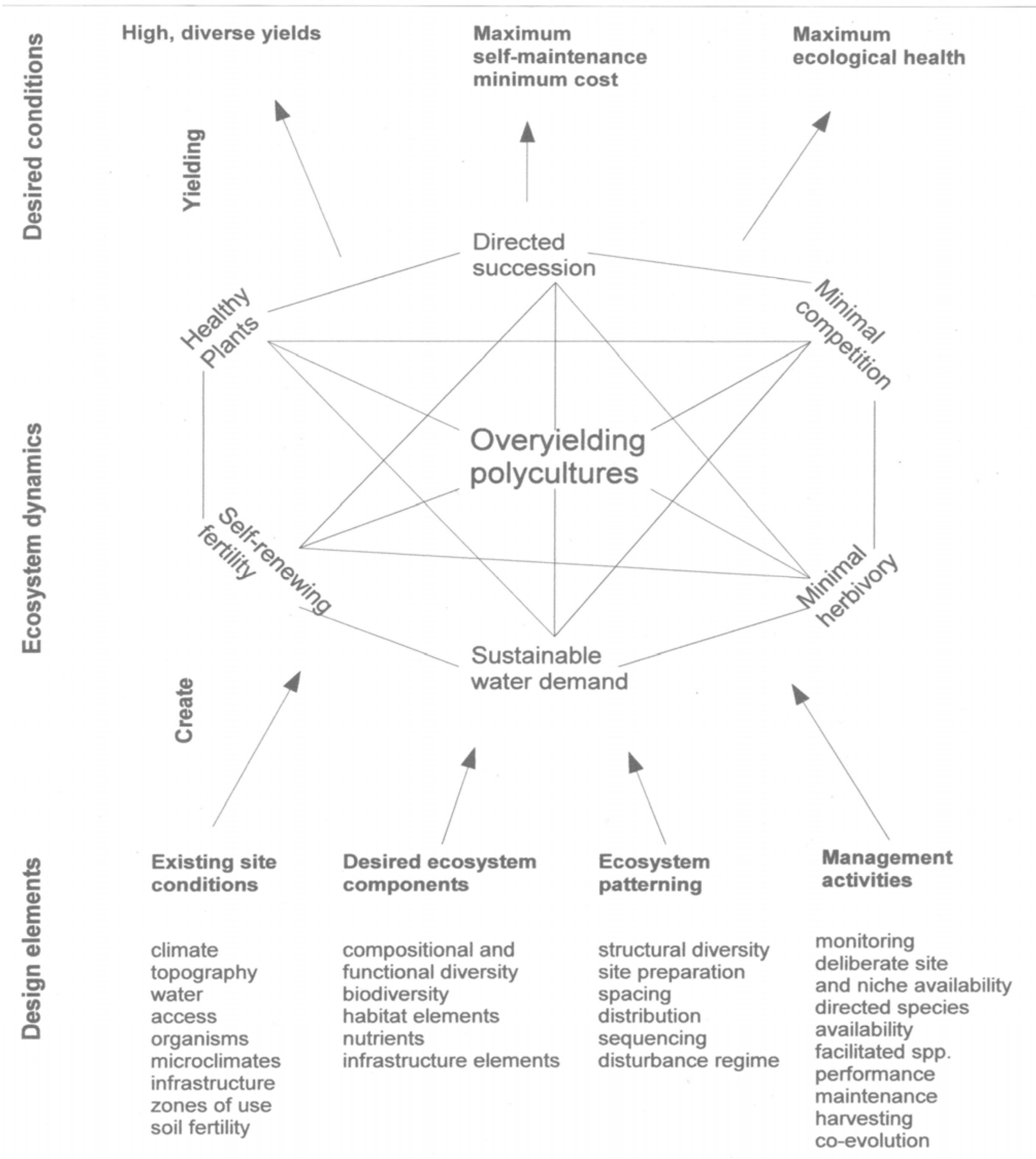


Figure 1.4 Framework for overyielding polycultures. Adapted with permission from Jacke and Toensmeier (2005, vol.2 p.6)

Nutrient Cycling. Trees benefit the soil by decreasing nutrient losses, enhancing internal nutrient cycling and increasing nutrient inputs (Sanchez 1997). Trees have the ability to recover nutrients that are leached into the subsoil and cycle them back to the topsoil. Nutrients that exist at rooting depths not accessible to most herbaceous plants can be taken up by trees and deposited on the soil surface in the form of leaf litter where it is then available to other more shallowly rooted species (Sanchez 1997).

Soil Biota. Trees have many positive impacts on benificial soil biota. Trees foster a fungal based soil, creating a network of synergistic relationships with mycorrhizal fungi. Mycorrhizae are known to facilitate nutrient uptake (e.g. phosphorous) and mitigate the negative effects of many soil pathogens (Borowicz 2001, Newton and Pigott 1991). Large networks of mycelial hyphae in the soil allow forested systems to maintain their integrity following a disturbance (Perry *et al* 1990).

Nitrogen Fixation. Planting leguminous trees and shrubs in an EFG facilitates biological nitrogen fixation, creating available nitrogen for other non-nitrogen fixing species in the system, via leaky root exudates, root decay and leaf litter deposition. These organic forms of nitrogen are less susceptible to leaching than inorganic forms and coincide with carbon sources used by soil microbes. Diverse and healthy soil biota creates stability and resilience (Sanchez 1997).

Erosion Prevention and Moisture Conservation. Tree based agriculture protects the soil and improves soil structure. Tree canopies and leaf litter deposition protect the soil from erosion caused by wind and water. These protective layers also reduce moisture fluctuations in the soil and the increased soil organic matter holds moisture in the soil. Tree roots hold soil within the rhizosphere, loosen soil and improve porosity via root decay (Sanchez 1997).

Carbon Sequestration. EFG sequester carbon from the atmosphere and can help reduce the negative impacts of greenhouse gas emissions. Adopting tree based agricultural systems in former annual monocultures reduces the need for deforestation, further reducing the release of carbon into the atmosphere (DeClerck and Negreros-Castillo 2000, Sanchez 1997). EFG have the potential to improve the structure and function of agricultural systems and remediate degraded lands (Singh *et al* 1995).

Biodiversity. Edible forest gardens promote and preserve biodiversity above as well as within the soil. Biodiversity creates stability and resilience, improves nutrient cycling, enhances pollination, reduces the impact of invasive species and mitigates pest and disease pressures, all of which has a positive impact on ecosystem function, maintenance strategy and economic return (Elevitch and Wilkinson 2001). These biologically diverse systems create refuge for threatened and endangered species and are repositories for genetic diversity. A diverse flora facilitates a balanced insect population, providing niches for insect pest predators and pollinating insects. Genetic diversity provides opportunity for disease resistance and adaptability (Jacke and Toensmeier 2005, Whitefield 2004). These ecosystem benefits contribute to the ecological health of the MSU EFG.

Section 1 Literature Cited

Alavalapati, J. R.R., and Nair, P.K.R. 2001. Socioeconomics and institutional perspectives of agroforestry. In M. Palo & J. Uusivuori (Eds.), World forests, society and environment:markets and policies. Kluwer Academic Publishers.

Alavalapati, J. R.R. and D.E. Mercer. 2004. Valuing agroforestry systems: methods and applications. Kluwer Academic Publishers.

Anderson, B. 2006. Adapting zones and sectors for the city. Permaculture Activist. Issue 58.

Association for Temperate Agroforestry (AFTA). 1997. The status, opportunities & needs for agroforestry in the United States: a national report. AFTA

Borowicz, V.A. 2001. Do Arbuscular Mycorrhizal Fungi Alter Plant-Pathogen Relation Ecology. 82:3057-3068

Budd, W.W. *et al*. 1990. Planning for agroforestry. Elsevier Science Publishers.

Clarke, W.C., and R.R. Thaman. 1993. Agroforestry in the Pacific Islands: systems for sustainability. United Nations University Press.

Combe, J. 1982. Agroforestry techniques in tropical countries: potential and limitations. Agroforestry Systems. 1:13-27.

Creasy, R. 1982. The complete book of edible landscaping. Sierra Club Books. San Francisco, CA. p. 365.

DeClerck, F.A.J. and P. Negreros-Castillo. 2000. Plant species of traditional Mayan homegardens of Mexico as analogs for multistrata agroforests. Agroforestry Systems. 48:303-317.

Elevitch, C.R. and K.M. Wilkinson. 2001. The overstory book. Permanent Agriculture Resources.

Fern, K. 2000. Plants for a future: edible & useful plants for a healthier world. Permanent Publications. p.300.

Gever, J., *et al*. 1991. Beyond oil: the threat to food and fuel in the coming decades, third edition. University Press Colorado.

Gold, M.A. and J.W. Hanover. 1987. Agroforestry systems for the temperate zone. Agroforestry Systems. 5:109-121.

Genauer, E. 2006. Peak oil and community food security. Communities: Journal of Cooperative Living. Issue 130.

Hart, R.D. 1980. A natural ecosystem analog to design of successional crop systems for tropical forest environments. The Assoc. for Tropical Bio. and Conservation. Biotropica. 12:73-82.

Hemenway, T. 2000. Gaia's garden: a guide to home scale permaculture. Chelsea Green Publishing.

Holmgren, D. 2002. Permaculture: principles and pathways beyond sustainability. Holmgren Design Services. p.286.

International Centre for Research in Agroforestry (ICRAF). 1997. Redefining agroforestry-and opening pandora's box? Agroforestry Today. Vol.9 no.1.

Jacke, D. and E. Toensmeier. 2005. Edible forest gardens: volume one vision & theory. Chelsea Green Publishing. p.378.

Jacke, D. and E. Toensmeier. 2005. Edible forest gardens: volume two design and practice. Chelsea Green Publishing. p.655.

Kehlenbeck, K. and B.L. Maass. 2004. Crop diversity and classification of homegardens in Central Sulawesi, Indonesia. Agroforestry Systems. 63:53-62.

Kourik, R. 1986. Designing and maintaining your edible landscape naturally. Metamorphic Press. Santa Rosa, CA. p.370.

Kovach, J. 2005. Ohio State University polyculture trials (IPM). Extension.

Kuepper, G. and M. Dodson. 2001. Companion planting: basic concepts and resources. Appropriate Technology Transfer for Rural Areas.

Lamoureux, G. 2001. The forest garden. Proceedings from the Seventh Biennial Conference on Agroforestry in North America.

Lassoie, J.P. and L.E. Buck. 1999. Exploring the opportunities for agroforesrty in changing rural landscapes in North America. Agroforestry Systems. 44: 105-107.

Leuty, T. 2001. Intensive intercropping in orchard agriculture an extension report. Proceedings from the Seventh Biennial Conference on Agroforestry in North America.

Mergen, F. 1987. Research opportunities to improve the production of homegardens. Agroforestry Systems. 5:57-67.

Miller, R.P. and P.K.R. Nair. 2006. Indigenous agroforestry systems in Amazonia: from prehistory to today. Agroforestry Systems. 66: 151-164.

Mollison, B. 1988. Permaculture: a designers manual. Tagari Publications. p.575.

Nair, M.A. and C. Sreedharan. 1986. Agroforestry farming systems in the homesteads of Kerala, southern India. Agroforestry Systems. 4:339-363.

Nair, P.K.R., 1989. Agroforestry systems in the tropics. Kluwer Academic Publishers and ICRAF.

Nair, P.K.R. 1994. Agroforestry. Encyclopedia of Agricultural Sciences 1:13-25.

Nair, P.K.R. 2001. Do tropical homegardens elude science, or is it the other way around? Agroforestry Systems. 53:239-245.

Nautiyal, S. *et al*. 1998. Agroforestry systems in the rural landscape – a case study in Garhwal Himalaya, India. Agroforestry Systems. 41: 151-165.

Newton, A.C. and C.D. Pigott. 1991. Mineral Nutrition and Mycorrhizal Infection of Seedling Oak and Birch. I. Nutrient Uptake and the Development of Mycorrhizal Infection During Seedling Establishment. New Phytologist. 117:37-44.

Perry, D.A., *et al*. 1990. Species Migrations and Ecosystem Stability During Climate Change: The Belowground Connection. Conservation Biology. 4:266-274.

Salcone, J. 2005. The edible landscaping toolkit: an informational guide for low-income housing settings to develop a healthy and productive landscape. Sacramento Hunger Commission.

Sanchez, P.A. *et al*. 1997. Trees, soils, and food security. Philosophical Transactions: Biological Sciences. 352: 949-961.

Sharashkin, L. *et al*. 2005. Ecofarming and agroforestry for self-reliance: small-scale, sustainable growing practices in Russia. Association for Temperate Agroforestry Conference Proceedings.

Shepard, M. 2003. Successional brushland and oak savanna as the ecological model for permanent staple crop production in North America.

Shepard, M. 2005. Forest agriculture enterprises. consulting papers and personal interview.

Shepard, M. and Weiseman, W. 2006. Permaculture: exceptional certification training course. Center for Sustainable Community.

Singh, P. *et al*. 1995. Agroforestry systems for sustainable land use. Science Publishers, Inc.

Smith, R.J. 1929. Tree crops: a permanent agriculture. New York: Harcourt, Brace. Chapters 1-3.

Soemarwoto, O., *et al*. 1985. The Javanese homegarden as an integrated agro-ecosystem. Food and Nutrition Bulletin. 7(3)44-47.

Thevathasan, N.V. and A.M. Gordon. 2004. Ecology of tree intercropping systems in the North temperate region: experiences from southern Ontario, Canada. Agroforestry Systems. 61:257-268.

Toensmeier, E. 2007. Perennial vegetables. Chelsea Green Publishing. White River Junction, VT. p.241.

Von Maydell, H.J. 1991. Agroforestry for tropical rain forests. Agroforestry Systems. 13:259-267.

Williams, P.A. and A.M. Gordon. 1992. The potential of intercropping as an alternative land use system in temperate North America. Agroforestry Systems. 19:253-263.

Wiersum, K.F. 2004. Forest gardens as an 'intermediate' land-use system in the nature-culture continuum: characteristics and future potential. Agroforestry Systems. 61:123-134.

Whitefield, P. 2004. The earth care manual: a permaculture handbook for Britain and other temperate climates. Permanent Publications.

Section 2
Development of the MSU Edible Forest Garden

Project Description

The Michigan State University Student Organic Farm Edible Forest Garden (MSU EFG) is a place for students, urban gardeners, farmers and landscape designers to investigate and demonstrate the food system and horticultural components of temperate permaculture. It provides an example of applied permaculture design for the Great Lakes bioregion and other similar temperate climates. The produce harvested from the MSU EFG is direct-marketed via the CSA program and on campus farm-stand.

Support for the development of the project from 2005 to 2007 came from the MSU SOF CSA, CSA member cash donations, Pear Tree Farm, The Taylor Farm, RISE (Residential Initiative for the Study of the Environment), volunteer work from students, CSA members and local community members, SOF student labor and the USDA Risk Management Agency (RMA). The 2006 to 2007 RMA project funding provided graduate student support, labeling, signage, irrigation, additional plant material and educational workshops for farmers and urban gardeners with emphasis on mitigating risk of food scarcity and promoting community food security. To accomplish this, the MSU SOF partnered with the Greening of Detroit and Earth Works Urban Garden to organize workshops and extension services to urban gardeners in Detroit. Additional tours and one-day workshops were also organized and provided at the SOF. The MSU EFG was established as an addition to the existing SOF projects and developed as time and labor allowed.

Plot Description and Development

The MSU EFG is in the climate zone 5b located at 42.6732 N latitude, 84.4881 W longitude at an elevation of 880 feet above sea level on the MSU Student Organic Farm (SOF). The rectangular 190ft (north, south) by 130ft (east, west) garden plot is in the southeast corner of the SOF, bordered by a gravel farm road to the north, conventionally grown tart cherries to the east, conventionally grown apples to the south and organic annual row crop production to the west. The SOF is located on the northwestern corner of the Horticulture Teaching and Research Center (HTRC) (3291 College Road, Holt, MI 48842) on the campus of Michigan State University.

The indigenous ecosystems characteristic of this region consisted of uplands of mixed hardwoods dominated by beech/sugar maple with other common species such as red oak, basswood, white ash and black maple. Lowland (i.e. wetter) areas included species such as silver maple, American elm, swamp white oak and red ash. Windthrow was likely the most common form of disturbance (USGS 2006). The region surrounding the SOF began being settled in 1837 and from there forth increasingly more forests were cleared and wetlands drained for agriculture. The land where the SOF is located was purchased by Michigan State University in 1964 and was known to be farmed before that.

The plots now in use for the SOF and EFG were planted into orchard trees from about 1965 to 1995. In 1998 to 2001 the orchard trees were removed. The transition period during which no materials except those approved for organic certification began in 2001 and the 10 acre SOF was first certified organic in 2004 by Organic Growers of Michigan.

The soil is a Marlette Fine Sandy Loam with 2-6% slopes (USDA NRCS soil survey) over a heavy, compacted clay soil. Decades of spraying the fruit trees with tractor-drawn spray equipment resulted in compacted soil in the alley ways. In 2003 organic matter was added consisting primarily of piles of wood shaving and or straw bedding (originally used for 2-3 day livestock judging or demonstration shows) from the university Agriculture Pavilion. The bedding therefore contained limited amounts of either cow or horse manure. The organic matter was deep enough to kill existing ground cover. The original intent was to use a self-propelled compost turner owned by MSU but the piles were initially too large. When the piles reduced in size due to decomposition, the compost turner was no longer available for use. The end result was static pile composting turned or rolled twice a year using a front end loader.

In June 2005 the decayed organic matter was spread out evenly with a front end loader and then power spaded into the soil. During the remaining part of the summer a drag was run over the plot approximately every three weeks to remove perennial weeds and reduce annual weed seed (Figure 2.1). In October 2005 a sub-soiler was run across the plot at a depth of 13 inches to break up the hard pan and in November winter rye cover crop was seeded using a grain drill. At this time the soil was tested for pH and nutrient availability.

Figure 2.1 MSU Edible Forest Garden during soil preparation prior to planting with the SOF in the background to the north (summer 2005)

The purpose of the following tables and figures is to provide a concise and easy-to-reference representation of the process and results of the MSU EFG.

