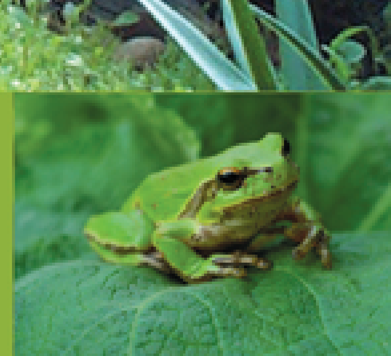
Darrell Frey

# Bioshelter Market Garden

## A PERMACULTURE FARM

BOOKS FOR WISER LIVING
MOTHER EARTH NEWS
RECOMMENDATION



PRAISE FOR

# *Bioshelter Market Garden*

Darrell Frey's inspirational book gives you all you need to know to create an energy-saving, food-producing bioshelter. It not only offers plenty of detail on the nuts and bolts of construction and maintenance, but it also provides the big picture: the concepts and principles behind these innovative structures. *Bioshelter Market Garden* covers everything you need to understand, build, or simply admire these important tools for sustainability.

—Toby Hemenway, author of *Gaia's Garden: A Guide to Home-Scale Permaculture*

Darrell Frey has mapped out the possibility of regeneration of individuality and of nature, of liberty, of community, of food security and of ethics such as the modern agricultural literature has never known — a harmony with nature, with the earth, with one another in a sharing society such as the world has often dreamed.

—Prof. Declan Kennedy - Chairman, Advisory Board, www.gaiauniversity.org

Darrell Frey's *Bioshelter Market Garden* is a welcome addition to the North American permaculture lexicon. Darrell has pondered and observed his systems — large and small — for a long time, and I'm glad he has shared his successes and lessons with us. The book is sensible, grounded, and practical, while offering a wide view of how to put the pieces together in a multifunctional way, on the ground, as a business, and as a way of life. The world needs more bioshelters, and this book contributes substantially to reinvigorating the development and deployment of this technology.

—Dave Jacke, Dynamics Ecological Design

The increasingly complex ecological problems we face today will require increasingly complex solutions, leaving the average person to wonder where to even start. Darrell Frey's example, as exhibited in this book, is as simple as it is essential . . . one must start here and now, with what nature has provided. Frey is no dreamer, but a practitioner, who shows us how the world can and must be changed, one farmer, and one small plot of land at a time.

—Brian Snyder - Executive Director,
Pennsylvania Association for Sustainable Agriculture (PASA)

It is no simple matter to create livelihood on a few acres and to preserve the biodiversity of that place. In *Bioshelter Market Garden*, author Darrell Frey shares the wisdom of his 20-plus years of doing so, and invites readers to work with the sun, the dragonflies, the muskrats, and the complexities of human enterprise to engage their own blessed swatch of land.

—Terril L. Shorb, Ph.D.,
Founder, Prescott College Sustainable Community Development Program

Some of us learn by reading, some by asking questions, and some of us just forge ahead and take risks. Darrell Frey is in that last category, and the lessons he has gleaned the hard way over the past 30 years, are now available to anyone who wants to plan for an uncertain future. Frey shows, with well-illustrated case studies, how to grow a four-season garden, turn sunlight and rainfall into sources of income, and live in the comfort of an architectural ecosystem that nourishes the planet as it shelters the family.

—Albert Bates, author of *The Biochar Solution: Carbon Farming and Climate Change*.

Darrell Frey is at once keen observer, adept teacher and consummate communicator, demonstrating to the reader in a style reminiscent of Aldo Leopold how we are all connected to the web of life and that our daily choices matter. *Bioshelter Market Garden* is equal parts inspired storytelling and how-to manual for living creatively and responsibly upon the earth. Through his own experience as a permaculture instructor and market gardener, Frey sets forth a detailed roadmap by which we might all reach a sustainable future and celebrate our interdependence.

—Dan Sullivan, managing editor *BioCycle* magazine and
former senior editor with NewFarm.org and *Organic Gardening* magazine.

*Bioshelter Market Garden* is a must read for home gardeners and farmers alike. Darrell Frey shares the secrets of creating a great year round growing system developed through a lifetime of farming. Best of all, he teaches readers simply how to grow things the right way, organically. The lavishly illustrated book is an essential tool for sustainable growing.

—Doug Oster, *Pittsburgh Post-Gazette* Garden Columnist and
Co-host The Organic Gardeners Radio Show

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## A PERMACULTURE FARM

**Darrell Frey**

NEW SOCIETY PUBLISHERS

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Visit our online book club at www.newsociety.com to share your thoughts about *Bioshelter*. Exchange ideas with other readers, post questions for the author, respond to one of the sample questions or start your own discussion topics. See you there!

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# Acknowledgments

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# Introduction

THIS BOOK IS ABOUT RELATIONSHIPS. All things, from the minerals of the earth to the energy of the sun and everything between, interact in a vast web of energy and elements, organisms and events. Each organism occupies a niche, a position within the ecosystem's network. The cumulative interactions of organisms, soils, landforms and climates evolve over time to a balanced, self-regulating state.

Over the course of human history, traditional cultures around the world have found a right relationship to the rest of creation. For many thousands of years, people have been sustainably harvesting and managing ecosystems by understanding and respecting the basic laws of nature. They developed stories and myths to help them remember and pass on these laws. They recognized sacred spaces to preserve the character and health of the ecosystem. They set limits to harvests and guided their lives by the cycles of the seasons.

Today the dominant world culture is barely beginning to recognize the relationships that make up the web of life. But our education systems teach ecology as a "personal value" rather than a science. The "environmentalist" is described as a special interest rather than a person with special understanding. Concern for the natural world is viewed as a philosophy rather than scientific reality. The world is seen as a commodity to be traded. But in reality, it is a commonwealth to be shared and cared for with informed stewardship.

As a people, we have lost our native sense of place. We have become tangled in our own web of science and technology. Our tools have become our master. The challenge ahead is to rediscover our land and ourselves as a part of the great web of life. Permaculture design is a tool to help us in the journey of rediscovery.

Permaculture design is a system of land-use planning that incorporates concepts of ecosystem dynamics, ecologically appropriate technologies, and an ethic of care of the earth into a comprehensive design system. It is a process of analysis and design that can unwind inappropriate technologies and unsustainable practices. Like nature, it has its own cycles — of study, design, planting, harvesting, more study, redesign and refining — that can lead us, as individuals and as a society, back to a right relationship in *all* our relations. When we choose technologies and materials appropriate to our locale and design our cities, homes and gardens to co-exist with and enhance the natural world around us, we re-enter — as co-participants — into the sacred dance of life.

Finding our own personal relationships to the planet begins at home. Choices we make as consumers, including what materials we use and what food we eat, are votes we cast and investments we make in the systems that surround us. In the 21st century, we, as consumers, can make many decisions with global impact.

I hope this book will inspire some of you to think big. Together, we can create the Garden. Dream your dreams. Then live them.

As a child I was captivated by wild fruit. It was my favorite of all foods, free for the harvest. Sweet, juicy raspberries and black mulberries grew along the stream in the town park. Delicious blue huckleberries and tiny, intensely flavored wild strawberries grew on my uncles' farms. Teaberries were a rare treat from the woods, and tart, wild grapes hung there in the trees. Early in my life I developed a personal vision of paradise. On a family trip to Niagara Falls, as my souvenir I bought a copy of Maurice Kains' *Five Acres and Independence.* My future homestead, I dreamed, would be filled with wild food.

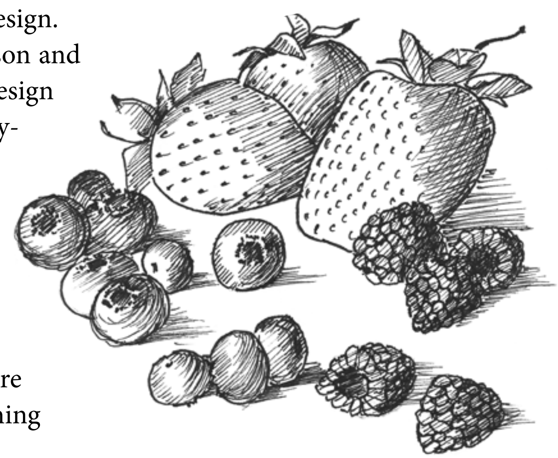
Another early childhood memory is my father's garden in the summer following the flood of 1964. I was six years old. A fast thaw of an extra heavy snow brought high water to our town. Soon, our house (safe on the hill) was full of displaced relatives. For several weeks we had cots in the living room and huge pots of food on the kitchen stove. That summer, my father planted a large garden in a vacant lot beside an uncle's house. The bountiful harvest from the flood-fertilized field was mostly given away to folks still recovering from the trauma of the spring.

As a young adult, these early influences combined with a growing disillusionment with the sciences. It was the 1970s. Nuclear waste and the threat of nuclear winter, rising cancer rates, and the industrial pollution epitomized by Love Canal, were, to me, issues urgently needing to be addressed. The growing body of information on how humans were impacting the biosphere likewise required our attention.

Like many others of the time, my partner, Linda, and I sought a life closer to the earth. We learned homesteading from friends and neighbors. Old-time farmers became sources of "heirloom knowledge." We devoured books and periodicals for clues on how to find the "good life" as described by Helen and Scott Nearing. Our free time was spent gardening, tending several goats and a small flock of chickens, learning to forage for wild foods and medicinal plants, making cider from wild apples, and canning, drying and otherwise preserving food.

Our search for right living led us to study alternative and energy technologies. We were inspired by the work of the New Alchemy Institute and their solar greenhouses and bioshelter prototypes. We were drawn to low-cost, owner-builder options and green design.

Early in the 1980s, we learned of the work of Bill Mollison and David Holmgren in permaculture design. Permaculture design pulled it all together for us, integrating all we had been studying into a coherent system of planning and development. We understood from the start that permaculture offered not an answer to the dilemma of humans on the earth, but a strategy for finding the answer. Permaculture presents a vision of humans striving for harmony with the earth. That vision provided us with a goal to move toward.



After ten years of intensive studies, six of which were devoted to learning permaculture design, I found myself teaching an annual permaculture course at a state university. The growing urge to teach by doing, rather than lecturing about the work of others, led to Linda and me making preliminary plans to create a bioshelter market garden farm. A *bioshelter* is greenhouse operated as an ecosystem. A *market garden* is a commercial-scale farm that supplies fresh produce to a regional market. We wanted our farm and bioshelter to reflect the permaculture vision. Our hopes were to create a research and demonstration facility for ecological farming in the 21st century. The farm we dreamed of would be diverse, small-scale, intensive and organic, and it would enhance the quality of life in our corner of the earth. It would be, we knew, a lifetime commitment to principles of caring for the earth.

On New Year's Day 1988, many points converged in our lives: Five acres of excellent farmland were available for our use; five friends were committed to the permaculture farm project; funding assistance was available; and we had some money in the bank. We took a dive, so to speak, into the future. We have not looked back.

The story of our lives in the time since 1988 is a common one in the permaculture world. We committed all our resources and time to what was, for a while (and to some extent still is), a self-funded research project. Many people have helped us on the way. Some of them we still see daily; some early associates have moved on to other, equally interesting projects. We have weathered downpours and droughts, late frosts and heat waves, confidence and burnout. When the burnout came, something or someone always showed up to revive us: the customer who appreciated our chemical-free produce; the child fascinated with a shamrock spider in its web and a monarch chrysalis on the milkweed; the first fruit of the season; and (especially) the exhilaration of being in a sunny bioshelter on a cold winter day. Through it all, we continued to develop the farm — reviewing, planning and expanding our plantings and gardens. Crop mixes were developed, relationships with customers established and ecological relationships encouraged. As you read these words we're probably working on some new phase of farm development, identifying a new species, designing a new garden or greeting a new visitor. A permaculture farm is an evolving, changing thing. With thoughtful, responsible stewardship it will, each year, get closer to our vision of integration with the local ecology.

CHAPTER 1

# Toward a Permanent Culture

*Life — all life — is in the service of life. Necessary nutrients are made available to life* by *life in greater and greater richness as the diversity of life increases. The entire landscape comes alive, filled with relationships and relationships within relationships.*

—Frank Herbert, *Dune*

## Prologue

Vast challenges face our relationship to our planet. Although these challenges are now topics on the evening news, they are not new. Many people have been working for decades to alert the general public to the myriad human-caused environmental problems and social and economic inequities, that are, in a word, unsustainable.

To the student of permaculture, problems are signposts pointing to solutions. Permaculture attempts to find solutions in cultural and ecological systems rather than technology. The environmentalist adage that technological solutions breed new technological problems has proven true. The converse can be true of ecological solutions. Thoughtful application of ecological design for problem solving can set in motion regeneration of soil, watersheds and local ecosystems that in turn help heal regional and global environments.

It is easy to forget that everything *is* connected. The choices we make in how we grow and sell our food, the energy we use to produce our products, and the way we manage our diminishing resources all have effects for the entire planet.

All the tools and information needed to design and plan sustainable communities are available now. The question is whether we decide to use those tools or not. And the consequences won't affect only us. As developing nations seek to emulate Western culture, Western culture needs to demonstrate stewardship based on scientific understanding and environmental consciousness.

One cannot predict what a long-term sustainable future will look like. But we believe it will be rooted in the land. It will come as an organic outgrowth of a rekindled dynamic relationship between people and their landscape. The book in your hands is intended to be a tool for those who want to participate in the continuing evolution of a sustainable society.

## Book Outline

This book is roughly divided into two parts. The first part, chapters 1 through 6, introduces permaculture concepts and methods for designing a permaculture market garden farm. The second part, chapters 7 through 15, provides a detailed study of permaculture design applied to Three Sisters Farm's activities, landscapes, and the bioshelter.

This first chapter introduces the concept of a sustainable food system and permaculture design with a first look at Three Sisters Farm. Chapter 2 examines issues relevant to safe, healthful and secure food systems. Chapter 3 looks at marketing options and strategies for the small farm. (Note that in this book the word "marketing" does not mean advertising. For us "marketing" and "selling" are almost interchangeable, but the word "marketing" evokes our role as farmers who produce crops to sell at a particular community's local *market.*) Chapter 4 details the use of permaculture to design and plan a small-scale, year-round, intensive farm, with staged development. Chapter 5 looks closely at sustainable energy systems on the farm. The final introductory chapter, Chapter 6, presents ecological strategies and methods for controlling pests and disease.

Chapter 7 and 8 begin a closer study of Three Sisters Farm, looking at the details of farm design and management, crops and tools and seasonal work cycles. Chapters 9 and 10 finally come to the study of bioshelter design and management. A bioshelter is essentially a solar greenhouse managed as an indoor ecosystem. Our bioshelter is the heart of our farm, and the preceding chapters provide the necessary context for understanding its role on the farm. Chapters 11 and 12 examine details of the role of compost and chickens in the bioshelter and on the farm. Chapter 13, "Permaculture for Wetlands," is offered as a tool for preserving wetlands and learning to use the special capabilities of wetland plants in our landscapes. Chapter 14 presents the farm as an education center, both as a source of revenue and as a service to the community. And finally, chapter 15, "Knowing Home," and the epilogue look at the ongoing development of the farm and the application of permaculture to our own homestead. The appendix provides facts and figures related to solar design.

## Five Acres and Interdependence

Three Sisters Farm began as a five-acre field of bare soil and corn stubble. The soil was good silt loam, but had been depleted of life and nutrients by decades of conventional agriculture. A scrubby tree line on the abandoned barbed wire fencerow defined the space but added little diversity. The year was 1983. We were starting with a clean slate. On this open field, we could put into practice the permaculture theory we wanted to explore. Our youthful idealism was influenced by philosopher Stephen Gaskin, of The Farm, an intentional community in rural Tennessee. To paraphrase Gaskin's Zen-inspired directive, "If you see a problem, you probably should fix it." Thus empowered, we began our preparations to become part of the solution — as permaculture market gardeners.

The chapters that follow provide a narrative of the changes that have occurred in this small field since 1983. Though our work is framed by human intent, our palette and canvas is provided by nature. As we've followed an unfolding vision of what we wanted the farm to be, we have been guided by the principle of caring for the earth so she will care for us. Our farm has been an experiment in permaculture design. And it has been an attempt to forge a right livelihood out of the universal struggle to survive and prosper.

This book functions on several levels. While it closely examines Three Sisters Farm and the bioshelter concept, it also presents a broader picture of sustainable food systems and the larger role farms can play in a sustainable society. Three Sisters is just one regional project among many. In this book, I also examine the work that others are doing developing gardens, landscapes and bioshelters, and integrating community and educational activities into the farm plan. There is a growing momentum toward the development of sustainable food systems. People of all ages, but especially young people, are drawn to a life closer to the earth and closer to the source of fresh food.

## The Value of the Small-Scale Farm

The small-scale intensive farm can offer many benefits to a community and a region: food security is enhanced, organic matter and excess fertilizer are removed from the waste stream, healthy soil is built, streams are cleaner, and groundwater is recharged. The organic farm, with its diversity of crops and other plantings, enhances local biodiversity and helps create and preserve critical habitat for wildlife, especially birds and pollinating insects. Farms offer jobs and training. They can also engender many related enterprises, including craft production and value-added processing. The small-scale intensive farm can offer a pleasant space for social gatherings and community events, and there are many opportunities for educational activities and for reconnecting the community to the earth. Local culture as a whole is enhanced when local foods are available, events are seasonal, and people have direct access to nature and agriculture.

### *Food*

Fresh, local, and organic food should be accessible to everyone. The fact that this is a political statement is unfortunate. "Be on good terms with all people," say the great teachers. But declaring oneself organic apparently implies that something is wrong with how the "conventional farmer" farms. Similarly, to promote the superiority of fresh, local food somehow impugns the entire food industry and the global economy. Although it's true we would prefer that no one use chemical fertilizer, herbicides or insecticides, we know that national and international trade is here to stay. And we recognize and applaud the moves toward more sustainable agriculture that many conventional farmers are making.

What we *do* mean to imply, or rather, to state clearly, is that much of our food can be produced locally, in a manner that helps preserve and heal the planet, build strong communities and make us healthier in the process.

### *Biodiversity*

We live in a world of expanding populations and diminishing natural resources. A changing climate is putting further stresses on the natural world. As wildlands continue to be developed, remaining habitat becomes ever more critical to the health of the planet. We can address these issues through thoughtful and informed land use. The ecologically designed agricultural landscape is a contribution to the preservation of natural habitat and biodiversity.

Protecting biodiversity includes protecting the quality of water in our streams and rivers, preserving critical habitat and undeveloped wildlands, managing forests sustainably, using and preserving native plants in our landscapes, protecting native pollinators and promoting habitat for the entire web of the natural world. Nature is the matrix within which we must develop our production systems.

*Spring Peepers.*

### *Education*

A farm is a valuable educational facility that offers many different types of instruction — organic gardening, diet and nutrition, nutrient cycling, diverse agricultural enterprises and the farm's interconnection with the natural world. Many young people seek internships on working farms to learn the trade. Home gardeners seek out advice and opportunities to learn. At a farm, children can learn to love the earth and begin to understand its processes. It all begins with personal contact with nature. All of these things are services the farm can provide to a community while at the same time earning income to keep the farm viable. As visitors learn the value of the farm on the landscape and of fresh local food in their diet, they become customers of the farm.

**Benefits of Small-Scale Intensive Agriculture**

- Food security
- Employment
- Nutrient cycling
- Biodiversity
- Pollinator preservation
- Water cycling
- Education
- Social space for gatherings
- Building a local food system
- Right livelihood in a community
- Sustainable food systems

## Creation of Sustainable Local Food Systems

Challenges to the revitalization and re-creation of regional food systems are many — and formidable — but they are not insurmountable. The economic viability of small farms is the foremost challenge. Competition with global food systems requires creative design, management and marketing. Start-up cost support and innovative partnership funding is often required. Other issues include access to land and resources, zoning and tax laws, insurance costs and the seasonal nature of most farm incomes. Because we are in the process of re-creating local and regional food systems, there are many missing links in support structures and market access.

Making a living from agriculture has always been difficult. One is dependent on the weather, the market and the quality of the labor force. All are variable. Because cash flow is seasonal and not always dependable, most agricultural enterprises rely on the farmer to wear a lot of hats. Besides being able to plan and manage crop production, soil fertility and other farm resources, the farmer needs to be a capable mechanic, carpenter, electrician, plumber, supervisor, planner, accountant, marketer, office manager — and gardener. An organic and permaculture farmer also needs to be an ecologist, an ecological designer and planner, a natural builder and an alternative energy specialist. Knowledge about regulations for organic certification, compost management, health and safety requirements and tax codes also is required.

Farming is rightfully said to be a lifestyle choice. You do not get rich farming, but you can profit in many ways. People are drawn to a rural lifestyle to be close to nature, to benefit from the slower pace of traffic and life in general and to engage in the care and nurturing of plants and animals. However, you need more than to eat well and have a roof over your head and shoes on your feet. Because health care and education are primary needs for most families, the majority of small-scale farmers are either part-time farmers or they have other income. Many people retire on a pension or savings account to become market gardeners as a second career. Part-time, seasonal work or a working spouse is often inevitable for the small farmer trying to compete with the global economy.

A local food system that truly supports the sustainable farm's economic viability requires not only creativity and innovation but also the support and assistance of community leaders, local government, national policy and consumers.

In a very real sense, a return to regional food systems is a return to life of a century ago. Home food systems, supported and supplemented by neighborhood farmers markets, grocers, butchers, and the milkmen, fed the nation well. As we attune to the role of being good earth stewards in our daily lives, we will see the value of lower energy-use models of the 18th and early 19th centuries.

All these issues are examined in the chapters ahead. The picture I portray, of a diverse agricultural enterprise, demonstrates permaculture farms' role in the regional food system and local community.

In the sustainable society we seek, each farm will be unique, with its own mix of crops, enterprises and relationships. To achieve this sustainable society we will need many more small-scale farmers, literally one in every neighborhood. Farmers will need stable, profitable markets and the organizations and infrastructure to support a diverse and economically viable local agriculture. The issues are complex. Many gaps in local food systems and many disconnects in our modern lifestyles discourage both local consumers and producers. However, as discussed in the next chapter, many groups and agencies are working to promote a resurgence of local agriculture.

## Integrated Systems: Permaculture Design

Permaculture (a.k.a. permanent culture or permanent agriculture) is a system of land-use planning that incorporates concepts of ecosystem dynamics, ecologically appropriate technologies and an ethic of care of the earth into a comprehensive design system.

Permaculture is also a growing and evolving network of individuals and organizations. Practitioners of permaculture are dedicated to searching for, creating and exploring sustainable solutions to the dilemma of our confused human relationship to the natural world.

My study of permaculture began in 1981, when I read an interview with Bill Mollison in *Mother Earth News.* Mollison described in detail a system for the design of agricultural ecosystems. He succinctly explained the concept of permaculture and summarized its main goals and principles, presenting a way for modern societies to rediscover cultural links to a healthy landscape. This is done by designing our homes, towns and regions with an understanding of ecology, energy dynamics and a logical ethic of caring for the earth — so it can care for us.

This system was first articulated in the book *Permaculture One,* which Mollison co-authored with David Holmgren, and further developed in *Permaculture Two*. In the 1980 *Mother Earth News* interview, Mollison stated that the essence of permaculture was to "apply the principles of environmental science to our production systems." In explaining the permaculture concepts of designing integrated systems, that is, of placing design "elements" into functional relationships to maximize productivity, Mollison presented the idea of combining a chicken coop, a forage yard and a greenhouse. Such an integration sets up ecological relationships: the exchange of oxygen and carbon dioxide; a nutrient cycle between plants and poultry; and poultry regulating their own temperature by being able to move outside during the day and inside at night.

Reading this interview forged new synapses in my mind, connecting many lessons of homestead management that my wife, Linda, and I had been learning from rural neighbors. I immediately knew I wanted to be a permaculture design consultant. For the next six years we did a thorough study of permaculture, beginning with the references Mollison and Holmgren used to write *Permaculture One* (first published in 1978) and those Mollison used in *Permaculture Two* (published in 1979). We studied ecology, design, native and useful plants, landscaping, and many other facets of sustainable design. In 1984, we began to specifically apply permaculture to the development of the land that became Three Sisters Farm and the ten-acre property our house was on. In 1986 I enrolled in Permaculture Design at Slippery Rock University taught by teacher, writer and publisher Dan Hemenway. This intensive course was a three-week, 120-hour class that provided an in-depth study and the opportunity to apply the permaculture design process. After my completion of the course work, Linda and I were re-invigorated to continue work on the development of the Three Sisters Farm property.

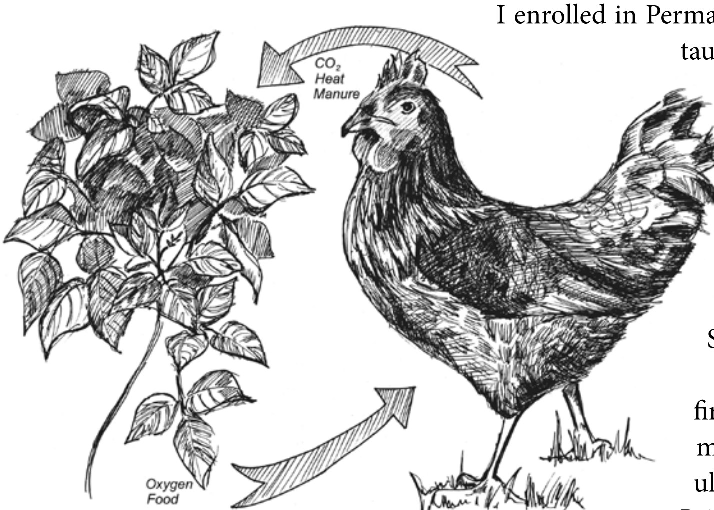


*Illustration of chicken and bioshelter exchanges.*

In the years since Mollison and Holmgren first articulated the principles of permaculture, many voices have been added to the permaculture design field. In 2002, in *Permaculture: Principles and Pathways Beyond Sustainability,* David Holmgren redefined the field with his 12 permaculture design principles. The principles built upon and expanded the literature on permaculture design.

Permaculture design has spread globally. The pages of *Permaculture Activist,* published in the US, and the UK's *Permaculture Magazine* feature the work of hundreds of permaculture designers around the world.

## *Ecological Design*

In the course of our studies, we soon learned about the developing field of ecological design. As with permaculture, ecological design draws its inspiration from nature and ecology. But, whereas permaculture was a grassroots effort that hadn't yet reached academia, ecological design as a field was already developing in colleges and universities and through the work of progressive architects and research institutes. Among these was the New Alchemy Institute on Cape Cod. Happily, the New Alchemists thoroughly documented their work in aquaculture, bioshelter design and sustainable agriculture in their journals, quarterly newsletters and several books, so there was solid information available.

A number of authors have developed principles of ecological design as tools to guide planners. John Todd and Nancy Jack Todd, writing in *From Eco-Cities to Living Machines: Principles of Ecological Design,* defined ecological design as "design for human settlements that incorporate principles inherent in the natural world in order to sustain human populations over the long span of time." They present nine "Precepts for Emerging Biological Design."

William McDonough, with Michael Braungart, developed a set of ecological design principles known as the Hannover Principles. These ten principles offer concepts to consider as design criteria. Fundamental to the Hannover Principles is the need to evaluate materials, and designs to reduce and eliminate negative environmental impact.

*The Ark Bioshelter at New Alchemy Institute. Original design.*

EARLE BARNHART

McDonough has also spoken of the need to keep the products of technology away from the natural world. The products of technology tend to disrupt and degrade the natural world, but they are too valuable to waste by allowing them to simply become pollutants. In effect, he calls for two "nutrient" cycles, one that produces and recycles the products of technology and industry, the other the natural biological cycle that nurtures life.

Sym Van der Ryn, with Stuart Cowan in their book *Ecological Design* call for design that focuses on *local* solutions implemented by *local* people using *regional* materials. Their approach necessitates an understanding of the surrounding environment and nature's processes.

These various approaches to ecological design have many similarities: a call for human-scaled and socially equitable planning, a need to set the design in the local and bioregional landscape, and the need to reduce negative impact on the biosphere. Beyond the need to reduce negative impact, ecological design calls for our buildings and landscapes to become integrated into and actually enhance the surrounding environment.

Since the 1980s, ecological design and permaculture design have become intertwined. Permaculture is taught at colleges and universities. Permaculture designers and teachers have integrated various schools of sustainable and ecological design into their work. In turn, the field of ecological design has borrowed from permaculture concepts.