Design Process

The design process began in summer of 2005 with informal conversations about desirable features in a permaculture garden and a visit to permaculture consultant and instructor Mark Shepard's farm in western Wisconsin (New Forest Farm). In November the SOF engaged Mark as a consultant on the project and to provide a site evaluation, and run a permaculture workshop at the SOF. From that workshop came a written site evaluation (see Appendix) and a list of design goals and objectives (Table 2.1).

Table 2.1 Design goals, objectives and considerations for the 130 by 190ft garden: balancing aesthetics and functionality. Jay Tomczak and John Biernbaum (12/26/05)

flowing tractor/annual row beds
traditional' style trellised grapes (zone 100x18ft)
Arbor with trellised vines (human space)
no or minimal strait paths
key hole beds/harvesting and maintenance access points
perennial root crop area (sunchokes, groundnuts, etc.)
asparagus area
biodiversity
appropriate spacing (succession)
ecosystem mimicry
home for 3 sisters annual guild
symmetry and asymmetry
minimize soil compaction
area for culinary herbs
minimize labor (over time)
many connected permaculture style guilds
guild 'replicates' for demonstration/research
budget?
native fruits
high yielding fruit and nut varieties
insectary plants
mulching plants (e.g. comfrey)
nutrient aggregating plants (dynamic accumulators)
N fixing plants
fill all ecosystem niches including trees, primary/secondary shrubs, vines,
herbaceous perennials, ground covers, annuals, shade&sun spp
weed' suppressing/excluding plants
good tasting plant varieties
pathogen resistance
landscape connectivity
no or minimal bare soil (ground covers, mulching)
maximize plants for human use w/o compromising ecosystem function
irrigation? drainage?
Sun direction? (seasonal aspect)
wind direction?
invasive/illegal spp?
beneficial/detrimental wildlife?
healthy soil biota

It was also in November 2005 that Permaculturalist Dave Jacke with co-author Eric Toensmeier's two volume text 'Edible Forest Gardens' became available. The books proved to be a valuable resource. Dave Jacke was then contacted and became another consultant for the project, while also giving several presentations in Michigan. As certified permaculture instructors and practitioners both Mark and Dave are considered two of the highest authorities on temperate climate permaculture in the United States.

In December 2005 rough sketches were drawn which incorporated all of the major elements of the garden. Major structural components (e.g. grape trellis and tractor beds) were the first to be considered, followed by foot paths, woody perennials and major groupings of herbaceous perennials. The design evolved from elements of greatest to least permanence. After thorough consideration had gone into the rough sketches the design was drawn to scale on a piece of graphing paper at a scale of 1mm equaling 2ft (Figure 2.1).

The two 100ft grape trellises were placed running north/south along the east side with the strawberry/bramble berry beds bordering to the west. One tractor bed was placed running from the NW corner to the SE corner in a gently curving 'S' shape. The other 2 tractor beds arc across the NW and SW corners of the garden. Trees were drawn according to their mature canopy width and shrubs were placed along the drip line of the canopies. Tree and shrub species were spaced according to pollination and pest management considerations. Foot paths were placed to create flow, connectivity and access for management. The pergola (aka arbor) and mandala shaped annual garden are near the center of the plot. Designated areas were also created for culinary, medicinal and starchy root herbaceous perennials. Each element in the garden was assigned a number or an abbreviated code for shorthand labeling (Table 2.2).

Figure 2.2 MSU Edible Forest Garden design plan (January 2006).

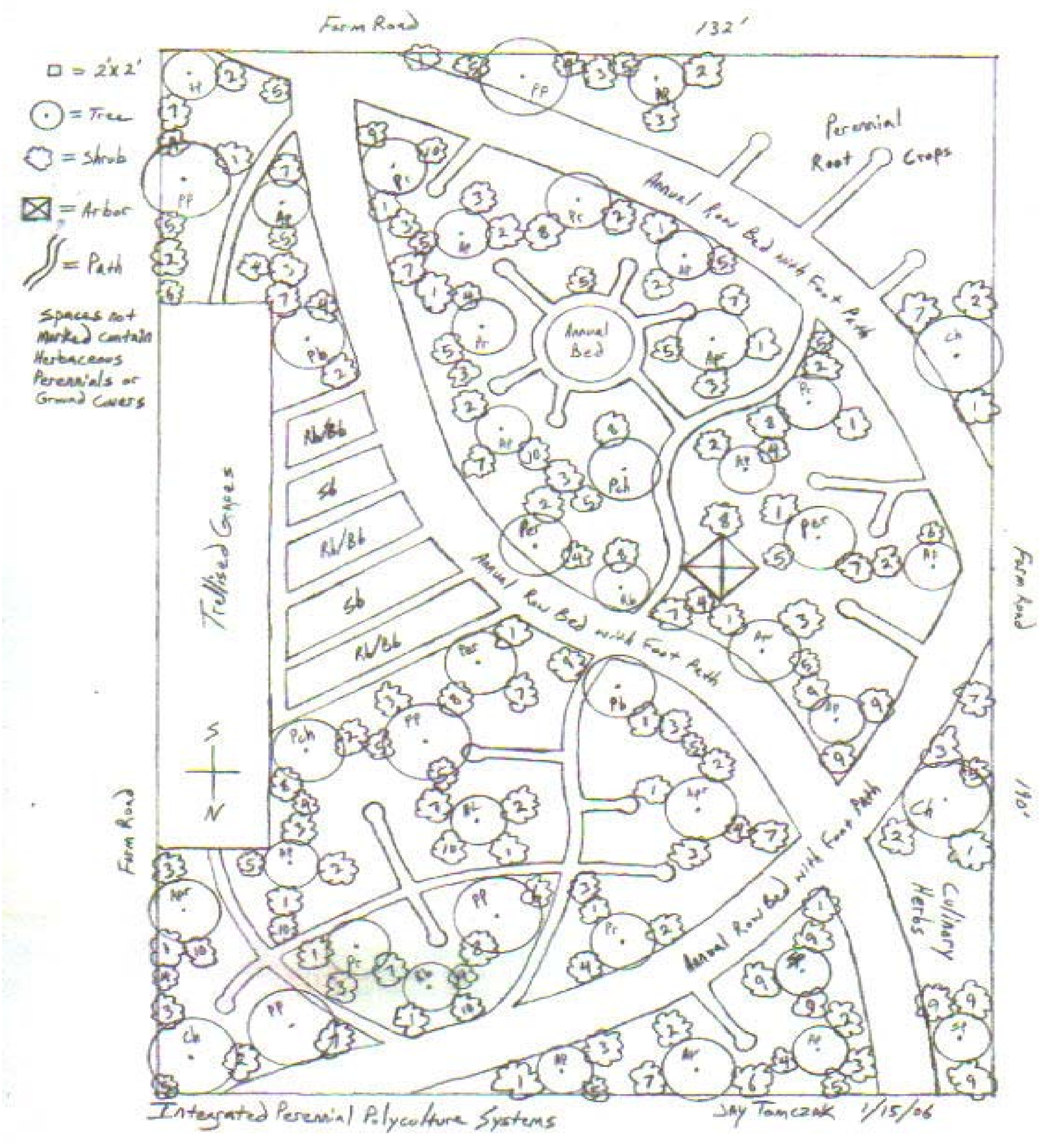


Table 2.2 Abbreviated plant labeling codes.

Species	**Code**
Pawpaw	Pp
Chestnut	Ch
Apple	Ap
Pear	Pr
Asian pear	Apr
Plum	Pm
Peach/Nectarine	Pch
Persimmon	Per
Honey Locust	HL
Redbud	Rb
Dwarf Spruce	Sp
Beach plumb	1
Hazels	2
Siberian pea	3
Currents	4
Gooseberry	5
Raspberry/Blackberry	Rb/Bb
Bush Cherry	7
Serviceberry	8
Blueberry	9
Cranberry	10
Strawberries	Sb

The resulting design was a balance of aesthetics and functionality that incorporated all of our desired elements and was easy to decipher. The main criticism of this method is that it is difficult to manipulate and add/subtract the elements of the drawing without spending a lot of time re-working it. For this reason I would recommend considering various types of landscape design software for early stages of design which allow for easy design manipulation.

Amended Garden Design July 2007

Although the garden maintained the structural integrity of the original design in Figure 2.2, substitutions, additions and alterations required a detailed inventory in July 2007. Figures 2.4 and 2.5 depict the state of the garden after final plantings in summer of 2007.

Implementation and Cultural Practices

This section includes the steps followed to establish the garden and any cultural details that might be unique or presented challenges. Common or traditional horticultural practices (e.g. pruning raspberries) are not covered in detail.

The major implementation of the design began in mid-March 2006. Because of careful planning and a well constructed design, the elements of the drawing translated onto the reality of the field very smoothly with no major surprises. In Tables 2.2 and 2.3, the major steps taken to implement and establish the garden and the time of year that it occurred are summarized. In 2006 the garden required approximately 335 hours of physical labor averaging about 13 hours per week (March to October) during the growing season and in 2007 it required approximately 203 hours of physical labor averaging about 29 hours per week (April to July) during the first half of the growing season. Labor data is not available for the second half of the growing season for 2007. As with many horticultural jobs a disproportional amount of labor is needed during the spring and early summer months. These estimates only include physical labor in the field and do not include design work, ordering plant material or other time spent researching etc. The estimate is meant to be a guideline for managing labor hours in the garden and it would vary considerably based on the skill levels and efficiency of people working in the garden. Post garden establishment (2008 and onward) labor requirements are expected to decrease.

Notes, Discussion and Critique of Implementation Steps

Measuring and Staking out Garden Elements. Staking was done by taking a measurement on the scale drawing and translating that onto the actual garden. To accurately stake out a garden with lots of curves requires making transects, so a few measurements sometimes have to be made to locate one point. A surveyors measuring wheel worked much faster than measuring tape and colored flagging helped identify what stakes were for certain elements (e.g. tractor paths with orange flagging and foot paths with pink).

Establishing Living Mulch. A mix of 80% Dutch white clover (perennial) and 20% medium red clover (short lived perennial) were frost seeded at a rate of 12lbs/acre (higher than necessary to insure good cover) evenly across the entire garden using a broadcast seeder. A winter rye had been seeded the fall before. The objective was to use the rye and the red clover as nurse plants because white clover is not as competitive with weeds and can be slow to establish. The long term goal is to have a primary ground cover of white clover. The white clover was able to establish slowly in the understory of the rye. The rye was allowed to grow until it produced seed and killed (using a gas powered weed trimmer with a plastic blade) just before the seed became viable. The clover was then fully exposed to the sun, allowing it to grow rapidly. The cuttings from the rye were partially raked off the clover into the tractor beds to help this process. A problem with the thick stand of rye was that it provided good habitat for rabbits which resulted in feeding damage to some of the shrubs. Once the rye was cut the rabbit problem subsided.

In some areas of the garden either the rye did not completely die or annual weeds (e.g. lambs quarters) dominated. The ground cover was managed with a gas powered mulching push mower set at a height of 5in. The weeds were mowed before viable seeds were produced. The garden was not mowed all at once to allow refuge for beneficial insects. The process of tall mowing the garden allowed the clover to out-compete most weeds and establish thickly.

Figure 2.2 MSU Edible forest Garden during staking process just after frost seeding with clover (March 2006)

Table 2.3 Major steps in MSU EFG implementation 2006.

Activities	Month
Ordering plant material	late winter
Measuring and staking out garden elements	March
Frost seeding clover	March
Initial mulching of paths	April/May
Initial trellis and pergola construction	April/May
Planting strawberries and bramble berries	April
Planting and temporary labeling of woody perennials	April-June
Tilling of tractor beds	May
First major weeding	May
Initial mulching around woody perennials	May
Tilled a sod barrier around garden border	May
Added straw mulch to strawberries and bramble berries	May
Tilled up mandala annual bed	May
Pinched flowers off all fruit producing plants	May
Prepped soil for medicinal herbs	May
Chicken wire wrapped around vulnerable woody perennials	May
Cut rye and raked off cuttings	May
Initial planting of sunchokes	May
Planted three sisters garden	June
First mowing of clover	June
Second tilling of border strip	June
Initial tree pruning and training	June
Second major path and tree mulching	June
Planted cut flowers and grains in tractor beds	June
Planted medicinal herbs	June
Second major weeding	June
Installed irrigation	June
Put side walls on pergola and planted hops	July
Mowing alternate patches of clover	July-October
Last major weeding of season	August
Added plastic tree guards around all trees	September
Last mowing of clover and tilling of border strip	October

Table 2.4 Major steps in MSU EFG implementation 2007.

Activities	Month
Inventory winter damage	March
Order plant material	March/April
Propagate seeds in greenhouse	April
Gather plant material from sources	April
Put landscape fabric skirts around trees and mulch	April
Prepare soil in tilled border strip	April
Plant comfrey and rhubarb in tilled border strip	April
Prune bramble berries	April
Planting/replacing a few woody perennials	April
Tilled tractor beds and mandala annual garden	April
Tilled and prepped soil for asparagus and sunchokes	April
Pruned and trained grapes	April
Major weeding of perennial weeds	April
First major plantings of herbaceous perennials	April/May
Planted asparagus and sunchokes	May
Mowed alternate patches of clover	May-October
Weeded strawberry and bramble berry beds	May
Weeded medicinal herbs	May
Added landscape plastic and mulch on foot paths	May/June
Heavy mulching around all plants	May/June
Prune and train trees	June
Plant three sisters in mandala annual garden	June
Second major planting of herbaceous perennials	June
Till tractor beds and plant cut flowers	June
Install remaining irrigation components	June
Finish building pergola	June
Second major weeding	July
Add plant labeling and signage	July
Additional mulch added where necessary	July
Tree guards and deer repellents installed	September

Planting Trees. Trees were planted with a square edged spade and the graft union was slightly higher (a few inches) than the surrounding ground with the soil surface. The hole depth allowed the roots to sit firmly on the sub-soil (i.e not loosened below the deepest roots). The diameter of the hole was large enough to for all existing roots on the tree to lie in their natural position (i.e. not bent awkwardly) contouring to the root architecture. The edges of the hole were perpendicular to the ground (i.e. not bowl shaped) and roughed with the spade to facilitate root penetration. The filled hole was firmed down but not overly compacted and then irrigated. A 3ft square of landscape fabric was skirted around each tree and mulched on top with wood chips to suppress weeds. Some trees were staked until establishment of a strong root system to prevent tilting in the wind.

Chipped or Shredded Wood Mulch. The fall prior to beginning planting a large supply of wood chips were attained from a local tree trimming service. Often local tree service businesses consider chipped wood to be a disposal problem and will donate it for free. Piling the chips in advance allowed time for some composting and stabilization.

If mulch is not used thick enough, it will not be effective and will have to be constantly reapplied. It might be necessary to use 6 to 8 inches. In the second year of the project we laid 3ft wide landscape plastic down on the paths to support the mulch and to reduce the rate of decay. A 3ft diameter permeable landscape plastic was used around each tree with mulch. Mulching is an annual process in this type of edible forest garden and typically when you think you have enough, you should double it.

Three Sisters Garden. The "*three sisters garden*" is an annual companion planting of corn, beans and squash commonly used by indigenous people in North America prior to the European invasion. The corn (usually flint corn) was planted near the center of 18in diameter, 1ft tall mounds about 3ft apart. The pole beans were grown near the edge of the mounds. Squash (usually winter squash) was planted on alternate mounds. It is helpful to plant the corn first and allow it to sprout before planting the beans and squash so the beans do not overtake the corn. The corn provides a trellis for the pole bean and the squash covers the ground suppressing weeds. All three plants are good at partitioning space and resources.

Planting Sunchokes. Sunchokes can be very aggressive and one way to help mitigate this is by planting in mounds similar to the three sisters garden. Groundnuts were planted around the edges of the mounds in the NW part of the sunchokes with Chinese artichoke planted in the spaces between to create a perennial three sisters garden of perennial root crops (Jacke 2006). The groundnuts and Chinese artichoke will need to be divided and established near the other sunchoke mounds as they begin to spread. It is important to plant sunchokes in a space were their growth can be controlled and they will not out-compete other crops.

Comfrey and Rhubarb Border Strip. A walk behind rototiller was used to cultivate a strip along the border of the garden to prevent the surrounding grass sod from moving in during the first year. During the second year comfrey was planted at 2ft centers in the tilled strip to create a permanent comfrey border. Comfrey also produces organic matter for mulching and composting. On the south side of the garden rhubarb was planted at 3ft centers in an attempt to achieve the same effect while producing an edible crop.

Pruning and Training Fruit Trees. Proper pruning and training has a major impact on fruit quality, especially in the early years. An effective method of pruning fruit trees to hasten fruiting which is not yet well known is to prune the dwarf tree into a pyramidal shape with horizontal branches. Shelves of branches parallel to the ground are established around a central leader. The first shelf should be about 3ft above the ground with three evenly spaced branches that grow just below 90 degrees. Horizontal branches flower and fruit earlier and more prolifically. The next should be a couple of feet higher with the three branches extending out above the gaps in the shelf below (i.e. the branches should not shade out the branch directly below). The upper shelves should be cycled out and replaced with the lower shelves becoming permanently established. The central leader should be pruned back to a weaker leader. All branches should be trained below 90 degrees to promote fruiting and vertical branches pruned off. Branches can be trained using rubber bands or weights (Michigan State University 2005).

Establishing Chestnuts. Chinese chestnut varieties were selected for the garden rather than the European crosses because of the smaller growth form which casts less shade (Fulbright 2005). Chestnuts are wind pollinated and yield best when planted in groups near each other, so we decided to plant them in three groups of two at a spacing of 15ft between the two. Some growers plant chestnuts at mature canopy width and some plant higher density orchards at closer to 10ft centers. We chose the middle ground between the two methods with the understanding that the trees would begin yielding long before reaching mature canopy width and some of the trees may not survive to maturity (Shepard 2006).

Irrigation. Managing soil moisture during establishment increases plant survival especially for the more delicate herbaceous species and high value crops. We installed an irrigation system in the garden using 300ft of 1in polypiping curving through the garden on the soil surface with 5, 50' long hose attachments spaced to reach the entire growing area of the garden. Drip tape was attached to the polypipe to irrigate the annual tractor beds, grape trellis and strawberry/bramble berry beds. The water supply allowed for plants to be watered-in during planting and extended periods of drought. Regular rainfall during the 2006 growing season resulted in a limited need for irrigation.