In this book, the terms *permaculture, sustainable design* and *ecological design* are used interchangeably. Both permaculture and ecological design are young fields. As new understanding of ecology and nature emerge and new insights into sustainable resource management develop, permaculture design continues to adapt and expand. Principles and concepts of sustainable design are tools, rather than dogma. Humility regarding the limits of our knowledge about nature's processes is perhaps the most critical principle in permaculture design.

## Sustainability

I once heard a Pennsylvania state energy official tell a group: "Sustainability is a society living in harmony with nature forever." But what does *sustainable* really mean and how can we achieve it?

Webster's defines "sustainable" as relating to a way of using a resource that does not permanently deplete or damage the resource.

In 1987, The United Nations' World Commission on Environment and Development (known the Brundtland Commission) presented this definition: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainable design, therefore, is design that focuses on sustainable *resource management* for any development project. Planning for sustainable development requires an understanding of the ecology of the region and the human impact on the local and planetary environment. In our global society, daily choices we make in our consumption can affect the entire globe. In a search for sustainability we have two needs: first, to live within our region in a manner that honors and protects its diverse ecology; and second, to choose goods, technologies and fuel that will keep the global ecology healthy. As the developing world seeks a Western lifestyle, it falls on Western countries to lead the way to a more ecological, truly sustainable way of life. As environmental educator and author David Orr has shown, we would need four planet Earth's for all humans to live as we do in the United States. We have a choice: to fight a global battle over diminishing resources, or to join a global effort to seek sustainable and self-renewing forms of agriculture, technology and development.

The unfortunate truth is that national governments will not act to protect and restore the environment nor will they work hard to develop sustainable systems unless citizen groups continue to demand and promote these alternatives. Industry, business interests, politicians and facilities managers are only beginning to take into consideration the need to reduce their impact on the local and global environment. The best way to promote a broad-scale sustainability movement is to join with others into influential blocks of voters, to engage with groups doing good work in the area, and to use the power of your purchases to support the development of sustainable societies.

## *Concepts for a Sustainable Design System: Care of the Earth*

Following the logic that human well-being is totally dependent on the health of our planet, the ethic of care of the earth is basic to permaculture design. This ethic of stewardship requires the permaculture designer to cultivate intensively and with ecological methods, allowing, as much as possible, for native wildness to return to the rest of the land. Wildness promotes the health of the farm system and enhances the health of the bioregion — and the planet we live on.

## Gaia

The Gaia hypothesis, developed by James Lovelock (with contributions from microbiologist Lynn Margulis) in the late 1970s, proposes that life on earth interacts with the chemical, geological and energy cycles of the planet (and perhaps the solar system) to maintain conditions necessary for life. Lovelock and Margulis suggested that certain "functions" of ecosystems are vital for the stability of earth's climate. These functions include carbon sequestration in the oceans, tropical forests and temperate soils; recycling of nutrients; oxygen cycling; and climate modification. Each bioregion is thus one of the many faces of Gaia. For example, mid-latitude temperate forests and grasslands and tropical forests act as reservoirs of biodiversity and modify the climate and atmosphere. As stewards of the earth, we must consider the impact of our lives on all different levels: on our local environment as part of a bioregion; on the ecology of other bioregions through international trade; and on the Gaian system through our impact on earth.

The most critical regions of the biosphere, including forests, wetlands, coastal estuaries, and the atmosphere, are also the most impacted by human activity. The damage to the planet's forests is well documented and continues. Our impact on the atmosphere is also becoming widely recognized. Our impact on the seas and oceans is from several fronts, primarily overharvesting of seafood and continuing pollution of our waters. Climate change is altering the acidity, salinity and the temperature of the oceans. And there is ongoing damage to biologically rich polar seas from excess ultraviolet rays because of ozone depletion. In each area, human activities are measurably weakening these systems, and therefore their ability to respond to climate change and overexploitation.

## The March of Civilization Continues

Modern agriculture is the result of a misguided science that cannot see the whole while peering through a microscope. The compartmentalization of disciplines and the war against nature raged by modern agriculture is a downward spiral, leading to further disruption of the natural world. We in the "developed" world are still on the path of environmental over-exploitation that our ancestors started down 10,000 years ago.

Good stewardship of resources and our environment is ultimately the only way to develop permanent agriculture and permanent cultures. Following the teachings of the Iroquois Nation, we must begin to think of the seventh generation to come. This is the generation we will not live to see. People living now are the receivers of choices made seven generations ago, when the petroleum era and Industrial Revolution began. So, now we face global climate change, overpopulation and mass extinctions. What will our great-grandchildren's great-grand children face? We hope it is a legacy of renewed respect for Mother Earth and a truer understanding of our place in the larger web of life.

## Concepts of Ecology

Certain concepts of ecology are essential to the understanding of a permaculture farm. Below, I examine some of the key concepts in ecology applied to the farm: community, flows and cycles, diversity, succession, patterns, edge effect, and entropy.

### *Community*

All life on earth exists in communities. To the ecologist, a community is a *group of organisms living in dynamic relationships in a shared environment.* Between the microenvironment of the garden soil and the community of customers the farm serves lay an intricate web of interactions. The goal of the farm manager is to establish, encourage and nurture these interactions so as to both reap an abundant harvest and enhance the health and stability of the total community. Each species has needs to be met by its community and yields that it contributes.

A permaculture farm is created with an awareness of its relation to the larger environment; it is itself an ecological system nested in the web of life.

### *Flows and Cycles*

Sunlight strikes the leaf. A photon's energy is absorbed and stored by the plant as sugars and other carbohydrates. The plant, assisted by symbiotic fungi, gathers nutrients from the soil. Plants process this energy and the nutrients into an incredible variety of compounds and substances. Animals, including us, consume plants to build tissue and fuel our lives. Animal waste, dead plants and bodies are broken down by a succession of fungus, animals and bacteria that feed off the remaining energy store, returning the nutrients to the soil. And so the cycle continues as a new day's sunlight strikes a leaf and the roots reach into the living soil. The seasons come and pass in an endless cycle, generating other cycles of birth, growth, decline, death, decomposition and renewal.

Nature has evolved within a complex of flows and cycles. Limited nutrients and erratic cycles disrupt the health and stability of natural systems and agricultural alike. With the ongoing changes to global and regional climates — and the local instabilities they cause — our ecosystems are under increasing stress.

An understanding of the flow of energy and cycling of materials through the landscape and through the year is the essence of permaculture. As Bill Mollison has repeatedly stated, the goal of good design is to maximize useful stores of energy, water and nutrients in a system.

### *Diversity*

Diversity ensures balance. Ecological communities are most stable where a diversity of native species co-evolve within an environment. A community of plants, each in its niche, mobilizes a full range of nutrients, keeping essential soil minerals available to the whole community. Diversity of animals gives resilience to a web of foragers, predators and parasites; diversity of fungi, bacteria and other decomposers ensures thorough reprocessing and return of nutrients to the soil. A diversity of niches and microclimates allow for the diversity of organisms to find their place in the system. On the farm, a diversity of crops provides security against disease and weather extremes and allows the farmer to exploit each season. Placing crops in purposeful relationships and arrangements can further increase yield or the health of the system.

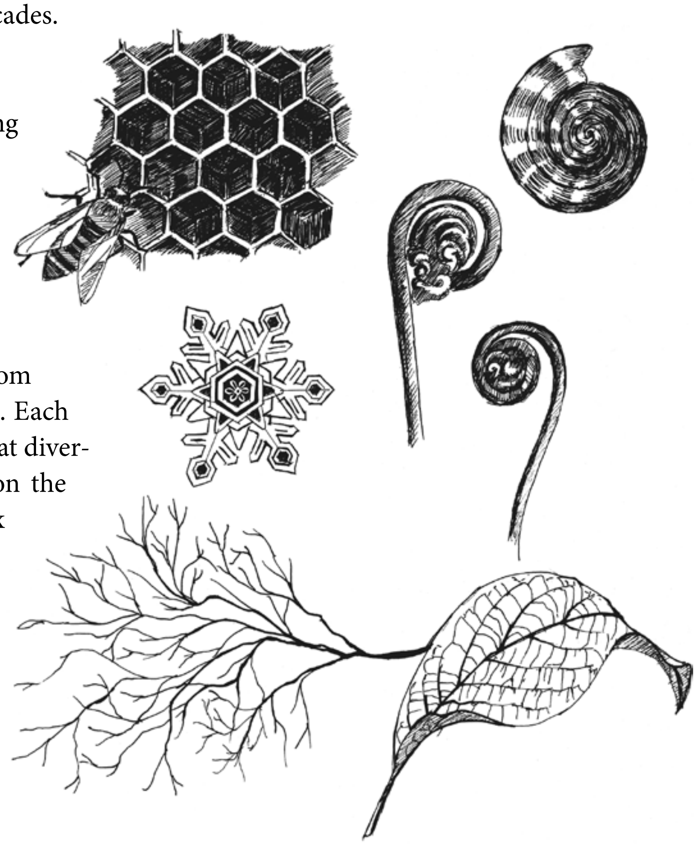
Diversity is even relevant to farm economics. Diverse marketing strategies help stabilize farm income; diverse activities on the farm, including production, processing and education events can balance the farm economy.

## *Succession*

After fire levels a forest, pioneer species take root and flourish because of decreased competition. Grasses succeed to brambles, brambles to shrubs and pioneer trees. Young trees create conditions for more shade-tolerant species. Through the year, a succession of flowers and fruits feed a succession of insects.

Permaculture designers use succession in crop rotation and soil building. They also use succession on a longer timescale by implementing designs in logical sequence. Gardens are protected from wind by berry bush hedges as perennials succeed annuals. Tree crops are established and the farm is steadily diversified into a network of gardens, hedges, wild areas and orchards. Succession is also managed to maintain a specific ecological state as desired. Some meadow species, such as goldenrods, suppress the germination and development of other plants and can keep a field relatively tree-free for decades.

*Pattern illustration.*



## *Patterns*

Patterns are forms created by energy interacting with matter. Nature is manifest as patterns: Spirals of tropical storms and galaxies, branching of trees and rivers, hexagonal beehive cells and snowflakes, sine waves of rivers and radiant energy, elliptical orbits and fractal coastlines — these are all patterns of nature. Nature gathers and scatters, random chaos leads to new order, new order to chaos. Each ecosystem is nested in larger systems. The great diversity of life is, at its base, simply variations on the patterns set by the ladder-bonded double helix of DNA.

Time is also an element in patterns of nature and design. On the farm, interlocking patterns of daily routines, seasonal change, and ecological interactions define our world. Much of good ecological design is working with these patterns in order to increase both the productivity and stability of the farm ecosystem. The patterns of our days and seasons and the pace of our lives make or break the success of the permaculture farm.

### *Edge Effect*

Edges are the interface of two or more systems. Whether it's the edge of the forest or the edge of the sea, the edge is a dynamic and productive place. Some species live only in the forest or the meadow, some move across systems, some inhabit only the edge. Habitat fragmentation by development can create *too much edge.* For example, some forest species require large areas — sometimes thousands of acres — of uninterrupted forest. When gaps appear and edges increase, there is an inevitable decline of native species within the forest. In permaculture, we try to use our understanding of edge to inform our design. An increasing edge can be a good thing in the permaculture garden when useful plantings of herbs, brambles, shrubs, trees and vines are used for windbreaks or at the edge of woodlots.

Humans evolved on the edges of forest and grassland. Our original habitat, the savannah, gave us access to the resources of the grassland and the fruits and shelter of the forest. The permaculture landscape can mimic the savannah, providing us with a mix of trees, shrubs, pastures and croplands to forage and tend.

### *Entropy*

One definition of entropy is "a measure of unavailable energy in a closed system." In the world of physics, entropy tends to increase. Entropy is related to the tendency of the universe to move toward a state of equilibrium. For example, life on earth feeds off the dissipating energy of the sun. As this energy moves through the chain of life — from capture by plants, to herbivore to carnivore and finally to the soil through decomposition — a quantity of energy is lost with each transaction. Every resource we use is diminished and degraded to some extent in the process. A micro-example: with each rainstorm, a small amount of soil is lost to erosion.

We generally do not see the disorder that industry has inflicted on the environment; in recent years, North Americans have literally made it invisible by shifting industrial production and its accompanying environmental damage to developing countries. From mountaintop removal for coal mining, to accumulation of plastic in the oceans, to excess nutrients in our waters and the decline of native habitat, our attempts at creating order in our world is creating greater disorder in the environment.

In his comprehensive examination of the role of entropy in all endeavors, Jeremy Rifkin describes life as a form of *negative entropy.* Life creates and builds order and structure from the process of decay. The community of life works together, in the face of entropy, to maximize the cycling of material and the use of available energy. A permanent agriculture must consider the physics of entropy and negative entropy to sustain the health of the farm and its environment. Our struggle with entropy includes complex tasks, such as using biological resources to build soil, but it also includes simpler acts, such as properly storing tools to prevent rot and rust.

## *Integrating Concepts*

Permaculture design applies these ecological concepts to farm design and planning. Farm components are examined for needs and yields. Crops and animals are chosen to fit local conditions. Plants and animals are linked to promote natural, beneficial interactions. Buildings are integrated into the landscape with earthen berms, windbreaks and other climate control plantings. Resources of climate and microclimate, soil, wind, water and sun are viewed in terms of their ecological associations. Native biodiversity is promoted by allowing as much area as possible to be left in, or restored to, a natural state. Farm components are laid out to maximize production, conserve time and energy and to promote good patterning and nutrient cycles. Building materials and supplies are chosen to minimize environmental impact. Materials with low embodied energy (the energy used to create the material) are preferred. When possible and practical, alternative forms of energy are developed and used. Planning allows for site evolution and maturation.

## *Permaculture Planning*

### Zone System

The zone system is a conceptual tool to help place elements in the system to save time, energy and labor. There are six zones ranging from Zone 0, the interior of the home, to Zone 5, uncultivated wildlands. The plants, animals and structures visited or managed daily are placed in

Zone 1 to allow the easiest access. Zone 2 has plantings and structures visited every few days or weeks. Zone 3 includes orchards and pastures, visited or managed seasonally. Zone 4 includes managed woodlots and low-maintenance perennial plantings. In a foraging sense, Zone 5 is the larger world; many resources can be gathered with permission, or purchased, from other people's land.

### Sector Planning

Sector planning deals with energies from beyond the site that affect the site. Wind, sunlight, streams, rain, brush fires and wildlife all can enter, affect and then leave a site. Understanding the dynamics of these energies allows us to design our buildings, farms and landscapes to control and effectively use these energies. Sector analysis also includes assessing views, sound, privacy and pollution. Farm planning using sector analysis gives an understanding of place and leads to design that capitalizes on special features of a specific location.

## *Other Concepts*

Several other concepts are common to permaculture and good design in general. These are concepts gleaned from many sources, including observation of nature, traditional wisdom and common sense.

**Multiple Functions:** Most elements in a system provide more than one function. A tree may provide fruit, shade, nectar and pollen for insects, a windbreak, nesting sites for birds, medicine and inspiration. Poultry provide body heat, $CO_2$, fertilizer and much more besides eggs and meat.

**Stacking Functions:** Every use of time and energy should be planned to integrate more than one purpose. A trip to town for the shopping one day and the bank the next and the post office the next is simply wasteful. Combining trips saves time and money.

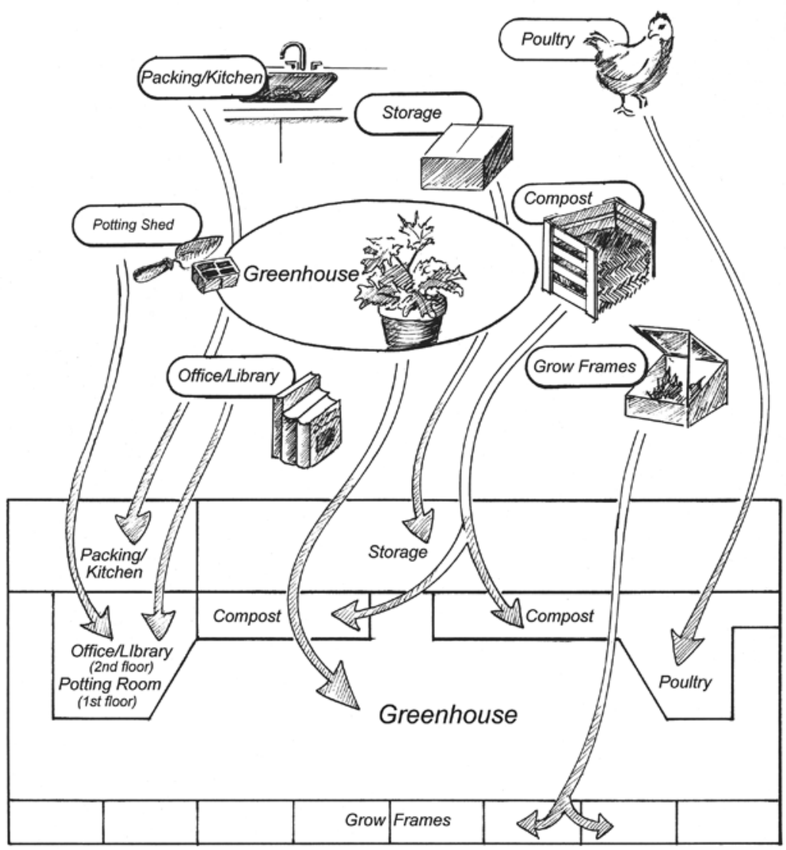
**Relative Location:** Placing elements in the right relationship to each other, through zone and sector analysis is a concept related to function in that it similarly increases efficiency and productivity of the system. Our namesake, the three sisters — corn, beans and squash — as companion plants, exemplify this concept.

**Redundant Systems:** For any important farm product or resource, we should have multiple ways of providing for it. The bioshelter has multiple and backup heating systems and various ventilation modes. Diverse crops ensure harvest if some crops fail. Wells, ponds and rain barrels all provide irrigation.

**Appropriate Scale:** Whether we garden with a trowel, shovel, tiller, or tractor depends on the size of the garden and the scope of the work. Appropriate tools are important design considerations; every tool is appropriate for a garden of a different scale.

**Biological Resources:** Permaculture tries to make use of biological resources whenever possible. For example, a windbreak reduces heat loss and thus fuel costs; recovering heat from compost in a hot bed can get seedlings off to a great start in the spring; and poultry can add $CO_2$ to the greenhouse.

*The integration of various farm components under one roof allows for efficient use of building materials and for efficient farm management.*




Energy efficiency and time efficiency are always considered in the planning stages and are reflected in choice of building design, materials and building management. Again, the aim of placing design elements with the zone system is a tool for enhancing efficiency.

## Permaculture and Agriculture

When permaculture design is applied to the small-scale intensive farm, the result is an evolving, diversified, ecologically integrated agricultural system. Permaculture farms are as varied as the landforms and bioregions of the earth because ecological design is site specific. Farm design begins with an assessment of resources and a survey of the factors impacting the farm. The farm's relationship to the surrounding community and ecosystem is reviewed. Farm products are chosen to make the best use of the specific soil types, aspect and exposure of the land, climate and microclimates, and other factors. Farm products are also determined by the tastes and demands of the farm's customers.

The word "sustainable" as applied to agriculture can be confusing. In the broadest sense the term includes everything from certified organic production to integrated pest control (which seeks to reduce rather than eliminate the use of synthetic chemicals in agriculture). The National Campaign for Sustainable Agriculture defines sustainable agriculture as being "economically viable, environmentally sound, socially just and humane."

To be permanent and sustainable, a culture must be able to interact with the Gaian system by maintaining a healthy ecosystem. This involves restoring, preserving and protecting natural areas of plants and other species unique to the bioregion. Farms can play a vital role in this preservation. When designed as part of the mosaic of the regional ecology, permaculture farms can provide habitat and restored ecosystems, protect groundwater and fix carbon by building soil — all while producing products for market.

The permaculture farm is an organism: the various systems (the inside propagation areas, animal housing, compost chambers and growing beds; and the outside gardens, nurseries, orchards, windbreaks, beekeeping and poultry forage) interact for the benefit of the whole by gathering, transforming and storing available energy. Life on earth is manifest as a vast network of systems within systems. These systems interact in a web of biochemical and energetic feedback cycles. A permaculture farm tries to develop and feed these cycles and work within them to promote the health and productivity of the farm. The compost piles, soil ecology, garden ecosystems, buildings and relationships to the larger community all interconnect.

Attainment of a permanent agricultural system requires understanding local conditions and which crops are suited to those conditions. Observation, design and labor are used to establish and guide the farm organism through a natural evolution of crops and enterprises to a steady state of mixed perennial and annual crops. Developing a seasonal cycle of cultivation and harvests brings steady income year-round while spreading the workload evenly throughout the year.

## Farm Ecology

The permaculture farm is set in the matrix of nature. This concept is the first of the major ecological design principles presented by John and Nancy Todd in their book *From Eco-Cities to Living Machines*. Ecological design proceeds from a study of natural systems and Indigenous cultures that at are tied closely to their ecosystems. Crops are selected to suit the local climate. Microclimates are identified or developed to extend the crop selection and growing season. Beneficial insects, birds and other predators are encouraged with habitat plantings. Soil life is nurtured.

### The Story of the Three Sisters

According to Iroquois legend, the three sisters — corn, beans, and squash — were gifts from the Great Spirit to the Native Americans. The three sisters are traditionally grown together as beneficial companions. The corn provides a trellis for the bean vine; the bean replaces nitrogen in the soil; and the squash's large leaves provide a living mulch, shading the ground and conserving moisture. Grown in this way, the three sisters are an excellent example of a sustainable agriculture system.

Corn, beans and squash can also be the basis of a healthy bioregional diet. The Iroquois knew them as "sustainers of life." When combined, the amino acids in corn and beans provide balanced protein, and both are good sources of vitamins and minerals. Squash is high in vitamin A and potassium and provides a complex carbohydrate that is low in calories. Squash seeds are high in protein and minerals.

Together, the three sisters were the basis of a nutritious, low-calorie, high-fiber diet for the original Americans.

The farm is viewed in its relationships to other systems: The neighborhood heron visits the farm pond on its regular rounds; the hummingbirds that live at our farm in summer spend winters in Central America; the source of our morning coffee can impact the hummingbird's winter home; the monarch butterflies born here in September winter in Mexico; rain comes from the west and drains via Mill Creek and French Creek to the Allegheny River, through the Ohio and Mississippi rivers and on to the Gulf of Mexico.

## Three Sisters Farm


Three Sisters Farm was first conceived in the early 1980s. Our friend and neighbor, John Schmidt, purchased ten acres of farmland and we purchased ten acres of forestland several miles away in Mercer County, Pennsylvania. We all intended to establish our respective homesteads on our two properties; Linda and I had vague plans to develop five acres of the Schmidt property into an organic permaculture farm.

The first step was easy, but very important. We simply allowed the land to remain fallow for, as it turned out, six years. During this time, a natural diversity of plants was allowed to grow. Red clover, yarrow, goldenrod, grasses, biennial taproots such as wild carrot, docks, dandelions, and other plants worked to heal the damage done from conventional agriculture. Inspired by the book, *Weeds: Guardians of the Soil,* by Joseph Cocannouer, and by Masanobu Fukuoka's writing on natural farming, we trusted in nature's ability to regenerate the soil. Both writers said that damaged land is best regenerated by a mix of what are usually considered weeds. From Cocannouer, we learned that annual and biennial plants such as purslane, ragweed, lambsquarters, amaranth, dandelion, docks and Queen Anne's lace will rejuvenate depleted soils. With their various root systems penetrating the soil and accumulating minerals, these and other weeds will, over time, increase fertility, loosen compacted soils and support a diverse soil ecology.

Allowing mixed species to grow started the process of healing the land. Decades of plowing, herbicide application and continuous cropping of corn or soybeans had depleted soil nutrients and damaged the soil structure. The clover provided nitrogen and organic matter. The biennial taproots delved deep into the soil to improve drainage by breaking up the plow pan and bringing minerals back to the surface. The successive increase in the field's diversity nurtured an increase in soil health. We also allowed the tree line to expand. Native dogwood shrubs and other plants seeded by birds or the wind became established and spread.

Following discussions with Bill Mollison at a weekend workshop in 1982, the concept for Three Sisters Farm became clear. Mollison suggested that a person wanting to bring permaculture to a region should collect useful plants and establish a permaculture nursery. Following his lead, we reasoned that market gardening would bring income while we waited for perennial plantings to grow into windbreaks, hedgerows, forage, habitat and crops. A permaculture farm could evolve to follow a seasonal cycle of cultivation and harvests that would bring steady income year-round while spreading the workload over time. Such a farm would serve as a demonstration of permaculture design, a resource for nursery stock, and a teaching center for the community.

## Resource Survey

The study of available resources is another important first step in designing a permaculture farm. Identifying a site's unique features and resources reveals a site's potentials and limitations. In our case, assessment of our local resources revealed the availability of massive quantities of horse manure and waste hay and straw from surrounding stables and farms, and sawdust and bark mulch from local hardwood sawmills.

The farm site was a five-acre field that sloped gently to the south and was bordered by a country road to the west. There was a mature tree line with shrubby understory to the north and east; and a young woodlot and wet floodplain and stream to the south. The rich, sandy loam glacial soil was ideal for gardening. With a natural pH of 5.5, the soil would only need an occasional application of pulverized limestone. The field had a pond site fed by a spring on a neighboring property. Groundwater was plentiful, with well depths of 30 to 60 feet in the area. When the most recent ice sheets plowed across the Lake Erie basin from Canada, they literally plastered northwest Pennsylvania and northern Ohio with sand, gravel, clay, rocks and boulders. At the site of Three Sisters Farm, this layer of compacted glacial till, 60 feet thick over bedrock, holds a pure freshwater aquifer.

We also counted as a resource our growing knowledge of intensive cultivation, agronomy, permaculture design and our desire to develop a model system.

Once we had performed our resource survey, we took several years to think over our plans and do the necessary research. During this time we collected plants, established homes, had children and practiced our designs on smaller scales.

*Interior view of planting in the Solviva Bioshelter, built by Anna Edey on Martha's Vineyard, MA.*

Darrell Frey

## *Early Stages and Planning*

From 1981 through 1987, we collected, purchased and planted various useful plants for trial. These included pea shrubs, honey locust, bamboo, hazelnuts, rosehips, currants, apples, pears, grapes, plums, numerous berries, herbs and other plants.

All the while, we studied and discussed permaculture topics. We were particularly inspired by Anna Edey's Solviva Bioshelter on Martha's Vineyard and the New Alchemy's Institute's work with bioshelters and composting greenhouses. Our plans began to coalesce around the idea of building a composting bioshelter. With freely available horse manure (and our 4WD dump truck), we could use compost to enrich a passive solar bioshelter with supplemental heat and $CO_2$. Finished compost would then be used to fertilize crops in the bioshelter and outdoor gardens.

## *A Bioshelter for Three Sisters Farm*

After six years of study and planning, we were ready when a funding opportunity came along. Federal courts had ruled that the major oil companies needed to refund profits from oil overcharges in the 1970s. The US Department of Energy was charged with distributing the funds through qualifying state agencies. The Pennsylvania Energy Office requested grant proposals for projects demonstrating ways to save energy in agriculture. We responded with a proposal to build our bioshelter.

When we received the grant to build the bioshelter, we were thrust into doing what we had so long studied and planned for. The bioshelter is the center of farm activities. It's where seedlings are started for the garden, tools and equipment are stored, and produce is processed for sale. A complete description of our bioshelter's design and management is given in subsequent chapters.

### Crops

Our basic crop is a salad mix chosen for our particular bioregion. Self-seeding wild edible greens are part of our mix. These are combined with cultivated greens and lettuces to create a salad unique to our farm. The diversity of seasonal ingredients provides crop security and keeps customers interested. Our other crops include herbs, cut flowers, edible flowers, fennels, radicchio, lettuces, tomatoes, greens, root crops, peas, beans, squash, and potatoes. This crop mix has evolved as we attempt to cater to the needs of our customers: chefs, caterers, grocers and household subscribers. We use a system of sales of mostly pre-ordered produce; this reduces unnecessary plantings and crop waste. Excess produce is either consumed, sold or given away. Recently, we started selling berries, crab apples, pears and apples.

### Gardens and Landscape

The bioshelter is built on the highest and most level part of the field, roughly centered on the property. Its central location allows for easy access to the main production gardens. Each year since 1988, we have

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Garden beds laid out on contour at Three Sisters Farm.

expanded our gardens and our production, so we have also used some of the adjoining land available to us. Today (2010) the bioshelter is surrounded on three sides by gardens. Each garden is composed of raised beds laid out on contour. Pathways between beds collect rainwater or can be flooded with water pumped from the pond. Wide central paths allow access to the contour paths. As we develop gardens, we allow uncultivated areas of goldenrod and wildflowers within or near them. These biological islands, together with herbs and flowers and other insectary plants, provide a healthy balance of predatory creatures. Birdhouses, rock piles and perennial plantings of fruits, nuts, berries, vines, shrubs and flowers are added each year. Plants create windbreaks and shade zones.

As we continue to develop our plant nursery enterprise, we are enjoying our trial varieties of filberts, hazelnuts, currants, grapes, plums, apples, pears, Juneberries, rosehips and more. Other fruits are wild-crafted from neighboring properties. Our ten-acre woodland, with three diverse forest systems, provides forest products for farm use and contains some of our plant collections.

## Energies

**Sun:** Much of the sunlight entering the bioshelter is absorbed — by plants, surfaces and materials (as thermal mass) — to provide our primary heat source. We also capture the sun's energy by using a photovoltaic panel to power an irrigation pump.

All our gardens receive full sun. Adding shade trees and shrubs to compost areas and some gardens is a continuing endeavor. Along the bioshelter's north wall, we have established a 2-foot-wide shade garden of native woodland wildflowers, ferns, vines and other useful plants. Fruit trees are mulched and planted with an understory of herbs and flowers. Other shade zones include a visitor's camp, picnic area and hammocks in the tree line. A kiwi arbor near the bioshelter kitchen provides a cool place to work or rest. A 600-square foot barn adjoining the bioshelter provides 4,800 cubic feet of shaded space. Cool air from this space is drawn into the bioshelter, naturally cooling the structure during summer months.

**Wind :** Wind is a major factor at Three Sisters Farm. Situated on the western slopes of the Allegheny Plateau, our site receives daily wind, often steady and strong. Reduction of garden level wind is a priority. The tree line to the north provides our primary windbreak, sheltering the bioshelter and our gardens from the northwest winds. We have added a secondary windbreak of roses, shrubs and small trees 100 feet west of the bioshelter. A third, mixed species windbreak provides extra shelter to the herb and flower gardens next to the bioshelter. The trellised kiwi arbor between the bioshelter and herb garden provides a fourth wind deflector for the bioshelter.

**Water:** The pond provides irrigation for the gardens via pumps and sprinklers. The pond also provides fish, cattails, duckweed, algae and other useful plants. We continue to add useful species. Snakes, toads, turtles, dragonflies and many wild birds make the pond their home or feeding ground, as do muskrats. Generally, we receive 40–45 inches of rain each year. Roof run-off is caught in swales and contour paths to recharge our well. The 60-foot-deep well provides water for the bioshelter and our home.

## *Strategies*

Good implementation strategies are imperative for successful permaculture design. Primary among these are staging and timing. We knew when we started that it would take up to five years to see income. Rather than go deeply in debt (beyond a loan for matching grant funds), we chose a more natural pay-as-you-go expansion. Each year we have expanded our gardens and increased sales. For the first ten years we averaged 20 percent growth in sales annually. After that, we began to diversify our activities to include more educational outreach. The bioshelter developed as we earned cash and learned more. Generally, bigger construction projects are planned for fall, when more money and time is available.

Our landscaping strategies follow Bill Mollison's suggestion that it is better to plant only what you can care for each year rather than overplant and lose trees. We've found that limiting our spring planting of new tree and shrubs to ten per year works well with the demands of our annual gardens.

## Season Extension

Season extension is creating and using microclimates and structures to extend the growing season. Spring season extension allows the gardener to get a head start in crop production by starting seedlings for the spring and summer gardens. Fall season extension expands the production time for summer and fall crops. Winter season extension allows the year-round production and harvest of crops.

Season extension has been an important tool for market gardeners for centuries. In northern climates, the ability to extend the growing and harvest season is vital to the development of sustainable regional food systems.

Season extension can be as simple as mulching your carrot beds so you (and the voles) can harvest fresh vegetables from under the winter snow; it can be raising a bit of salad or cooking greens in a cold frame; or it can be winter gardening in a bioshelter.

## Outreach

Fritjof Capra, writing in *The Web of Life,* declares the *network* to be the basic pattern of life. Networks of systems within systems form the basis of our biological existence, from the micro flora and fauna of our bodies and the soil to the biomes of the whole of the biosphere. We see our farm as part of several networks: sustainable agriculture in our bioregion; regional outlets for organic products; sites demonstrating sustainable practices; and the many farms and citizens in our region exploring sustainable organic gardening.

Since 1988, several hundred people have visited Three Sisters Farm. They come for tours, workshops, internships and celebrations. They come to buy produce and plants. We hope they learn a little about ecology and permaculture.

Three Sisters Farm is a working model of permaculture design. It is not a model in the sense of a completed project, but a model of the living laboratories needed to fully develop sustainable permaculture farms in temperate climates. We see bioshelter market gardens as a key to sustainable living in our climate. As we continue to observe, create and implement our designs, we move closer to the idea of permanent agriculture.

## Back to the Earth

The best way to describe the changes permaculture development has brought to our farm is to compare it to what came before. A small field that was previously plowed each year and planted in corn or soybeans now contains many dozens of species of plants. It is home to a thriving natural diversity of animal life. Bats, moles, mice voles, and weasels live between our gardens and along the edges. Swallows, orioles, bluebirds, catbirds, wrens, redwing blackbirds and many others songbirds nest here. Herons, ducks, geese, owls, and hawks forage our pond and fields. Turtles, snakes, frogs, toads, spiders, bees, wasps, and other native creatures live here as well. Wildflowers and new insects constantly amaze us as they join our evolving system. Together the gardeners, gardens and nature manifest the essence that is greater than the sum of its parts.

## PROFILE

### Homescale: The Jenkins Homestead

While the garden at Joe and Jeanine Jenkins' Homestead evolved and grew as a result of their own ideas and planning, it is laid out in a classic permaculture landscape, from a Zone 1 kitchen garden to the Zone 3 orchard and Zone 4 and 5 woodlots beyond. Fifteen paces from the kitchen door, after passing through a tree-shaded dining deck, one enters the garden. The 4,200 square foot space has one side facing the house and three sides surrounded by a double-fenced poultry run.

The east side of the garden, bordering the house, is edged with flowers, ferny asparagus and small shrubs. A cooking pit and picnic table are placed under the shade of a friendly young maple tree. A slate-roofed chicken house, sheltering a small flock of hens, is in the northwest corner. The chickens have free access to a 6-foot-wide run, where weeds and unusable produce are tossed for the chickens to forage. Two fences provide double protection from deer, rabbits and woodchucks, and they give the chickens the chance to intercept slugs and other crawling garden invaders. Joe Jenkins explains that the poultry run design evolved from a need to keep deer out of the garden. He had read that a deer would not cross a double fence. Connecting the area between the fences to the poultry yard was a logical way to keep the weeds down in the space and to use the birds' natural foraging habit to keep the fence lines clean. The inner fence doubles as a trellis for beans, peas and flowers. Grapes hang from the outer fence. The northern third of the garden, adjoining the chicken house, is weeded and fertilized by foraging chickens during the fall and winter months. Each summer, sweet corn and companion crops grow well in this annually renewed plot.


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Jenkins' zone one garden.

Apples, peaches, peonies, gladiolus and other perennial flowers are planted along the outer garden fence. Gates through the fences provide easy access to compost and mulch stockpiles and to the orchard area. The half-acre orchard includes apples, pears, hardy kiwi, plums, peaches, hazelnuts, raspberries, blueberries and chestnuts. Mulberries are located near the chicken house, where newly hatched chicks can peck at the fallen fruit each June. Native patches of Joe Pye weed, ironweed and jewelweed are encouraged in the few wet spots in the orchard, creating excellent habitat for butterflies and beneficial insects. The orchard and yard area is surrounded by forest edge to the north and west and a perennial border to the south. Dogwood, and other shrubs and trees provide winter forage for birds. A dwarf hydrangea on the garden border gives summer shade for understory plantings of daffodils and other spring flowers,


DARRELL FREY

Jenkins' garden with grape arbor.

and provides seeds for cardinals, juncos and doves well into the winter. The birds are also provided with fully stocked feeders most of the year.

When Jeanine Jenkins describes her garden, she mentions the *I Ching,* in which stable lines move to change, and a balance is achieved between natural wildness and cultivated beauty. Jeanine explains that the garden, developed and worked by both her and her husband, Joe, is a result of the dynamic tension between garden labor and the organic evolution of the growing space. Her plants form a natural balance instead of being forced from a plan. Beauty and bounty meet in simple grace and elegance. Self-seeded scarlet poppies and biennial purple-throated foxgloves intermingle with cabbages and beans. Permanent, stone-edged beds line a gravel path leading to a garden bench. These stone beds protect alyssum, yarrow and thyme, marigold and sage, calendula and cosmos, gladiolus, and daisy, as well as kitchen and tea herbs. Branching off at right angles from this central path are smaller paths and beds of various sizes. A second bench and small grape arbor are placed in the southwest corner of the garden.

Most of the beds are fluid, changing size and shape each year as crops are rotated. Wild edible purslane, lambsquarters, and other plants self-seed. Large, crispy cabbage, sweet kale and broccoli, tangy tomatoes, peppers (both sweet and hot), eggplant, potatoes, summer and winter squash, cucumbers, peas, beans, carrots, onions, garlic and beets trade companions and positions annually and seasonally in a colorful fairy dance of succession, season and gardener's whim.

*Jeanine Jenkins gives a tour of her poultry forage area along her zone one garden.*

Darrell Frey

From numerous birdhouses and nests, wrens, phoebes, robins, bluebirds and swallows patrol the gardens and orchards for caterpillars and other pests. Bees and other beneficial insects forage on the succession of flowers in the stone-lined beds and garden borders. Ducks, fenced out of the main garden, forage and fertilize the orchard. The ducks also love to clean up fallen fruit, helping to break the life cycle of pests and keep the orchard clean.

This garden and landscape evoke a sense of balance, bounty and wholeness.

Its encircling symmetry and colorful beauty combine to give the gardeners and their guests a feeling of satisfied well being. Sitting on the deck, sipping iced herb tea in the dappled tree shade and afternoon sun, while hummingbirds flash past to sip the gladiolus or foxglove, is as relaxing an experience as one may find, and it is just outside the kitchen door.

## *A Nutrient Cycle — Full Circle*

Readers may be familiar with the Jenkins's garden from Joe's book, *The Humanure Handbook,* wherein he details the humanure toilet and safe composting of human manure: A toilet receptacle (usually a five-gallon bucket) containing feces, urine and sawdust is added to the wood-framed compost pile every few days. Each addition to the pile is covered with straw, garden weeds or other fibrous organic material. The compost generates sufficient heat and micro-biodiversity to destroy pathogens as it composts and ages. One bin is filled over the course of a year. The two-bin compost system ensures a bin will age for a year after the initial one-year thermophilic composting period.

The finished compost is used to fertilize the Jenkins's garden and landscape each spring, returning nutrients to the soil. Every summer solstice, a new pile is started in the emptied bin. The Jenkins' continually monitor the temperature and biological activity of their composting system and have developed an elegant and effective system to ensure the safety of their crops and the quality of their compost. The result is thriving, healthy gardens; thriving, healthy people and a wondrous and magical garden ecosystem. (Note: Most farms and facilities with composting toilets restrict humanure compost use to trees and other Zone 3 and 4 perennials. One reason for this is to prevent misunderstandings with customers who buy produce. At Three Sisters Farm we do not use humanure in our production gardens.)

Permaculture principles are very well demonstrated in the Jenkins's Homestead garden. Every element is in a good location relative to the house and each other. The poultry house and run are designed to serve multiple functions and make good use of the biological resource of chickens as foragers and recyclers. David Jacke, writing in his book *Edible Forest Gardens, Vol. II,* calls this type of double-fenced chicken run a "chicken moat." The poultry house, fencing and border plantings break the wind and create a sheltered, sun-trapping microclimate. As mentioned above, the entire landscape is laid out in a zone system. Everything is designed for efficient use and management. The fencing and chicken house are built to last (the slate roof on the chicken house mirrors the care taken on all the Jenkins's buildings). Nature is nurtured, even celebrated, with birdhouses and feeders and natural art. Living space and garden have been integrated into one system. The nutrient cycle between gardener and garden is complete. The Jenkins's home embodies the sense of permanence we seek in good permaculture design.

Chapter 2

# Sustainable Food Systems: Safe, Healthful and Secure

*Tending my garden, I saved the world.*
— Zen wisdom, paraphrased

A food system is all the activities that bring food to your table. That includes food production, processing, transportation, storage and distribution. It may be further defined to include preparation, cooking, consumption and waste management. Our food system should provide food that is safe to eat, promotes good health (for consumers as well as soil), and provides food security for all consumers. With this chapter, I seek to place the market garden farm in the larger context of the regional food system by looking at three aspects of the food system: food safety, healthful diets and food security.

## Sustainability for Food Systems

A permaculture perspective on what a sustainable food system really is takes into account the ecological and cultural effects of the food system, both local and global. A system should be able to provide sustenance for consumers, a profitable livelihood for producers, support for healthy biodiversity, and support for the cultural vitality of a region.

While some level of international food trade is desirable, the need to support and develop local food systems is vital for a sustainable society. The global economy provides an incredible array of foods to the far corners of the planet. But it does so at a high cost to the biosphere and local cultures. High energy inputs are required to produce, process, transport and store both basic commodities and specialty foods. Excess nutrients and agricultural chemicals pollute surface water and groundwater. Many people rightfully object to the mass production of milk, eggs, beef, pork and poultry in the mega-farm industry on the basis of personal philosophy and out of concern for environmental impacts. There is great potential for disruption, contamination and slow accountability in the system. Overfishing, soil erosion, deforestation, groundwater depletion, population increase and climate change already undermine the foundations of the global food supply. The need for biogenic energy sources (such as biodiesel and ethanol) to replace fossil fuels is removing crops and cropland from the food system.

Understanding and acknowledging these issues is crucial to the public debate. Also critical is the need for working examples of sustainable systems, and a broad understanding of the economic, social, health and ecological benefits of a sustainable food system. We cannot affect positive change without proposing positive solutions.

There are countless examples of work toward sustainable systems in towns, cities and the countryside around the world. Whether the efforts are large or small, each is a piece of the puzzle, and together they provide a glimpse of a sustainable future. Small farms incorporate alternative energy into their operations; environmental centers build worm bins to recycle organic matter; municipalities offer mulched leaves to residents; urban gardeners grow produce and teach age-old skills to new generations. Hope grows for a green and healthy planet.

Yet, on closer study, most sustainable projects are struggling. New market gardens start up and fade away. Customer turnover in a Community Supported Agriculture program (CSA) may be 20 percent each year. Farmers have to rely on off-farm income and innovators rely on grants and tax breaks. A disparity can exist in the cost of managing a small farm and the market value of the farm's products. Trying to compete with the highly subsidized global food system will keep local sustainable agriculture at a disadvantage as long as our personal shopping choices support the former and our political systems hide the true costs with subsidies and infrastructure.

Permaculture offers a design system to help bridge this divide. Clear assessment of a farm's assets, innovative design strategies, and planning to integrate sustainable systems all help to reduce a farm's energy and maintenance costs. Planning for diversity and the long-term development of ecological relationships and community service help create sustainability.

The permaculture ethics, care of the earth and care of people, imply, at the very least, an organic approach to agriculture and food production. Permaculture applied to agriculture is a process of design and management for the farm to be productive, culturally relevant and positively integrated into the larger environment. Permaculture design for a bioregional food system implies a sensitivity and response to cultural diversity, seeking to develop relationships with customers by satisfying their tastes and traditions. These approaches in turn can increase a farm's long-term viability.

For the near future, the development of sustainable agriculture will continue to need financial support, including subsidies and grants, as we put into place new local food systems. True national security depends on the strength of these systems. Education of consumers and political leaders must also continue. It is far better to see the future coming and prepare for it than to react to a crisis.

In the long term, these farms must sustain themselves. A garden is more than a place to grow food. It is a place for nature to reside and for us to learn about our intricate web of connections with nature.

## *Local Food*

Fresh, local, organic food is obtained either by growing your own or buying it from local growers, grocers and restaurants. (Here, and throughout, local is considered to be within 100 miles; regional is within 300 miles to 500 miles.)

Home food production is a widely practiced cultural tradition. While the percentage of a household's food produced by gardening has generally declined in recent decades, gardening continues to be a popular activity. Fresh seasonal vegetables from your own organic garden cannot be improved on for flavor and nutrition.

For urban dwellers and others without their own land, community gardens are an important asset. As demand for fresh produce grows, demand for community garden space will increase.

### Market Gardens in the Sustainable Food System

Next to growing your own produce, market gardens provide the most direct access to locally grown fresh produce. From the time the first cities were founded, until sometime in the past century, market gardeners and regional farmers supplied people with most of the food they ate. But the local farmer has become almost unknown because farmland near urban centers is disappearing. Today, urban sprawl and commercial development continue to transform former farmland into bedroom communities and shopping centers. Moreover, many issues complicate the preservation and maintenance of farmland. Zoning, taxation, land value, public awareness and government regulations all influence the ability of farms to compete for land and markets. If land is to be preserved and access to local food ensured, it will only be as a result of concerted efforts by community groups and sustainable agriculture organizations.

As we build a sustainable society, the role of market gardens in local food systems will continue to grow. Market garden farms tend to be small and diverse, offering a wide range of seasonal products. Because of their smaller size, diverse crops and local distribution, these farms can be highly responsive to the needs of their customers. Seasonal and cultural specialties can be grown to suit local tastes. As you will see in following chapters, market garden farms established on small parcels can provide a wide range of products and services to the local community.

Small- to medium-scale commodity producers will play an expanding role in the sustainable food system. For example, shiitake and other mushroom production, flour milling, maple syrup and honey production all can be done on a family farm. Dairy, livestock, eggs, and cheese are also well suited to small-scale production.

Season extension for vegetable crops is an essential component of any local and regional food system. Winter crop production techniques that are profitable and do not rely on fossil fuel will increasingly supply salads, greens, herbs and other products.

## Value of Local Agriculture

The reasons for preserving local agriculture are numerous, chief among them, nutrition and quality. Vegetables begin losing nutrients when they are harvested; flavors are richer in fresh foods. A fruit or vegetable shipped thousands of miles, from across the country or from a different country, will not be the same quality — or even look as good — as food purchased from local growers. A more direct link between consumers and local producers creates a positive feedback loop: local customers ensure markets for farm products, which encourages local production, thus ensuring a continued supply of locally produced food. Because they are more closely linked to the consumer, local farms have more incentive to be responsible in ensuring the safety of the food they produce; thus, they are more likely to be concerned with the reduction and elimination of pesticide residues and food-borne pathogens through organic production and sanitary practices.

The potential disruption of food supplies by natural and political disasters is another reason to promote local food systems. And energy costs for processing and transporting food is greatly reduced with local production.

## Food Safety and Public Awareness

"Are you organic?"

When we began selling produce from our farm in 1988, no customers asked us this question. When we did mention that our crops were grown with organic methods, customers showed vague disinterest. Price and quality were the primary concerns. But change came soon. After a 1989 Natural Resources Defense Council report on potential health effects on children of the chemical alar was publicized, many of our customers began to ask: "Are you organic?"

Alar, the trade name for a chemical called daminozide, was sprayed on apples to promote uniform ripening. Researchers concluded that alar degraded into a chemical that was a potential carcinogen. The ensuing outcry was perhaps the most significant shift in public awareness of chemicals in the food system since the publication of *Silent Spring* in 1963. Alar was banned by the EPA in 1989. The organic food market has been growing ever since.

Similar shifts in public awareness and concern about the safety of the food system continue to occur. In September 2006, between 50 and 60 million dollars worth of spinach was recalled due to fear of contamination with *E. coli* bacteria. According to the Centers for Disease Control, this particular bacteria, *E. coli* 0157:H7, originates in the intestines of livestock, including cattle, sheep, goats and deer; it can cause severe diarrhea and, in young children and the elderly, kidney failure. There were 200 reports of illness in at least 20 states. The nationwide recall of spinach greatly raised awareness of the concept of "local food." The fact that the FDA is often unable to trace the origins of such contaminations points to the need for traceability in the food distribution system. When the customer buys directly from the farmer, accountability is immediate. Also, should problems occur in locally produced products, the impact isn't so widespread.

It is up to the farmer to understand food safety issues and ensure that the farm's composting methods, irrigation, harvest and packaging are safe. By learning food safety issues and practices — and keeping the consumer informed — the small-scale farmer is better positioned to ensure product safety than the giant commercial producers are.

### *Healthy Food*

Providing an interesting and healthful diet with locally grown food is a challenging prospect for most people in the United States. Consumer trends, shopping patterns and government policies of the last 50 years have led to centralization of our food systems. For example, most produce consumed in the northeast is imported from Mexico, California, and a few other states. This, in turn, has decreased the availability of locally grown foods.

Nutritional science and diet planning are continually evolving fields. Some controversy revolves around various theories of consumption of fats, carbohydrates and proteins in relation to obesity, heart disease, and other diet-related illness. However, consensus is emerging: unrefined whole grains and legumes, with plenty of fresh vegetables and fruits, are the ideal basis for a healthy diet. Dairy products, meats, eggs and plant oils are needed — in moderation — to provide protein and energy. Use of saturated fats, refined sugars and refined grains should be minimized. Most researchers recommend low-fat dairy products.

A healthful diet consists of eating the right amount of a variety of foods. Correctly chosen, these foods should provide the proper amounts of the necessary elements of nutrition. Elements of nutrition include water, protein, carbohydrates, fats, vitamins (and their precursors) and minerals. Recent research has begun to identify the role of micronutrients, including phytochemicals (phyto = plant) and other antioxidants in a healthy diet. Dietary fiber, found in plant-based foods, is also vital to a healthful diet.

When developing a diet based on local foods, one must select from among the region's products to provide adequate nutrients from local foods. A wide variety of locally raised meat and dairy products are readily available. Milk and cheese are important sources of calcium and are a complete protein. Eggs are low in fat and are a valuable source of protein, especially for growing children. From late spring until fall, a good variety of locally grown fruits and vegetables are available to those who seek them. Regionally produced grains and beans can also be found. However the quantities of produce, grains and beans available regionally can be small compared to the population to be served.

During the winter, when fresh food is limited, stored root crops, cabbages and squashes can be supplemented with canned and frozen foods and greenhouse-grown salads and greens.

Large-scale transition to local food systems will require a concerted effort among producers, consumers and government agencies. Developing a local food system that addresses regional health needs will require both increased consumer demand for local products and increased local food production. In the meantime, conscious consumers can enjoy the benefits of local foods through careful shopping and menu planning.

## *Food for Permanent Culture: Embracing Cultural Traditions*

As permaculture design seeks to forge a path to sustainable living, we must propose solutions that people will love. Food choices result from a complex blend of cultural, social, religious, behavioral and personal influences. For example, many of the world's cultures derived sustenance and pleasure from adding insects to their diet, Europeans and North Americans outside of Mexico cringe at the thought. Milk and dairy products, considered an essential food group in the US, are indigestible to most of the world's adults.

When considering food systems, understanding cultural influences is essential. Food often conjures pleasant memories and provides a touchstone in our lives and a connection with our families. Every Easter, Grandma Reeder hosted the traditional baked ham dinner. On New Year Day, we had to have baked sauerkraut ("very brown" — Mother insists!) and pork. Christmas and Thanksgiving featured the traditional turkey dinner with all the fixings. In our family, all these meals included mashed potatoes and gravy and several vegetables, usually green beans, corn, brussels sprouts, cauliflower or broccoli. Being raised with Pennsylvania Dutch staple meals, like beef and noodles, chicken pot pie, and boiled ham and cabbage, it was a cultural surprise to experience Georgia hospitality and cuisine as a teenager. I had never even seen black-eyed peas, grits, or greens, much less in such generous helpings! When a brother married into an Italian family, we all learned that great Italian food extended far beyond spaghetti and lasagna.

Discovering new foods and food traditions is a pleasant way to learn about other cultures. Tofu, miso, tempeh and other Asian foods are now a regular part of our diet. Chinese-American, Thai, Mexican, fine Italian, European nouvelle cuisine and the new American Fusion cuisine all have inspired our own home cooking. The work of Alice Waters and her restaurant Chez Panisse in developing new American cuisine has influenced a generation of chefs and helped create restaurant demand for fresh local ingredients across the nation.

Even in small cities, restaurants have menus that read like lists of UN member countries. The US is truly the melting pot of culture; each addition to the ethnic diversity of the country brings a unique cuisine.

### Gardening and Health

Exercise goes hand in hand with diet for maintaining good health. It would be wonderful if everyone got a free health club membership as part of a national health care system. (Those who participate in weekly exercise regimens would get a discount on their premiums.) In the meantime, we have to find our own health clubs. The ideal health club would provide a variety of activities that allow members to exercise their entire body: muscles, lungs and heart. It would include outdoor activities in the fresh air. It would be in a psychologically and spiritually stimulating environment that allowed for relaxation and reflection amid beauty — along with the exercise. Included would be a reward mechanism, providing positive feedback for invested effort. What if this place also provided its members with the freshest food possible, especially a plentiful assortment of seasonal fruits and vegetables? Does such a place exist?

Yes. It's as close as your home garden. Gardening at home can provide all these benefits: occasional cardiovascular workouts and overall exercise in a stimulating environment with the reward of fresh food. (Of course as with any workout, exercise through gardening requires a few warm-up stretches, proper equipment, and proper use of that equipment.) Additionally, gardening relieves stress, channels energies, and helps one maintain a youthful health and vigor.

Providing the ingredients for these diverse cuisines is an opportunity for the enterprising farmer to develop relationships with chefs and create marketing niches. Targeting production to supply special foods for specific holidays, like the traditional Thanksgiving turkey, also offers local farmers marketing opportunities.

### Seeking a Native Diet

As we seek a permanent agriculture for any bioregion, it is instructive to study the traditional food systems of the indigenous people of that region. We cannot soon restore the native ecology and biodiversity as it existed in 1492, but study of the traditional diet of earlier inhabitants can provide insight into planning a healthy and ecologically sound diet based on local foods.

Our farm is located in the former territory of the Iroquois. The Iroquois Nation, also known as the Hau-de-no-sau-nee (People of the Long House), are native to western New York, northwestern Pennsylvania and southern Ontario. The Six Nations of the Iroquois Confederacy are the Seneca, the Onodaga, the Mohawk, the Oneida, the Cayuga and the Tuscarora peoples. At the time of first contact with Europeans, in the 17th century, the Iroquois were primarily an agricultural people. They had lived in a sustainable manner in the north central Appalachians for many hundreds of years, practicing natural resource management without depleting their resource base. In many ways, their diet was typical of the Eastern Woodland Indians of that era.

The Iroquois diet at the time of first European contact was a complex mix of both cultivated and foraged plants, fish, shellfish and hunted game. Writing in the book *Native Harvest,* E. Barrie Kavasch reports that the Iroquois generally had one large mid-day meal and one or two smaller meals throughout the day. They used little or no salt, though various ashes, which provide ☞

*The Three Sisters are corn, beans and squash. They are considered gifts of the Great Spirit by the Iroquois Indians, and have been traditionally grown together as beneficial companions. The corn provides a trellis for the bean vine, the bean replaces nitrogen to the soil, and the squash's large leaves provides a living mulch, shading the ground and conserving moisture. Corn, beans and squash can also be the basis of a healthy bioregional diet.*

*The three sisters represent to us the vision of native agriculture we strive to rediscover here at Three Sisters Farm.*

minerals, were used in cooking (these included ashes of plants, such as mineral-rich coltsfoot leaves, and various wood ashes, including cedar and hickory).

The primary crops of the Iroquois were the Three Sisters: corn, beans and squash. To this day, the Iroquois promote the use of these foods and maintain traditional varieties of some of their ancient strains.

Corn alone is inadequate as the basis of a healthy diet. Corn is deficient in the amino acid lysine, one of the nine amino acids people must obtain from food. Corn eaten as a primary protein source will lead to protein deficiency. Additionally, 95–97% of the niacin in corn is in a form which is unavailable to humans. Niacin deficiency, which can be fatal, is common in "corn-dependent people." Similarly, beans are low in the amino acid methionine. Native Americans solved this dilemma in two ways. One was to combine foods with complementary proteins to provide a balance of amino acids. Corn was often eaten together with beans or combined with meat, shellfish or nuts. The other method was to prepare corn with ashes or lime. The lime or ash treatment made niacin available and balanced the overall quality of the protein. Hominy grits, a southern staple, are traditionally prepared this way.

*The sunflower is another traditional crop of Native Americans.*

Corn, beans and squash were eaten year round, either fresh or dried. Many traditional recipes include combinations of the three, often with other foods. For instance, there is a traditional corn bread that is baked with beans included.