Establishing Herbaceous Perennials. The ground cover of clover that was established in the garden to suppress the invasion of undesirable and aggressive species can itself become aggressive if not managed properly. Three methods were used to establish herbaceous perennials in the clover.

Method 1. The method used to establish the medicinal herb area, perennial root crop area and asparagus was to break up and till the clover sod across the entire section designated for planting. The herbs were planted into bare soil and weeds managed as in a traditional garden by hoeing and hand weeding to allow the herbs to spread and fill the space.

Method 2. The method used to establish the culinary herb area was to lay black plastic over the designated area the season before to kill the clover sod. The following season the herbs were planted and managed in the same way as the method above. During bright sun conditions, clear or black plastic cover can kill the ground cover in a matter of days or weeks.

Method 3. The method used to establish most of the rest of the herbaceous perennials in the garden was to identify an appropriate location for a plant (given its life history and niche), turn over the sod with a spade, plant into the resulting bare soil and mulch thickly around the circumference. The inverted sod provided nutrients and together with wood chip mulch allowed the plant to get established and compete with the clover. This method can be difficult to implement properly when there is a large amount of plant material that needs to go into the ground in a short period of time with minimal labor. Be sure there is ample buffer space between the plant being planted and the clover.

Spring ephemerals and shade tolerant species can present some establishment challenges when planting into an early successional ecosystem after they are allowed to produce shade adapted leaves. Most of the spring ephemerals that were allowed to leaf out in the shade and were transplanted into sunny areas of the garden lost their leaves. The same plants transplanted to a shaded area of a different garden maintained most leaves. The ostrich fern (not a spring ephemeral) senescenced but new growth adapted to the sunny conditions. The spring ephemerals when dug up and inspected still had living tissue and may produce new growth next growing season. Die back could have been avoided if the plants were planted during dormancy and allowed to produce sun adapted leaves. However, when transplanting herbaceous perennials it can be very difficult to find them while dormant. Potting them and growing them in the shade (i.e. in a nursery) the first season and then planting them while dormant the second season is an option. Perhaps the most desirable thing to do would be to just plant them in the shade of a late successional system.

Tilled Annual Tractor Beds. A tractor was used to till 4ft wide annual beds into designated parts of the garden to grow annual crops such as cutflowers, beans, small grains, edible soy beans and tomatoes to demonstrate how space can more efficiently be used during early succession (Figure 2.3). Annual beds allow for crop production in early years before perennials develop an economically viable crop. Space was available for additional annual production but was not fully used due to resource and labor restrictions at the SOF.

Figure 2.3 Early successional MSU Edible Forest Garden with fresh tilled annual tractor bed in foreground ready for planting (June 2007)

Establishing Paths. Paths are established to facilitate management and create aesthetic appeal. In 2006 paths were mulched with wood chips but this was ineffective at suppressing the clover and they were soon over grown. In 2007 landscape plastic was laid down on the paths and wood chip mulch laid on top to suppress the clover. The paths are about 2.5ft wide which is wide enough to walk down with a wheel barrel but not a garden cart. The edges of the tilled annual tractor beds are also designated as walking paths and are managed by mowing at a height of 3in.

Nutrient Management. Whenever possible, organic matter from the garden is composted and cycled back into the garden (with the primary exception being harvested materials). Most weeds and plant material are placed on the ground near their location after they are killed. Large amounts of plant material are composted in a designated pile in the SE part of the garden and turned with a pitchfork periodically. Diseased foliage is always removed from the site and composted in the SOF compost piles. If perennials appear nutrient stressed they are top dressed with compost from the SOF or in rare circumstances a solution of Bradfields alfalfa based fertilizer is used.

Planting Blueberries. Blueberries were planted by excavating a hole large enough for 1 cubic foot of peat moss mixed with the excavated soil and 0.275lbs of elemental Sulfur. This is a rate of 1500lbs/acre to drop the pH one unit in the top 6 inches of soil.

Plant Material Sources and Costs

We first attempted to acquire plant material via divisions from existing, non-pesticide treated plants and donations. Many species spread vegetatively and can be easily divided and propagated from the mother plants of other neighborly gardeners. We then attempted to source plants from local nurseries and remaining plants that could not be found locally were ordered from traditional tree and berry fruit nurseries, native plant nurseries and conventional landscape suppliers. Some of the uncommon species could only be found at one source and in some cases they could not be found at all or were out of stock. Limited availability of certain crops recommended for temperate permaculture will likely continue to be an issue for several years.

Table 2.5 is a comprehensive listing of all the plant species purposely planted in the MSU EFG. It also includes a few species that are recommended for future planting in the garden. Table 2.5 includes the common name, botanical name, a brief description of some of the main functions and uses, plant material supplier, estimated quantity and estimated cost. Undoubtedly the composition of species in the garden will change over time as some species fail to become permanently established and others are added to the garden. Table 2.5 does not include the annual crops, tender perennials or the myriad of weed species (e.g. wild buckwheat, yellow dock, dandelion, queen ann's lace, pigweed, lambsquarters, plantain, quack grass, purslane, chicory, smartweed, velvetleaf, nutsedge, Canada thistle, ragweed) interacting in the garden.

In Table 2.5 species that were donated, taken from mother plant divisions, or from existing seed at the SOF have NA (information not available) in their row/column because that information is either not available or not relevant. Professors of horticulture Eric Hanson and Jim Flore helped us to acquire traditional fruit trees and small fruits. The variety names and root stocks are in the description column of the traditional fruit trees.

Abbreviations for Table 2.5:

- PTF (Pear Tree Farm)
- WT (Wildtype)
- NA (not available)
- B.I. (beneficial insect attracting)
- N Fixing (nitrogen fixing)
- SOF (Student Organic Farm)
- IPC (Indiana Plant Company)
- MBC (Michigan Brewing Company)

Non-plant Materials and Resources. Most of the non-plant materials and resources were provided by the SOF and the HTRC. Hand tools (e.g. spades, hoes, watering wands), a tractor, a Troy-Built walk behind rototiller, gas powered weed whip, temporary plant labeling material and straw mulch were provided by the SOF. The HTRC provided larger tractors, a front-end loader, a flat bed wagon, tractor implements (e.g. power spader, grain drill, sub-soiler, drag, Land Pride 4' wide PTO rototiller), trellis wire and hardware, bamboo stakes, surveyors measuring wheel and wood chipped mulch.

The wood chipped mulch is one of the major inputs of the MSU SOF EFG and was donated to the HTRC by local tree service businesses. The mulch was moved to the MSU SOF EFG via a front-end loader and a flat bed wagon pulled behind a tractor. From March 2006 to July 2007 an estimated 2,940 cubic feet (100+ cubic yards) of wood chipped mulch was applied to the garden. The amount of mulch used could have been reduced significantly if landscape fabric and landscape plastic had been utilized in 2006. An additional 840 cubic feet of wood chipped mulch is estimated to be used during the second part of the 2007 growing season. If the estimated 3780 cubic feet of wood chips were spread uniformly over the 24,700 sq ft plot the layer would have been 1.8" thick.

Lumber for the pergola, landscape farbric, irrigation hardware (e.g. poly-piping, drip tape, hose, connectors) and permanent plant labeling materials and signage were purchased with funding from the USDA Risk Management Agency grant.

Conclusion

The preceding outline of the methods used for development is presented not as a recommendation for how to develop an EFG plot. It is presented as a summary of the methods used based on the observation of and recommendations from practitioners and published resources. Continued observation and experience will be the best indicator of what recommendations to make to others.

The final plant list and maps follow. The numbers on the maps correspond to the number on the plant list. This is the amended design that accounts for changes in plant species and cultivars. An additional plant list and map that shows the cultivar names and locations is provided in the appendix.

Table 2.5 Plant List for the MSU EFG

No.	Common Name	Botanical Name	Description	Plant Source	Quantity	Cost ($)
1	american hazel	*Corylus americana*	nut crop	New Forest Farm	21	63
2	american persimmon	*Diospyros virginiana*	fruit crop	Oikos	4	30
3	angelica	*Angelica astropurpurea*	B.I.	WT	10	12.5
4	anise hyssop	*Agastache foeniculum*	culinary herb	SOF	NA	NA
5	apple	*Malus pumila*	Liberty, Enterprise, Goldrush, M26	Willow Dri, Boyer	12	85.2
6	asian pear	*Pyrus bretschneideris*	var. Korean Giant, Olympus	Boyer	6	42.6
7	asparagus	*Asparagus officinalis*	perennial vegetable	IPC	25	20
8	beach plum	*Prunus maritima*	fruit crop	Oikos	10	55
9	beebalm	*Monarda didyma*	tea plant and B.I.	WT	10	10
10	black current	*Ribes nigrum*	fruit crop	Hartmanns, Hanson, PTF	NA	NA
11	blackberry	*Rubus fruiticosus*	fruit crop	Hanson	NA	NA
12	blackeyed susan	*Rudbeckia hirta* L.	B.I.	PTF	NA	NA
13	blue lobelia	*Lobelia siphilitica*	B.I.	WT	10	10
14	bonset	*Eupatorium perfoliatum*	B.I.	WT	10	10
15	canada anemone	*Anemone canadensis*	B.I.	WT	10	12.5
16	chamomile	*chamaemelum nobile*	tea plant, B.I.	SOF	NA	NA
17	chicago hardy fig	*Ficus carica*	fruit crop	Hartmanns	3	NA
18	chinese artichoke	*Stachys affinis*	root crop	Companion Plants	3	13.5
19	chinese chestnut	*Castanea mollissima*	nut crop	Nash Nursery	6	150
20	chives	*Allium schoenoprasmum*	culinary herb	SOF, PTF	NA	NA
21	columbine	*Aquilegia canadensis*	B.I.	Tomczak Farm	4	NA
22	comfrey	*Symphytum* spp	medicinal, mulch, compost, B.I.	SOF	NA	NA
23	coneflower	*Ratibida* spp	Aug 02	WT	10	10
24	cow parsnip	*Heracleum maximum*	Jun 21	WT	10	12.5
25	cup plant	*Silphium perfoliatum*	Aug 23	WT	10	10
26	daffodils	*Narcissus jonquil*	weed suppression, cut flower	Van Atta's	NA	NA
27	day lily	*Hemerocallis spp*	perennial vegetable	PTF, Tomczak Farm	NA	NA

Table 2.5 Plant List for the MSU EFG (continued)

No.	Common Name	Botanical Name	Description	Plant Source	Quantity	Cost ($)
28	dunbars plum	*Prunus* x *dunbari*	fruit crop	Oikos	5	17.5
29	dwarf spruce	*Picea glauca 'Conica'*	tea plant	Van Atta's	2	95.38
30	echinacea	*Echinacea angustifolia*	medicinal herb	SOF	NA	NA
31	epazote	*Chenopodium ambrosioides*	culinary herb	SOF	NA	NA
32	european pear	*Pyrus communis*	var. Moonglow, Potomac, BA29C	Boyer	6	42.6
33	feverfew	*Chrysanthemum parthenium*	medicinal herb	SOF	NA	NA
34	french sorrel	*Rumex acetosa*	perennial vegetable	Companion Plants, Taylor Farm	NA	4.25
35	giant solomons seal	*Polygonatum biflorum*	perennial vegetable	Perennial Pleasures	4	30
36	golden alexanders	*Zizia aurea*	Jun 06	WT	10	10
37	good king henry	*Chenopodium bonus-henricus*	perennial vegetable	Sand Mountain Herbs	NA	NA
38	gooseberry	*Ribes hirtellum*	fruit crop	Hanson, IPC, PTF	NA	7.25
39	grape	*Vitis vinifera*	fruit crop	SOF		NA
40	groundnut	*Apios americana*	root vegetable, N fixing	Oikos	4	46
41	hardy kiwi	*Actinidia aguta*	fruit crop	IPC	6	NA
42	highbush blueberry	*Vaccinium corymbosum*	fruit crop	Hanson	11	NA
43	hoary vervain	*Verbena stricta*	Aug 02	WT	10	10
44	hop	*Humulus lupulus*	culinary herb, var. Cascade	MBC	5	25
45	horsemint	*Monarda punctata*	Aug 16	WT	10	10
46	horseradish	*Armoracia rusticana*	culinary herb	Taylor Farm	NA	NA
47	indian potato	*Heliianthus giganteus subtuberosum*	root crop	WT	10	10
48	ironweed	*Vernonia missurica*	Aug 23	WT	10	10
49	japanese burdock	*Arctium lappa*	medicinal herb	Richters	NA	NA
50	jinenjo yam	*Dioscorea japonica*	root vegetable	Oikos	2	8
51	lavender	*Lavandula angustifolia*	medicinal herb	SOF	NA	NA
52	lemon balm	*Melissa officnalis*	culinary herb	SOF	NA	NA
53	lovage	*Levisticum officinale*	perennial vegetable	Taylor Farm	NA	NA
54	marshmallow	*Althaea officinalis*	medicinal herb	SOF	NA	NA

Table 2.5 Plant List for the MSU EFG (continued)

No.	Common Name	Botanical Name	Description	Plant Source	Quantity	Cost ($)
55	meadowsweet	*Spiraea alba*	Aug 09	WT	10	16
56	mint	*Mentha* spp	culinary herb	PTF, SOF	NA	NA
57	motherwort	*Leonurus cardiaca*	medicinal herb	PTF	NA	NA
58	multiplier onion	*Allium cepa aggreatum*	root vegetable	PTF	NA	NA
59	nanking cherry	*Prunus tomentosa*	fruit crop	New Forest Farm	16	40
60	new england aster	*Aster novae-angliae*	Sep 20	WT	10	10
61	oregano	*Origanum* spp	culinary herb	Taylor Farm	NA	NA
62	ostrich fern	*Matteuccia struthiopteris*	perennial vegetable	Bordine Nursery	4	42
63	pale-leaved sunflower	*Helianthus strumosus*	Aug 30	WT	10	10
64	pawpaw	*Asimina triloba*	fruit crop	Tollgate Gardens	7	164.5
65	peach	*Prunus*	var. Allstar	Boyer	2	21.5
66	penstemon	*Penstemon hirtus*	Jun 14	WT	10	10
67	pilgrim cranberry	*Vaccinium macrocarpon*	fruit crop	Hartmanns	2	9.5
68	plum	*Prunus domestica*	var. Stanley	Boyer	1	10.75
69	prairie turnip	*Psoralea esculenta*	root crop	Morning Sky Greenery	3	23.85
70	ramps	*Allium tricoccum*	root crop	PTF	NA	NA
71	raspberry	*Rubus idaeus*	fruit crop	Hanson	NA	NA
72	red clover	*Trifolium pratense*	ground cover, N fixing, B.I.	SOF	NA	NA
73	red current	*Ribes silvestre*	fruit crop	Hanson, Hartmann's, PTF	NA	NA
74	rhubarb	*Rheum* spp	perennial vegetable	PTF, SOF	NA	NA
74	sage	*Salvia officinalis*	culinary herb	SOF	NA	NA
76	sand coreopsis	*Coreopsis lanceolata*	Jun 21	WT	10	10
77	saskatoon	*Amelanchier alnifolia*	fruit crop	Oikos	7	17.5
78	serviceberry	*Amelanchier lamarkii*	fruit crop	Oikos	5	15
79	siberian pea shrub	*Caragana arborescens*	perennial vegetable, N fixing	New Forest Farm	25	62.5
80	silver buffaloberry	*Shepherdia argentea*	fruit crop, N fixing	Oikos	3	12
81	skirret	*Sium sisarum*	root crop, B.I.	Perennial Pleasures	NA	NA

Table 2.5 Plant List for the MSU EFG (continued)

No.	Common Name	Botanical Name	Description	Plant Source	Quantity	Cost ($)
82	smooth aster	*Aster laevis*	Sep 27	WT	10	10
83	soapwort	*Saponaria officinalis*	medicinal herb	Richters	NA	NA
84	st. johnswort	*Hypericum perforatum*	medicinal herb	Richters	NA	NA
85	stinging nettle	*Urtica dioica*	perennial vegetable	SOF	NA	NA
86	strawberry	*Fragaria* x *ananassa*	fruit crop	Hanson	NA	NA
87	sunchokes	*Helianthus tuberosus*	root vegetable	PTF	NA	NA
88	swamp milkweed	*Asclepias incarnate*	Aug 02	WT	10	10
89	sweet cicely	*Myrrhis odorata*	culinary herb, B.I.	Taylor Farm	NA	NA
90	sweet goldenrod	*Solidago odora*	Tea, B.I.	Companion Plants	2	12
91	tansy	*Tanacetum vulgare*	fragrance herb	Taylor Farm, PTF	NA	NA
92	taragon	*Artemisia dracunculus*	culinary herb	PTF	NA	NA
93	thyme	*Thymus vulgaris*	culinary herb	PTF	NA	NA
94	trout lily	*Erythronium ameranum*	perennial vegetable	PTF	NA	NA
95	twisted stalk	*Streptopus rosea*	shady fruit	Sunfarm.com	NA	NA
96	valerian	*Valeriana officinalis*	medicinal herb	Richters	NA	NA
97	violet	*Viola odorata*	edible greens	SOF	NA	NA
98	white clover	*Trilium repens*	ground cover, N fixing, B.I.	SOF	NA	NA
99	wild ginger	*Asarum canadense*	culinary herb	Taylor Farm	NA	NA
100	wild strawberry	*Fragaria virginiana*	May 24	SOF	NA	NA
101	willow	*Salix* spp	B.I., basket making	Taylor Farm	NA	NA
102	winter savory	*Satureja montana*	culinary herb	SOF	NA	NA
103	wormwood	*Artemisia absinthium*	fragrance herb	Sand Mountain Herbs	NA	1.95
104	yarrow	*Achllea millfolium*	medicinal herb, B.I.	SOF	NA	NA
105	yellow giant hyssop	*Agastache nepetoides*	Aug 16	WT	10	10

Figure 2.4 Final woody perennials (trees and shrubs) plant map.