Cultivated sunflowers were another high-protein food and source of oil for the early Native Americans. Sunflower seeds are a very good source of the minerals phosphorus, potassium and iron and are known as a rich source of vitamin B-6. Sunflower oil is high in polyunsaturated fat and, therefore, one of the more healthful oils.

The Iroquois ate a great variety of seasonal foods. In addition to cultivated crops, they foraged wild foods. The succession of roots, shoots and fruits utilized was extensive. Nut trees provided a source of protein and healthful oils. American chestnuts were abundant before the chestnut blight all but eliminated their presence in the early 20th century. Many other nuts were used as well. Acorns, hazelnuts, beechnuts, walnuts and hickory nuts all provided high-quality protein and oils. Easily stored, nuts were especially important in the winter, when other foods were scarce. Nut trees do not generally bear every year, however. They typically give a heavy yield every second or third year. Nuts were and still are an important mast crop, providing food for wild game populations.

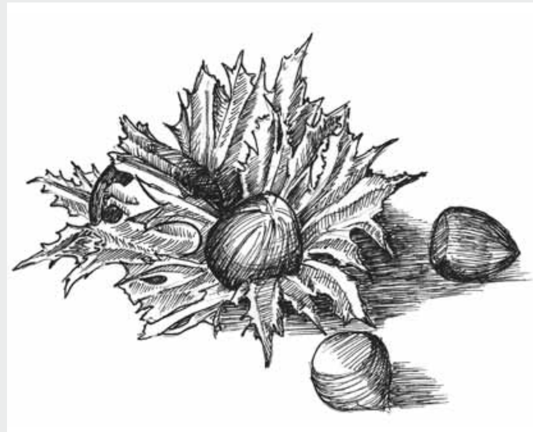
The list of plant shoots, leaves, pods and roots used as vegetables is long and includes cattails, milkweed, Jerusalem artichoke, ground nuts, ramps, jewelweed, ☞

ferns, violets, nettles, bulrush and coltsfoot. Many semi-wild plants introduced by Europeans after the 16th century were adopted, including watercress, dandelion, daylily, plantain, sheep sorrel, chicory and lambsquarters. These and other wild foods contributed essential vitamins, minerals and other micronutrients to the diet. An abundance of spring greens quickly rejuvenated the body after a long winter diet of stored foods. Pine needle tea supplied vitamin C through the winter. A variety of mushrooms also were gathered in their particular seasons.

A succession of fruits were eaten fresh and dried for storage. Juneberry, strawberry, blueberry, cranberry, raspberry and blackberry are all native to the central Appalachians and were used by the Iroquois. Wild plum, grape, elderberry, currants, gooseberry, mulberry, nannyberry, strawberry and wild apple were also harvested for fresh use and stored for the lean winters. Like the vegetables, these various fruits provided important vitamins and other micronutrients for the Iroquois diet. As with vegetables, the Iroquois adopted some European fruits. Apples, peaches, pears and European plums were grown after contact with Europeans. The Iroquois had extensive orchards and cornfields around their settlements in the Susquehanna Valley of southern New York at the time of the American Revolution.

There is some evidence that the pre-historic Native Americans maintained agroforestry systems. An account by a pioneer in western Pennsylvania, Captain A. McGill, in *In French Creek Valley* describes an abundant forest garden at the convergence of Woodcock Creek and French Creek:

> The banks of French Creek were fringed to the water's edge with evergreen bushes and trees, while ranged along on the higher bank was a row of stately pines beautiful in their majesty as the cedars of Lebanon. In rear of the pines half a mile in extent was a very gently undulating plain on which grew great old oak trees with spreading tops, the rare old oak that tells of Centuries, a variety that now seems to be extinct. They grew with ample space between without underbrush or obstruction to the view, to the limits of this wonderful park. Around the outer semi-circle of the park there arose a little plateau, not 10 feet in elevation, and from its base flowed springs of pure cool soft water, which fed a circlet of mighty elms, unrivaled in size and beauty ... there were hundreds of these great trees with wide spreading branches supplementing in grandeur the great oaks they encircled. Beneath these grew ☞



*Hazel nuts and other native nuts, grown in the farm's tree line and windbreaks, are important bioregional food crops.*

> hazel bushes, blackberry and raspberry bushes, hawthorn and crabapple trees and many varieties of beautiful shrubs and plants while near the northern extremity there was a veritable orchard of wild plums bearing a great variety of large red and yellow fruit. The ground rose from the river margin in regular successive plateaus of easy grade covered with the finest timber of the most valuable and useful kind. The view was enchanting and they moored the canoe to the bank to make further explorations. Here they were met by John Fredebaugh, who had located a claim that took in Woodcock Creek and joined on the north the land that had attracted their attention. His land ... was naturally alluvial and very rich ... a forest of white walnut (butternut) with here and there a great sycamore towering above and extending its weird white arms over the umbrageous growth beneath. The wild grape vine interlaced the trees and hung in festoons from the branches, forming arborial recesses of rare and inviting beauty.

This scene would have been a paradise of food to the Iroquois and their game animals and was most probably managed, if not created by them prior to the arrival of Europeans. It serves us today as a model for the development of productive forest gardens, yielding building material, nuts, fruits, wildlife forage and medicinal plants.

Fish and game were used year round by the Iroquois. The abundance of game described by early explorers of the 18th century was astounding. Bear, deer, elk, woodland buffalo, ground hog, beaver, turkey, passenger pigeon, quail, and rabbits were all hunted. Because it provided valuable skins for clothing and other crafts, venison was the primary meat in their diet. Bear was hunted in the fall for its high quality fat, used both for its food energy and to make bear oil. Bear fat and oil was used for lamps, softening leather and other crafts. Rivers provided abundant species of mussels, turtles, eels, and a great variety of fish. The protein and fats from fish and game supplemented crop nutrients.

The Iroquois practiced a seasonal cycle of sustainably using the resources around them. In the spring they would plant their gardens, fish and forage for wild foods. After the crops were planted, many people would leave the villages for nearby hunting grounds. In late summer, the villagers would gather again to harvest the crops and gather fruits and nuts for winter. In the colder fall and winter months, hunters would supplement the village's stored crops and fruits with game. In the late winter, maple sap as well as the sap of various nut trees was gathered and boiled for sugar. Villages were moved as frequently as every ten years as croplands became depleted and game scarce.

Botanically based condiments such as wild leeks, wild allspice and bergamot, supplemented the Iroquois diet. These plants provided minerals, vitamins and other micronutrients. Many plants were used medicinally as well.

The diet of the Iroquois was a healthy one. Wild game tends to be leaner and richer in omega-3 fatty acids, and lower in saturated fat than modern grain-fed meat products. The abundant fish and shellfish also provided high-quality protein and omega-3 fatty acids. The cultivated crops, including corn, beans, squash and sunflowers also provided a balance of protein, vitamins and minerals. The sunflower's seeds provided valuable polyunsaturated oils as well. Variety was a key component ☞

of the diet. Fresh plants in their season and stored plants during winter provided many nutrients.

Most modern Americans eat many of these native foods, including corn, beans, squash, sunflower seeds and some of the same wild fish and game. Although life is different for us (we certainly have lower calorie requirements and less access to natural systems than the early Iroquois did), we can use the diet of earlier inhabitants to guide us as we develop new models of sustainable agriculture and sustainable food systems. As we seek to restore health and vitality to our forests through sustainable management, clean our waters through good stewardship, and manage wildlife ecologically, we should pay attention to what was once the diet native to our region.

## Food Security

> Community food security is a condition in which all community residents obtain a safe, culturally acceptable, nutritionally adequate diet through a sustainable food system that maximizes community self-reliance and social justice.
>
> — Mike Hamm and Anne Bellows,
> The Community Food Security Coalition

In November of 1996, the United Nations Food and Agriculture Organization released the Rome Declaration on World Food Security. This document "re-affirms the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger."

Among the stated commitments the document makes is "the pursuit of sustainable food, agriculture, fisheries, forestry and rural development." While the signatory nations, through the international body, recognized "the need to adopt policies to achieve food security" it falls, as is too often the case, to individuals and non-governmental organizations to achieve this end.

At the dawn of the new century, the international trend is for globalization of the food system. In "The Argument for Local Food," Brian Halweil of the World Watch Institute reports that, due to advances in technology of food preservation, cheap fuel and transportation subsidies "the value of international food trade has tripled since 1960; the volume has quadrupled." He tells us that a food item will travel 2,500 to 4,000 miles from farm to plate. Globalization, unfortunately, leads to exploitative, energy-intensive systems and processes, which create and support international commodity markets at the expense of local food systems, local cultures and the environment. Government policies and research often promote large-scale centralized agriculture and agricultural industry special interests at the expense of small-scale local production and local markets. Competition with large-scale agriculture creates low food profits and limits access to markets. While a graduate student at Slippery Rock University, Heather House did research in this area and concluded that the government bias toward large industrial agriculture results from four aims:

- the desire to prevent disruptions of the food production (maintain status quo)
- the maintenance of existing farm and rural policies
- the promotion of cheap food to deter civil unrest
- the use of food as an economic and political weapon

These policies create social and economic barriers to small farmers while promoting large-scale industrial agriculture. And these policies come with costs, some more obvious than others. The costs begin with the erosion of rural social and cultural life. Money leaves local economies to pay for fertilizers and farm chemicals. Commodity prices kept low by the global trade system mean that profits are more likely to go to food processors and distributors than the farmers that grow the crops. The environmental costs are likely all too familiar to readers by now: soil erosion, synthetic pesticides in the air and water, monocultures that decimate biodiversity — to name but a few. The current high input-high output agriculture promoted by agribusiness and governments can only result in further displacement of traditional agro-ecosystems and farming methods with chemical dependence and environmental degradation.

Beyond food production, institutional food purchasing practices and preparation methods can be roadblocks to the use of local agricultural products. Also, consumer habits and lifestyles limit the use of fresh food. Single parent households and homes with two working parents combined with commuter lifestyles and busy schedules make it difficult for families to shop for local food or prepare meals with fresh food. Fast food consumption represents nearly half of the food dollars spent in the US. These foods tend to be high in undesirable fats and calories and low in other nutrients. Thus, a challenge to local food producers is to promote healthy eating while seeking to make products accessible to consumers. Access to local foods and consumer education can both be provided through well-planned promotion of local farmers markets, direct sales, and subscription produce programs such as Community Supported Agriculture (CSA).

Happily, beneath the wave of international trade there is a growing countercurrent of developing local food systems. Farmers are responding to consumer demands for fresh, safe food. Consumers are responding to the farmer's need for secure markets and customer support. Whether through an alliance of CSA farms, a marketing co-op or an organic certification group, farmers and consumers are coming together to discuss the need for regional food systems.

As urban sprawl consumes more and more farmland, states are beginning to enact conservation easements, land trusts are setting aside farmland and natural areas, and individual farm owners are working to keep a foothold on the land.

All these elements are part of the movement to build regional food security. A sensible food policy for a sustainable society promotes the production and processing of many agricultural products close to home. Regional agricultural systems should address the community's need for a safe, accessible and secure food system.

## *Planning for Food Systems*

Professional planners have long overlooked the value of planning for food systems. This lack of planning on the part of public officials leaves local populations dependent on the global commodities trade, with all the associated environmental, economic and social costs. If, instead, farms were viewed in the context of the community they serve, diversified systems could be developed to meet specific, local needs. Integrating fresh food sales into local networks or creating local markets helps ensure the farm's place in the community.

Access to food for urban dwellers is a concern. Many inner city neighborhoods do not have sufficient access to grocery stores and farmers' markets. New trends in markets and urban farming are helping to solve many of these problems. Local governments and community organizations across the country are responding by promoting farm markets. This helps the small farmer by providing access to retail customers. Community gardens also allow urban dwellers access to fresh seasonal food by providing growing space. Subscription marketing brings weekly deliveries of fresh produce to customers while allowing farmers to receive retail prices for produce deliveries. Food banks have developed innovative relationships with nearby farmers, gleaning excess produce or using donated capital to purchase produce directly from farmers.

### *Farmland Protection*

Local agriculture and local food systems depend on the preservation of farmland. The high value of land near urban and suburban areas creates economic difficulties for farms in the form of high property taxes. Pressure for development is eliminating farmland. The characteristics of good farmland — relatively level, well-drained sites — make it just as desirable for housing and business. Highway systems have promoted the conversion of farmland into commuter communities by allowing easier access from new suburbs to cities. This in turn forces the farmer out or onto marginal land. In many rural areas, farmland is subdivided into small lots as people seek homes in the "country."

Many states offer conservation easements, i.e., reduced property taxes, to help solve this problem. Other regional planning organizations seek to promote an understanding of the value of farmland preservation for the region. County and state agencies concerned with farmland preservation and food security offer farmer assistance programs to support these aims. These and similar national programs such as ATTRA and SARE are very important because farmers are often too busy with production and other jobs to effectively innovate with new methods and new markets on their own.

**Search for Solutions**

A number of state and national organizations are working hard to engage government agencies to shift support toward local food systems. Every year, more diverse organizations come to understand the issues of food security and join the effort to support local sustainable agriculture. The National Campaign for Sustainable Agriculture (NCSA) and the Organic Consumers Association both promote consumer education on issues of food security and safety and organic standards. The Sustainable Agriculture Research and Education Program (SARE) is a government-funded program promoting farmer and university research into sustainable production. Another government-funded program is Appropriate Technology Transfer to Rural Areas (ATTRA). ATTRA staff and researchers disseminate a wide range of detailed information on sustainable agriculture.

While it is not practical for regional farms to produce all the products consumed locally, a community benefits when it supports a strong regional agriculture network. Agencies and organizations can and are promoting local food systems by educating the consumer and the

### Home-scale Food Systems: The Benek Homestead

The home food system is the first step in a sustainable food system. To best illustrate a home food system, I offer the example of my first garden mentors. Ellen and Bob Benek have been producing abundance on a small farm for 30 years. Their home food system is built around a seasonal cycle of animal husbandry, gardening and home processing.

Their rabbits, goats, chickens and riding horses have assured a plentiful supply of manure and bedding for creating compost. After 30 years of applying the farm's compost to the intensively planted raised beds, the soil is extremely productive. Vegetables are on their table 12 months of the year. Home food processing of fruits, sauces and vegetables is an annual tradition. Squash, cabbage, potatoes and apples are stored in the basement. Onions and garlic are stored on a cool side porch. A small herd of goats provided milk for cheese, yogurt, custards and puddings as they raised their family of five children. Hens provide fresh eggs. Most summers, the family raises a few dozen meat chickens. These are processed and frozen, along with venison and goat meat. Some years they may raise a pig, also destined for the freezer or smoker.

The Beneks' garden begins literally at the doorstep. Each spring they set up a small propagation greenhouse on the south-facing deck just outside the kitchen door. Here they start many of their garden plants. In the summer they move the metal-framed greenhouse to the side, where it is then used for curing onions and garlic, to dry herbs and to cure seeds for the next year's garden. A picnic table replaces the greenhouse on the deck each summer. An adjoining terraced herb and flower ☞

Galina Benek

*Ellen Benek cold frame with endive*

Galina Benek

*Ellen Benek's squash harvest*

garden provides an intimate setting for outdoor dining and fresh herbs for the kitchen.

The main garden consists of about 4,000 square feet of raised beds. There are beds of asparagus and small fruits, many annual crop beds, and abundant flowers. The rich soil yields superior harvests. Carrots, given special treatment with rabbit manure compost, are huge, yet tender and juicy. Sweet corn ears are long and full. Cabbages, head lettuces and other greens also seem extra large and healthy here. Ellen is a sharp observer of her garden's biodiversity. She plants her cabbages, other brassicas and potatoes close to the sweet corn because corn attracts swarms of minute pirate bugs, which devour cabbage worms, Colorado potato beetles, aphids and other garden pests. Hoverfly, ladybugs, parasitic wasps and other beneficial insects are plentiful in the flower-filled landscape. Favorite herbs, like sage, chives and thyme are planted at the end of many garden beds. Patches of parsley, basil and cilantro, some newly sown and some in flower, are found interplanted with vegetables. Dill, borage, mache and annual red poppy self-sow and scatter themselves throughout the garden.

Other smaller gardens are located around the farmstead. These are planted in a regular rotation of main crops of sweet corn, potatoes, squash and other staples. The landscape includes many flowers, both perennial and annual, flowering shrubs as well as native trees and shrubs. Wild birds are fed in winter and are present in large numbers. Ellen reports that the maligned invader, the house sparrow, *Passer domesticus,* has been observed snatching the occasional cabbage worm and helps control pests both winter and summer.

Bob has constructed several small season extenders — cold frames, hot beds and a small plastic tunnel. These provide earlier crops in spring and summer and salads and cooking greens well into winter. The chicken house and pig pen are located at the far end of the garden.

Garden prunings, comfrey and weeds supplement purchased grain to feed the animals. Goats especially relish larger weeds, corn stalks and unusable produce. The gardens are fenced with "fake electric fence." Once trained to an electric fence, the horses avoid the highly visible wire strands of recycled romex and baler twine tied with ribbons. The horses are rotated through sections of the lawn to keep the grass neatly trimmed. The farm dog, the third in 30 years, keeps the gardens free of marauding groundhogs and rabbits. Goats are kept in their place behind heavy pasture fencing. Frequently, they are tied out to browse the edge of the surrounding woodland.

The landscape includes a lot of fruit. Apples, both homegrown and foraged from abandoned trees on neighboring farms, provide cider and sauce. (Ellen also makes her own vinegar from the apples.) Hardy kiwi provides heavy yields most years. A wild patch of blackberries has been encouraged and has, for three decades, provided more berries than they can pick. Red raspberries and blueberries are also harvested and devoured, with any excess frozen for later use. A family favorite is thawed berries with dried fruit.

The Beneks tap a dozen maple trees during thawing weather, between January and March, to make their year's supply of maple syrup. The sap is simmered into syrup on the wood cook stove. Firewood cut from the surrounding forest supplies the cook stove and the larger wood stove that heats the house.

The farm's old-time barn stores garden equipment and baled hay and houses goats and horses. Each year the family contracts with a neighborhood farmer to ☞

receive several wagonloads of hay. Family and friends share the sweaty but satisfying labor of filling the barn with scratchy hay.

Much of the rest of the household food is purchased in bulk through a local buying club or from natural food wholesalers. Whole grains, beans, flour and other staples are stored in containers in the basement. Most foods are made from scratch, with a focus on economy and healthful vitality.

The Benek household avails itself of the convenience of the local grocer regularly, but purchases are far fewer than for the average household. Dinner at the Beneks' is always a pleasure. A midsummer meal might begin with a salad of mixed lettuce, spinach and wild edibles, snap peas and early tomatoes. An appetizer may be slices of herbed goat cheese (chevre), or crumbly hot pepper goat feta. The main course is likely rich venison or goat stew, heavy with potatoes, onions and carrots with a side dish of steamed asparagus. Red raspberry pie for dessert and a cup of Ellen's Power Woman Tea (a personal blend of beneficial herbs) is a fitting end to a perfect meal.

Abundance is the word that comes most to mind at the Beneks' farm. Ellen's work as a midwife and Bob's construction contracting business keep them off the farm much of the time. Yet all this home food production is done with a rhythm and a schedule that does not seem to overtax the family; there is abundant time for family activities and travel. Boy Scouts, 4-H Club, horseback riding, cross-country skiing and just plain relaxing all somehow fit in.

Certainly, the entire family works hard. But the work is so integrated into their lives that a balance is achieved. Bob and Ellen and their teenage children all help with the spring garden rush. The animal stalls are cleaned regularly and the bedding is piled to compost. Beds are fertilized as needed. Many crops are mulched. Weeding the garden becomes feeding the goats and chickens. Harvesting and tending the garden are a natural part of daily life. The pleasures of tending the land and producing abundance and beauty hold many rewards. Less than five acres of pasture, gardens and bountiful landscape are managed to support a healthy and happy family.

farmer to issues of sustainable agriculture. The sustained health and welfare of our communities depend on their success.

## *Community Access to Local Foods*

If we are going to create sustainable, low energy, healthful and dynamic local food systems, farms need to be close to customers. Prior to the 20th century, most cities were interconnected with agricultural landscapes. The geographic interweaving of the two landscapes, urban and agricultural, benefited both. People need access to nature; farmers need access to markets and the city's cultural activities.

To get a sense of how farmers once provided a city with its food, read F.H. King's description, in *Farmers of Forty Centuries,* of a visit over one hundred years ago to the farmers' markets of Shanghai. He saw over 60 varieties of fresh produce as well as nuts, poultry, fish, pork, tofu, oat and eggs. Goods were brought to the markets daily from the surrounding countryside, by barges through canals and then by wheelbarrow to the city markets.

The Parisian market gardens were so numerous, they nearly encircled the city just outside the old city walls and moat. The goods sold at those and similar markets all over Europe were, by definition, regional, leading to unique regional cuisines that reflected the local landscape and climate.

As cities expanded over the past century or so, market gardens and local farms have been largely displaced by other development. But as our energy supplies become dearer and local food systems develop, prime agricultural land should again be recognized as too valuable to develop for other uses. State and local zoning and tax policies are required to support the protection of agricultural lands and to provide incentives for farmers and gardeners. And, as already mentioned, many states do offer programs such as conservation easements and land trust designation.

In sustainable towns and cities, nature and agriculture would interact even in densely populated areas. Small public parks and community gardens within walking distance of each home can bring the city dweller into contact with the food system and nature. Private or community garden space is critical to the deep sense of well being that comes from a connection to natural processes. Many people do not have time or the inclination to garden, but every neighborhood needs some type of garden. Not everyone needs a garden, but everyone should be able to know a gardener. Providing accessible community garden space to those who want to tend a garden would be a municipal priority in a sustainable food system.

Landscape architect and urban planner Ian McHarg, in his landmark book *Design with Nature,* calls for the identification of ecologically and agriculturally important land in and around our towns and cities. These are the areas that have intrinsic values to nature and society that are not reflected in local property values: prime agricultural soils, wetlands, forests and woodlands, floodplain, aquifers and aquifer recharge areas. Biodiversity preservation, horticultural and agricultural productivity, recreational opportunities, and watershed functions of the regional landscape must inform the regional and local planning process.

Seeking to improve on the concept of green belts around cities, McHarg says:

> Rather than impose a blanket standard of open space, we wish to find discrete aspects of natural processes that carry their own values and prohibitions: it is from these that open space should be selected, it is these that should provide the pattern, not only of metropolitan space, but also the positive pattern of development.

Such is the mission of the permaculture designer: to study the land and learn from its form and function where and how we should or should not develop it in order to preserve intrinsic ecological values. On a local and regional scale, this is a political statement. Zoning has always been contentious but is deemed necessary by the community; to suggest that certain lands should not be developed deprives an owner of perceived rights and potential rewards. Although difficult to calculate, it is in society's best interest to compensate landowners with tax incentives or other rewards for appropriate land use. In the US, zoning regulations are set by counties, townships and communities and are, in general, supported by federal court precedents. Groups and individuals concerned about preserving and enhancing natural biodiversity and local agriculture should participate in the planning process as much as possible.

The prime challenge for preserving and building local and especially urban agriculture is the fact that the best land to build on — flat, well-drained land — is also the best agricultural soil. This pits economic development against agriculture. The smaller potential for income and jobs creation of agriculture generally makes it the loser. When agriculture does find a way to maintain a foothold on the edge of suburbia, other challenges appear. Complaints of farm odors and crowing roosters turn into restrictions on livestock. There are still many issues to address if the regional, suburban and urban farms are going to thrive, or even survive.

## *A Place in the World Economy*

Small-scale intensive farms are playing an important role in revitalizing communities in the US and abroad. Harvest festivals, workshops and educational activities all contribute to the health of communities as much as the good food they produce. Ultimately, farms will thrive and community food security will develop if local consumers come to understand the many benefits these farms provide.

There is an inherent contradiction in calling for reliance on local food systems that needs to be acknowledged. Local and regional foods

### Food Security Resources

**Community Food Security Initiative (CFSI):**

> Helping nonprofit groups, faith-based organizations, state and local government agencies, tribes, and individual citizens fight hunger, improve nutrition, strengthen local food systems, and empower low-income families to move toward self-sufficiency.

The USDA's Community Food Security Initiative seeks to cut hunger in America in half by the year 2015 by creating and expanding grass-roots partnerships that build local food systems and reduce hunger. The USDA is joining with states, municipalities, nonprofit groups, and the private sector to strengthen local food systems by replicating best practices of existing efforts and by catalyzing new community commitments to fight hunger.

To review the USDA's text and get more information on CFSI, go to: www.attra.ncat.org/guide/a_m/cfsi.html.

**The Community Food Security Coalition**

> Dedicated to building strong, sustainable, local and regional food systems that ensure access to affordable, nutritious, and culturally appropriate food for all people at all times. We seek to develop self-reliance among all communities in obtaining their food and to create a system of growing, manufacturing, processing, making available, and selling food that is regionally based and grounded in the principles of justice, democracy, and sustainability.

The Community Food Security Coalition, with over 325 members, is a network of organizations working to promote community food security throughout the US. Their website lists six principles of food security:

- Addressing the needs of low income communities
- Addressing the broader issues of the food systems, such as urban sprawl, access to food markets in the inner city, and environmental issues related to food production
- Community focus through the promotion of urban farms, farmers' markets, neighborhood grocery stores and community food processing
- Promotion of individual self-reliance and empowerment of communities to plan and implement programs to increase food security
- Development of local agricultural-based food systems that provide good food, equitable farm income, preserve farmland and build ties between producers and consumers
- Promoting food security through an "interdisciplinary, systems-oriented approach" that includes many agencies and organizations

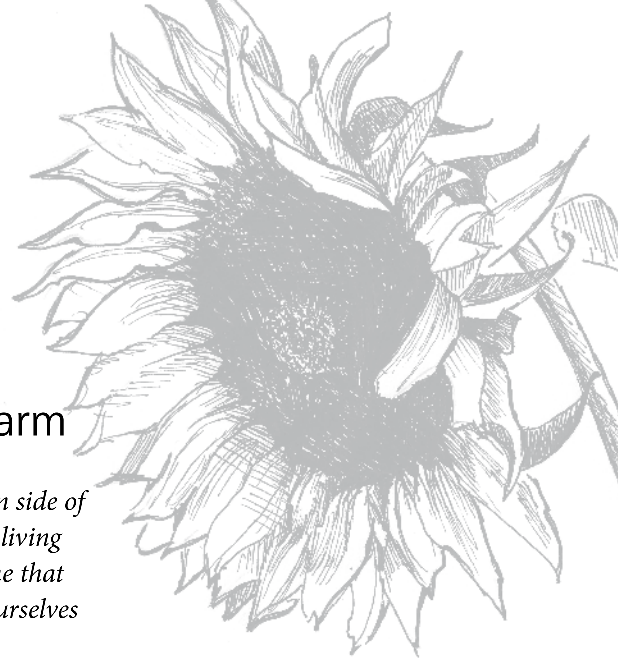
For more information, go to www.foodsecurity.org/.

will never completely replace national and global trade. A certain amount of trade is good for all economies. For example, the ability of the US Midwest to supply grain to the world has done a great deal to help make food affordable worldwide. Local production benefits local food systems, but it won't do it to the exclusion of international trade. For one thing, we are all used to consuming products from all over the world. As a purveyor of fine farm products to upscale restaurants, I can appreciate the connoisseur's desire to partake of the good life. And yet, as a student of ecology, I understand the need for balance and restraint. The answer lies, I believe in the age-old wisdom: "All things in moderation."

Freshly brewed, freshly ground coffee is a prime example. The aroma alone can alert the senses and sharpen the weary mind. Chocolate too has the power to awaken and inspire. Combined in mocha cappuccino, they can be the perfect pick-me-up. I personally prefer the subtler stimulation of a cup of tea, but regardless of the choice of stimulant, coffee, tea and chocolate are probably never going to be local products in western Pennsylvania. Neither will vanilla, avocado, citrus, coconut, luscious mangos, or the many other tropical fruits we so love. And the wine some of us enjoy — French Beaujolais or California cabernet (or that occasional sip of tequila) — will never be produced locally.

One way to balance the ecological equation of global trade is to support environmentally and socially responsible sustainable agriculture when we purchase imported products. Because they increase the economic security of the peasant farmer, fair and just international trade is a valuable tool to promote world peace and stability. Fair trade coffee and chocolate continue to enjoy expanding sales. Other crops marketed as fair trade include tea, herbs, fruits, sugar and rice. Worldwide sales of fair trade products are at least one billion dollars annually.

Sustainable food systems, both local and global, will grow and evolve through complex interactions among marketplace, lifestyle and availability of local commodities. We cannot predict today what such a system will look like in a generation. What we can do is offer consumers new food choices that fit their lifestyle and continue to educate them on the value of buying local farm products. Consumers, in turn, can support fair trade at home by developing long-term relationships with regional farmers and paying a fair price for their products.



Chapter 3

# Direct Marketing for a Small Farm

*Our focus is to bring about those changes in the human side of the economy that can help preserve and reconstitute living systems, to try and show for now and all time to come that there is no true separation between how we support ourselves economically and ecologically.*

— Paul Hawken, Amory Lovins, and L. Hunter Lovins, *Natural Capitalism*

Market gardening is a business. The term "sustainable" must also refer to sustainable economic viability of a farm. This chapter offers a look at the concepts and practices that make a market garden sustainable. These include business planning, sound business management, appropriate marketing strategies and related income-generating enterprises.

When we began making plans for Three Sisters Farm, we had three goals. We wanted to: (1) grow high-quality farm products; (2) provide a place for others to learn about sustainable design; and (3) enhance the local environment.

Similar objectives are described by Trauger Groh and Steve McFadden in *Farms of Tomorrow Revisited.* According Groh and McFadden, creating farms with such objectives requires "a leading concept that concerns itself with the wisdom that lies in nature and with the relationship of the human being to nature." While they arrived at this proposition from the study of biodynamic agriculture, we at Three Sisters Farm found this "leading concept" in our study of permaculture.

For the first few years of operation, we focused on developing the market garden business. Later we phased in more education outreach in the form of tours, lectures and permaculture classes. This combination of selling farm products and providing education services brings a good balance of work and income to the farm. This chapter examines the first two of our three goals for our farm: growing high-quality products and providing a place for others to learn about sustainable design.

## Preparation

We entered the market gardening business after a brief study of entrepreneurial ventures. An entrepreneur is anyone who organizes a business — and assumes associated risks — in pursuit of profit. We understood that the ability to pay our bills would make or break our business.

The plan for Three Sisters Farm, however, developed over a period of several years. We had been offered the use of a five-acre property (which we subsequently bought) for a permaculture project. The intention was to apply permaculture design to a market garden farm. The plan expanded to include a nursery business and teaching programs. We were willing to devote much effort, most of our savings and as much time as necessary to turn our ideas into our reality.

In that strange synchronicity that life sometimes manifests, just when we were ready to begin farm development, a request for grant proposals addressing energy in agriculture appeared in our mailbox. The Pennsylvania Energy Office was offering matching funds to agricultural projects that would demonstrate energy conservation and efficiency. The funding came from the US Department of Energy judgments against major oil companies in the US for excessive pricing of crude oil between 1975 and 1981. The Department of Energy was charged with distributing over $3 billion of oil overcharge funds to state agencies for energy conservation projects.

For the next month we prepared and submitted a grant proposal for building our bioshelter. When we were awarded the grant, we spent nine months preparing our site, building the bioshelter, and setting up business.

We began slowly and expanded our production and sales as we completed the bioshelter and developed our gardens.

## Business Management

Managing a small business requires an understanding of the specific enterprise, the market, and basic business practices. We chose a partnership as the most reasonable business structure. This enables us to keep personal affairs somewhat separate from the farm activities while still retaining a simpler structure than incorporation would require. A partnership is the simplest form of business structure for two or more people to enter. While a partnership does not offer the liability protection of a corporation, it has less complex tax and management requirements. Linda and I are general partners; we plan and manage all aspects of the business.

We highly recommend that the would-be entrepreneur seek out qualified advice as to the best legal structure for his or her own needs. The complexities of tax codes, state and federal regulations and individual business needs are beyond the scope of this book. We found a knowledgeable tax accountant who helped us determine our best structure. She has continued to provide us good advice and service.

Many types of farm insurance are available, and appropriate protection should be obtained. A good insurance agent will help you plan for your particular needs. Liability insurance is a necessity, both for farm products and for occasional visitors. Institutional and restaurant customers require us to carry a certain amount of liability insurance to cover any litigation related to our products. We have never had to use this in all our years of business. The best insurance is to establish and follow basic safety and sanitation practices. However, in a litigious society it best to be fully insured.

## *Market Surveys*

Once we had agreed upon a business structure, we began market research. As we completed our bioshelter and began to establish gardens, we distributed samples of our crops. Our initial focus on specialty crops, such as salad mix, herbs and arugula, was met with indifference by local chefs and grocers. However, our first attempts at marketing in Pittsburgh, 60 miles away, were immediately successful. Pittsburgh chefs were very receptive to buying fresh and local products. Several chefs took us into their coolers and showed us exactly what they were buying and began to instruct us on custom growing for their needs. We also found a ready market in a specialty food store in Pittsburgh. This store provided a good market for our salad and gourmet greens. Continuous feedback from early customers helped us refine our products and improve our production as we expanded our gardens.

### *Planning*

A clear business plan that considers all areas of the operation is the first step in business development. These areas include production strategies, accounting, inventory management and marketing.

Our business plan was simple. We would develop our gardens over a period of several years, as our experience and sales grew. Key to the whole process was the availability of free manure for compost. Keeping a small dump truck parked at a nearby stable and bringing home a load of horse manure and bedding each week allowed us to keep up with the nutrient demands of an expanding operation. As our reputation for quality and service grew, so did the demand for our products.

Many customers pay on delivery. All pay within 30 days. We keep clear records of all sales and expenses with a sales ledger and a business checking account. Expenses and income recorded in the ledger and checkbooks are entered into a computer bookkeeping program (I use Microsoft Money), which allows us to generate various useful reports on sales and expenses. We hire a tax accountant each year to process our tax returns.

### *Cash Flow*

Farm cash flow can be directly correlated to available sunlight. During the winter, harvested crops are fewer, but many costs are the same. In our own snowbelt climate, crop production can be slow from December 1 until January 15 due to short and cloudy winter days. This can be a trying time without careful planning. Happily, we've found that bioshelter production can provide winter income; during the darker days of winter, we sell eggs, plants, and holiday and seasonal crafts, such as herbal wreaths and pressed flower cards.

Increasing day length increases production from the bioshelter and the outdoor cold frames in late winter. The sales of produce subscriptions and plants in late winter and early spring provide a much-needed increase in farm income, allowing us to purchase the upcoming season's gardening supplies. In the fall, a farm needs to have adequate cash reserves to meet financial needs and obligations through the shorter days ahead. A farm also needs to enter the winter with enough funds to purchase seeds, plants and other supplies for the following year. Planning an annual budget that accounts for costs and income, with reserves for the year ahead is critical to sustaining a farm.

### *Inventory and Supply*

#### Produce

We do not keep our products in inventory. Basically, we only harvest the amount of produce we need to fill orders plus a small amount for farm sale. We generally eat whatever produce is left after weekend sales, but we actually have very little unsold produce. Bolted lettuce and other crop residue are fed to the chickens.

#### Supplies and Maintenance

We do maintain an inventory of supplies. The garden manager keeps track of seed and plant material, fertilizer and potting soil, flats, pots, garden tools and related items. The farm manager (me) keeps track of general accounting, utility bills, and kitchen supplies such as packaging, boxes, labels and harvest tools. I also develop and maintain the facilities. Like the farmers of my grandfather's generation, I am, on various days, a mechanic, a plumber, an electrician, a carpenter, a designer, and a horticulturist. Each activity requires an inventory of tools and printed references. Tools are stored in the "barn," or tool shed, attached to the bioshelter. Service manuals and maintenance schedule are also stored there. Important references are kept in a small library in the bioshelter, or in the farm office.

Together, as farm manager and garden manager, we direct a small garden crew and interns.

## Marketing Farm Products

Market gardening is two interwoven businesses; growing produce and selling produce. Writing in their book *Natural Capitalism,* Paul Hawken, Hunter Lovins and Amory Lovins, show that farmers' income represent less than one percent of the gross domestic product of the US. However, "those who sell to and buy from farmers ... have a share 14 times as large … These interests tend to squeeze out small, independent, and diversified farms." Therefore, by selling farm products directly to retail customers, rather than to wholesale customers, a farmer can realize a better profit and develop a more secure position in the market.

The largest obstacles to profit in farming are the national and international policies that keep prices and wages low and resource-intensive production methods the norm.

## *Markets*

Options for marketing produce include pick-your-own operations, on-farm markets, urban farmers' markets, subscription sales, selling to wholesalers and processors, and direct sales to grocers, restaurants and other consumers. As explained by Janet Bachmann, in ATTRA's *Market Gardening: A Startup Guide,* the direct marketing options of "farmers' markets, roadside stands, pick-your-own, subscription marketing arrangements and sales to restaurants [help farmers] "maximize their income [by] bypassing the middlemen."

Our sales strategy at Three Sisters Farm is a mix of several approaches. Our primary strategy has been direct sales and subscription sales; we also do some Saturday on-farm sales. In pursuit of the best price we could get for our produce, we set up a delivery system to pass over the wholesalers. Direct marketing also allows us better control over the quality of our produce. When our label reaches the customer, we want the product to be as fresh as possible.

Our marketing strategies reflect our gardening system and philosophy. Developing a rotation of diverse annual crops and establishing perennial plantings ensures a healthy garden and minimizes the effects of crop failures. We grow lettuces, herbs, flowers, various salad crops and other gourmet vegetables. The crop mix and planting schemes have evolved as we attempt to cater to customers' specific needs.

Our *mixed* sales strategies reflect an important permaculture principle: we have designed diversity into the system to create stability.

## *Direct Sales to Grocers and Restaurants*

After a study of outlets for farm products, we concluded that selling directly to restaurants and grocers would be our best starting point. The local market was not large enough to support our sales goals. But driving 60 miles to Pittsburgh put us into a very large market. We began our sales promotion by calling chefs and arranging times to bring them samples. Face-to-face meetings allowed us to ask them directly what it was they needed and wanted.

Getting to know your customers' needs is very important in marketing. Anticipating new and interesting produce they may want and discussing this in advance of the growing season helps with planning and instills confidence in the customer. And understanding a restaurant's annual schedule of peak and slow times allows the grower to schedule plantings to avoid waste.

Each week during the main growing season, we produce over 40 pounds of our salad mix and cases of lettuce, herbs and other crops. We deliver to 12 to 15 regular customers, many of whom have standing orders. Weekly contact with customers allows for adjustments and special orders. Continuous discussion with customers allows us to plan our planting and adjust to changes in the market. This minimizes waste. Most of what we plant is pre-ordered, sometimes months in advance.


TOM GETTINGS

*Produce delivery to chefs.*

Personal interaction with customers is fulfilling. Both our customers and the farm benefit from discussion and feedback on gardening, cooking and sales. Several of our customers have been with us for over 20 years.

Customers benefit from the direct relationship with a farm in several ways. They receive top-quality produce within 36 hours of harvest at a reasonable price. Since our crops are pre-ordered and waste is minimal, our prices remain stable, even when other markets are fluctuating. While it was tempting to follow rising lettuce prices one spring, we felt that we should be fair to our customers; *our* costs did not rise because of flooding in California. In other seasons, our produce may be more expensive than California's, but our customers stay with us because our exceptional quality, freshness and dependability are worth a few extra dollars a week.

Our customer base is very stable from year to year. Each year, as we've expanded production, we've added one or two new restaurant customers. We occasionally drop a customer whose orders are only sporadic; sometimes we'll lose a customer if a restaurant changes ownership or staff. We generally seek new customers along our established delivery routes.

### *Demands and Costs of Delivery Service*

There are certainly some drawbacks to our sales strategy. We absolutely must produce pre-ordered crops weekly, through the entire growing season, come dry spell or downpour. This requires precise planting schedules and a careful assessment of irrigation needs. Chefs and grocers want to receive top-quality produce — every week — for as long as the season lasts. The occasional crop failure is inevitable, but when they occur, customers are generally understanding. Restaurants also want their deliveries on time. And delivery is not something to take lightly. Delivery takes up to nine hours each delivery day, which means either time away from the farm or hiring someone else to do the deliveries.

There are significant costs associated with delivery: the delivery van, coolers, packaging, time on the road, and time spent interacting with customers. Additionally, special packaging and sorting procedures are necessary.

A drawback to restaurant sales is that restaurants often experience reduced business in the summer. Then, just as *our* season slows down, restaurant demand increases. Development of a seasonal subscription sales strategy helps to bridge this gap.

Be aware that direct selling is not for everyone; you have to enjoy dealing with people.

### *Subscription Marketing and CSAs*

"Subscription marketing" is a system of providing a pre-ordered and prepaid bag of produce to customers each week, for an agreed time period. This is different from the early concept of a Community Supported Agriculture (CSA) program. In its original meaning, Community Supported Agriculture was a process whereby the farmer is guaranteed funding for a fair wage and expenses by a "community" of consumers. The "community" households received a weekly share of the farm's products.

Many people mistakenly apply the name CSA to subscription produce programs. In a subscription program, the customer *is* guaranteed the value they pay for, but the farmer's income *is not* guaranteed. We point out the difference because we believe the CSA model is valid and important even though at Three Sisters Farm we have not attempted to find the committed community to support us with a CSA program. Instead, we have the subscription program. The subscriptions provide a reason to grow long-season crops such as cabbage, broccoli and sweet corn — vegetables that are needed for proper crop rotation in the garden beds. Our subscriptions tend to be "gourmet," and may include arugula, tea bouquets, heirloom tomatoes, shitake mushrooms, our salad mix, fingerling potatoes and other high-value crops. Generally, we do not sell many long-season crops to the restaurants. For restaurants, we focus on higher-value herbs, greens, salads and lettuces.

Subscription customers make three payments. The first is in early June, the second is due around August 1, and the last payment is due September 15. Weekly deliveries or pick-ups begin in the third week of June and continue for 16 weeks, into October. For $320, the customer receives $20 worth of produce each week. We charge a small per-week handling fee for deliveries to co-operative drop-off locations.

We offer a limited number of "spring greens" subscriptions, which is a lower-priced subscription that features salad, herbs, and cooking greens, plus a few other early crops. Many farms offer longer — even year-round — subscriptions. Increasingly, farms are joining together to form co-operative multi-farm subscription programs.

Most of the subscriptions we deliver are to private homes and small stores. Some customers pick up their produce at the farm. We try to keep in communication with subscribers with a newsletter every week or two. The newsletter provides recipes and updates on crop production. Each spring, a brochure describing the year's subscription program is sent to customers. New customers receive a brochure describing how fresh produce fits into a good diet and how to wash and prepare the main items in the weekly subscriptions.

### *Farm Sales*

Produce and plants are also sold at the farm. Our weekend farm market is simple. We sell the produce left from our weekday harvest as well as products from the bioshelter kitchen. We have a core group of regular customers. Each year this market grows a little larger, solely by word of mouth. For our regulars, we'll often grow small amounts of certain crops, such as red celery. Fresh farm eggs are a big draw for local sales.

Customers are encouraged to call ahead and see what we have, because we often sell out fast. Some customers arrange specific pick-up times for pre-ordered produce.


Leo Glenn

*Darrell Frey and Chris McHenry-Glenn, with Ossian Glenn at spring plant sale.*

### *Plant Sales*

One of our original goals was the development of a useful plant nursery. The collection, testing and propagation of useful perennials is ongoing.

Many people stop by expecting to buy vegetable plants from our greenhouses. We explain that it is difficult to keep up with our own demands for seedlings. We never intended to develop a large vegetable plant enterprise because several farms in the area already had established spring plant businesses. We sell a few flats of vegetable plants from the farm each year, but this amounts to less than 2 percent of our gross sales. Instead, we found a market niche: our spring plant sales focus on heirloom tomato seedlings, native plants, herbs and flowers, unusual perennials and plants that are good for beneficial insect habitat. We divide many herbs and wildflowers and gather self-seeded plants from among our gardens, and pot them up for sale. We also start plants from seed we gather or buy locally. School gardens and other groups often pre-order specific plants.

Our native plant and useful plant nursery is a growing enterprise, with several part-time, limited partners involved each year.

### *Processing the Excess*

Farm products not sold fresh can be processed into value-added products. We have made small market tests of crafts such as herbal wreaths and dried flowers, herbal vinegars, herbal body oils, and pesto. Each of these will require better production planning and marketing to be major contributors to the farm income. We would like to eventually develop these and similar products and sell them together as gift baskets. (Note: If you want to sell processed food from the farm, make sure you thoroughly investigate your state's regulations for the safe production of food products.)

### *Household Production vs. Growing For Market*

Many people get started in market gardening by selling excess produce from their home garden. This is a reflection of the origin of traditional farming around the world. In traditional economies, the farm household produced many products for home use. Excess crops were sold or traded for other products and services. The opposite end of the marketing spectrum is growing only one or just a few crops for sale, with little or no home consumption. But this is the kind of commodity production that eventually leads to monocultures and using land as a site of production rather than within an integrated system. A permaculture farm, on the other hand, is a return to the traditional farm economy. Home processing and consumption is an important aspect of the sustainable farm. Producing posts, poles, fuel wood and other garden supplies and materials can reduce costs to the farmer and help balance the farm accounts.

A plan for feeding the farmer and a community of customers entails planning for a healthy diet and menu. So, creating a diverse food system for the farmer is as important as selling crops. We eat very well, with plenty of herbs and vegetables. Our diet varies with the seasons. Fruits include currants, raspberries, blueberries, strawberries, apples and pears. Asparagus and wild edibles such as cattails and fiddlehead ferns are used seasonally. Fish from the pond and sometimes the wild rabbits that threaten to eat our crops end up on our dinner table. Many farm products under trial are first used in family meals and work crew lunches.

## Outreach and Education Programs

Integral to Three Sisters Farm's development was our initial inspiration to establish a permaculture farm as a teaching center. The demands of developing gardens, products, markets and a functional ecological landscape initially restricted our outreach effort. The first five or six years of operation, we were limited to giving tours and holding the occasional open house for local and regional customers. Otherwise, we focused on developing the farm.

In the mid 1990s, we began to market the information and experience we had been gaining by giving permaculture workshops and more tours. Since 1999 we have hosted a permaculture design course at the farm each year in August (when the restaurants and grocers

Farm based education.

are having their slow periods). Students camp on the farm and participate in two weeks of classes, field trips, farm work and design sessions. We use the design course to develop short- and long-range plans for further application of permaculture design to the farm. The permaculture design course and other workshops bring supplemental income to the farm.

Some crops are planted specifically to feed course participants — three meals a day for up to 12 people. The course fees pay the farm account for the produce. This aspect of the program — harvesting and eating fresh produce — greatly enhances the process for all involved.

### *Brand Recognition/Reputation*

The name "Three Sisters Farm" is widely recognized in western Pennsylvania. Our farm business has maintained a reputation for high-quality produce and excellent service to our customers. Our reputation precedes us in our marketing and often leads new customers to seek out our products.

Our business logo is a colorful painting of the Three Sisters; corn, beans and squash. It is an easily recognized and attractive image. We use it for letterhead and business cards.

We are on the Phipps Conservatory's list of horticultural speakers in Pittsburgh. We give an average of four paid presentations to herb clubs in western Pennsylvania each year. This allows us to share our knowledge of ecological gardening and, at the same time, inform our audience about our various enterprises.

Our farm received a lot of publicity right from the start. Local and regional newspapers sought us out for interviews. We were featured in *New Farm Magazine,* and the book *Real Dirt.* Our farm is featured in a children's book about organic farming, *One Good Apple,* by Catherine

Paladino. In March of 2002, we were featured in *Organic Gardening Magazine* as an example of a permaculture farm. All this publicity has promoted both our sales and our outreach work.

### *Our Plans*

One drawback to our marketing strategy is the need to drive to Pittsburgh. Although the Pittsburgh market allows us to sell all our weekly produce in one delivery, we would like to develop more local and on-farm sales strategies.

We view our farm as a small-scale agricultural enterprise incubator. Three Sisters Farm has developed to the point where several associated businesses could operate at the farm simultaneously. (See the sidebar for a list of some business possibilities we see for the farm.) Since 1998, through our permaculture design workshops, we have created basic design plans for a number of associated businesses. Some we have begun, some are in the planning stages. Some businesses are just waiting for the right person to do them. Implementation of most of these plans has been held up by the lack of capital. The uncertainty of markets and weather often makes profit margins slim. Consequently, available funds for labor limit the farm's ability to obtain and retain qualified workers. The cost of financing also limits extending farm enterprises.

Trials have already been made — with varying degrees of success. For example, we raised 50 broiler hens as a trial. They sold out well in advance, so we then developed a plan to raise 500 chickens in spring and again in the fall on rotational pastures and feed crop residue. We haven't found the time to do this yet, but we have the space and there is clearly a demand; the plan is described in more detail in Chapter 12.

We plan to greatly expand our fruit production in the coming years. Based on our trials, we will be developing a "forest garden" of fruits, perennial vegetables, herbs and flowers (the concept of "forest garden" is explained in Chapter 7). Many of the plants in the forest garden will be propagated on site. We plan to graft the best fruit varieties from our trial plantings and will divide and propagate herbs as we expand.

Each year, we make and freeze pesto and can salsa. We also freeze a lot of our berries. A long-term goal of the farm is to have a larger processing kitchen where we can make soups, sauces and otherwise process excess produce. We plan to begin this process by putting an addition on

Three Sisters Farm

*TSF logo courtesy of Three Sisters Farm and Mary Grandelis, original design by Dawn Shiner.*

the bioshelter. We will expand the current kitchen from 8 feet by 22 feet to 24 feet by 22 feet. This will give us a larger area to prepare produce, display products for sale and host classes. Above the expanded kitchen, we will build an office for the farm and our design and consultation business. The addition will improve our ability to attract local customers to our farm store.

### *Small-Scale Enterprises*

The term "small-scale" is important in our development plans. We do not want to grow too big or hire a lot of workers. Rather, we see the small-scale intensive permaculture farm as a model of sustainable community development.

Allowing enterprising individuals to develop associated businesses at Three Sisters Farm accomplishes several goals. Each will contribute to the gross farm income to help take some financial burden off the market gardens. Some of the businesses are ideal for people seeking part-time and seasonal income. An expansion of products offered at the farm should bring more customers and so also increase our local produce sales.

The idea of providing consulting services on sustainable systems and organic gardening and farming is one we are currently exploring.

We share the enthusiasm of two ecological design pioneers, Nancy Jack Todd and John Todd. In their excellent book, *From Eco-Cities to Living Machines,* they are optimistic about the potential for urban enterprises surrounding a bioshelter: "The limits are as yet uncertain but such a local enterprise, drawing on the community for full- and part-time staff, has the potential to reverse the present agricultural equation."

### *New Partnerships*

We have already entered into a partnership with associates who have worked with us to develop a native plant nursery at Three Sisters Farm. We grow about a thousand plants each year from seeds we collect or purchase. We start the native seeds in February to have them ready for sale in early spring. This is a month before we start our vegetable seeds, so it allows make use of our otherwise idle grow lights.

It has been great to see our permaculture workshops evolve into co-operative events. Each year, I coordinate a group of co-teachers and presenters to conduct class on harvest days and at other times. This allows me to do the behind-the-scenes management of food and facilities and gives the class a variety of qualified teachers to learn from.

A plan in which associated enterprises are combined into a whole system — managed by a co-operative group or non-profit corporation — is sound. Such a system would serve as a vital link between the local food system and the community.

**Small-scale Agricultural Enterprise Incubator:**

A Co-operative Sustainable Agriculture System

A small-scale permaculture farm can be an incubator for a number of enterprises. Combined into a whole system managed by a co-operative group or a non-profit corporation, these can provide seasonal and part-time incomes for those with a creative impulse.

Each of the enterprises and products listed below could be developed on a five-acre permaculture farm. No doubt others could be added.

- Processing facility for pesto, salsa, herbs, vinegars, jellies and other home-canned products.
- Weekend café with outdoor picnic areas.
- Storefront selling garden supplies, books, crafts, tools and farm products.
- Gift baskets containing farm products and crafts made from natural materials.
- Cut flowers, dried flowers and related crafts and products.
- Herbal teas and medicinal herbs.
- Bee products: honey, candles and bees wax.
- Organic poultry: meat and eggs.
- Aquaculture: pond-based fish farming and indoor fish tanks.
- Perennial nursery and plant sales and garden installations.
- Educational programs: tours, workshops and classes.
- Consultation services in sustainable systems and organic gardening and farming.
- Compost and potting soil sales.
- Vermiculture: sales of earthworms and vermiculture bins.
- Goat milk and cheese production.

CHAPTER 4

# The Permaculture Farm: Design

*The Design* — *'A beneficial assembly of components in their proper relationship'*

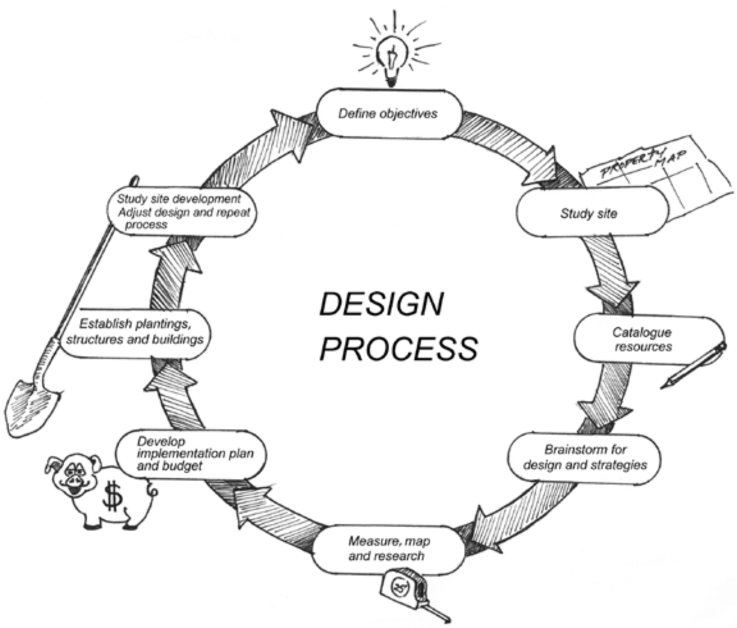
— BILL MOLLISON,
*PERMACULTURE: A DESIGNER'S MANUAL*

PERMACULTURE HAS BEEN, from its very beginning, a design system. In *Permaculture: Principles and Pathways Beyond Sustainability,* David Holmgren defines permaculture design as the use of systems thinking and design principles that provide the organizing "framework for implementing … the vision of permanent agriculture and permanent (sustainable) culture." Bill Mollison, in *Permaculture: A Designer's Manual,* describes multiple approaches to design. These approaches range from the random scattering of seeds to detailed planning and management. This chapter examines several of these approaches and their application to Three Sisters Farm. The dedicated student of sustainable design is encouraged to seek out the references listed in the resources section for further study of systems of design and planning.

## Farm Design and Planning

Design and planning of a permaculture farm includes planning for placement of buildings and gardens, energy conservation and green energy production, soil management, watershed management, pest control, crop production, arrangement of living spaces, and promotion of biodiversity. This chapter examines many these as they relate to farm design.

Design and planning for sustainability through energy efficiency, environmental integration, and positive social and economic impact is *site specific* and *situation specific.* In many cases, it means beginning




*Sustainable design is an ongoing, circular process.*

the process of transition to more ecological and sustainable practices. For a farm, this may mean converting to organic farming methods and including steps to promote biodiversity. Later, development of multiple crops and enterprises can be implemented in stages as funding and time allow.

To speak in simple terms, *designing* is identifying the farm's goals and studying its landscape, ecological and market niche, and available resources. *Planning* includes laying out a course to get there, developing a strategy of staged development, and deciding on a budget. It also includes deciding on management approaches, what technology to use, and what skills might need to be learned.

Permaculture design begins with assessment of the site, its resources, and the goals of the developers. Objectives should be defined. The goals of the site developers, both long-term and near-term, need to be examined. The skills, resources and experience of the developers are assessed. Strengths and limitations are listed.

Design sessions include researching and considering options for obtaining these goals. Options are compared with the needs of the developers and the needs of the land. What emerges is a preliminary design for the site. Preliminary plans lead to a new round of research and then design adjustments.

## Site Analysis: The Land, the Community and the Environment

Soil types, water resources, landforms, geological features, existing species, and other aspects of the site are catalogued. Existing ecological relationships are noted. Special attention should be given to existing habitat for beneficial insects, birds and other vertebrates so that critical wildlife habitat and wetlands can be preserved. Potential problems are noted (examples: a deer trail crosses your planned garden site; rabbits and voles are plentiful in the orchard site). This stage of site study should involve research into the potential for wild crafting and the use of site materials for construction and soil building.

The relationship of the site to the surrounding environment and bioregion should also be studied. *Sector analysis* (mentioned in Chapter 1 and discussed in more detail below) gives an overall view of the site in its relationship to the larger environment, e.g., climate, existing microclimates, solar access, the presence or absence of windbreaks, fire hazards, and floodplains. (Floodplain information is available from state and local officials.) Wildlife corridors, such as a tree line connecting woodlands, are noted.