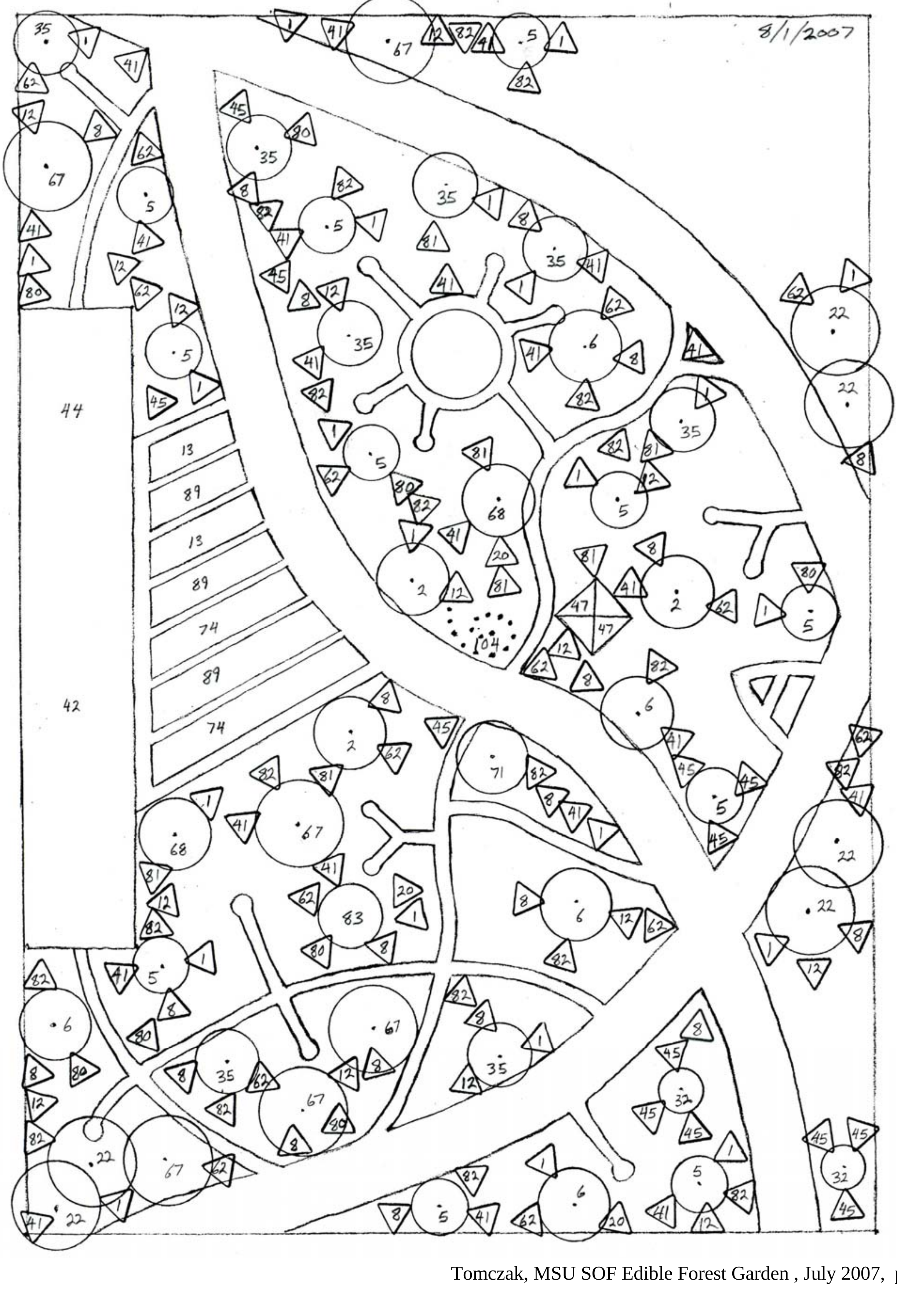
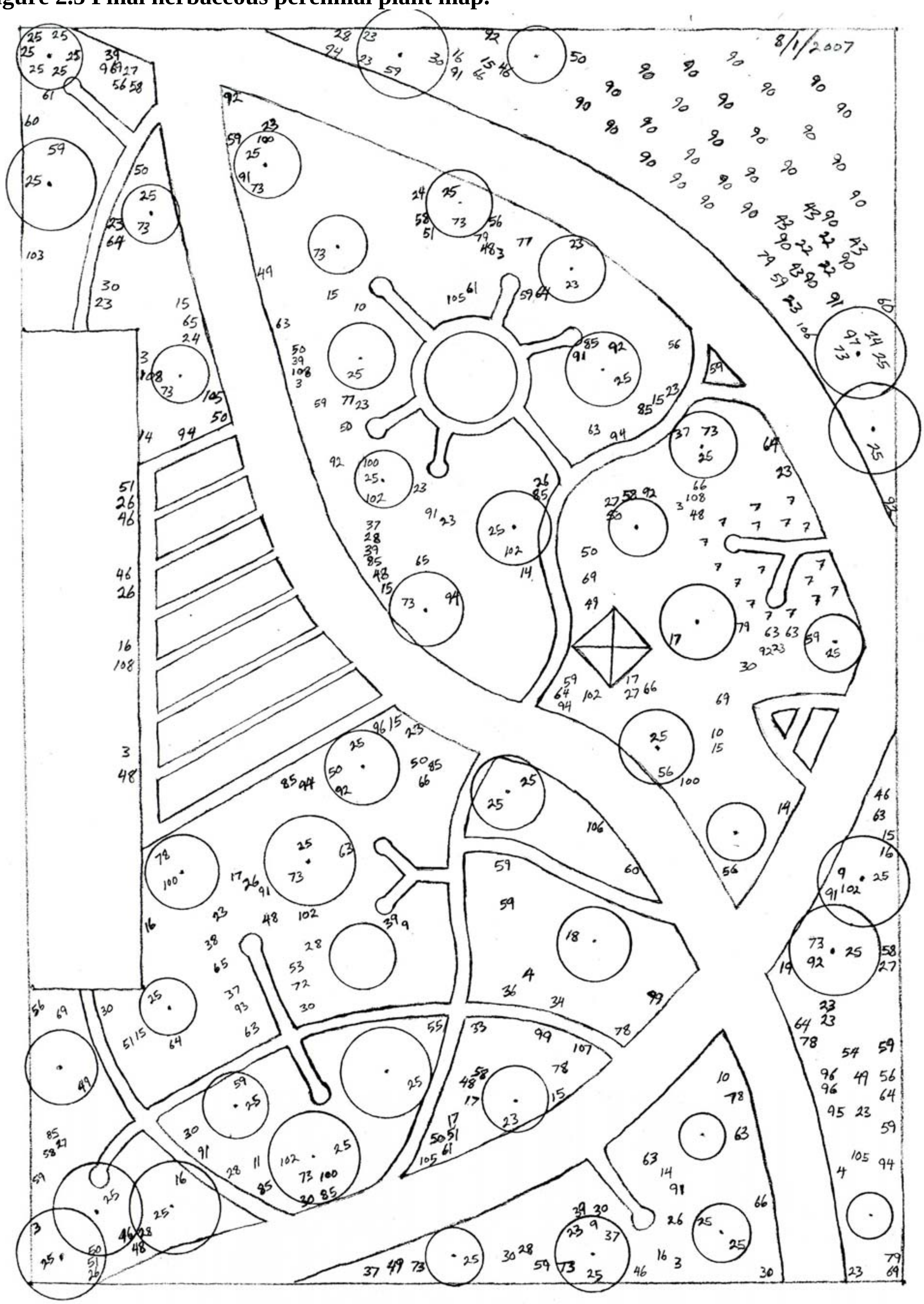


Figure 2.5 Final herbaceous perennial plant map.



Section 3
Management and Maintenance Plan for the MSU Edible Forest Garden

General Seasonal MSU EFG Management and Maintenance

An edible forest garden is a constantly changing and evolving agroecosystem. Management is considered over several years in contrast to the somewhat repetitive process of managing the seasonal cycle of annual cropping systems. Cultural practices are adapted to efficiently manipulate ecosystem succession through time and space. With this long term vision in mind, there are also many routine annual management considerations such as pruning, planting, weeding, mulching and harvesting. Table 3.1 is a summary of a typical seasonal timeline for major management practices and considerations in the garden. Practices such as weeding, mowing, mulching, irrigating and harvesting are ongoing throughout the growing season and their needs are monitored and timed appropriately. Management of this garden requires careful observation and consistent monitoring at least on a weekly or bi-weekly basis by a skilled horticulturist to assess labor and management needs. The major establishment phase of the garden has been completed, however proper establishment of perennials is an ongoing process and can take years. To properly maintain desired yields of crop plants and aesthetic appeal for this garden it should require at least if not slightly more labor hours as an annual organic crop field of comparable size.

Table 3.1. Typical seasonal timeline for major MSU EFG management practices and considerations.

Activity	Month
Inventory winter damage	March
Prune and train trees	March
Order any needed plant material	March/April
Prune bramble berries	April
Propagate seeds in greenhouse if necessary	April
Replace any damaged or dead woody perennials	April
Till tractor beds and mandala annual garden	April
Prune and train grapes and kiwi	April
Major weeding of perennial weeds	April
Mow alternate patches of clover (as needed)	May-October
Heavy mulching around all plants	May/June
Plant three sisters in mandala annual garden	June
Vegetative propagation and expansion of perennials	June
Till and plant tractor beds	June
Mow over strawberry beds	July
Major weeding	July
Additional mulch added where necessary	July
Tree guards and deer repellents installed	September
Winterize irrigation and tender perennials	October

Long Term Management of MSU EFG

Since very few edible forest gardens have been planted in temperate climates and those that have, have not existed for long, it is hard to know exactly how the interaction of management practices and plant species will develop in the long term. Certainly, whatever happens could be considered a success because as nature teaches us we will gain valuable knowledge of how to improve such cropping systems in the future. Working with ecosystem succession is not a passive process but a deliberate manipulation of design elements to create the ecosystem dynamics that yield the desired outputs of high, diverse yields, maximum self-maintenance, minimum cost and maximum ecological health (Jacke and Toensmeier 2005). This type of manipulation would mimic a shifting mosaic model of forest disturbance, with patches in the landscape at various successional stages.

Currently (2007) the garden is in early succession. The trees are short and cast almost no shade, the shrubs are small with minimal foliage and everything gives the illusion of being spaced too far apart. The grape vines and the hops are just beginning to form a canopy. The bramble berries and strawberries are thick and lush. The annual beds and medicinal herb area are thick and lush. Most of the newly planted shade intolerant herbaceous perennials are just beginning to establish themselves amongst the dominate clover and medley of volunteer (weed) species. Species diversity and richness is very high. Manipulating competition by weeding, mowing and mulching are primary management considerations. The garden is full of light and space and the primary yields come from herbs, cut flowers, annual vegetables, strawberries, raspberries, hops and sunchokes.

In the next few years everything will continue to grow rapidly as tree canopies begin to fill with foliage, trunk diameters thicken, shrubs expand vegetatively and put out suckers, many herbaceous perennials will spread and thrive as others fail and disappear. Perennial weeds may also become more prevalent. Manipulating competition will still be very important with an emphasis on pruning and manipulating the growth of crop species. Shade tolerant herbaceous perennials and spring emphemerals will be introduced to the garden in greater abundance and begin establishment. Clover will become a less dominant member of the plant community. The garden will still produce all the same yields as before but now with a dramatic increase of berry fruit and the beginnings of some tree fruit and nut production.

Five to ten years into the future the tree canopies of most of the trees will be at mature canopy size with the paw paws, chestnuts and persimmons still with potential for more. The shrub species will be at expected mature size. Most herbaceous perennials will be at mature expanse with others disappearing completely, unable to compete. The garden will have an increase of microclimates with a diverse landscape texture and balance of sun and shade. Shade tolerant species and spring ephemerals will become more competitive as the shade allows them to better exploit their niche space. The hops will grow thickly over the pergola and the perennial three sisters will produce a thick herbaceous mass. Plants will be beginning to encroach more on the paths and pruning and manipulation of growth will be a dominant management consideration. The garden will now be a truly over-yielding polyculture, with fruits and nuts from the trees and shrubs, fruit from the vines, medicinal and culinary herbs, perennial and annual vegetables, mushrooms and cut flowers, as well as a host of other species providing various ecosystem services. Some of the crops will be eaten fresh by CSA members, SOF farmers or sold at farm stand. Some of it will be canned, dried or preserved. Some of it will be damaged by pests and disease and will be composted or fed to livestock. The garden will produce an abundance of plant material as species expand vegetatively. This plant material should be removed and divisions potted and used in other gardens or sold by direct market. A small nursery area should be created at the SOF for this purpose and to allow students to learn about various forms of propagating perennial species.

The garden will never become static. As individual plants or species prove or disprove their value in the garden, they will be removed, replaced or selected out naturally. Succession can be set back or manipulated at any time or location to best suit the overall goals of the garden and CSA using permaculture principles as the guidelines. It is hoped that this garden will provide a space for future students to practice permaculture principles and experiment creatively with manipulating succession and polyculture combinations in a systematic as well as an organic way. The garden is a nucleus of intensive perennial polyculture and it is hoped that the long term values of perennial polyculture systems be expanded and connected to other areas of the MSU Student Organic Farm. Guilds (i.e. companion plantings) that seem to provide the most successful combinations should be encouraged, documented and replicated if possible. Even in the absence of management the garden will still produce relatively high yields of useful crops, although it might not be as aesthetically pleasing in a conventional sense. Individuals accustomed to tilled soil and straight rows may not be comfortable at first in the EFG.

This section is meant to focus on some aspects of managing the various plant niche types over time without going into detail about the specifics of common or traditional organic horticultural practices.

Trees. As trees mature they will need to be pruned and trained to maximize yields. All of the trees with the exception of the three American persimmons are grafted varieties and if damaged need to be replaced or pruned back to viable growth above the graft union to be retrained. In some circumstances it may be desirable to remove a tree completely due to disease or space considerations. The rooting area of trees should be kept free of weeds via mulching, weeding or exclusion by more desirable species (e.g. spring ephemerals or shade tolerant herbs). It is ideal for trees to be kept watered during fruit development and soil compaction above the rooting area (roughly 1.5 times the canopy width) should always be avoided.

Vines. The grape and hardy kiwi vines on the trellis will require training and pruning. Eventually some of the kiwis will need to be removed because only one viable male plant is required to pollinate (i.e. remove all males except one as they reveal their sex). The hops should be allowed to inundate the pergola to provide a shady space for visitors and growth expanding away from the pergola should be mowed, pruned or removed.

Shrubs. All of the shrubs (i.e. berry and nut bushes) will spread themselves vegetatively and once they reach their desired expanse will require aggressive pruning (e.g. Ribes species) to maintain fruit quality and aesthetic appeal. The figs will need to be mulched with straw in the fall to protect them from winter temperature fluctuations. A chicken wire cage around the plants helps to keep the mulch in place.

Cane fruit. The brambles (e.g. summer and fall bearing raspberries and blackberries) can become very aggressive if not pruned. Canes that grow outside of their beds should be removed as with any other weed. If disease becomes an issue it might be necessary to remove them completely and fallow the beds and start over. Blackberries may need to be trellised with a simple trellis of T-posts and galvanized wire.

Herbaceous Perennials. Some of the more delicate herbaceous perennials will need encouragement to expand. In some cases this may mean maintaining a mulched and/or bare soil buffer area between them and their desired expanse. It may even be necessary to reintroduce some of the more desirable species as they lose ground or transplant them to other areas of the garden where they are better able to exploit their niche. Growth from aggressive species may need to be removed or mowed down as part of the mowing regime. Additions of shade tolerant (e.g. some spring ephemerals) species should be incorporated into the understory of trees as shade increases with time. As desired herbaceous perennials establish in new areas of the garden they should be marked with a stake or label so they can be differentiated from undesirable species. Valuable species that were not planted during 2007 because of limited availability that should be planted during the 2008 season are twisted stalk (*Streptopus rosea),* good king henry (*Chenopodium bonus-henricus*), skirret (*Sium sisarum*), and daffodils (*Narcissus* j*onquil*). Twisted stalk is a shade tolerant herbaceous perennial that produces watermelon flavored berries in full shade. Skirret is a perennial root crop and good king henry is a perennial vegetable which can be planted in any sunny location. The daffodils should be planted in tight spacing around the border of some plants sensitive to competition to create a barrier against other encroaching species. Plant material sources for these species are found in Table 2.5.

Ground covers. It is important to provide good air flow within the foliage of strawberries to reduce pathogens. A gas powered weed whip can be used to create a strip in the center of the bed to increase air flow. At the end of the fruiting season the foliage should be mowed over with a gas powered mulching push mower with a mulch collecting basket attachment (to collect any diseased foliage) to mitigate disease and encourage new growth. If disease becomes prevalent they should be removed from the beds in the same way as the brambles. The primary ground cover of the garden is the clover which fixes nitrogen, attracts beneficial insects and suppresses undesirable species. It should be maintained by mowing and in cases where it is encroaching on more desirable herbaceous perennials it should be removed to create a buffer space.

Annuals. Annual vegetable, herbs and cut flowers will be maintained in designated beds and managed the same as annuals in other areas of the farm but with more of an emphasis on companion planting and mulching.

Summary

Maintaining plant productivity in high density plantings requires routine management and what to the untrained eye might be considered a “heavy hand”. Pruning, training, deadheading, restricting vegetative spreading and other horticultural methods to improve flowering and fruiting while maintaining plant diversity need to be done in a timely and aggressive manner. The ground cover must also be managed to support pest management, moisture retention and nutrient availability. The challenges and teaching opportunities for the MSU EFG are many and over time a more detailed management plan and schedule will need to evolve.

Section 4
MSU Edible Forest Garden Pest Management

Organic and IPM Principles

Organic pest management requires an integrated and holistic strategy. With comparatively little pest management research specific to organic systems, it is necessary to draw on literature from fields such as landscape and applied ecology, and more conventional agriculture sciences. Integrated Pest Management (IPM) research has provided a framework for pest management in organic systems. IPM is a holistic system of pest management that emphasizes enhancement of natural enemies, plant resistance, cultural methods and minimal pesticide use and can be described as a four phase strategy for mitigating pest pressure (Batra 1982, Zehnder *et al* 2007). This four phase pest management strategy is hierarchal, with the early phases being focused on prevention and later phases using more reaction type methods (Zehnder *et al* 2007). Phase one uses cultural practices compatible with natural processes to make crops unavailable to pests through time and space. Some examples of cultural practices used in phase one are proper farm and field location, crop rotations, soil management and non-transgenic host plant resistance. Phase two focuses on vegetation management to enhance natural enemies such as conservation biological control, intercropping and trap cropping. Phase three focuses on augmentative and inoculative biological control and phase four focuses on organically approved biological and mineral pesticides and the use of pest mating disruption. Organic farmers will often accept lower levels of success from individual biological control attempts because they are not heavily dependent on them, but rather dependent on a more holistic approach (Zehnder *et al* 2007).