Local and state zoning regulations are researched; each state, county and township may have different ordinances and codes. It is best to have a good relationship with the local officials and follow their guidelines for establishing new systems. You may find that local officials are aware of the need to develop alternative systems and are willing to work with you if you have done your homework and have prepared a good plan.

Many other legal issues relate to farm development. Business and tax laws, zoning rules, organic certification regulations, and other licenses need to be researched and addressed. Study of the property's deed and a title search will alert you to easements, right of ways and other restrictions on development.

Available local resources are catalogued. Sources of organic matter for preparing compost such as leaves, manure, straw and hay, food-processing wastes, sawdust or tree bark should be found. Sources of local building materials and soil amendments are also located during the planning stages.

Elders or mentors can be sought out for their knowledge. Whether gardener, farmer, beekeeper or builder, neighbors with years of experience in the local area can be of invaluable service. Many folks are willing to share their knowledge of the climate, soils and weather, as well as the local markets.

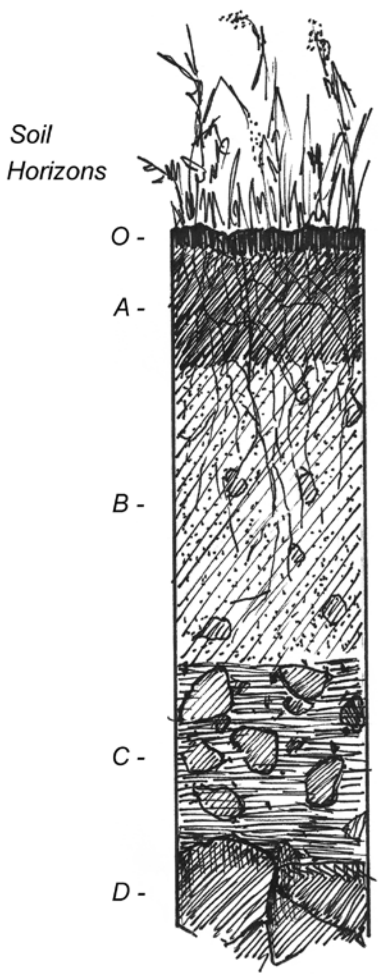
Potential markets are investigated and a community's needs assessed. As I already mentioned, when we started our farm, there were plenty of greenhouses offering bedding plants and vegetable seedlings. Rather than compete with them, we sought a new market niche as specialty produce growers. Talking with grocers, chefs and other produce buyers helped us plan what to grow. As our farm developed, we found more niches in the market for native plants and useful herbs.

### *Site Analysis: The Soil*

The management of living, breathing soil is the essence of gardening. Understanding your soil's characteristics is the beginning of ecological management. The starting point is obtaining a soil survey report from the Natural Resources Conservation Service (NRCS). The NRCS's online *Web Soil Survey* tool will generate a detailed soil report with digital maps. The report provides general information on what characteristics to expect from the soil in any given location, assuming it has been undisturbed in the decades since the original survey was made.

Actual field conditions will vary from the report, so direct observation is vital to planning soil management and farm development in general. Placement of farm components should follow the best use of the site's soils and drainage patterns.

*A simple post hole will allow a view the soil profile . The depth of various horizons reveals much about the condition of the soil.*




#### Soil Profile

Study of the soil profile reveals the depth and quality of the top soil, and subsoil, and also the site's drainage. Digging a post hole will reveal a number of things about the soil. A soil probe tool can also be used for a quick view of the soil's profile.

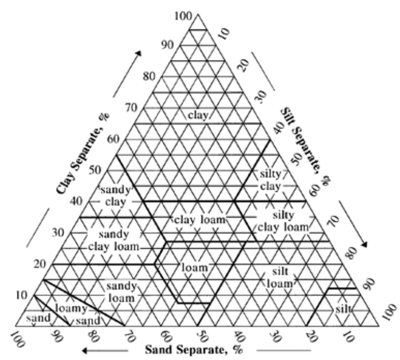
The soil layers are known as horizons. The O horizon is the top layer of organic matter in a forest, meadow or grassland. This layer includes leaf litter or old sod, animal wastes and dead creatures. Mulch serves as the O layer in the garden. The A horizon is the topsoil, with the most organic matter, air and life; depth ranges from a few inches to a foot. (In our area, it is usually about 6 inches.) The B horizon is the subsoil — more mineral than vegetable, and less lively, though still an active zone for roots and earthworms. It's enriched with nutrients leached from above, or decaying plant roots. This layer too can vary from a few inches to a foot or so, depending on the depth of the parent material. The C horizon is the underlying material that forms the mineral component of the soil. The A, B and C horizons are subdivided into layers, A1, A2, B1, B2 and so on, if clear differences are visible. Some locations have a D horizon, which is bedrock or other parent material near the surface.

All soils, presuming they drain sufficiently, can be improved with organic matter. The A horizon can be increased by incorporating organic matter into the B horizon. The question is how much and how long it will take? The answer is usually: a lot and a long time. One is much better off developing a farm on land with good healthy soil from the start. Many urban sites require soil to be restored or imported.

## Determining Soil Type: Quart Jar Method for Finding Ratio of Sand, Silt and Clay

The relative size of the layers of sand, silt and clay is used to define the soil type. A soil that has too much sand will drain quickly and can be low in nutrients. A soil high in clay will compact, drain poorly and be low in air. To figure out what soil type(s) you are dealing with, fill a quart mason jar half full of the soil. Add water to within an inch of the top. Tighten the lid and shake until the soil is thoroughly mixed in the water. After about 30 minutes the soil will settle by weight into layers. The heaviest particles, small stones, and sand, will be on the bottom. Next will be a layer of silt, then the clay and then the organic matter.


*To determines the ratio of sand, silt, clay and organic matter in soil, put one cup of soil in a mason jar , add two or more cups of water, shake well and allow to settle.*




*Soil triangle.*

## Soil Testing

Chemical soil tests are a vital tool in farm planning and management. Testing kits range from inexpensive and possibly inaccurate to kits with very expensive equipment. Soil test kits give you what you pay for. The basic kits test for pH, nitrogen, phosphorus and potassium — the last three are known by their chemical symbols, N, P, and K.

A better test kit will range from $50 to $200 depending on the quantity of tests that can be done. Because the chemicals in the kit do not have long shelf lives, they need to be replaced each year, so buy only the size you need for the number of tests you want to conduct in a season. Keep accurate records of the areas tested to help manage the farm and to show to the organic inspector. You only need to test an area every few years if you know your inputs and follow a sound management plan. Testing will help you see the effects of crop rotations and inputs on fertility. Soil testing does have its limitations. Nutrients that become available through the biological activity in the soil during the growing season may not test accurately. But the tests will give a general idea of soil chemistry.

Testing for pH should be done every few years for all gardens. Wet and rainy years can leach out calcium and other water-soluble nutrients. Testing for pH helps to reveal lost soil minerals. As electrically charged mineral ions leach away, they are replaced by hydrogen, which increases acidity. Most crop plants cannot absorb minerals from acidic soil. On the other hand, adding too much lime will make the soil alkaline, which also limits a plant's ability to absorb nutrients. All application of lime should be informed by testing.

Testing for trace elements and the quality of farm-made compost requires special equipment. Commercial testing laboratories and state universities offer testing for a reasonable fee. The test results generally show what nutrients are in the soil, or what nutrients are needed to grow a specific crop, measured in pounds per acre. It is important to

### Toxic Soils as a Design Element

Lead in the soil can be a significant problem in urban and suburban sites. Airborne lead from car exhaust and industry entered the soil for many decades in the 20th century. Soil near houses and on reclaimed vacant lots also can be high in lead from the paint used prior to the 1970s. State governments generally have programs addressing the problem and offer a lot of information on dealing with lead.

People, especially children, can be poisoned by soil-borne lead by breathing in dust from contaminated soils, from ingesting soil and, to a lesser extent, from eating plants grown in high-lead soils. Dust masks and gloves are required when working contaminated soils to prepare planting beds.

Soil pH, organic matter, moisture level, and plant health can all affect uptake of toxic minerals. Leafy greens are more likely to uptake lead than fruits, such as peppers, tomatoes, squash, tree crops and berries. Root crops grown in contaminated soil should be thoroughly washed or peeled.

Lead is relatively immobile in the soil, so levels can vary greatly across a site. A lot of testing may be required to determine the extent of the pollution. Initial testing from several locations on a site will give an indication of whether lead is present and in what concentration. Samples with more than 100 ppm (parts per million) are a problem. When results vary on a site, further testing can reveal the pattern of contamination.

Once a pattern of contamination is found, this information becomes an element to consider in the design process. The level of concentration, if present, can be a major influence on site design and development. It is possible that gardens can be located in clean soils, and areas with contaminated soils can be used for other purposes.

Soils with very high levels — over 300 ppm — may need to be removed and replaced. Some states require the removal of soils above a certain level of contamination. Gardens should not be developed in soils with lead levels higher than 100 ppm, although some agencies set the limit at 200–300 ppm. Some agencies recommend ☞

use a testing service that gives you the service you require. For example, we have our compost analyzed to help us gauge how much to apply to our crops. Be aware that many soil testing labs traditionally offer advice geared for chemical fertilizer applications, which must then be interpreted to the use of organic fertilizers.

Livestock feed crops and pasture forage can be tested with *leaf tissue testing*. This can help the farmer determine supplemental feed requirements and soil improvement strategies. Leaf tissue testing of green manure crops can also help determine the quality of soil fertility.

### *Site Analysis: The Watershed*

Water management on the permaculture farm is approached by viewing the farm as a watershed and understanding its relationship to the larger

mixing contaminated soils with uncontaminated soil to reduce the levels present in any one site. Careful consideration should go into a decision to mix soils to determine expense, practicality and desirability of diluting the contamination. Other options should be ruled out first. Covering the soil with an impermeable barrier and importing new soil, or gardening in containers of imported soil mixes are options to consider when establishing gardens in contaminated sites.

Children, especially those under age 6, and pregnant women should have no contact with contaminated soil. It should be kept covered with sod or mulch. Even pathways should not be bare soil.

For soils with less than 100 ppm of lead, the following steps are recommended for reducing lead exposure: soils should not be tilled or dug when avoidable (mulch gardening is a good strategy for gardening without turning the soil); maintain a pH above 6.5; keep phosphorus levels high (this reduces lead uptake in plants); and maintain a high level of organic matter because it helps lock up lead in soil.

The presence of lead in the soil may be indicative of other contaminants. Copper, cadmium, zinc and arsenic can all be present in toxic levels. Residential sites may also have motor oil residue, asbestos and other contaminants. State public health agencies may have documentation of a site's potential for contamination from past industrial activities.

Phytoremediation of soil contamination is possible for some contaminants. This process involves planting crops known to absorb toxic elements. Harvesting and removing the plants can reduce levels of specific elements. Phytoremediation is still a relatively new area of research and the practical results are highly dependent on numerous factors. Cleanup may take many years and involves removal and careful disposal of the remediation crops. High levels of contamination may make the process impractical.

watershed. Issues of concern include catching, storing and using rainwater, sizing swales and developing rain gardens, wetlands and ponds. These last three are discussed in Chapter 13.

Nutrient management to keep excess nutrients from entering groundwater and streams is an important part of farm water management. Other concerns include planning for irrigation, water conservation, self-watering systems, riparian buffers, and preventing contamination of water with vehicle and equipment management.

The farm's relationship to the larger watershed is important in several ways. In many areas groundwater contamination from nearby pesticide use, excess fertilizers and industrial pollution can be a concern. Leaking gasoline tanks and industrial pollutants can send plumes of toxic substances moving through groundwater. It is important to research the area and the history of the area before planning to use well water in suburban and urban areas. The farm can affect the watershed if excess nutrients from on-farm composting, livestock, or fertilizer application leaches through the soil into the groundwater. Care should be taken to manage nutrients at the appropriate scale to prevent this. Soil testing is a valuable tool to help determine nutrient needs each year.

Streams passing through a farm may be quick to flood if the upstream watershed is not forested. A forest canopy and its understory reduce the impact of rainfall and help store it. Pastures and grasslands are more likely to drain quickly into streams. The riparian zone, or seasonal floodplain of a stream, is best kept in a cover of native trees and shrubs to prevent erosion. Cultivation too close to a stream allows excess nutrients to pollute the water. Allowing livestock uncontrolled access to streams breaks down the banks, leading to erosion, and also allows excess nutrients to enter the water. However, the riparian zone can be a valuable part of the farm landscape, providing woodland products, food and habitat for beneficial wildlife.

At our farm, we can expect to receive between 32 and 48 inches of precipitation distributed evenly throughout the year. Winter snows, averaging 50 inches each winter, tend to melt slowly and recharge groundwater. Summer storms bring a lot of rain — and potential for surface runoff. Storms bring 2.2 inches in 24 hours at least once a year, and 3.3 inches in 24 hours once every five years.

At least one summer growing season in ten, we have periods of six to eight weeks with little or no rain. Conversely, we have had 4 inches of rain in less than a half hour. That one storm flooded the pond 8 inches above the drainpipe, and the pond took nearly a day to get back to its normal level.

All these factors are of concern in the design process. Planning for irrigation in dry years, and proper drainage and catchment in wet years begins with calculations of both the watershed area (square footage of roof surface, pond site drainage acreage) and possible quantities of rain. Water needs are also assessed. Conservation and wise use of water is always important. It is commonly said that garden plants need an average of 1 inch of water each week. Our five-acre field will receive that much water three to four times each month in a normal spring and summer. Regular rain builds a reserve in the soil, especially under mulch.

For planning purposes, it is important to comprehend the volume of water needed. To cover one acre with 1 inch of water requires 27,154 gallons of water. Adding 1 inch of water to a 200 square foot garden bed requires 124 gallons of water (200 square feet = 28,800 square in./231 cubic inches per gallon = 124 gallons of water). One acre of beds this size need about 27,000 gallons per week.

Water needs for the 2,000 square feet of bioshelter growing space are an average of 1,240 gallons a week. In practice this varies through the year. On cloudy winter days, we do not water as much. Hot, sunny summers can require extra watering.

A polytunnel, measuring 45 feet by 15 feet has about 600 square

### Keyline

When developing the permaculture concept, Holmgren and Mollison incorporated P.A. Yeomans's *keyline system* of water management as detailed in his book *Water for Every Farm.* The keyline system is a whole-farm watershed management approach used to direct water flow and maximize water retention on a farm. Keyline water management involves a close study of a property to take advantage of existing topography in the placement of ponds and swales to direct and retain water. Pastures, pathways and other farm elements can then be positioned to take advantage of the system of swales and ponds.

On sloping land, surface water moves downhill and into small valleys. The term *keyline* refers to a contour line system that catches water moving toward these small valleys and directs it along contour swales and furrows, horizontally across a hillside. It is a broad-scale strategy of contour plowing specifically designed to maximize water infiltration into the soil.

Keyline water management was developed for dry lands, but it has applications in all climates to help prevent soil erosion, build soil and manage rainwater. On our farm, we have incorporated the concept to both catch water for irrigation and to lead it away from our building to infiltration areas.

feet of beds and so will require about 372 gallons each week. Because a tunnel does not get rain and has higher temperatures, the tunnel needs to be watered heavily at least once each week. New seedlings and transplants in a polytunnel may need to be watered twice daily in sunny weather.

## Water Conservation

One would hope for that average inch of rain to fall just after the weekly planting is in the ground and the weekend harvest is complete (on Friday, around noon please!). But, since nature generally has her own schemes, we must be prepared to catch, store and move rainwater where and when we need it. The huge amounts of water we need for our farm dictated that our primary strategy be pumping water from a well. Construction of cisterns to store rainwater would be extremely impractical on such a large scale.

Our farm, as already mentioned, is set on the surface of 60 feet of dense glacial sediment consisting of clay, sand, gravel, rock and boulders. This glacial sediment is a perfect filter and storage medium for water. We struck water at 32 feet, but took the well down to about 50 feet to allow for dry years and heavy use. This well provides household water, farm kitchen water and irrigation water. Our landscape collects rainwater in swales and contour beds to maximize the recharge of our groundwater.

Water conservation in the garden begins with garden design. Pathways are laid out as close as possible to level. These pathways become compacted with use. The beds are basically terrace gardens,

### Water Facts

- A gallon of water weighs 8.34 pounds.
- 1 gallon of water equals 231 cubic inches.
- 1 cubic foot of water equals 7.5 gallons.
- 1 acre equals 43,560 square feet.
- 1 acre equals 6,272,640 square inches.
- 1 inch of rain provides .623 gallons per square feet of catchment area.

These are handy facts for figuring out water needed or water received.

**Example 1:**

To cover one acre with 1 inch of water requires 27,154 gallons of water: (Calculated using the area in one acre [in square inches] divided by cubic inches in a gallon of water: 6,272,640 ÷ 231 = 27,154.29.)

**Example 2:**

A 1,000 square foot roof receiving 1 inch of water would yield 623.4 gallons of water:

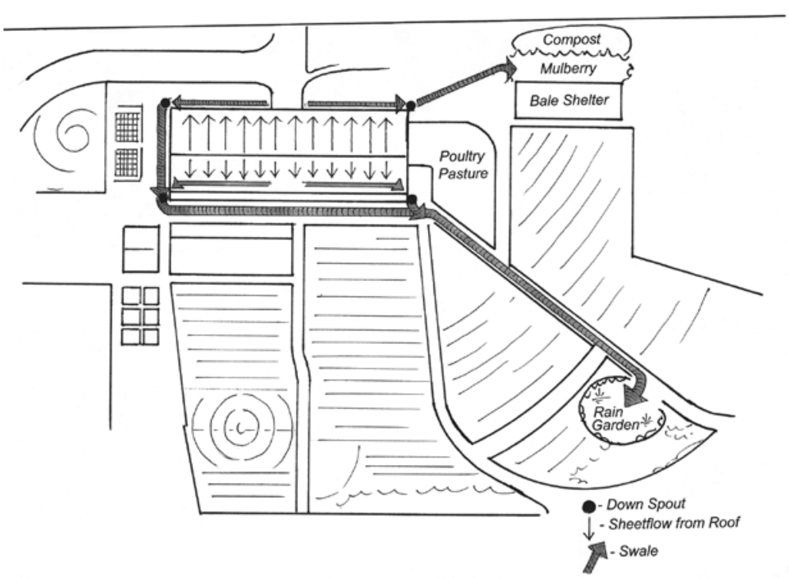
(Calculated by converting the area of the roof in square feet to square inches [the multiplier is 144], then multiplying by the number of inches of water received, and then dividing by cubic inches in a gallon of water: 1,000 x 144 x 1 ÷ 231 = 623.4.)

gradually dropping downslope through the gardens. Whether from rain or a sprinkler, each bed is watered on the surface and excess runoff is caught in the pathways between beds. Because the beds are cultivated deeper than the pathways (and the pathways themselves are compacted and do not absorb the water) water collected in the paths seeps underneath the beds to help ensure deep watering.

Planting in blocks of four to six beds makes watering more efficient. The sprinkler covers an area up to 30 feet wide. Crops need water daily until they germinate or are established as transplants. Our solar-powered pump actually averages about 2.2 gallons per minute from morning until evening. With about 1,000 square feet of new plantings to irrigate each week, we need to run the pump for about five hours a day. Long-season crops that will be in the bed more than six weeks are mulched. Checking soil moisture, plant condition, germination and transplant vigor are a part of the daily routine.

## Structures as Watershed

The amount of precipitation falling on a structure should be part of the calculations used to determine water management on the farm. For example, the south, glazed roof of our bioshelter measures 105 feet by




*Rainwater running off the bioshelter is directed into swales. These wide shallow ditches allow water to collect and seep into the ground, recharging groundwater.*

14 feet, or 1,470 square feet. Runoff from the roof is caught in rain gutters and directed into a swale located 10 feet from the south side of the cold frames.

Bioshelter south roof calculation:

> 1,470 square ft of roof catchment x 144 square inches per square feet = 211,680 square inches. One inch of rain falling on the roof is 211,680 cubic inches of water. Dividing that by the 231 cubic inches per gallon, means that 1 inch of water on the roof produces 916 gallons of water that can be directed where we want it.

The swale we constructed is 30 inches by 3 inches deep by 100 feet long and can hold 75 cubic feet of water, which is about 562 gallons. The swale continues downslope between the East Garden and the Southeast Garden through a space planted with currants, rugosa rose and goldenrod. The swale and any runoff from the bioshelter's foundation drain end up at a grassy uncultivated area.

The north roof of the bioshelter measures 105 feet by 26 feet, or 2,730 square feet, which equals 393,120 cubic inches. This divided by 231 cubic inches per gallon equals 1,701 gallons every time it rains 1 inch. The west half of the north roof drains through a swale along the west side of the bioshelter into the south swale. The other half enters a north side swale. This is directed past the poultry yard to the east, then to the row of mulberry trees and then dispersed into the yard. This swale also helps water the shaded native plant garden along the bioshelter's north wall.

Another rain catchment system is connected to the roof of our composting outhouse in the far southeast corner of the property. The roof measures 10 feet by 8 feet. The rain gutter is connected to a 50-gallon rain barrel. One inch of rain falling on this roof produces 49 gallons of water, so one night of hard rain will easily fill the barrel. This rain barrel is used for hand washing and occasionally to add water to speed up composting.

Roofing material is a concern when planning to catch and use rainwater from a roof. Acidic rain can leach potentially toxic minerals from treated wood shingles, zinc-plated roofing and zinc-impregnated asphalt shingles. Old and worn asphalt can leach toxic compounds and metals into the water. Slate, tile and metal roofs are preferred.

### Nutrient Management and Water Quality

Farm watershed management includes maintaining the quality of water leaving the farm by keeping nutrients out of streams. Water leaving the farm with excess nutrients (or worse, eroded soil), is a pollutant and a loss to the farm ecosystem. As much as possible, water should be collected in the pathways and swales. In a heavy downpour or rapid snowmelt, some runoff is inevitable. We have located swales to direct heavy runoff drainage from compost piles toward trees, shrubs and berry plants. Buffer areas of native goldenrod between the gardens and ponds keep excess nutrients from entering our pond.

Riparian zones are the banks and floodplains of streams and wetlands. Riparian zones are best managed as mixed woodlands. Trees, shrubs and other perennials help stabilize stream banks and absorb nutrients before they can leach into the water.

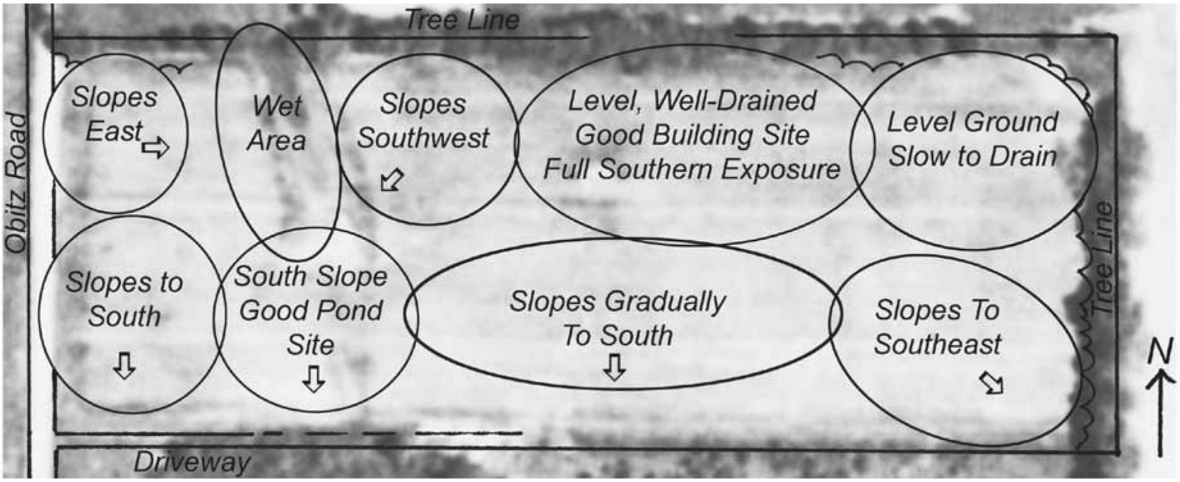
## *Site Analysis: Mapping*

After observing a site and cataloging resources, the next step is making a map of the property. The map is first used to help plan the placement of elements in the design. It is also a tool to convey and store information about the property. Drawing plans to scale on paper allows for testing and refinement of the plans before site work begins. Maps also serve to record species planted. Together with good garden records, maps aid in planning and documenting soil management and crop rotations. Organic certification procedures require such records and maps. A certification inspector or certifying agency will review these to assess the farm's management.

Mapmaking begins with gathering information on the site from existing maps, deeds and other property descriptions, and from site analysis. We were able to use topographic maps, soil survey maps, and a surveyor's map of our property to build our own base map.

The next task of mapping is putting it on paper. The scale of the map is determined by both the size of the area being mapped and the desired size of the finished map. An architect's ruler has inches divided into one-tenth-inch increments and is therefore very useful in mapping at scales of ten units per inch.

Standard notation and illustrations help to make a map look professional. Clearly marked scale and direction and legible labels are needed to make a map useful.




*Bubble map of topography and main features.*

For planning, transparent paper overlays are usually used; overlays are a good way to add information or make plans without cluttering a map. Final versions of overlays can be made on "acetate paper" or clear plastic with a fine-point permanent marker.

Other useful drawings include a *plan drawing,* which is an overhead view of the site or building and a *section drawing,* which is a side view, often a cross section of a particular part of a building or landscape.

In the early design phases it is good to identify key features of the landscape. Making a base map of the property is the place to start organizing the design process. A base map can begin as a rough sketch of the property's dimensions and key features.

As the process develops, better maps are needed. To make an accurate site plan map requires a lot of measuring and drawing. The effort is worthwhile if you use it as a development and planning tool. The process can be greatly shortened if you begin with a survey map of the site. Overhead aerial photographs are also very helpful in making a base map accurate, especially when the land in question covers several acres. When mapping individual gardens, the scale may be too small for aerial photographs to be useful.

Once you have a base map, you can use it as a template for making zone system analysis maps and sector analysis maps. The very process of creating the base map will help the designer understand site dynamics. More detailed field garden maps will be helpful for annual planting.

Soil types, water resources, landforms, geological features, existing species and other aspects of the site are catalogued. Soil survey maps from the US Department of Agriculture provide a wealth of information for a site. These maps provide information on the site's soil types, including a soil's depth and pH, drainage patterns, soil characteristics relating to construction, and a soil's suitability for various uses, i.e., ponds, driveways or agricultural development. Formerly, the soil survey maps were compiled into soil survey books by county. These books also provide information on local weather, including rainfall patterns, frost-free dates, and weather extremes. These resources can be found in the local library. Printed versions may no longer be available for purchase, but the county office of the Natural Resources Conservation Service usually has electronic versions available. The NRCS website also provides the online soil mapping services described above.

## Digital Mapping

GIS (geographic information systems) mapping is a computer mapping system. The most widely used is the ESRI ArcView series of digital mapping tools. With GIS mapping software, various digital maps can be set to the same scale and coordinate system and then combined in layers to produce a wide range of maps. GIS maps can include digital links to site data, and be linked with Computer Aided Drafting (CAD) files. For example, on a GIS map we are developing of Three Sisters Farm, clicking on the data files on our buildings links to building plans and photograph files.

GIS tools include the use of a GPS (global positioning system) to provide coordinates for site mapping. GIS tools and programs cost thousands of dollars and require training and time to learn to use, but are powerful tools once mastered. While the average farm does not have the budget for a GIS program, the Natural Resources Conservation Service can provide GIS-based maps for site planning, and will include soil data and other information.

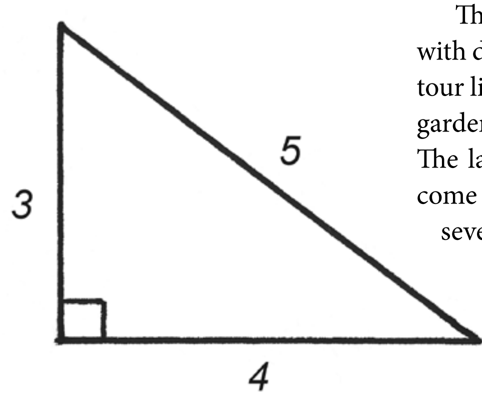
## Mapping your Site

Measuring a garden or landscape for mapping is best done by two people. One person takes, and one person records the measurements. Begin at a known point, such as a corner of a building. From this known point,

### Measuring a Site for Mapping

- Mapping tools:
  - compass
  - 250-, 100-, and 25-foot measuring tapes
- Contour study tools:
  - A-frame
  - water level
  - sight level
  - transit and measuring rod
  - field drawing board and pencils
- Drawing tools:
  - drawing table or board
  - T-square, engineers rule
  - pencils
  - assorted drawing triangles and curves

*When measuring for a base map or laying out a building, knowing the dimensions of the right triangle improves accuracy. When the two sides of the 90 degree angle measure 3 feet and 4 feet, the hypotenuse will be 5 feet.*




one line is measured parallel to the edge of the building and another line perpendicular to the building. All other notable points on the site are measured in relation to the two perpendicular lines.