Various types of biocontrol (i.e. introduction, augmentation and conservation) are important in every phase of this IPM strategy. Although introduction and augmentation are both important tools for organic pest management, conservation biocontrol to enhance local natural enemies is the foundation. The key to conservation biocontrol is biodiversity and managing for the attributes of diversity that enhance the efficacy of natural enemies (Landis *et al* 2000). Organic systems have been shown to increase biodiversity, species richness and the abundance of natural enemies, making them ideal for the application of conservation biocontrol. Soil fertility management is an important component of pest management in organic systems because crop resistance to arthropod pests and pathogens is optimized with proper physical, chemical and biological soil properties. Greater pest resistance for plants grown with organic fertilizers compared with those grown with synthetic have been reported (Zehnder *et al* 2007).

Conservation biocontrol deserves special consideration in terms of its role in organic pest management because it seems to be inherent in the cultural practices of organics. There is also a significant amount of room for improving conservation biocontrol in organic systems by way of improved vegetation management (Landis *et al* 2000). Cultural practices such as crop rotations, cover cropping and conservation tillage, optimize ecosystem health by proper management of both above-ground and below-ground ecology (Batra 1982, Zehnder *et al* 2007). The primary objective of conservation biocontrol is to maximize the efficacy of local natural enemies, which is well suited for organic systems where all pesticides are discouraged and synthetic pesticides are prohibited (Altieri 1999, Zehnder *et al* 2007). Vegetation management in organic pest management can involve both top-down and bottom-up approaches. A top-down approach is what we typically intend when enhancing a system for natural enemies. However, a good IPM system should also include bottom-up approaches such as intercropping and trap cropping which make host plants more difficult for pests to exploit. The two approaches are compatible in that plants used in intercropping can provide benefits to natural enemies and increase the search time of pests for host plants making them more susceptible to attack by natural enemies (Zehnder *et al* 2007). An example of a top-down conservation biocontrol practice that has gained popularity in Europe and is starting to be recognized more in the U.S. is the creation of 'beetle banks'. These are simple beneficial strips of perennial vegetation in agroecosystems that create refuge for natural enemies such as carabid beetles (Zehnder *et al* 2007, Landis *et al* 2000). These beetle banks can provide over-wintering sites for more than 1000 predatory arthropods per square meter (Zehnder et al 2007). Another similar strategy that benefits parasitoids and other predatory natural enemies is the creation of flowering insectary strips, which provide nectar and pollen (Zehnder *et al* 2007, Landis *et al* 2000).

Biodiversity plays a major role in the success of conservation biocontrol strategies and provides many ecosystem services beyond crop production that enhance the level of internal regulation in agroecosystems. The ever increasing impacts of agricultural pest populations has been linked to the expansion of monocultures and consequent destruction of local habitat diversity (Altieri 1999). Although biodiversity in general mitigates pest pressure in agroecosystems, there are certain attributes of diversity that have the most significant impact. These selective attributes are what should be managed to enhance the efficacy of natural enemies. This may mean incorporating plant species into the landscape that enhance availability of food sources (e.g nectar), alternative prey or hosts and refuge for natural enemies (Batra 1982, Landis *et al* 2000). It is important to consider these elements through time and space in order to maximize their effectiveness (Landis *et al* 2000).

Organic systems generally have positive impacts on biodiversity and species richness (Bengtsson *et al* 2005, Hole *et al* 2005). In a series of studies surveyed on the diversity of biota in organic verses conventional agricultural systems, higher levels of species diversity and/or abundance were found under the categories of flora, earthworms, butterflies, spiders, beetles, other arthropods, small mammals and birds (Hole *et al* 2005). The studies that showed the most striking comparisons between conventional and organic were those conducted on the plot scale and on average non-crop organisms were 50% more abundant in organic systems. The results of these species richness and abundance studies indicate that local densities of soil fauna and natural enemies is higher in organic systems but there is little evidence that shows higher densities of pest insects (Bengtsson *et al* 2005). It has been suggested that most of the differences in diversity between conventional and organic agriculture are due to management practices used on organic farms in order to compensate for conventional pest suppression. Polyculture is a beneficial management practice used on many organic farms which can enhance habitat diversity for natural enemies. This can be done in the form of strip cropping of annual crops or with the integration of perennials (Batra 1982). When comparing the success of classical biocontrol in unstable (annual), intermediate (orchard/perennial) and stable (forest or rangeland) systems, the systems of intermediate disturbance had significantly more successes (Hall *et al* 1980). Several studies have indicated that perennial systems provide better habitat for natural enemies because they have lower levels of disturbance (Batra 1982, Landis *et al* 2000). This evidence suggests that an organic perennial polyculture system of intermediate disturbance such as edible forest garden permaculture has the best chance of successfully using biocontrol to regulate pests and diseases.

Practices

Pest management for this project started with preparing the soil. Healthy soil yields healthy plants (better able to repel attack) and minimal weeds in the soil reduces competition. To help control arthropod pests both a top down and a bottom up strategy were used. The bottom up strategy is the basis of using polyculture to mitigate pest pressure. Placing crop plants in a polyculture makes it more difficult for pests to locate them through space and time. The top down strategy involves planting native herbaceous perennial species to attract natural enemies, such as predatory and parasitoid insects. The plant species chosen for the MSU EFG have the highest ratings for attracting natural pest enemies and pollinating species with peak bloom dates that spanned the entire growing season based on a collaborative study done by Doug Landis and Rufus Isaacs *et al* of the MSU Department of Entomology using plants available at Wildtype native plant nursery. Table 4.1 shows a list of the species used in the garden and their peak bloom dates. The plants were dispersed in the garden in diverse aggregates of species to provide nectary resources in all parts of the garden through time and space. The plants in Table 4.1 provide the basis of the conservation biocontrol strategy but many other plant species in the garden including crops species (e.g. cut flowers) also have perceived benefits for beneficial insects and provide additional nectary resources and habitat and will hopefully fill in any of the gaps in resource availability.

Table 4.1. Native perennial beneficial insect attracting species from Wildtype Plant Nursery in order of peak bloom date.

Common Name	Latin Name	Bloom Date
wild strawberry	*Fragaria virginiana*	24-May
golden alexanders	*Zizia aurea*	6-Jun
penstemon	*Penstemon hirtus*	14-Jun
angelica	*Angelica Astropurpurea*	14-Jun
Canada anemome	*Anemone canadensis*	14-Jun
cow parsnip	*Heracleum maximum*	21-Jun
sand coreopsis	*Coreopsis lanceolata*	21-Jun
swamp milkweed	*Asclepias incarnata*	2-Aug
coneflower	*Ratibida pinnata*	2-Aug
hoary vervain	*Verbena stricta*	2-Aug
meadow sweet	*Spiraea alba*	9-Aug
horseming	*Monarda punctata*	16-Aug
beebalm	*Monarda didyma*	16-Aug
yellow gian hyssop	*Agastache nepetoides*	16-Aug
blue lobelia	*Lobelia siphilittica*	23-Aug
boneset	*Eupatorium perfoliatum*	23-Aug
ironweed	*Vernonia missurica*	23-Aug
pale-leave sunflower	*Helianthus strumosus*	30-Aug
New England aster	*Aster novae-angliae*	30-Sep
smooth aster	*Aster laevis*	27-Sep

Since this garden is in early succession (2007) we have not yet encountered most of the pests that could potentially affect an organic perennial polyculture and cannot claim expertise in this area because we are still learning. This section provides some of the common pest management strategies that we have used or perceive will be needed. One pest management concern pertaining to the location of this garden is that it is bordered to the east by conventional (i.e. systems that use synthetic pesticides) cherry and apple production and to the south by conventional apple production, with other conventional perennial production systems in the surrounding area. This is a concern because our organic perennials could become an unintended "trap crop" for the pests in the conventional systems providing them with hosts. However, there are plenty of reasons for hope. Unmanaged fruit trees and berry bushes planted in polyculture on the Student Organic Farm in 2002 have produced quality fruit with marginal damage, with the exception of tart cherries. Many useful Integrated Pest Management resources can be found at http://www.ipm.msu.edu/ .

Current SOF Pest Management Strategies. The SOF currently uses a holistic pest management strategy common on many organic farms for controlling pests on annual crops, implementing phase 1 and phase 2 preventative measures (e.g. row covers, polyculture, trap cropping, crop rotations, maintaining soil health). When a damaging pest outbreak does occur phase 4 strategies are used. For example Colorado potato beetle is managed by periodically walking down the rows of infested nightshades with a bucket of water and knocking the adult beetles and larva in to drown. Flea beetles are physically sucked off the plants with a vacuum. Striped cucumber beetles are usually managed with row covers and trap crops. Cabbage loopers and other lepidoptera are sometimes dusted with diatomaceous earth and in rare cases sprayed with Bt (*Bacillus thuringiensis*). To control powdery mildew on cucurbits kaolin clay or baking soda are sometimes sprayed.

Future Educational Opportunities. Since the SOF is an educational farm the fruit trees in the MSU EFG will provide opportunities for learning about various organic pesticides. Students will be able to learn pest identification and see the results of spraying verses not spraying on crop yield and quality. The garden will also provide a space to compare arthropod diversity and community structure, pest density, pollinator efficacy and natural enemy efficacy in a perennial polyculture with that of a more traditionally managed system.

Considerations for Some Common Pests

Four Legged Herbivores. The best way to prevent mammalian herbivores from damaging woody perennials is by excluding them. Most shrubs can handle some damage because they usually sprout back from the roots but if a grafted tree is damaged it often needs to be replaced. Young shrubs and trees can be protected from rabbits by using small chicken wire cages or tree guards. Rodents will often girdle trees during the winter months and this can be prevented by making sure that mulch is not piled up on the base of the tree and plastic tree guards extend all the way to the ground. Deer are more difficult to control and typically bucks will girdle trees by rubbing on them during the rut. This can be discouraged by making sure tree guards are placed on trees before the fall rut. Browse damage from deer is more difficult to prevent because it can occur during any time of year. Tree guards are still the first line of defense to prevent complete destruction of the tree but other measures can be used such hanging soap or human hair around the tree. Commercial deer repellents are also available, but be sure to check with your organic certifier if this is a concern. The only sure way to exclude deer is with fencing.

Quack Grass and Other Undesirable Perennials. Quack grass is one of the most difficult weeds to manage organically in a perennial garden and requires special consideration. For this it is best to have a strategy of exclusion, removal and tolerance (which could be applied to any weed pest). If at all possible it should be removed prior to planting during the sight preparation phase. In this garden we removed as much as possible by running a drag across the soil pulled by a tractor. Once the garden is planted it can be excluded from smaller garden spaces by using rhizome barriers. In larger areas its progress can be impeded by using plants such as comfrey, rhubarb or daffodils but in most cases it is not likely to ever be completely eliminated. Quack grass is one of the first plants to leaf out in early spring making it very visible and this is the best time physically remove it using a digging fork. It is worth the effort to remove as much as possible during this early period, focusing on patches of highest concentration. The best time to do this is right after a spring rain when the ground is soft. In the end some level of tolerance will likely be necessary.

Plastic films, either clear or black, can also be used for short periods of time to kill quack grass or other vegetation by heat or "solarization". This method can be demonstrated during the highest light periods of the summer by covering the ground cover with a piece of clear plastic film. Plant foliar damage is evident within hours. We do not have experience with the killing time for rhizomes. It likely would take days or weeks.

Pathogens and Arthropods. When preventative measures fail and tolerance thresholds are reached, reactionary methods of pest control may be necessary. In organic systems this usually means the use of pest mating disruptrs, sticky traps and mineral or plant based pesticides approved for organic certification. The details of this are beyond the scope of this paper but it is important to attempt a diversity of methods and to do your best to knock down an entire generation of a pest to prevent the reproduction of the next generation (Phillips 2005). Here are a few examples of sprays used in organic systems. Many lepidopteran pests can be controlled using Bt, surround, entrust and neem oil. Sulfur and copper sprays can work for many fungal and bacterial diseases and a spray of baking soda can help control powdery mildew. Many arthropod pests can be controlled with botanical sprays such as rotenone, pyrethrum, ryania and nicotine. Garlic can be used as a repellent. Japanese beetles (a particularly damaging pest to grapes) should be sprayed with pyrethrum upon arrival before they are able to deposit large amounts of a hormone they use to signal their location to other members of the species. However, these materials are non-selective and can be damaging to beneficial predators and in some cases humans. Use of "restricted" materials must be justified. All of these sprays should be used with caution and with proper instruction (Phillips 2005).

Section 4 Literature Cited

Altieri, M.A. 1999. The ecological role of biodiversity in agroecosystems. Agric. Ecosyst. Environ. 74:19-31.

Batra, S.W.T. 1982. Biological control in agroecosystems. Science. 215:134-139.

Bengtsson, J., J. Ahnstrom and A. Weibull. 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. J. Appl. Ecol. 42:261-269.

Fulbright, D. 2005. Personal communication.

Hall, R.W., I.E. Ehler and B. Bisabri-Ershadi. 1980. Rates of success in classical biocontrol of arthropods. Bulletin of the Entomological Society of America. 26:111-114.

Hole, D.G., A.J. Perkins, J.D. Wilson, I.H. Alexander, P.V. Grice and A.D. Evans. 2005. Does organic farming benefit biodiversity? Biol. Control. 122:113-130.

Landis, D.A., S. D. Wratten and G.M. Gurr. 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. Annu. Rev. Entomol. 45:175-201.

Michigan State University. 2005. HRT 491 Fruit tree production and management. Department of Horticulture.

Phillips, M. 2005. The apple grower. Chelsea Green Publishing. p.343.

USDA. Natural Resource Conservation Service web soil survey. http://websoilsurvey.nrcs.usda.gov/app/

USGS. 2006. Regional ecosystems of Michigan, Minnesota and Wisconsin. Northern Prairie Wildlife Research Center. Sub-section VI.4.1.Lansing. http://www.npwrc.usgs.gov/resource/habitat/rlandscp/s6-4-1.htm

Zehnder, G., G.M. Gurr, S. Kuhne, M.R. Wade, S.D. Wratten and E. Wyss. 2007. Arthropod pest management in organic crops. Annu. Rev. Entomol. 52:57-80.

Edible Forest Garden Summary

The MSU EFG was conceived from a diverse body of literature pertaining to Integrated Perennial Polyculture that includes the interrelated disciplines of agroforestry and permaculture. The design of the system follows a systematic approach to creating over-yielding polycultures that can be replicated and applied to any scale of land use in any bioregion. These tree based polyculture systems provide many ecosystem benefits, perform many ecosystem functions and provide useful services and products. This has many applications to year-round diversified farming systems, including urban agriculture and home landscaping. Less common species can be integrated with conventional perennial fruit and vegetables crops as well as annuals, cutflowers and herbs to yield a productive, ecologically sustainable landscape. Figure 4.1 shows the garden after final plantings with the author out standing in his field.

Figure 4.1 MSU Edible Forest Garden with the apple orchard in the background to the south (June 2007).

Appendices

Frequently Asked Questions about the MSU Edible Forest Garden

What is Edible Forest Gardening? (EFG)

Edible forest gardening is an emerging method of landscape design and maintenance which incorporates principles of horticulture, ecology, permaculture, agroforestry, and indigenous agriculture methods. Plant species are mixed to capitalize on beneficial associations and to create an efficient three dimensional structure for collecting light energy above ground and water and nutrients below ground. Management strategies are implemented to conserve water, build soil fertility and organic matter, reduce the competition from "weed" or ground cover crops, and minimize yield reducing occurrences of plant damaging insects and fungi.

What is Permaculture?

Permaculture is a more extensive and integrated philosophy and method of landscape, homestead and community design and maintenance that includes the principles and practices of edible forest gardening. Permaculture planning includes ethical principles for community interactions and human interaction with the natural landscape as well as efficiency considerations used to incorporate areas such as energy, water conservation and use, animal agriculture, housing, etc. Permaculture seeks to honor and incorporate long standing successful traditions of indigenous peoples for living in harmony with the landscape. Permaculture as a named and formalized system emerged in the 1970's in tropical and subtropical climates/geographic regions and continue to evolve and be applied to temperate and cold climates/geographic regions.

What is Ecology and Ecological Design?

Ecology is a branch of scientific investigation and education focused on understanding the interactions of organisms and their environment. The prefix "eco" comes from the Greek word "oikos" which means home. One definition describes ecology as "the study of home". Subcategories might include "forest ecology", "soil ecology", "marsh ecology" based on understanding ecosystems consisting of plant, animal and microorganism communities. We can be hopeful that the human species is growing and evolving from a vision or paradigm rooted in the industrial/scientific revolution to one rooted in ecological evolution. Proposed components of an ecological agriculture are 1) crop diversity, 2) self sustaining fertility, 3) ground cover management to conserve soil and organic matter, 4) three dimensional plant canopy and root systems, and 5) consideration of the natural changes over time (temporal shifts) that occur both seasonally and as an ecosystem matures.

What is Polyculture? (Integrated Annual Perennial Polyculture)

With the application of the principles of the industrial revolution to agriculture, output per unit time of human labor was increased by use of extensive "monocultures" of individual plant species. Such monocultures result in the loss of plant, soil and animal health that arises from ecological interactions and diversity. One aspect of polyculture is capitalizing on the health benefits of a diverse cropping system. A second aspect of polyculture is capitalizing on the advantages of both perennial and annual crop species. Perennial crops such as tree fruit (apples), brambles (raspberries), shrubs (blueberries) and vines (grapes) require pruning and training methods and ground cover management systems with limited or no annual plowing. Often farmers or gardeners have kept perennials and annuals separate as opposed to interplanted.

Is edible forest gardening "gardening in a forest" or "making a garden like a forest"?

Making a garden like a forest is the better method to describe the EFG. By observing natural ecosystems, we can see that often the zone between an open field and a closed canopy forest can be a very productive "margin" or "fringe" area or ecosystem with unique properties. With some trees and some open areas, plant growth and productivity of a wide diversity of plants can occur. This zone is also characterized or explained by understanding the "succession" of plant species that occurs when an open field area gradually converts to shrub growth and eventually trees and finally a closed canopy forest.

How is the tree canopy managed to let enough light for shrub and ground cover species?

Light penetration is managed by planting of tree species taking into account their ultimate size and by continuous pruning or removing of trees as the canopy matures. Vining crops like grapes are also allowed to either trellis on trees or are provided trellises to allow greater light efficiency.

How are plants grouped to more efficiently mine water and nutrients from the soil?

Plant root systems are often described as either fibrous, shallow and spreading or as "tap" or deep rooted. By mixing plants with deep and shallow root systems, more of the soil profile can be used by roots to collect water and nutrients.

How are "weeds" or over-aggressive vegetation managed?

In any ecosystem there are plants that will establish to fill the space available. If the species is overly competitive, of limited human value for harvesting, or restricts the growth of the desired agricultural species, the plant growth can be restricted by mulching with either more competitive plants (comfrey, for example) or with layers of natural (bark, straw, cut plants, etc) or synthetic (plastic, landscape fabric) materials that limit the availability of water, nutrients or light. Other physical methods include pruning or mowing.

How is soil fertility managed?

Plant nutrients in soil minerals gradually become available by weathering and biological absorption by microorganisms and nutrient efficient plant species. The cycling of the nutrients depends on maintaining the organic matter that develops from the microorganisms and decaying plants and carefully managing the rate of decay. Vegetation that is pruned is recycled by either leaving on the soil surface for slow composting or by managed composting in piles.

What are some examples of who would use an Edible Forest Garden?

- Schools and educational programs seeking to demonstrate gardening and farming methods, principles of ecology, ecological agriculture, food system management, and disciplines such as design, soil fertility management, ground cover management, and plant maintenance.

- Families and small communities seeking to develop personal food security, increase dietary diversity, provide supplemental income from sale of fresh vegetables, fruits, herbs and flowers, and outdoor, physically active recreational activity with multiple health benefits without car travel necessary. Could be implemented with personal landholdings as small as 100 square feet or in community allotments or communal plots for urban agriculture.
- Market gardeners and farmers seeking to develop low input, alternative production systems using a mix of perennial and annual crops for year round production and harvesting.
- Large plot land owners seeking a method of generating income from the sale of agricultural products that does not require annual large scale cultivation of the land.

Is the MSU EFG modeled after some place or an example we see in nature?

When cultivation is stopped a field will gradually revert back to forest through a process called "ecological succession". The intermediate step or field in mid succession typically has both more species and diversity and is potentially more productive. Trees are developing, but the canopy is still open so there is adequate light for understory plants, vines and ground covers. This intermediate and constantly changing stage is one possible natural example of the EFG.

When did planning for the MSU EFG begin and what was the process?

Soil improvement for the EFG plot started in 2003 and continued through the summer of 2005 when regular cultivation began to incorporate the sheet composted organic matter and to reduce weed seed populations. A rye cover crop was planted in the fall of 2005 and a mixture of white and red clover where frost seeded during the spring of 2006. The design process started late in 2005 and continued through winter 2006. Planting started in spring 2006 while the rye cover crop was just emerging and developing and continued through the summer and into July of 2007.

What is a three sisters garden?

The three sisters garden used by Native Americans across north and south America is an example of an efficient polyculture and is one of the inspirations of the MSU EFG. Corn seeds were planted in mounds of soil at a spacing that allowed growth of bean and squash crops planted later. After the corn became established, trailing beans were planted adjacent to the corn so that the beans grew up the corn stalk and fruit was well above the ground, reducing the access of predators. Squash seeds were planted so that the vines covered the ground between the mounds of corn which both reduced the growth of other competing species and helped to conserve water. The prickly, scratchy nature of the squash vines also helped to reduce the access of predators to the corn and beans. The dried corn and beans together with the hard rind squash provided food through the winter months.

Edible Forest Garden Permaculture Resources

Temperate Permaculture Reading List

Edible Forest Gardens (vol 1&2) by Dave Jacke and Eric Toensmeier (2005)
Gaia's Garden by Toby Hemenway (2000)
Permaculture: a designers manual by Bill Mollison (1988)
Permaculture: Principles and Pathways Beyond Sustainability by David Holmgren (2002)
The Earth Care Manual by Patrick Whitefield (2005)
Food Not Lawns by Heather Flores (2006)
Introduction to Permaculture by Bill Molison (1991)
The Apple Grower by Michael Phillips (2005)
Perennial Vegetables by Eric Toensmeier (2007)
The Complete Book of Edible Landscaping by Rosalind Creasy (1982)
Plants for a Future by Ken Fern (2000)
Plant Propagation (Royal Horticulture Society, UK) by Phillip McMillan Browse (2004)
Growing Fruit (Royal Horticulture Society, UK) by Harry Baker (2004)

Many books such as these can be found at Chelsea Green Publishing. http://www.chelseagreen.com/

Permaculture Material Sources

Hartmann's Plant Company (small Fruit)
http://www.hartmannsplantcompany.com/index.html, 269-253-4281
Indiana Berry and Plant Company (small fruit)
http://www.inberry.com/index2.html, 1-800-295-2226
Southmeadow Fruit Gardens (fruit trees)
http://www.southmeadowfruitgardens.com/, 269-422-2411
Gurny's Seed and Nursery (almost everything)
http://gurneys.com/, 503-266-9814
Oikos Tree Crops (native fruits)
http://oikostreecrops.com/, 269-624-6233
Wildtype (native plants)
http://www.wildtypeplants.com/ , 517-244-1140
Richters (herbs)
http://www.richters.com/ , 905-640-6677
Bailey Nurseries (fruit trees)
http://www.baileynurseries.com/ , 800-829-8898
Nash Nurseries (chestnut trees)
4975 W Grand River Rd, Owosso, MI 48867, 517-651-5278
Tollgate Gardens & Nursery (pawpaws)
http://www.tollgategardens.com/index.html, 269-781-5887
Johnny's Selected Seeds (vegetable seeds)
http://www.johnnyseeds.com/ , 877-564-6697
Fedco Co-op Garden Supplies (vegetable seeds)
http://www.fedcoseeds.com/, 207-873-7333

Trickl-eez (irrigation)
http://www.trickl-eez.com/, 800.874.2553
Farmtek (greenhouses, hardware and tools)
http://www.farmtek.com/farm/supplies/home, 800-457-8887

Rare herbaceous perennials for permaculture:
Perennial Pleasures http://www.perennialpleasures.net/
Morning Sky Greenery http://www.morningskygreenery.com/
Bordine Nursery http://www.bordine.com/
Companion Plants http://www.companionplants.com/
Sand Mountain Herbs http://www.sandmountainherbs.com/
Sunshine Farm & Gardens http://www.sunfarm.com/

Other informational resources (in order of recommended use)**:**

Permaculture Activist (large U.S. permaculture network)
http://www.permacultureactivist.net/
Midwest Permaculture (certification and other resources)
http://www.midwestpermaculture.com/
Edible Forest Gardens (permaculture/agroforestry consulting and services)
http://www.edibleforestgardens.com/
Michigan State University Student Organic Farm
http://msuorganicfarm.com/home.htm
Michigan State University Integrated Pest Management
http://www.ipm.msu.edu/about.htm
Association for Temperate Agroforestry
http://www.aftaweb.org/
National Sustainable Agriculture Information Service (ATTRA)
http://www.attra.org/
New Forest Farms, LLC (permaculture/agroforestry consulting and services)
(608)6270-TREE, forestag@mwt.net

For more information contact:

Jay Tomczak
Earthtrust Services, LLC
jay@earthtrustservices.org
http://earthtrustservices.org/
phone (616)293-7208

Examples of Permaculture Principles Being Implemented in Communities

Holmgren (2002) believes that it is inevitable that the permaculture ethics and design principles will be used as a framework for developing a sustainable global society, regardless of whether or not they progress under the banner of permaculture or diffuse obscurely into the broader culture. Very few permaculture influenced projects and organizations are explicitly labeled as such. Therefore when researching examples of permaculture influenced projects, I focused on projects that either had a known connection to permaculture (e.g. The project was influenced by a known permaculture practitioner), the organization or movement facilitating the project has a known relationship with permaculture (e.g. the relocalization movement) or the project blatantly uses known permaculture practices (e.g. edible landscaping). I chose examples of projects which had community food security as one of the primary objectives and contained lessons that could be applied to low-income urban communities.

There have been several organizations from the permaculture movement that have facilitated community action at various scales. The relocalization movement initiated by the Post Carbon Institute is a movement with close interactions with the permaculture movement. Relocalization is about making efficient use of local energy and resources to provide for local needs. Central to this is a focus on community food security (Genauer 2006). Across the northern hemisphere regional relocalization organizations are developing and implementing a framework for their communities to procure all their needs sustainably. Some of these groups are, the Willets Economic Localization plan in California, the Tompkins County Relocalization project in New York, Capital District Relocalization Plan in New York, Bay Localize in California and Kinsale Energy Decent Plan in Ireland (also very influential in the U.S). All of these projects implement permaculture principles and employ the energy of permaculture educated individuals. These groups have created inventories of community resources and networks to provide policy makers and community members with the information they need to make effective decisions (Genauer 2006).

Two prototype permaculture neighborhood projects found in the U.S. are the Prescott Ecohood and Kennedy Estates Edible Landscaping Project. The development of an 'ecohood' in Prescott, Arizona is a permaculture project in the mid to low-income neighborhood of Lincoln-Dameron. This neighborhood is about half Latino/Native American, with the rest being college students and retirees. The community members are developing rainwater collection systems, gray water systems, organic gardens with fruit trees and animals, and they have created a network of individuals that share information, tools, skills and resources (Defreitas 2006). In California, the Sacramento Hunger Commission developed the Kennedy Estates Edible Landscaping Project as a community food security program. Their mission is to make access to affordable, nutritious and culturally appropriate food a basic human right. The edible landscape created by the project includes a diversity of perennial fruit bearing trees, shrubs, annual vegetables and herbs. An assessment was made of available space, water, information, financial resources, material resources and human resources, focusing on health, community empowerment, the environment and social cohesion for the low-income community of Kennedy Estates (Salcone 2005). The project includes working with city clerks and county extension to understand zoning codes, a comprehensive landscape design and a timeline for long term maintenance and care. An important component of the project is the facilitation of community ownership through nutritional and horticultural education, and community events. Guidelines were established for harvest, distribution and maintenance of food crops. Projects such as these must be specifically adapted to a community's climate, space and resources (Salcone 2005).

In Russia, agriculture was nationalized during the Bolshevik revolution and peasant farmers were moved off the land. But with pending food shortages in WWII, the people were authorized to reclaim the land and their agrarian traditions. Currently, permaculture techniques are used on a large scale in the traditional dacha gardens, the Russia-wide Ringing Cedars movement, dacha cooperatives and ecovillages. These practices produce 40% of Russia's agricultural output, which includes 92% of the potatoes, 77% of the vegetables, 87% of fruits and berries, 59.4% of meat and 49.2% of milk. This does not include the important contributions of fishing, hunting and gathering of wild plants (Sharashkin et al 2005). More than 50% of urban dwellers have access to dacha gardens and it is considered a sustainable, productive and socially important practice. In a survey conducted by Artemov (2002) it was reported that 86% of gardeners thought that their garden plots were essential and important to their survival. People often share their surplus or turn it into economic opportunity in the market. Besides contributions to social, economic and environmental stability, advocates of this new garden movement claim an enhanced spiritual connection with the natural world (Sharashkin et al 2005).

The most commonly cited example of successfully applied permaculture is the post Soviet collapse story of Cuba. Permaculture was only one of many contributions to the agrarian revolution occurring during this Cuban transition period. Prior to the collapse of the Soviet Union, Cuba had one of the most industrialized food systems anywhere in the world and was heavily dependent on pesticides, herbicides, fertilizers and mechanization (i.e. fossil fuels). They exported citrus, sugarcane and tobacco, and imported basic food staples. With unrelenting U.S. trade embargoes and the collapse of the Soviet Union, Cuba lost its support system and went into almost instantaneous economic collapse. It lost 50% of its oil imports and 85% of its trade economy. During this time the average Cuban lost 30 pounds (Quinn 2006). Starving communities instantly mobilized to plant vegetables wherever they could and obtaining enough food for the day became the primary activity of most Cubans. In 1993 a group of Australians came to teach permaculture. With a modest grant from the government, the Foundation for Nature and Humanity's urban permaculture demonstration project center began in Havana. The permaculture principles then spread rapidly across the country. People began growing food organically, in raised beds in parking lots, on roof tops and patios. Urban gardens replaced the need for long distance transport of food, compost replaced fertilizer, polyculture replaced monoculture, people ate less meat and in rural areas oxen replaced tractors. Today 50% of Havana's vegetables are grown within the city and in other towns 80-100%. Farmers formed cooperatives and neighbors worked together to build a strong local economy. Cuban institutions have begun large scale production of bio-pesticides and bio-fertilizers and have exported them to other Latin American countries. Complementary to this food security centric revolution was the government facilitated development of mass public transit, ride shares, thousands of bicycles, renewable energy and energy conservation technologies, a holistic health care system, more doctors and nurses, more teachers and soccer (Quinn 2006). The government reorganized provinces for the benefit of agriculture and opened up public land to private growers and neighborhood gardens. This was a top-down and bottom-up effort in which government policy and grassroots organization came together for the common good. Cuba changed its 30 year motto of “Socialism or Death” to “A Better World is Possible” (Quinn 2006).

Establishing increased food security in a community requires a holistic approach. A food system cannot be sustained in isolation and needs to be integrated with a network of social, economic and environmentally sustainable practices. Permaculture ethical and design principles were developed to create a holistic framework for developing community food security and community sustainability. The maturation of the permaculture movement has created a stable network of permaculture educated individuals and access to the permaculture principles, setting the stage for the widespread adoption of these principles in communities in need. The permaculture philosophy can be used as a framework to connect people physically, mentally and politically to their food system. Permaculture has been used successfully across the globe to create positive synergistic relationships in homes, neighborhoods and nations, for the purpose of creating stable, diverse, resource independent communities.

Literature Cited

Defreitas, S. 2006. Prescott's sustainable ecohood. Communities. Social Science Module 131.

Genauer, E. 2006. Peak oil and community food security. Communities: Journal of Cooperative Living. Issue 130.

Holmgren, D. 2002. Permaculture: principles and pathways beyond sustainability. Holmgren Design Services. p.286.

Mollison, B. 1988. Permaculture: a designer’s manual. Tagari Publications.

Quinn, M. 2006. The power of community: how Cuba survived peak oil. The Permaculture Activist.

Salcone, J. 2005. The edible landscaping tool kit: an informational guide for low-income housing settings to develop a healthy and productive landscape. Sacramento Hunger Commission.

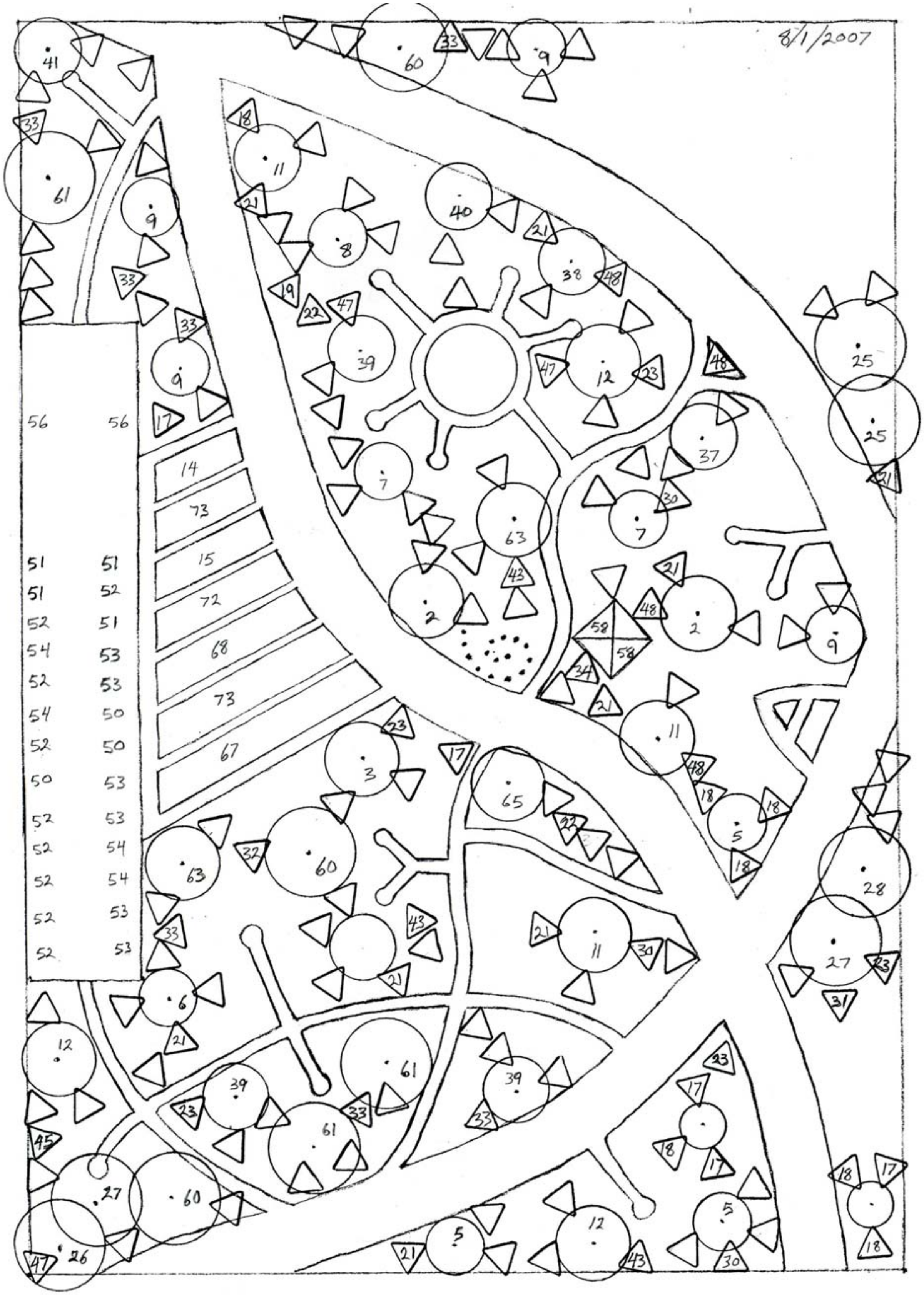
Sharashkin, L. et al. 2005. Ecofarming and agroforestry for self-reliance: small-scale, sustainable growing practices in Russia. Association for Temperate Agroforestry Conference Proceedings.