At Three Sisters Farm, all maps use the bioshelter's corners or the property lines as a starting point. Because the building is aligned along an east-west axis and faces south, our maps are also aligned to the cardinal points. This is not actually necessary, but it works well with our solar-oriented planning.

To map the south garden, we laid out a 250-foot tape measure on the ground, beginning at the southwest corner of the building and stretching due south to the property line. This provides a square grid, with the building forming one edge and the tape running from the building to the south forming the second edge. We then marked the key locations of fencing, polytunnel, and garden paths on this grid. This is done by measuring with a 100-foot measuring tape the distance, at right angles, from the edges of the grid to the site feature.

Next we moved the tape, first to the middle of the south wall and then to southeast corner of the building, again marking key features along the line between the building and the property line.

This process, of starting with a known point and working at right angles to mark points on a grid is simple and straightforward. When laying out the tape on the edges of the grid you can check that the angle is 90 degrees by measuring the edges of a right triangle formed at the corner of the grid. Mark a point 3 feet along one axis and 4 feet along the other axis. A line connecting these points, the hypotenuse of the triangle, should be 5 feet. This is the 3, 4, 5 rule.

Laying out contour lines:

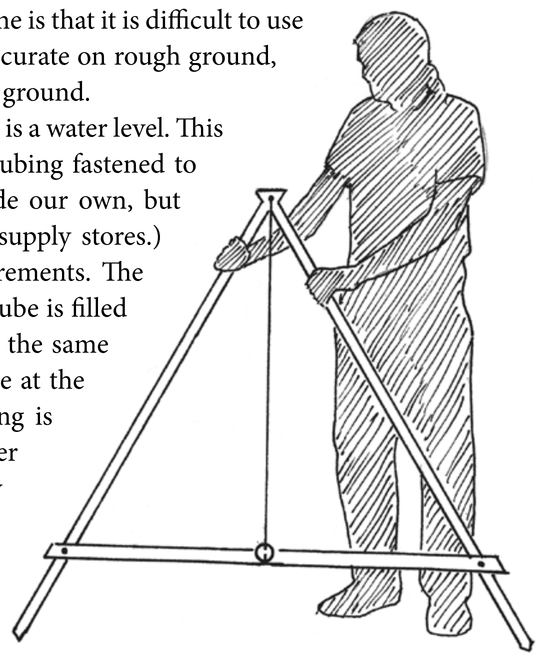
The scale of available contour maps is generally too large to help with detailed garden development. Several tools are used to lay out contour lines on the ground for building drainage, swales construction and garden pathways. These are the transit, the A-frame, and the water level. The latter two are low-tech tools and can be made at home. Transits come in many styles depending on use and can cost anywhere between several hundred and several thousand dollars.

A transit is the easiest tool to use. (You may be able to rent one.) At the simplest, a transit is a standard surveying, construction and engineering tool with a swiveling viewing scope and leveling knobs mounted on a tripod. Once the transit is set up level, the operator sights to a measuring rod held by an assistant. Keeping the scope level, you can move the measuring stake measure to find points of equal elevation and mark a contour line across the property with stakes. We also used a transit for laying level foundations and walls. Complex property surveys are made with a surveyor's transit.

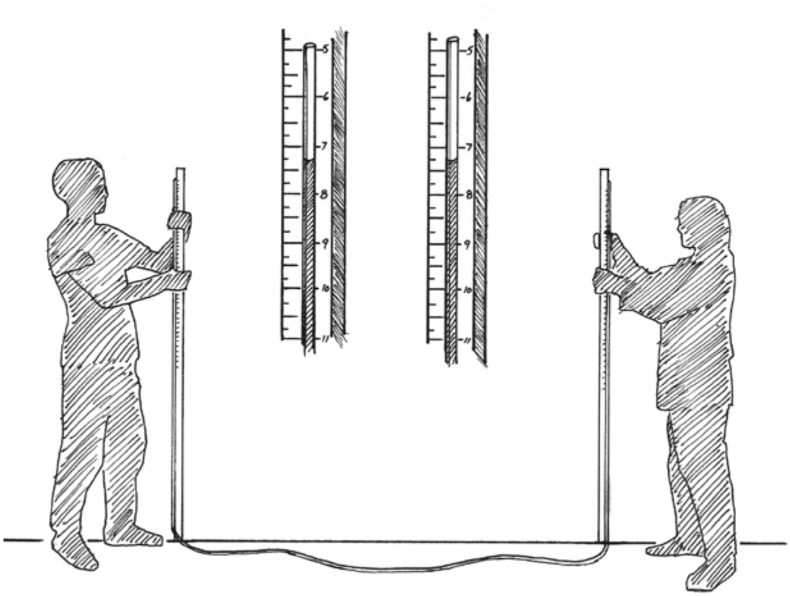
For the low-tech and budget-conscious designer, an A-frame is a good tool for finding contour lines. An A-frame is generally made of wood and looks like a letter "A." Two legs, about 4 feet long and bolted together at top, are connected with a cross bar about a foot above the bottom of the legs. A weighted string is hung from the top of the "A." When both legs are set at the same elevation, the weighted string will point to the middle of the cross bar. To measure a contour line across a garden or field, simply "walk" the A-frame across the ground: start at one staked point and find the second level point. Then pivot the frame from the second point to the third level point. Set a new stake every few yards as you go, depending on how exact you want to be. For making a ditch or swale to drain water from one point to another, mark out a series of gradually descending points as you walk the A-frame across the landscape. A drawback of the A-frame is that it is difficult to use in the wind, and it can be hard to be accurate on rough ground, but it works very well on relatively level ground.

My favorite tool for finding contours is a water level. This is a 20–30 foot length of clear plastic tubing fastened to two six-foot measuring rods. (We made our own, but they can be purchased from building supply stores.) The rods are marked with ¼-inch increments. The stakes are held upright and the plastic tube is filled with water. When both rods are set on the same level and held upright, the water will be at the same height along the stake. The tubing is corked when being moved to keep water from spilling, and uncorked when they are in position.

Two people are required to use the water level. Each holds a rod. Beginning at one edge of a garden



*The A-Frame is a low tech tool used to lay out contour lines.*



*The water level, made from two measuring rods and clear plastic tubing, is used to measure relative elevations, lay out contour lines and to lay out level walls and foundations.*

or field one person holds their rod at a starting point. The second person then sets the stake at another point and both check the water level. When the water is at the same level both points are at the same elevation, or "on contour." A little food coloring can help make the water easier to see. The first person moves past the second person to find the next point on the contour. Again, stakes are used to mark the contour line. The water level can also be used to measure changes in elevation for laying out foundations, leveling walls, and for laying out swales and drainage ditches. To measure elevation drop, plot a line downslope from the starting point and each time you move the rod record the difference in elevation between the rods. The water will always stay the same elevation, so the downhill rod will have water closer to the top of the rod.

During a permaculture workshop we had a race between teams using a transit, a water level and an A-frame. The transit team had laid out a 100-foot-long contour line by the time the water level had measured 50 feet, and the A-frame had measured 25 feet. So in that case, the transit was the most efficient tool to use. But with practice, both the A-frame and water level are effective and affordable tools.

The map is only a useful tool if it is used to plan and document work done on the farm. Accurate maps help plan the placement of gardens and structures in relation to windbreaks, pathways, perennial plantings and so forth. They are useful for communicating to others the plan for site development; they also serve as a record of the farm's assets.

## Planning

Permaculture planning addresses farm components and activities as interconnected elements. Each facet of the farm — energy systems, water management, soil management, crops, enterprises, buildings, structures, and the landscape — should be reviewed for integrated design. After the infrastructure is in place, many microclimates can be developed and niches filled with useful species.

### *Brainstorming*

Brainstorming is a planning technique in which you allow the free flow of ideas without critical filtering. Wild ideas, sensible ideas, random thoughts and logical conclusions can all add different perspectives. Pick a general topic such as land potential, development plans or staging schedules and write down ideas without making any judgment about the ideas' merits. Later, the ideas from the brainstorming session are reviewed for potential. Even impulsive and impractical ideas can lead to new, productive ways of thinking.

### *The Plan*

Once the results of the brainstorming are reviewed and options are chosen, the development plan is created. This process begins with working out the details. The site should be measured and mapped accurately if this has not been done already. Again, ecological relationships are noted. Permaculture principles are applied to create ecological interactions and to conserve energy and resources. The zone system is used to place elements of the system in the right relationship to each other. Research is done on the plants, animals and structures needed for creating the design. The use of native plants and local and environmentally sound materials and practices are preferred throughout the development.

Budget planning is vital to the success of a project. The more accurate your projections, the more smoothly and successfully your site will develop. Establishing a permaculture farm requires a lot of hard work and a lot of time. Budgeting your time is as important as budgeting your money. Of course, there is often a difference between projections and reality. Equipment breaks down and holds up progress until repairs are made; there are weather delays; and generally life just happens.

Implementation of the design begins with staging the work in a logical progression. Early work includes soil building programs and gathering materials such as composts, mulches and plant materials. Perennials are added at a manageable rate. As trees and shrubs grow, they create niches for other plants, insects and vertebrates. Customers of the vegetables grown in the early years will eagerly purchase fruits when they become available.

Review and monitor progress and adjust to new observations and changing needs. Good record keeping of crop yields, weather patterns and worker productivity provides ongoing feedback for a process of annual design review and planning. Conducting trials of crops and markets allows you to adjust to what works best.

Phenology, the study of how plants and animals interact with the seasons, also provides continual insight into design development. When the spring peepers sing their spring song, it is time to prepare the beds to plant peas, spinach and onions. We try to be sensitive to the seasonal fluctuations and the cycles of the place. We are trying to develop the native knowledge that is lost to many modern farmers. Eventually the need to "design" is superseded by a cultural knowledge of land and resources. We must begin somewhere. Humility as to our own ignorance of nature's complexity will lead to the true permaculture farm. As a new traditional wisdom replaces design, we can find our way back to a deep knowing of the place as Indigenous cultures.

## Season Extension

Season extension involves the creation and use of microclimates to expand the growing season. You will probably use some combination of the strategies listed here.

**Windbreaks:** Windbreaks help extend the season by cutting down the wind chill, allowing plants to get an early start or last longer into the year. A windbreak as small as a bale of hay can extend the harvest of greens for a week or two. Tree crops, berry bushes and other useful shrubs can be arranged to provide windbreaks for nearby plantings. Garden walls, fences, berry patches and tree lines can all afford some degree of protection until full winter sets in.

**Mulch:** Mulches can help extend the season on semi-hardy herbs like thyme and rosemary. Mulch minimizes the freezing of the soil and can extend a season by helping "store" a crop in the soil. Loosely mulched plants will stay fresh under leaves or hay until a heavy freeze. Cabbages, kale and other brassicas keep quite well this way. Mulch can also *slow* the warming of the soil in the spring.

### Permaculture and Architecture

Buildings and other structures are an integral part of farm design. The Permaculture Institute, established by Bill Mollison and others in the 1980s through a series of International Permaculture Convergences, offers diplomas in ten areas of permaculture, one of which is Architecture and Building (see: www.tagari.com/courses/DiplomaOfPermacultureDesign). The permaculture books written by Bill Mollison and David Holmgren present only general recommendations for actual building design; although they present ecological design principles and make general suggestions, it is left up to the designer to apply permaculture principles to building design.

In *Permaculture Two,* Bill Mollison describes the elements of what he calls the reactive house — a house that reacts to its environment, thus minimizing the need for "external energy for climate control." Mollison lists essentials aspects of a reactive house:

- shelter from winds with windbreaks
- oriented for solar gain
- minimize windows on shaded sides
- well-insulated and sealed from drafts
- natural air conditioning with shade trees

He also suggests:

- a greenhouse on south side
- a shade house on the north side
- high thermal mass masonry stoves

In *Permaculture: A Designer's Manual,* Mollison only devotes one page to home design. David Holmgren's *Permaculture: Principles and Pathways Beyond Sustainability* similarly provides little direction in actual home design. Rather, he stresses the need to design for energy efficiency and recommends the use of recycled and natural building materials and materials with low embodied energy (the energy use to create and transport the material). Holmgren also stresses designing for ease of maintenance and durability.

Both Mollison and Holmgren stress the importance of placing homes and settlements in the proper relationship to the landscape according to zone and sector analysis. Basically, sector analysis is concerned with harnessing or controlling the energy, such as wind, sunlight, or water flow, entering a site. Zone analysis is the layout of site components to create time- and energy-efficient relationships between components of the site. These two design tools aid in understanding the energy dynamic of a site and provide a basis for creating an integrated and sustainable system.

As permaculture has evolved, architecture, especially natural building, has become a prominent part of the movement. In the process, many teachers and proponents of permaculture have integrated regionally appropriate building design into their work. Straw-bale and clay-straw insulation and cob (clay reinforced with straw) walls are common in permaculture projects. Local lumber, stone and other materials are preferred. Similarly, green building concepts, such as energy efficiency, use of non-toxic natural materials, and ecologically responsible resource management are integrated into permaculture planning.

**Green Design:** Green building has much in common with the goals of permaculture design and provides an important tool for sustainable community development. The US Department of Energy (DOE) defines green building as an integrated approach to design used to create environmentally sound and resource-efficient buildings. Energy efficiency, resource conservation, renewable energy, and water conservation are important design ☞


DARRELL FREY

*Clay straw is a local natural building material.*

considerations. Interior environments are planned to be healthy — lit and ventilated naturally when possible.

To quantify and standardize green design concepts, the LEED (a trademark of the US Green Building Council) system was developed by the US Green Building Council. Many project funders and state and local governments now give preferential consideration to LEED-certified projects.

LEED stands for Leadership in Energy and Environmental Design. It is a checklist system that provides measurable guidelines for green and sustainable building design and construction. Certified LEED consultants work with design and construction teams to meet goals in six areas of concern: sustainable site development, water efficiency, energy conservation and air quality, material and resource use, indoor environmental quality, and innovation and design process. Some of the items that can qualify a project for LEED certification are reuse of old industrial sites (brownfield development), storm water management, reduced site disturbance, water use reduction, use of renewable energy, use of local materials, optimizing energy performance, management of construction waste, maximizing daylight in a building, reduction of indoor air pollution and innovative design. Projects can be LEED-certified Bronze, Silver, Gold and Platinum, depending on the total LEED score of a project.

There is a LEED checklist that gives a project a possible 69 points. Completed projects are rated according to the points earned in the review process. To be LEED certified, a project needs 26 to 32 points. A Silver LEED rating is given for projects with 33 to 38 points; Gold to projects with 39 to 51 points; and Platinum to projects with 52 to 69 points. The LEED standards are readily available online to serve as a guideline for builders (www.usgbc.org). The cost for the review process varies depending on the size of the building project. There are now LEED standards for private homes. Points are awarded based on assessment technologies that gauge indoor air quality, ventilation and efficiency. The location of the home is also a factor; points are given for homes located in areas of high-housing density.

**Natural Building:** Local and natural materials can be interesting to work with and provide unique character to a house. The low cost of the materials is, however, usually balanced by higher labor costs. When a building owner has more time than money and wishes to avoid excess debt, going local can be a good tradeoff. We highly recommend gaining hands-on experience with ☞

natural building before proceeding on one's own project. Many natural building workshops are offered each year throughout the US. Building codes and other regulations relating to natural building vary and should be thoroughly reviewed before proceeding with design and construction projects.

Including natural materials in a bioshelter design can and should be a primary design criteria. A well-designed building, insulated to conserve energy, will last for decades or longer. Such a building pays back the energy embodied in the construction with the heating and cooling energy saved. When choosing natural materials for a high humidity building such as a bioshelter, care must be taken to insure the long-term stability of the materials. Local lumber is preferred, though rough-cut lumber can be difficult to work with, and finished local lumber can be expensive.

Straw bales, used as insulation, are especially vulnerable to decay from moisture. Any use of straw in a bioshelter needs to be well protected. Cob and clay-straw are not as good at insulating a wall but may be more appropriate for bioshelters.

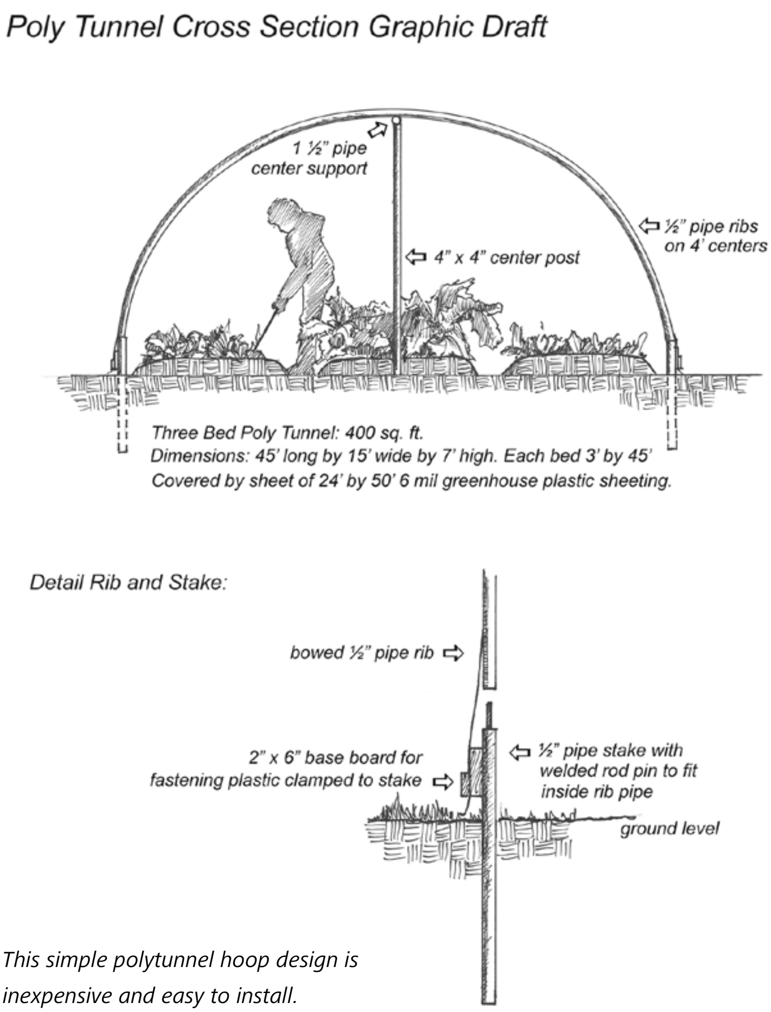
**Row Covers:** Row covers are synthetic or natural fiber translucent blankets that lightly cover a crop to break the wind and trap the heat of the ground and the sun. They are often made from spun polyester or cheesecloth. Row covers only provide a few degrees of protection, but they can add weeks to a growing season — on both ends. They allow spring crops to get a head start and protect established crops from light frost in the fall.

**Cold Frames:** Cold frames are small, unheated structures designed to create a microenvironment to protect plants in harsh weather. Cold frames come in many shapes and sizes. Many materials have been used in the past. The American Garden Calendar, published in 1806, mentions the use of paper painted with linseed oil as a cold frame covering. Oiled sheepskin and parchment have been used for the same purpose. Today, the best cold frames are freestanding boxes with hinged lids or, even better, structures attached to the south side of a building. But a sheet of plastic or an old window laid over a hay bale frame will provide some protection. (Be sure to fasten and support plastic sheets, as a heavy rain or snow will quickly collapse them. And old windows can collapse or break if not properly supported.)

Although glass would seem a more sustainable option than plastic; many factors need to be considered. Primarily, one must consider scale and cost of the structure. Smaller frames can be built of glass at reasonable cost. Larger structures glazed with glass may be prohibitively expensive and heavy. Whatever you use, make sure it is properly fastened; wind gusts can turn unfastened frames into flying health risks.

**Hot Beds:** A hot bed is a cold frame with heat. The ancient method is to bury composting manure under 6 to 10 inches of loose soil. The heat released by the microorganisms in the compost provide warmth to the soil and frame. Hot beds are discussed in detail in Chapter 11.

**Polytunnels:** A polytunnel is a single layer, unheated plastic greenhouse. Polytunnels can provide six to eight weeks of season extension for most crops. Tunnels should be large enough to walk into but small enough to allow the ground to provide thermal mass. A width of 15–24 feet allows for headroom and enough curve to shed rain and snow. A maximum length of 50 feet allows for natural ventilation through the end walls. For tunnels longer than 50 feet, rollup sides are needed to help ventilation. Clearance for rotary tilling equipment may be a design consideration, depending on the management plan. "High tunnel" is a name increasingly applied to polytunnels. High tunnel greenhouses, also known hoop houses, are becoming important components of agriculture in Pennsylvania and cold climates nationwide. Their relatively low cost and potential for extending the growing season provide a valuable tool for the market grower to increase productivity and profitability. Cultivation in high tunnels allows three crops to be grown in the same space in one




*This simple polytunnel hoop design is inexpensive and easy to install.*

extended growing season. For example, spring salad can be followed by summer eggplants and then a fall kale crop.

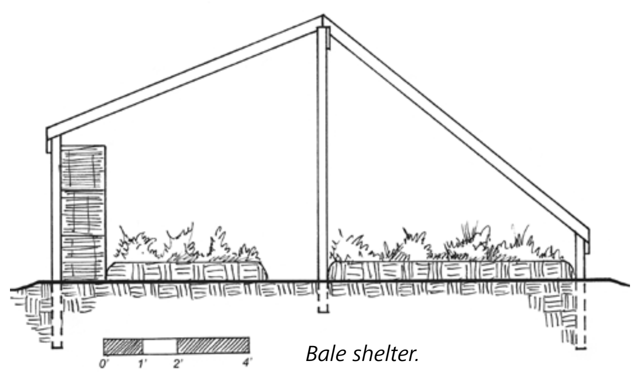
It is important to build strong end walls and to use sturdy frames. Otherwise the tunnel can collapse in a storm or under snow. Pipe frames are most common. Framing with local lumber is preferred when practical (if the wood is a renewable local resource).

Although an unheated polytunnel can add six to eight weeks to each end of the growing season for hardy crops, frost-tender crops will only get about four weeks of extension beyond frost dates. Using mulches and row covers on crops in the tunnel further protects plantings. Adding thermal mass such as stones, brick pathways and buckets of water to polytunnels can help stabilize temperature extremes and create microclimates.

**Bale-shelters:** A bale-shelter is a modified polytunnel. Bales are stacked inside the polytunnel to form the north wall and end walls. This provides insulation and so increases the performance of the structure. In the spring, the bales are taken down and used to mulch summer crops. Tunnels and bale-shelters can also be used in summer as poultry housing.

**Greenhouse:** A greenhouse is a more heavy-duty, double-layered polytunnel or some other type of glazed building with a heating system. A greenhouse is used for year-round production. The design, heating and ventilation are determined by the crop mix desired.

**Bioshelter:** A bioshelter is a well-built greenhouse managed as an indoor ecosystem. Bioshelters often contain some form of animal life (livestock, poultry, or people) for gas exchange and body heat. The plantings include insectary plants for beneficial insects. Chapter 9 and 10 provide a detailed study of bioshelters.



*Bale shelter.*

## *Integrated Design for Season Extension*

The more beneficial combinations we make, the higher our overall productivity can be. For example, mulched crops in a cold frame protected by a windbreak will provide a high degree of protection. In Maine, Barbara Damrosch and Eliot Coleman of Four Season Farm use a system of cold frames inside polytunnels to nurse crops through the harsh winters. Continued development of season-extension strategies is imperative as we seek more sustainable and regional food systems.

## Case Study: Design of Three Sisters Farm

Before we started to develop our farm, we had the opportunity to study our site for several years. We were able to walk the tree line, field and surrounding woodlots to learn the terrain, note the practices of neighboring farmers, and study the surrounding natural systems. We were able to witness several seasons of important details: the patterns of the snowdrifts; the small, seasonal spring seeps at the base of the slopes; the wetland plants in places with poor drainage; and the annual floods of the nearby riparian zone of Mill Creek.

The property is a five-acre rectangle measuring 260 feet north to south and 842 feet east to west. The north and east property lines, adjoining a neighboring dairy farm's crop fields, had the beginnings of a young tree line. The west property line is a county road, and the south property line bordered our neighbor's five acres, which included his homestead, several acres of woodlot and forest riparian zone along Mill Creek.

### *Site Analysis*

During planning stages, we conducted a more thorough study of the property. Understanding the environmental history and the nature of the human impact on the regional ecology is critical for long-range planning for any sustainable development. Sustainable land use on the farm benefits from this initial consideration of the region's natural history by informing the farm designer about the site's hydrology, soils, past use, native biodiversity, and most important, its relationship to the watershed and bioregion.

#### Climate

The climate of northwestern Pennsylvania is "humid continental." *Continental* refers to our location in the interior of the continent, which results in relatively stable seasonal weather patterns; *humid* refers to the average annual rainfall of 40 to 45 inches per year. The region is characterized by cold, snowy winters and warm, temperate summers. The primary influences on the regional weather are the latitude, atmosphere, terrain and the effects of Lake Erie. The latitude is around 42 degrees north of the equator; this brings both hot summer days, when the sun is as high as 72 degrees above the horizon at noon, and cold winter days when the sun is as low as 22 degrees above the horizon at noon.

The atmosphere in this region is subject to extremely variable daily weather because it receives the effects of the jet stream coming from the dry west, the arctic wind from the cold north and the warm, moist air coming from the Gulf of Mexico. The interaction of these systems provides variable and often stormy weather as the different air masses meet in the Midwest. Wind speeds can reach 60 miles per hour as storm fronts roll in. This is an important concern when designing buildings, polytunnels, cold frames, and other season extenders. During the early winter, cold wind crossing Lake Erie from the north and west picks up moisture; this can develop into "lake effect" snow over much of the region.

Throughout the year, the region has an average of 200 cloudy days and 64 clear days; the rest are partly cloudy. November through January, there are often only a few sunny days a month, although there are sometimes a few partly sunny days and an occasional long period of sunny weather. When Lake Erie freezes in winter, the lake effect is reduced, allowing more sun in February and early March.

The frost-free growing season ranges from 135 days in the northern section to 150 days in the southern section. Within two to five miles of Lake Erie (50 miles north of Three Sisters Farm), the lake moderates the climate, providing a growing season up to six weeks longer than the surrounding region.

## Topography

We live in the Appalachian Plateau bioregion. Our farm is a rolling landscape, which is typical of the region. The field varies in elevation by about 10 feet from the original lowest point (now under the pond) to the highest ground. The farm property is above the highest flood level of the adjoining Mill Creek. The lowest part of the field, in the western half, drained a seasonal wetland and spring on a neighboring property to the north (making it a good candidate for our pond site). This area also serves as surface water drainage for several acres to the north of the property.

The northeast corner of the property contains a seasonal wetland covering several hundred square feet. Part of the headwaters of a spring the runs through a neighboring field, this wet spot is partly fed by a swale located along the edge of the north tree line.

## Hydrology

The glacial deposits of the region help create extensive reserves of clean groundwater. The underlying sandstone in much of the region also contains major aquifers. These aquifers are recharged by rain and snow infiltrating porous soils, wetlands and streams. Numerous springs feed the many streams and wetlands.

Agricultural development during the 20th century drained many wetlands and soggy soils. Current federal regulations prohibit installation of new pipes to promote soil drainage and restrict repair of drains to those installed prior to the 1980s, unless permits are obtained. Some of the drained fields are reverting to wet soils as drain tiles clog in abandoned fields. Pastures often develop small sinkholes as soil above the old drain tiles erodes.

## Soils

Soils in the glaciated region of northwest Pennsylvania are geologically young, having evolved in the 10,000 to 12,000 years since the glaciers retreated. The parent material from which the soil formed is generally weathered glacial till in the uplands and slopes and weathered glacial outwash and till along stream valleys and associated terraces. The formation of the present soil began with the complex prairie ecosystem that colonized the region as the ice retreated. Subsequently, the successive forest systems and related ecosystems built up the organic matter to feed the soil ecology.