Plant list for identification of MSU EFG woody species cultivars.

1	**American Persimmon**	*Diospyros virginiana*
2	Ecos	
3	Pipher	
4	**Apple**	*Malus pumila*
5	Enterprise	
6	Golden Gala	
7	Goldrush	
8	Lliberty	
9	Smoothie	
10	**Asian pear**	*Pyrus bretschneideris*
11	Korean Giant	
12	Olympus	
13	**Blackberry**	*Rubus fruiticosus*
14	Chester (thornless)	
15	Illini	
16	**Blueberry**	*Vaccinium spp*
17	Blue crop	*Vaccinium corymbosum*
18	Jersey	*Vaccinium corymbosum*
19	Lowbush blueberry	Vaccinium *angustifolium*
20	**Bush plum**	*Prunus spp*
21	Beach plum	*Prunus maritime*
22	Dunbars plum	*Prunus x dunbari*
23	Nana plum	*Prunus maritima 'nana'*
24	**Chinese Chestnut**	*Castanea mollissima*
25	Benton Harbor	
26	Eaton	
27	Norm Higgins	
28	Williamette	
29	**Current**	*Ribes spp*
30	Black current	*Ribes nigrum*
31	Jonkeer Vantets	
32	Josta	
33	Red current	*Ribes Silvestre*
34	Rovada	
35	White Imperial	
36	**European pear**	*Pyrus communis*
37	Clapps Favorite	
38	Kieffer	

39	Moonglow	
40	Potomac	
41	Sweet Harrow	
42	**Fig**	*Ficus carica*
43	Chicago Hardy	
44	**Gooseberry**	*Ribes hirtellum*
45	Consort	
46	Hinnomaki	
47	Invicta	
48	Johns Prairie	
49	**Grapes**	*Vitis vinifera*
50	Elmer Swenson	
51	Himrod	
52	Mars	
53	Marquis	
54	Vanessa	
55	**Hardy kiwi**	*Actinidia aguta*
56	Ananasnaya (Anna)	
57	**Hop**	*Humulus lupulus*
58	Cascade	
59	**Pawpaw**	*Asimina triloba*
60	Lynns Favorite	
61	Taylor	
62	**Peach**	*Prunus persica*
63	Allstar	
64	**Plum**	*Prunus domestica*
65	Stanley	
66	**Raspberry**	*Rubus idaeus*
67	Heritage (fall)	
68	Prelude (summer)	
69	**Saskatoon**	*Amelanchier alnifolia*
70	Regent	
71	**Strawberry**	*Fragaria x ananassa*
72	Honeoye	
73	Jewel	

Plot Map with Wooody Speicies by Cultivar



Agroforestry/Permaculture Conversion & Management Outline

Michigan State University
Student Organic Farm
John Biernbaum, Jason Tomczack

Prepared by:
Mark L Shepard; Consulting Agroforester
Forest Agriculture Enterprises LLC
P O Box 24
Viola, WI 54664
608-627-8733

Nov 16, 2005

Introduction

The following is a summary of priority practices/projects that can be undertaken by the MSU Student Organic Farm that will help to enhance the future sustainability and productivity of the site. Much of the content of this report was discussed by the group of students and visitors to the site on Nov. 5, 2005. This report merely summarizes what I feel should be prioritized based on the greatest effect for the least amount of work. Productive systems (yielding either crops or beneficial ecosystem services) are given priority. For each recommendation I will give some basic reasons as to why a specific project or practice would be undertaken and I will leave it up to the students and researchers to delve more deeply into the details.

This summary is my attempt to integrate the "Goals, Hopes, Ideas and Aspirations for the MSU SOF" (Jay Tomczak & John Biernbaum, Nov 2, 2005) with the ecological realities of the site and the practical realities of managing a farming enterprise. It is my hope that all of the proposed practices will be researched and documented by students at MSU.

-Complete site drainage plan & add sedimentation basin
-Install Alleycropping/windbreak/hedgerow systems:
- **-Edible fruit/nut systems**
- **-Woody ornamental/craft systems**
- **-Perennial cutflower/ herb systems**

-Daffodils beneath fruit trees
-Create Silvopasture system
-Install "built" structures for beneficial organisms
-shade tolerant demo

-Complete site drainage plan & add sedimentation basin

The first field that the group visited on Nov 5, was field #8 and overlooking #9 (from MSU Student Organic Farm: Site Layout and Plan document). The fact that a potential excess water problem exists was obvious. Initially a small sedimentation pond/ephemeral pond was discussed for the intersection between fields #8 & #9, but upon seeing the larger site drainage plan as described by John Biernbaum and seeing that work has already been done to complete this, I tend to agree that fields 8 & 9 should be graded so that they drain gradually to the west, then to the south along the western edge of the compost area and future root cellar area. At the SW corner of the Root cellar site, the drainage could be connected with the previously enhanced roadside drainage ditch coming from the East. This corner is an excellent site for the creation of a prairie wetlands habitat/ephemeral pond. Amphibians currently breed in a wetland area several hundred feet to the west in the woodlands in an area that is nearly eutrophied. Excavating a sedimentation basin in the proposed location will create additional amphibian habitat, beneficial insect habitat and can be a very attractive element in the landscape. Prairie wetlands species can be planted in and around the sedimentation basin and habitat structures for frogs and toads can be located in the pond as well. (toads are one of the few creatures known to eat Plum Curculio a common fruit pest insect) Flowering plants will provide visual appeal to people and provide food sources for wild pollinators and predatory insects. If it is desired to keep water in the pond all season, a liner could be installed. When evaporation exceeds inflow, water could be added from the hoses in the greenhouses. It is likely that either a lined or an unlined basin would need to be cleaned out every few years as sediments from the road and fields fill it in. Late summer excavation of accumulated sediments will help to limit the crushing of hibernating amphibians.

-Install Alleycropping/windbreak/hedgerow systems:

Several objectives can be accomplished simultaneously by dividing the annual produce fields with hedgerows of perennial plants. (agricultural fields between hedgerows or tree rows = Alleycropping) Wind erosion soil losses will be reduced by the presence of hedges between fields, snow drifts can be captured and soaked into the soil upon melting, visual beauty can be added to the whole farm and additional yields can be gathered from them. (fruit, nuts, herbs flowers etc.) Hedgerows extending into and between annual fields will also create a very important connectivity within the landscape for beneficial organisms. Hedgerows provide permanent habitat for spiders, for example where an annual field might not. Hedgerows provide safe(r) travel corridors for toads and frogs and can even provide nesting sites for insectivorous birds. Some commonly overlooked benefits from perennial hedgerows are accumulations of leaf litter which may contain nutrients accessed by the perennials deep root systems and refugia for soil biota. A key to the success of an organic operation is to have an active soil life. Whenever a field is tilled populations of soil organisms crash. Their recovery can be enhanced by having undisturbed soil nearby providing the source of organisms for re-colonization of the field soils. With hedgerows connecting wild areas of the farm to the interior of the annual crop fields, the disturbed area is effectively reduced and "ecosystem services" (pest & disease control, soil fertility etc) penetrate the entire farm. (some great research can be done in determining how far spiders or tree frogs or other non-flying beneficials travel from undisturbed habitat)

An important cultural technique when using alleycropping systems is called "root plowing". In order to prevent the hedgerow plant from sending roots into the annual field and competing with the annual crop for nutrients and moisture, the roots of the perennial need to be severed annually starting within a year or two of establishment. A single shank subsoiler that reaches 18" deep or more will suffice. This is especially important on heavy water users such as the willows. If you don't keep the hedgerow's roots out of the annual field, you will see crop yield reductions especially in dry years.

Finally, the hedgerows in these alleycropping systems can produce additional yields to the farm. I've divided these into three types starting with:

-Edible fruit/nut systems

Since the MSU student Organic Farm markets its produce through CSA subscriptions, hedgerows of edible shrubs are an excellent choice. Uncommon fruits are useful for CSA customers since the fear of buying "unknown food" is overcome by the element of surprise and included recipes. (I wonder what's in the box this week?)

Some ideas for edible hedgerows include Cane fruits: raspberries (red, yellow, black, june-bearing and everbearing), blackberries, salmonberries, currants (red or black), and gooseberries.

For slightly more acid soil or amended soil blueberries, lingonberries or cranberries. Strawberries grow well beneath blueberries especially in mulch, so this would provide two crops in the same space.

For neutral soils, the Prunus family provides several options from the Nanking Cherry and Hansen's Bush cherry (very similar in taste and appearance) to beach plums (very nice 1" mini plums) and sandcherries. PawPaw should do OK in your location and the issues that the fruit has with short shelf-life can be somewhat ameliorated by picking and shipping immediately to your CSA customers. Cornelian groundcherry (Cornus mas) & goumi's can be planted for the more adventurous. Hardy Kiwi can be used, though must be trellised. Sea Buckthorn (Seaberry/

Hippophae ramnoides) produces abundantly though shold be completely harvested in order to avoid being spread by birds.

Badgersett hybrid hazelnuts will work well in alleycropping systems. They are much smaller shrubs than the hazels adjacent to the SOF and much more resistant to eastern filbert blight. Their nut size and shape is somewhat more unpredictable.

Allegheny chinkapin is a shrub-type chestnut that will probably survive at MSU, although the nuts are quite small and even your CSA customers might not like peeling them. Seguin chestnut, a Chinese chinkapin equivalent, is available through Badgersett.

If you were to plant one row of each edible fruit or nut listed here, you would be able to divide every annual field from the other by a hedgerow, then surround it on all sides! You have no shortage of material that will work at this site.

Some nursery sources are attached to this report.

-Woody ornamental/craft systems

The woody ornamentals market has received a lot of attention from researchers these days, and perhaps there is a call for more research on the dollar yields from woody ornamental systems. It is not so likely that your CSA customers would be able to use all of the material that you produce, so it would be prudent to find additional markets in order to utilize your plantings so that they do not become a "problem" that needs to be solved. Woody ornamental species include material that is harvested in winter and early spring providing a cash-flow in the produce off-season. For additional information on woody ornamentals & nursery sources, check out the material produced by the National Agroforestry Center as well as research conducted by the University of Nebraska's Scott Josiah.

Some woody ornamental species:

Willows: curly willow (several different variants), pussy willow(dozens of different colors, shapes & sizes) flame willow (colorful stems) basket willow (for weaving) and more. Used as stems.

Birches: yellow, black, river, white, grey, weeping etc. Cut stems or small diameter trunks (white birch). Girdle grey birch and allow them to become naturally inoculated with bracket fungi. etc.

Flowering Shrubs: Contact your landscape/hort department to see which of several thousand flowering shrub varieties will do best at your site. Flowering shrubs that can be forced in the greenhouse for late winter sales are a great choice. (apple, cherry, forsythia and many others) Flowering shrubs that subsequently have ornamental berries (such as the dogwoods and highbush cranberry) can be sold as stems with flowers, stems with unripe berries or stems with ripe berries. Flowering shrubs associated with nitrogen fixing rhizobia (eastern redbud) can be strategically placed beside fields intended for heavy N feeding crops such as the brassicas.

-Perennial cutflower/ herb systems

Hedgerows of non-woody perennials can be used in alleycropping systems as well. Flowering plants are important as nectar sources for predatory insects as well as wild pollinators who need something to eat before and after your crop is flowering. Many culinary herbs can fill this role as well as medicinals. Some of the more maintenance-free non-woody perennials are oregano, mint (spearmint, peppermint & catnip appear to be quite competitive) asters, yarrow (comes in several bloom colors) stinging nettle (harvested as a green in early spring), lovage (also harvested as a green in spring) and Jerusalem artichoke (edible tuber and fall cutflowers).

Whether or not the decision is made to plant an entire hedgerow to non-woody perennials, these plants should be included all throughout the hedgerow plantings. A diversity of flowers in your hedgerows will provide beauty throughout the season an food and habitat for pollinators and predators.

-Daffodils beneath fruit trees

One of the problems that the fruit trees to the east of the work house have, is soil compaction and sod competition. One way to gradually eliminate the sod from beneath fruit trees is with daffodils. These can be planted as food sources for early season wild pollinators, or to be cut and included in your ornamental sales program. Daffodils come in a wide variety of sizes, shapes and colors, tall and short growing plants as well.

In addition to daffodils, Iris can be planted. Both daffodils and irises eventually form thick clumps and will eradicate even the toughest of sod. Irises come in even more colors and sizes than daffodils and the root can be harvested and marketed to medicinal herb companies. For an enormous variety of daffodils and iris at wholesale quantities and process call: 1-800-ALL-BULB

-Create Silvopasture system

The mature chestnut, hazelnut and walnut plantings to the west of the SOF in combination with the open pastureland to the south of them, provide one of the premier opportunities to establish a mature silvopasture system on a university campus! Cattle, sheep or hogs (with rings in their noses) can be rotationally grazed beneath and between the trees. The animals benefit from the added shade in the summertime and the trees benefit from weed control and fertilizer. Hogs and sheep will utilize chestnuts as feed in the fall. Before undertaking this enterprise, be sure to research the topic carefully. (University of Missouri, Columbia is the center of agroforestry research in the US.

Cattle are an excellent choice for silvopasture systems. One reason being that browse is their last food choice. If you have problems with the cattle eating your trees you didn't rotate them soon enough. Also, cattle actually have a "lighter" footprint than hogs (fewer PSI spread on their wider hoof) and do not sink into the soil as much. This is a serious consideration in grazing beneath the mature chestnut/hazel and walnut trees to the west of the SOF. These trees have never been "root plowed" and consequently they probably have extensive surface roots out in the grass alleys between rows of trees. When grazing beneath these trees DO NOT let the animals graze when the soil is wet and soft. Also, do not graze them beneath the trees from mid-July until fall, since the added boost of late summer nitrogen can cause winter hardiness stress.

If you choose to plant additional trees for a silvopasture system, consider deeper rooting trees such as oak or walnut, since they are not as likely to get root damage. Also, root-plow your silvopasture system to insure that the tree roots stay within the tree row and do not rob nutrients from the forage.

Some woody plants can be planted in a silvopasture system that are intended to be utilized as feed. (I will e-mail a table showing the relative feed values of various woody plant species) An intentionally browsed system and a non-browsed system will have different rotation times. (animals stay in a browse system longer than in a non-browsed system)

Unless animals are grazed only AFTER the tree crop is harvested, silvopasture systems are not allowed under USDA Organic certification. In order to be USDA certified, the animals must be removed from the crop tree system 180 days prior to the harvest of any crop intended for human consumption.

-Install "built" structures for beneficial organisms

All of the systems discussed so far, enhance the biological "thickness" of the SOF. Undisturbed areas penetrate disturbed areas and natural processes are brought further into the annual crop areas. All of what has been described heretofore enhances wildlife habitat. In addition to biological habitat enhancement, some "built" items can be added to the system.

Bat houses: more than several, near water. Outstanding moth control.)cabbage looper, coddling moth etc)

Bluebird/tree swallow nest boxes: Bluebirds and tree swallows use houses of the same size. Plant on field edges or on tall wooden poles to attract swallows (house wrens and English sparrows, too). Plant on metal T-post fenceposts in open areas for bluebirds.

Raptor Roosts: erect wooden poles throughout the farm within a hedgerow to keep it out of the way of equipment. For rabbit & rodent control.

Wood Duck nest Boxes: These can be installed on forest/field edges or on raptor roosts in the field not to attract Wood Ducks, but to provide nest sites for Kestrels and Merlins.

Wild Pollinator Nesting sites: this can be as easy as drilling 5/32" diameter holes at an upward slant, 3" deep into any wooden fence post or raptor roost that you may have. Or, special drilled wooden blocks can be placed on posts throughout the farm. These can be protected from woodpecker predation (drilling to eat bee larvae) by bringing them into a cold space for the winter or by covering them with 1/2" mesh hardware cloth 2 inches out from the drilled holes. Tin cans packed full of paper drinking straws (tilted downward to eliminate rain) will also work, but in my experience not as well as the solid wood.

Toad Homes: Broken, large clay flowerpots tilted on their side can provide shelter for wandering toads. Place them beneath hedges in your hedgerows to provide cooler, moister refugia for your toads.

Some things to look out for: Raccoons will enjoy the additional cover provided by hedgerows and additional amphibians and bird nestlings to eat. Keep an eye on your raccoon populations and take harsh measures if needed. If you're going to let your bluebirds get eaten by raccoons, don't lure them to the farm in the first place.

Rabbits: Rabbits will enjoy the shelter provided by hedgerows and be less afraid to raid your annual crops. Raptor roosts will keep them wary. Defend your crop when necessary.

Ground Squirrels: Also will enjoy more sheltered access to your crops. Rat traps baited with peanut butter work well. CD's hung by a piece of string from shrubbery or fiberglass fenceposts act as a distractor and help deter rabbits as well as ground squirrels.

-shade tolerant demo

The wooded area adjacent to the SOF provides a unique opportunity for the demonstration of the agroforestry practice of "Forest Farming". Various shade-tolerant crops can be grown within the forest stand and be completely compatible with high-yield forest management. The most easily marketed forest farming crops at this time are predominantly medicinal herbs. Ginseng, goldenseal, black cohosh and blue cohosh being but a few. Since the primary marketing activity for the SOF is a CSA a shade tolerant food crops demonstration would be a better fit.

Some crops that would work well are maple syrup & sugar and a wide array of edible mushrooms. Shiitake and enoki mushrooms are grown on oak or hornbeam thinnings while oyster mushrooms can be grown on elm or maple thinnings. Reishi and miataake mushrooms are considered medicinal mushrooms having high concentrations of antioxidants (as well as other supposedly therapeutic compounds) and are used in teas and broths. Regardless of the mushroom type, both fresh mushrooms as well as dried mushrooms can be offered to your CSA customers.

Summary

The above mentioned practices/techniques are all designed to enhance the biological diversity of the MSU Student Organic Farm as well as to provide additional income streams and product lines. They are especially intended to enhance beneficial insect habitat and soil biota. They are multi-purpose, high yielding, low-maintenance and will provide ample research opportunities.

The field intended for Permaculture Guild research will be dealt with in a separate document and yet is integrated into this overall plan.

Successional Brushland and Oak Savanna as the Ecological Model for Permanent Staple Crop Production in North America

The United States of America is the self-proclaimed "breadbasket of the world". There is no denying the massive quantity of staple food crops (corn, soybeans, wheat, rice) that the US produces. However, more and more people are coming to realize that there's something moldy in the breadbasket and not all is well.

There is mounting evidence (with supporting documentation courtesy of the USDA) that annual agriculture, as practiced today, is now one of the most destructive technologies on the planet.

1. What could possibly be more destructive than turning over the top 16-24 inches of the soil every single year?
2. Agriculture kills <u>everything</u> in a given area except the crop. (which is the point, of course.)
3. For up to 8 months of the year annual agriculture leaves the soil exposed, free to blow away in the wind. (which it does.)
4. Or wash away in the rain. (which it also does.) Even when a mature crop is in the field, the soil surface is usually bare, exposed to erosion.
5. Annual agriculture contaminates the water supply, in many ways, including direct runoff of highly toxic chemicals. (their extreme toxicity is why they are used in the first place.)
6. Tillage oxidizes organic matter, releasing CO_2 into the atmosphere contributing to the greenhouse effect. Soluble nitrogen fertilizers oxidize into nitrous oxides, greenhouse gasses that are even more effective at trapping heat than CO_2. American agriculture is claimed to be responsible

for up to 17% of all greenhouse gas emissions in the form of CO2, nitrous oxides and methane.

7. Annual agriculture in the midwestern USA is the largest contributor to the collapse of the multi-billion dollar fishery in the Gulf of Mexico because of sedimentation, overfertilization, and the creation of the anoxic (lacking oxygen) "dead zone" that seasonally effects up to 1/3 of the entire Gulf.

As the flaws in our agricultural system become financially apparent, family scale farmers are going broke as fast as ever. Farm size is increasing. Large "efficient" confinement livestock operations are becoming the rule rather than the exception. Even with greater economic efficiencies, these large farms are in trouble.

1. Their resource base (the soil) is degrading
2. Their costs (equipment, fuel, fertilizers, pesticides, herbicides, antibiotics) are increasing. (especially with recurring threats of war and political instability in petroleum extracting countries)
3. The federal government continues to subsidize this unprofitable industry (for obvious reasons such as national food security) causing tensions with trading nations because of the inequity this causes in world-trade.

Are there any REAL alternatives to this? Most of us reading this ate today. You and I today are <u>totally</u> dependent upon this economically troubled, ecologically flawed agricultural system. While we're at it, we might as well dispel the illusion that Organic Agriculture will be our saving grace. The above mentioned flaws in our agriculture apply to Organic systems as well, differing only in degree and kind. What are we going to do about this problem while still remaining fed and while we still have the time?

The ecological model

Before the "breadbasket of the world" was ever farmed using "modern" industrial agricultural technologies, it was a wilderness… forests, prairies, wetlands, and savannas. For millions of years America's prime agricultural farmland was maintained in incredible health and vitality by natural processes with no human intervention whatsoever. Human intervention began in North America a mere 14,000 or so years ago. The first 13,700 years of human intervention was rather low-intensity due the fact that the inhabitants were not industrially organized and had not yet developed the tools to go with the industrial/mechanical world-view.

The appearance of the landscape has radically changed in the past three hundred years. The old-growth eastern hardwood forest that once spanned from the Atlantic seaboard to beyond the Mississippi river has been decimated. It really exists only in patchy, cut-over remnants. In its place (aside from cities, suburbs and highways which is another series of articles!) are vast tracts of agricultural land separated by ditches, weedy fencelines and highway rights-of-ways. The fate was the same for the savannas and prairies. The forest, savanna and prairie biomes formerly supported life, permanent groundcover and even photosynthesis year-round. The agricultural land that replaced these systems lies barren for eight months of the year and supports little to no life at all. When the season is favorable for plant growth, millions of square miles of this former American wilderness, grows but a handful of crop species. The soil is bathed with chemical fertilizers and herbicides. An increasing majority of these staple food crops are genetically modified to tolerate the harsh chemical environment in which they must survive.

The appearance of the landscape may have changed, but the natural processes governing life have not. When farmland anywhere from Maine to Florida, from the Jersey Shore to the Rocky Mountains (anywhere on earth, in fact) is abandoned, a miraculous process occurs… It is the process of plant succession. Briefly summarized, it is the process by which plant communities and their associated animals change over time. An abandoned corn field in Ohio, for example, will first be colonized by aggressive, fast growing annual and biennial "weeds". By occupying the site they change the site conditions providing opportunities for perennial grasses and broad-leaved plants to invade, either by wind and animal borne seed, or by underground roots or shoots. Dead stems and roots from previous plant populations increase the organic matter content of the soil which becomes the energy source for increasingly diverse populations of soil biota from bacteria and fungi to insects and worms. Once the bare soil has transformed into a perennial grassland ecosystem (perhaps taking as little as 3 years on rich, moist sites or as many as hundreds of years in sandy, droughty or rocky sites) fire and grazing become significant factors affecting species composition. (in addition to the usual seasonal rainfall and temperature changes) Fire, grazing and moisture are the most significant factors in the natural maintenance of grassland and shrubland ecosystems. It is during absences of fire that brambles, shrubs and "pioneer" trees begin to invade this formerly bare soil. Some of the common brambles and shrubs to invade grasslands are raspberries, blackberries, wild plum, crabapple and hazelnut. Of these shrubs, the one with the widest historical distribution is the American Hazelnut (*Corylus americana*)with a range from 8,000 ft in the Colorado Rockies to the Atlantic coast; just shy of the tundra in Manitoba to the southern Appalachians west to the Ozarks and Texas.

The first trees to move into the grassland would differ slightly, depending on the region of the country, but on the whole they are the same species for the entire continent east of the Rockies. These first trees into the brushy grasslands (successional brushlands) are the oaks, aspens, cottonwoods, white pines, red cedars, box elders and others. The most common sun-loving, grasslands tolerant tree in North America is the Oak. The genus *Quercus* in the family *Fagacea*. One of the reasons for its wide range in grassy systems, is its ability to survive fire. During times of frequent fire, young oak seedlings lose their tops then re-sprout. This can occur for decades, if not hundreds of years with the oak roots remaining in the ground and increasing in size and energy resources. These large "topless" oak roots were called grubs by the early European settlers, presumably because they had to be "grubbed out" with pick axes and shovels.

In the absence of fire, or other catastrophic event, grassy oak savanna will become populated with more and more trees and become an oak forest. This oak forest will in turn be invaded by shade tolerant and fire intolerant trees. The mixed forests of eastern North America are the result of this process of disturbed and undisturbed periods (time) and locations (space) over hundreds and (formerly) thousands of years.

The above summary is an incredibly brief description of a process that is more complex than humans have been able to fully understand. Plant succession as described above, is how this law of nature occurs through time. Its occurrence in time is dictated by disturbance. Historically disturbance has meant fire and grazing. (locally/regionally significant events such as tornado, hurricane and wind-shear contribute to the disturbance regime as well)

How this successional pattern occurs in space (distribution across the continent) has been a function of the frequency and severity of these disturbances. The frequency of these disturbances has been driven to a great degree by climate. In moister regions such as the Atlantic seaboard, most sites were too moist for frequent fires. In the great plains where drought was the norm, fires were frequent events. In moist regions (east coast) drier sites with well-drained, sandy soils saw more frequent fires and hence supported fire and drought tolerant plant communities (xeric communities). Likewise in arid regions such as the great plains, moist zones such as found along streamsides and in poorly drained areas supported fire intolerant and moisture loving plant communities. (mesic) In between these two extremes was a broad, patchy spectrum of successional systems dominated in the east by forest and the great plains by prairie. This "middle ground" between forest and prairie has been much overlooked by researchers; prairie researchers treating it as a degraded prairie that hasn't been burned enough and foresters treating it as a forest in its establishment phase. Both foresters and prairie ecologists have often overlooked the fact that prior to European colonization, this "successional stage" or sere occupied 25% or more of the landmass east of the Rocky Mountains. It is primarily due to agriculture and the fact that this biological treasure has escaped our perception, that the savanna has been declared the most endangered ecosystem on the continent, occupying less than .1% of its original range. The heartland of these savanna systems is, significantly, the heartland of America: The corn and soybean capital of the world.

Since we know that the savanna was self-replicating and self-maintaining for millennia would it not be prudent to examine this system and use it as the ultimate model for a truly ecological, permanent agriculture? If we were to produce our crops in systems that mimic the physical characteristics and ecological functions of savanna systems wouldn't the forces of nature which maintained the savannas for millennia also maintain our agricultural savannas?

How could we do this? The first step would be to identify the actual native savanna and brushland species and identify the ones with promise as food crops. Preferably we would choose species with similar nutritional characteristics as the annual crops that they would be replacing. We would then plant them in such as way as to mimic the savanna system as nearly as possible. We would manage these agricultural savannas much the same way that nature would manage them and attempt to mimic the disturbance regime of the particular savanna subtype appropriate to the location. These associations of plants would, of course, be slightly different between regions and soil types. The basic research identifying the various different savanna sub-types has been accomplished. What were the most significant species in savannas? The following list clearly shows the potential for large-scale agricultural production in savanna systems.

Oak
Crabapple
Wild Plum
American Hazelnut
Raspberries
Wild Grape.

(Due to space constraints, less widespread or locally adapted species are not listed here.)

All of these species have naturally occurred in association with one another across North America, managed only by nature for millennia.

The work of creating a savanna agriculture is not ecological restoration in the commonly known sense. We are not "saving" remnant savannas by restoring them to their pre-settlement condition. The work of restoration has a significant value and should be done by those who feel that it is their mission to do so. Those involved in the establishment of agricultural savannas are doing what is commonly known as farming. Farming is the production of basic commodities for food, livestock feed, industrial ingredients, chemical feedstocks, and fuels (such as biomass, biodiesel, methanol and ethanol). Since the majority of farms are not concerned about the fact that their corn fields do not mimic nature and are not concerned about non-native plants (soybeans are not native to North America and currently cover millions of square miles), we are likewise not as concerned as a restorationist might be. A reasonable approximation of a savanna ecosystem, with commercial cultivars of savanna species, is infinitely more diverse, sustainable, and natural than a field of genetically modified annual crops. That aside, lets look at an agriculture that reasonably approximates a successional brushland ecosystem. Moreover, lets design a savanna agriculture to replace corn and soybeans using plants that already exist with markets that also exist.

Corn is a high in carbohydrate, relatively low in protein and fat. Soybeans are high in protein moderately high in oils. Together corn and soybeans are the majority of all food and feeds produced in the former savanna biome. Both of these are easily replaceable with fire-tolerant, woody species.

The soybean is most easily replaced with a natural, native savanna specie. As previously mentioned, *Corylus americana*, the American hazelnut was the most common savanna shrub species. Locally, the hazelnut shrubland was a dominant savanna type. Remnants of the vast hazel shrublands still exist in several states, most notably in the Cedar Creek Natural Area in central Minnesota. Hazels came to dominate a shrubland when fires occurred less frequently than 5-10 yrs, yet more frequently than 20yrs. When fires were more frequent than 5-10yrs, hazels were not able to establish. When less frequent than 20 yrs, Oaks grew to a fire resistant size and dominated the site. From Virginia to Colorado, Missouri to Manitoba, the author has observed hazels and oaks coexisting in degraded savanna remnants.

What would an agricultural Hazelnut Shrubland look? Hazels would obviously be the dominant woody shrub. They would be planted in high-density plantings, arranged so they could be mechanically planted, maintained and harvested. They would not be planted as orchards which would require weed, pest and disease control and continual pruning. They would be planted as savannas with many of the plants that would naturally be found in association with them in the wild. When possible, marketable prairie plants would be planted between rows of hazels providing yet another yield for the farmer. Ecosystem functions such as natural pest and disease suppression which are all but absent in annual crop fields would be intact in a hazelnut shrubland. Pests and predators would be allowed to come into a naturalized equilibrium, which in the long term, is the lowest cost pest and disease control possible. Annually, seed would be harvested and shells utilized as biomass. Periodic coppice would be used to imitate the rejuvenating effects of fire, removing older and diseased wood and setting back pest populations. The removed wood chips would represent yet another yield to the farmer. In order to mimic natural processes even more closely, a newly coppiced hazelnut field could be burned immediately after coppice or late the following winter.

Although this agricultural savanna technology might sound pie-in-the-sky to some, it is currently being practiced across the upper midwest by dozens of growers from Ohio to Nebraska. Mechanized planting, maintenance and harvest technologies have already been developed. The techniques are mature enough for rapid, widespread adoption. Hybridized hazelnuts have been developed that out yield wild hazels with higher quality kernals and can be rapidly multiplied using tissue-culture propagation.

Replacing corn with a similar crop grown in a savanna system requires slightly more intellectual flexibility, in that the dominant savanna tree species, the Oaks, would be replaced by a tree not in the same genus, but in the same family, *fagacea*. The *fagacea* that produces seeds of similar nutritional value as corn is the chestnut, the *Castanea.*

Traditionally, chestnuts have been grown in an orchard setting. Orchard floors have been mowed, laboriously grafted trees have been pruned, and crops sprayed with fungicides and insecticides. The processes are entirely mechanized. Mature chestnut trees resemble their cousins the oaks in form and in many of their functions. Although fancy, niche-market varieties of chestnut may require orchard conditions in order to produce satisfactorily, hybridized seedling chestnuts have been bred to thrive in savanna systems. Hybrid savanna chestnuts can be grown to tree size, or can be managed as a shrubland much like the hazels. Livestock can be grazed beneath an open chestnut canopy in silvopastoral systems, and forage can be harvested from between the rows. Chestnuts managed as a shrubland would be coppiced more often precluding timber harvests, but allowing for the use of sway-type bush harvesting equipment. Once again, this is not pie-in-the-sky. Growers across the midwest are successfully growing various species of chestnut in savanna systems. Once again, with the technology of tissue culture propagation, millions of acres of these savannas could be planted within a few short years.

Chestnut savannas and hazelnut shrublands are but two agricultural savanna ecosystems that can be used anywhere in the corn belt of central USA. They both produce crops that are direct nutritional replacements for corn and soybeans. Although current varieties and practices don't quite equal the yield per acre of corn or soybeans, they allow for the growing of other crops in the system. Like the corn and soybeans they would replace, these production systems are completely mechanized. Elimination of annual soil preparation and seed planting would dramatically reduce fossil fuel use on savanna farms. Erosion would be virtually eliminated. The long-term dollar cost savings of a perennial savanna agriculture are nearly incalculable. Plant it once, then manage it for eternity.

The conservation and environmental benefits of these savanna crops cannot be equaled by any annual crop. Long-term carbon sequestration in woody stems and roots is significant in these crops, unlike in the annual crops they would be replacing. Surface runoff would be virtually free of suspended solids. Since herbicides are not needed, (used only during establishment if at all) they would not be able to wash into rivers and streams. Wildlife would find its habitat greatly expanded. Drought and flood tolerance and long-term sustainability of such systems has been proven by the legacy that they have left behind. Despite nearly 200 years of the axe and plow and sixty years of herbicide we have not been able to eradicate the savanna. The natural forces that sustain savannas in North America have sustained them for millennia. If we design our agricultural practices to fit in with these natural forces rather than fight or deny them, our agriculture may at long last prove to be as enduring.

Curtis, J.T. The vegetation of Wisconsin. University of Wisconsin Press, Madison. 657 pp. 1959.
Holtz, S.L. Cutting and burning a degraded oak barrens: management techniques that stimulate natural disturbance. M.S. thesis, University of Wisconsin, Madison. 80 pp. 1985.
Nuzzo, V.A. Extent and status of Midwest oak savanna: presettlement and 1985. Natural Areas Journal 6(2):6-36. 1986.
Ahrenhoerster, R. and T. Wilson Prairie Restoration for the Beginner, Des Moines, 1981 Prairie Seed Source.
Aikman, J.M. and A.W. Smelser The structure and environment of forest communities in cental Iowa, Ecology 19:141-150
Anderson, R.C. The eastern prairie-forest transition-an overview. Pp. 86-92 in R. Brewer (editor). Proceedings of the Eight North American Prairie Conference, 1982. Kalamazoo, MI
Axelrod, A.N., and F.D. Irving. Some effects of prescribed fire at Cedar Creek Natural History Area. 1978. Journal of The Minnesota Academy of Science 44:9-11.
Bray, J.R. The savanna vegetation of Wisconsin and an application of the concepts order and complexity to the field of ecology. Dissertation. 1955. University of Wisconsin, Madison, Wisconsin, USA.
Diboll, N. Mowing as an alternative to burning for control of cool season exotic grasses in prairie grass plantings. Clambey and Pemble 1986.
Dyksterbuis, E.J. The savanna concept and its use. Ecology 38: 435-442. 1957.
Haney, A., and S.I. Apfelbaum Characterization of Midwestern oak savannas. In Proceedings of Midwest Savanna Conference, Feb, 20, 1993. Northeastern Illinois University.
Jackson, L.E., R.B. Strauss, and M.K. Firestone Influence of tree canopies on grassland productivity and nitrogen dynamics in deciduous oak savanna. Agriculture, ecosystems & environment. 32:89. 1957

Long, Charles A. and Claudine F. Long Some effects of land use on avian diversity in a Wisconsin's oak-pine savanna and riparian forest. Passenger Pigeon 54(2):125-136. 1992

McClain, W.E., M.A. Jenkins, S.E. Jenkins, and J.E. Ebinger Changes in the Woody Vegetations of a Bur Oak Savanna Remnant in Central Illinios. Natural Areas Journal 13:108-123. 1993.

MacClintock, L., R.F. Whitcomb, and B.L. Whitcomb. Ecology and management of North American savannas. The University of Arizona Press, Tucson, Arizona. 1977

Merriam, G. Ecological processes in the time and space of farmland mosaics. In Zonneveld and Forman. 1989.

Nuzzo, V. Extent and status of Midwest oak savanna: presettlement and 1985. Natural areas Journal 6:6-36. 1986.