At our site, the soil is primarily silt loam, underlain with a dense fragipan (a hard mix of clay, silt and stones that is poorly drained). The soil, while depleted when we started our farm, and seasonally wet, was still considered to be prime agricultural land for field crops. After the winter snowmelt drains away below the fragipan, the cultivated topsoil layer is reasonably well drained. This is especially true with our raised beds. Because the fragipan acts as a barrier to excess mineral leaching, when loosened with subsoiling tools and organic matter is added, the subsoil provides a good mineral base for expanding the topsoil layer.

Our soil is marginal for fruit trees because the high water table kills roots, leading to shallow root systems. This makes the trees susceptible to drought in dry years and to toppling over in wet, stormy years. Such trees must be planted in the better-drained portions of the property.

## Sector Analysis

**Solar Access:** Sunlight access is extremely important in farm design. Because we had an open field, we were able to place the bioshelter and season extenders in full light. For us, the lack of shade was the problem. We have added trees and other plants and made use of the shade cast by the bioshelter to provide shady microclimates for shade crops, such as woodland plants and medicinal herbs.

**Wind:** Prevailing winds on our site are from the west and northwest. During certain weather conditions (usually only a few days each year), wind also can blow from the east. Even rarer is the approach of storms from the south, such as a hurricane's final downpours.

Control of the wind at the farm has been a priority. The existing tree line provided the beginnings of a good windbreak for the farm. A windbreak will filter the wind and slow it for a distance downwind. This distance is generally considered about ten times the height of the windbreak, so trees 50 feet tall will moderate the wind for 500 feet. A hedgerow of 6- to 8-foot-tall shrubs will reduce the wind speed for a distance of 60 to 80 feet.

When we began farm development, the young tree line was thin and needed to be expanded. We were concerned not only about the wind, but about stopping airborne herbicide spray from neighboring fields to the north and east from entering the farm. In the years since, we have allowed dogwood shrubs to expand 25 feet into our side of the tree lines, and added other species. This proved a very good strategy. When the neighbor decided to brush cut his side of the tree line in 2006, our side's shrub layer had become dense enough to act as a good barrier to the wind.

As we have developed the farm, we have been aware of the site's potential for wind-powered electrical generation. A tower would need to be located away from wind turbulence caused by the tree line. For this reason, a location on the eastern, leeward side of the pond is reserved for a windmill site.

**Privacy:** Privacy is a concern for a family farm. Living in a public space has many drawbacks. Visitors can show up anytime unexpectedly. (You should plan ahead if you care to visit any farm.) By locating our home in the northeast section of the property, behind the bioshelter, we allowed our family a sense of privacy.

**Floodplain and Stream:** The floodplain of Mill Creek is on the adjoining property to the south. This area is subject to inundation up to a foot deep after major storms every year. Beavers reside upstream a few hundred yards, and downstream a few hundred yards. While not part of our property, the wooded floodplain and stream are important habitat for many birds and other creatures that visit and live on the farm. Raccoons, skunks, opossums, and weasels live or travel through this area. Turtles and snakes pass back and forth between the riparian zone and the farm. Woodchucks, rabbits and many other creatures do not respect the property line either.

Along the south side of the driveway, on the neighboring property, a power line has an understory of dogwood shrubs and wild plants. These shrubs suppress tree growth and so are allowed by the power company.

**Other Existing Features:** The tree line species we inherited were mostly silver maple and black cherry, with a few shrubs. Over the years, birds have added the seeds of diversity. As we began to develop the farm, we allowed a gas pipeline to cross the northwest corner of the property. This pipeline became the location of the path to and through the west garden.

## Overlaying the Farm onto the Landscape

During the six years we observed the property and made initial plans for our farm, we had time to walk the property and observe the changes occurring as the field began to develop. In 1983, we began to establish useful plant trials along the southern edge of the field. We left room for an access road at the field's edge and established Siberian pea shrubs (*Caragana arborescence*), rugosa roses, and honey locust trees just beyond the late-summer shade line of the woodlot to the south of the field. With the property owner, we also established a row of a dozen hazelnut bushes 30 feet farther into the field. A planting of 25 honey locust trees was established in the southeast corner of the field.

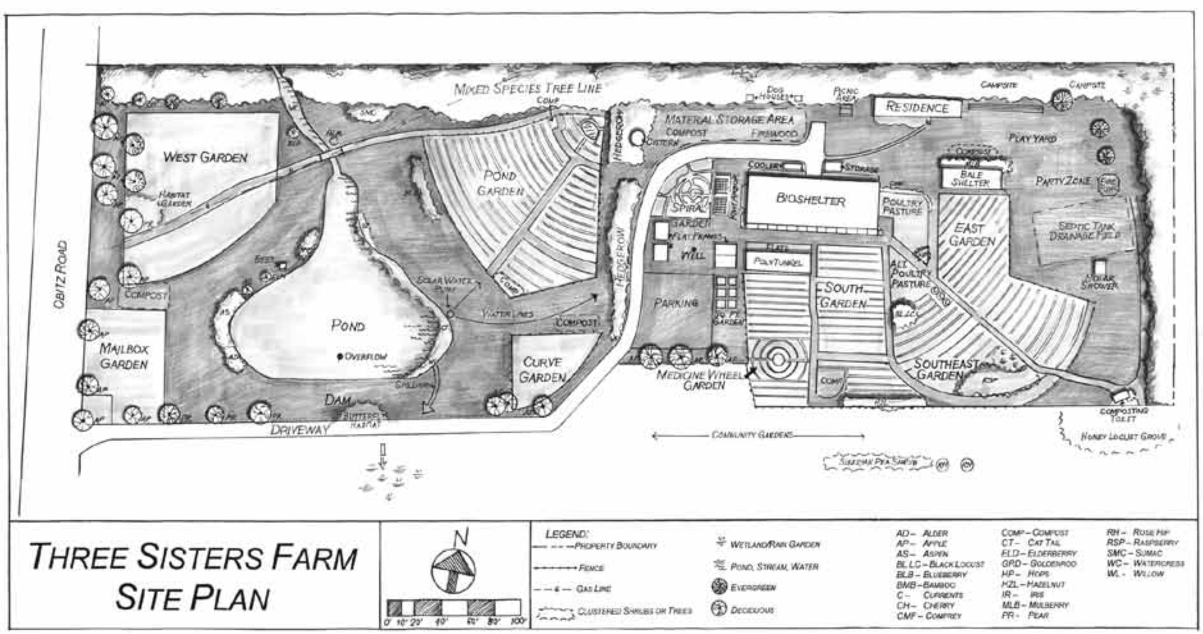
## Bioshelter

When we finally had the opportunity to apply for funding to build the bioshelter, we had long known what we wanted to do with the site.

The first step was to locate the building. We wanted the site to be high, dry and level so foundation drains and the septic system could be easily placed. The property only offered one such space — in the north central area of the property. We wanted to set the building far enough in from the north property line to allow for the tree line to expand and for supply storage.

The next step was to locate the building's support structures, including a water well, buried electric and telephone lines, and the septic system. We put the well between the parking area and the west side of the bioshelter. This allows access for drilling equipment if the well ever needs to be serviced. Waterlines are buried running from the well to the bioshelter's west end. Electric and telephone lines also enter the bioshelter there. The sand mound septic system is near the west property line. Drainage lines for the bioshelter's foundation run southeast from the southeast corner of the building.

*Farm map with basic structures outlined.*



Other needs included a driveway, public and private parking areas, and access to the north side of the building. Here we allowed space for compost yards and storage areas for leaves, mulch, sand, and firewood.

We share the first part of the driveway with the neighbor to the south, who built his home overlooking Mill Creek. The driveway follows the property line along the south edge, then turns north in the center of the field toward the bioshelter. Parking for visitors is located just inside our property line southeast of the bioshelter. Private parking is to the north of the bioshelter.

We also allowed space in the plan for a future home for the farm managers. Currently, there is a renovated mobile home located along the tree line north of the bioshelter. This location allowed for connections to the phone and electric service and well water and to the septic system. We reserved an area of about one third acre for open space, variously a yard and meadow. This gave our children a play field and camping space. A fire circle near the east end of the yard provides a setting for social events.

### *Pond*

Our pond is described in detail in Chapter 13. Located in the lowest spot of the field and naturally fed by a spring in the neighboring yard, the pond is a key feature in the landscape, providing irrigation, fish and habitat. Pond water is used to water newly transplanted crops via a sprinkler, and to irrigate mulched, long-season crops by flooding the pathways. This has greatly reduced our need for well water and associated energy use.

### *Building The Pond*

During the initial fallow period, between 1981 and 1986, a small spring and wet meadow in the neighboring yard drained through our gently sloping field. A small patch of cattails and a young willow tree were establishing themselves. These were eliminated in 1986, when the entire field was plowed and planted with mixed clover hay. About the time we began to garden around the bioshelter, in 1988, a neighbor diverted the spring away from our field, drying the area. When we wanted to build the pond, we had to negotiate with the neighbor; we ended up burying a four-inch pipe through their yard to re-establish the original watercourse.

The pond has evolved from a newly bulldozed site to a diverse habitat (for more description and a list of species, see Chapter 13).

## Wildlife at Three Sisters Farm: Many Neighbors

Our efforts to apply permaculture design to the farm include integrating the farm into the matrix of nature. Although, it would be highly arrogant of us to think we could actually design ecosystems, we believe that we can create a balanced ecological agricultural landscape by allowing nature to return to the land.

As mentioned earlier, the five-acre field that was to become Three Sisters Farm was in 1983 just sparse corn stubble and bare soil. The 1,200-foot tree line on the north edge of the property and the 300-foot tree line on the east edge had a minimal understory developing under a row of red maple and black cherry. Shrubs included scattered panicled dogwood, osier dogwood, and Juneberry.

*Above: Garder Snake.*
*Below: Ladybug with larve.*

While the tree line probably provided habitat for birds and other small creatures, the field was, ecologically, near death. From 1981 to 1986 the field was left fallow. Weeds such as Queen Anne's lace, yellow dock, dandelion, quackgrass and other herbaceous plants established themselves in the field. In 1986, a neighbor planted a mixed clover hay. In 1988, we took over full-time management of the farm when we built our bioshelter and began our market garden development. One of our primary goals was to create a farm that would enhance habitat and support diverse wildlife. The farm would, in addition to producing marketable products, restore a local ecology. As we worked to develop the landscape plan, nature moved in.

After several years, the farm was already quite diverse. I awoke at dawn one spring morning and went into the bioshelter to do the chores. On a whim I opened the window overlooking the pond garden. I was just in time to see a great horned owl lift off from a rabbit he had killed during his nightly patrol. Now, during the day, a red-tailed hawk patrols the sky overhead. On rare occasions, the local bald eagle passes over as well. Often the small group of crows in the neighborhood will harass the hawks for fun. In the winter of 2006–2007, a pileated woodpecker began knocking about in the tree lines early in the morning.

The pond is visited each morning by a number of birds. Each dawn, spring through fall, you can see a great blue heron hunting in the pond, while Canada geese and wild ducks forage nearby. Mallard and crested merganser ducks feed in the pond. The green heron and kingfisher rotate between the pond and the nearby wooded stream. However, none of these water birds have been observed nesting here. This is probably due to the small size of the pond and the high level of activity near the pond (fishing and gardening) during the springtime. Some birds do nest on the farm. Baltimore orioles forage in our garden from their nest near the stream and killdeer have nested in gardens near the pond. On several occasions an osprey, which nests at a nearby lake, has been seen diving into our pond.

Redwing blackbirds nest in the cattails around the pond. Acrobatic barn swallows swoop and tumble, competing with dragonflies for mosquitoes. Bluebirds nest in boxes around the farm, as do English sparrows, swallows and wrens. Sleek grey catbirds mew in the bushes. Phoebes and robins nest in the eaves. Yellow warblers and thrushes flit and hop through the tree line and goldfinches hang on the weeds. Hummingbirds delight us as they sip from the scarlet runner beans. In the twilight, undetermined species of bats emerge to skim the pond for water and hunt for insects.

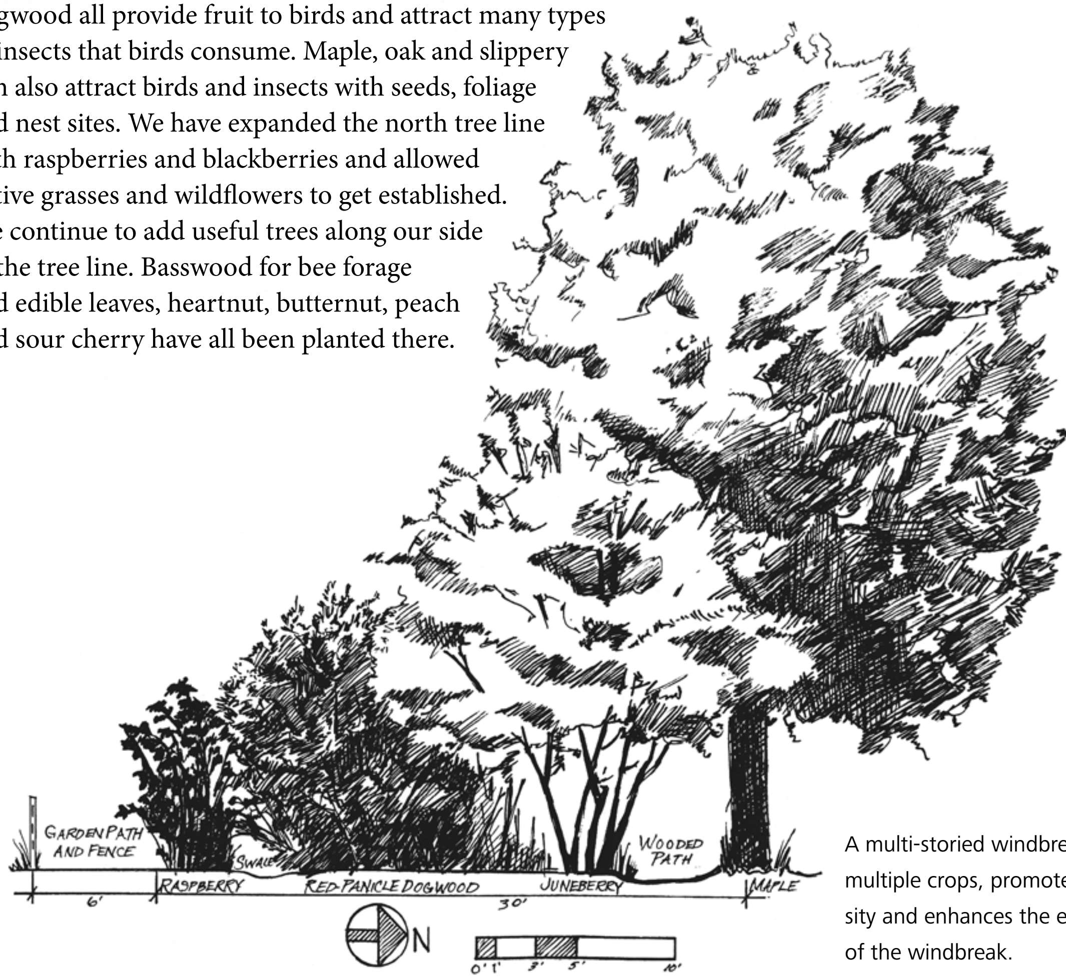
The deer seem to avoid our farm. For 15 years, our well-trained Australian shepherd/collie mix, Nick, assured that with his presence. Because of him, the wily woodchucks retreated to the edges of the tree line. Skunks and opossums pass through but do not dally. The raccoons stay close to the stream, avoiding the farm. Rabbits come and go in cycles,

- Changes in the five-acre field have contributed to increased biodiversity on Three Sisters Farm
  - the building of the pond
  - expansion of the shrub layer in the tree line
  - planting of habitat species and other trees
  - promotion of beneficial habitat with crop plantings and farm management
  - allowance for unmanaged fallow areas between gardens
  - state efforts to restore the bald eagle and osprey to nearby Goddard State Park
- Natural elements that promote species diversity
  - neighboring wood lots
  - neighboring stream floodplains
  - natural expansion of the tree line

but they, too, are wary of dogs. After Nick passed away, the population of woodchucks and rabbits began increasing. A new team of dogs now patrols our gardens — and again the wildlife is under control.

The farm cat helps out by hunting young rabbits in the spring, the moles that tunnel through soft garden beds hunting grubs, and the voles that follow them, hunting our crops.

Many species of animals use the tree lines for either homes or forage. In addition to the animals already mentioned, countless insects and birds either live there or visit in their foraging rounds. Juneberry, black cherry, nannyberry, sumac, elderberry, red ossier dogwood and panicled dogwood all provide fruit to birds and attract many types of insects that birds consume. Maple, oak and slippery elm also attract birds and insects with seeds, foliage and nest sites. We have expanded the north tree line with raspberries and blackberries and allowed native grasses and wildflowers to get established. We continue to add useful trees along our side of the tree line. Basswood for bee forage and edible leaves, heartnut, butternut, peach and sour cherry have all been planted there.




A multi-storied windbreak provides multiple crops, promotes biodiversity and enhances the effectiveness of the windbreak.

STACY DOMER

Bee balm: edible flower, tea herb and a favorite of hummingbirds.

DARRELL FREY

Cardinal flower is a popular wildflower for damp soil.

### *Promotion of Beneficial Habitat with Crop Plantings and Farm Management*

Promoting biodiversity on the farm meant including plants that encourage beneficial insects to dwell in our gardens. Some of the plants we have used include tansy, flowering oregano, milkweed, ironweed, asters, goldenrod, Joe Pye weed, jewelweed, native grasses, clovers, motherwort, anise hyssop, bronze fennel. Most of these provide nectar and pollen for insects.

We manage our mowing and pruning with a sensitivity to the lifecycle of birds and insects, watching for nests and larvae. Herbs are allowed to flower to provide forage for a range of pollinators and beneficial insects. Dill, cilantro and flowering oregano blossoms all are valuable habitat for insects.

We watch for turtle nests near the pond as we work the gardens, and similarly try to avoid injury to snakes, frogs and toads when tilling. Piles of rocks near gardens encourage snakes and toads to take up residence as well.

### *Allowance For Unmanaged Fallow Areas between Gardens*

When we began farming, the field was planted in a mix of clovers and alfalfa. After one season of laying fallow, self-seeded red clover establishes itself in our beds. The next year, aster and goldenrod moves in, and the third year goldenrod moves in. This is an ongoing process, anytime we quit tilling this process happens. As much as 25 percent of our property is dominated by goldenrod. This plant suppresses other plants by its dense growth and allelopathic properties; its roots exude chemicals to inhibit other seeds from germinating. Some sections of the farm have been in goldenrod for 15 years. The suppression keeps trees and brambles from establishing and probably dampens biodiversity. However, goldenrod does supply plentiful nectar in the fall and is known as a host to many beneficial insects. Meadow birds nest in it. Unfortunately, woodchucks like to hide and burrow in the goldenrod meadows.

We generally allow for short-term fallow periods in the gardens and for a lot of "weeds" in and among the gardens. Species such as thistles, burdock, dandelion, chickweed, purslane and lambsquarters all have high food value for wildlife. (For more information, see Martin et al., *American Wildlife and Plants*.) Bull thistles and burdock are allowed to grow in and around our tree lines and orchards. Burdock leaves, stalks and seeds are cut and fed to the chickens spring through fall.

## Applied Observation

As an ecological farm, we strive to continually observe and remember the lives and habits of our many neighbors. The timing of the emergence of various species in the spring, the return of migratory species and their nesting and other reproductive habits are observed — and nurtured when possible. When we see metallic bees emerging from the pith of tansy stems in the spring, we know we should use care when cutting last year's dead stems; we place the stems where the bees will be unharmed. We remove any unwanted milkweed from the gardens before July 5th, when the monarch butterfly returns to lay eggs on them.

As the sparrow population has increased, bluebirds and swallows have declined on the farm. We say each year we will institute a more aggressive campaign to control the population of English sparrows, which compete with swallows and bluebirds for the birdhouses. But it is hard to keep up with them.

Through ongoing observation, we notice new plants and use them as indicators of microclimates and seasonal changes to help guide our land management. It also allows us to do selective weeding and mowing, which are important for habitat management.

Observation is a continuous activity at the farm. Each new species observed is identified with field guides. As best we can, we try to learn about its habits and lifestyle. Just 15 minutes spent observing the myriad syrphid flies, bees, wasps, and other tiny pollinators in our Spiral Garden on a hot summer day will convince any observer of the diversity of life on this plot of land. An hour observing the bird life will likewise testify to the health of the ecosystem. As the farm ecosystem has developed, our production and harvest of diverse products also increase. Yet, we still see room for expanding both productivity and wildlife habitat on the farm.

**Wildlife Observed at Three Sisters Farm since 1988**

- Mammals
  - Common muskrat, *Ondatra zibethicus*
  - Eastern mole, *Scalopus aquaticus*
  - Hairy-tailed mole, *Parascalops breweri*
  - Star-nosed mole, *Condylura cristata*
  - Meadow vole, *Microtus pennsylvanicus*
  - White-footed mouse, *Peromyscus leucopus*
  - Deer mouse, *Peromyscus maniculatus*
  - Norway rat, *Rattus norvegicus*
  - Eastern cottontail, *Sylvilagus floridanus*
  - Woodchuck, *Marmota monax*
  - Eastern chipmunk, *Tamias striatus*
  - Striped skunk, *Mephitis mephitis*
  - Common raccoon, *Procyon lotor*
  - Long-tailed weasel, *Mustela frenata*
  - Short-tailed weasel, *Mustela erminea*
- Rare: Transient visitors
  - White tail deer, *Odocoileus virginianus*
  - Common gray fox, *Urocyon cinereoargenteus* (presumed)
  - Red fox, *Vulpes vulpes (Vulpes fulva)* (presumed)
  - Virginia opossum, *Didelphis virginiana*
  - Common porcupine, *Erethizon dorsatum*
  - Coyote, *Canis latrans* (presumed)
- Amphibian and reptiles
  - Snapping turtle, *Chelydra serpentina*
  - Painted turtle, *Chrysemys picta marginata*
  - Gray treefrog, *Hyla versicolor*
  - Spring peeper, *Pseudacris crucifer*
  - American bullfrog, *Rana catesbeiana*
  - Northern leopard frog, *Rana pipiens*
  - American toad, *Bufo americanus*
  - Eastern milk snake, *Lampropeltis triangulum triangulum*
  - Smooth green snake, *Opheodrys vernalis (Liochlorophis vernalis)*
  - Eastern ribbon snake, *Thamnophis sauritus*
  - Common garter snake, *Thamnophis sirtalis*
  - Racer snake, *Coluber constrictor*
  - Northern two-lined salamander, *Eurycea bislineata*
  - Eastern red-backed salamander, *Plethodon cinereus*
- Fish
  - Bullhead catfish, *Ameiurus* spp.
  - Bluegill, *Lepomis macrochiru*
  - Smallmouth bass, *Micropterus dolomieu*
  - Largemouth bass, *Micropterus salmoides*
  - Yellow perch, *Perca flavescens*
- Birds
  - Ruby-throated hummingbird, *Archilochus colubris*
  - Redwinged blackbird, *Agelaius phoeniceus*
  - American woodcock, *Scolopax minor*
  - Mourning dove, *Zenaida macroura*
  - Common yellowthroat, *Geothlypis trichas*
  - Song sparrow, *Melospiza melodia*
  - Field sparrow, *Spizella pusilla*
  - Dark-eyed junco, *Junco hyemalis*
  - House sparrow, *Passer domesticus*
  - Indigo bunting, *Passerina cyanea*
  - Black capped chickadee, *Parus atricapillus*
  - House wren, *Troglodytes aedon*
  - Eastern bluebird, *Sialia sialis*
  - Eastern phoebe, *Sayornis phoebe*
  - Baltimore oriole, *Icterus galbula*
  - Cardinal, *Cardinalis cardinalis* ☞

  - Blue Jay, *Cyanocitta cristata*
  - Cedar waxwing, *Bombycilla cedrorum*
  - Robin, *Turdus migratorius*
  - Tufted titmouse, *Parus bicolor*
  - White-breasted nuthatch, *Sitta carolinensis*
  - Golden-crowned kinglet, *Regulus satrapa*
  - American crow, *Corvus brachyrhynchos*
  - Northern flicker, *Colaptes auratus*
  - Red-bellied woodpecker, *Melanerpes carolinus*
  - Downy woodpecker, *Picoides pubescens*
  - American goldfinch, *Carduelis tristis*
  - House finch, *Carpodacus mexicanus*
  - Eastern meadowlark, *Sturnella magna*
  - Common nighthawk ,*Chordeiles minor*
  - Tree swallow, *Tachycineta bicolor*
  - Barn swallow, *Hirundo rustica*
  - Gray catbird, *Dumetella carolinensis*
  - Brown-headed cowbird, *Molothrus ater*
  - Killdeer, *Charadrius vociferus*
  - Green heron, *Butorides virescens*
  - Great blue heron, *Ardea herodias*
  - Belted kingfisher, *Ceryle alcyon*
  - Canada goose, *Branta canadensis*
  - Hooded merganser, *Lophodytes cucullatus*
  - Mallard, *Anas platyrhynchos*
  - Great horned Owl, *Bubo virginianus*
  - Red-tailed hawk, *Buteo jamaicensis*
  - Osprey, *Pandion haliaetus*
  - Bald eagle, *Haliaeetus leucocephalus*
  - American kestrel, *Falco sparverius*
  - Cooper's hawk, *Accipiter cooperii*
  - Red-shouldered hawk, *Buteo lineatus*
  - Sharp-shinned hawk, *Accipiter striatus*
  - Turkey vulture, *Cathartes aura*
- Important beneficial insects
  - Honeybee, *Apis mellifera*
  - Orchard bees, *Osmia* spp.
  - Eastern carpenter bee, *Xylocopa virginica*
  - American bumblebee, *Bombus pennsylvanicus*
  - Paper wasps, *Polites* spp.
  - Potter wasps, *Eumenes fraternus*
  - Eastern yellow jacket, *Vespula maculifrons*
  - Braconid wasp, *Apanteles* spp.
  - Black-and-yellow garden spider, *Argiope aurantia*
  - Shamrock spider, *Araneus trifolium*
  - Goldenrod spider, *Misumena vatia*
  - Crab spider, *Misumenoides formosipe*
  - Marbled orb weaver, *Araneus marmoreus*
  - Jumping spiders, *Metaphidippus* spp.
  - Ladybugs, *Coccinella, Adalia* and *Hippodamia* spp.
  - Asian ladybug (Harlequin ladybird), *Harmonia axyridis*
  - Pyralis firefly (Eastern firefly), *Photinus pyralis*
  - Pennsylvania firefly, *Photuris pennsylvanica*
  - Amercan hoverfly, *Metasyrphus americanus*
- Gall midge various types
  - Preying mantis, *Mantis religiosa*
  - Lacewing, *Chrysopa* spp.
  - Brown lacewing, *Hemerobius* spp.
  - Ground beetles, *Pterostichus* spp.
- Butterflies and moths
  - Tiger swallowtail, *Papilio glaucus*
  - Monarch, *Danaus plexippus*
  - Viceroy, *Limenitis archippus* ☞

- Mourning cloak, *Nymphalis antiopa*
- Spangled fritillary, *Speyeria cybele*
- Black swallowtail (parsley), *Papilio polyxenes asterius*
- American painted lady, *Cynthia virginiensis*
- Red admiral, *Vanessa atalanta*
- Cabbage, *Pieris rapae*
- Sulfur, *Phoebis sennae*
- Questionmark, *Polygonia interrogationis*
- Hummingbird moth, *Hemaris thysbe*
- Woolly bear moth, *Isia Isabella*

Chapter 5

# Energy Systems on the Farm

Anyone reading this book is already aware of global climate change and the urgent need to slow or stop global warming. And if you are reading this book, it is likely that you are interested in how a permaculture farm might contribute to that effort. This section looks closely at the issues related to farm energy use and presents strategies for reducing the use of fossil fuels on the farm. It is intended as a primer in solar energy design and the use of biothermal heat from compost and poultry.

Crop and livestock production in the US currently accounts for 6 percent of all fossil fuel consumption. Our food systems, including production, processing, storage and transportation are responsible for nearly one fifth of all energy use in the US. More sustainable agricultural operations — that do not rely on fossil fuel — reduce the release of greenhouse gases that are creating global warming. Moreover, agricultural operations can contribute to the search for alternatives to fossil fuels. An advantage that the market gardener has is the ability to tailor small-scale production systems to specific tasks. The non-industrial farmer can try various conservation strategies, rediscover traditional farming practices, and work with the cycles of nature. These systems can be much more efficient than electricity from the power grid.

*Bioshelter in spring.*

**Approaches to Better Energy Use on the Farm**

- Farm Facilities and Operations
  - Sustainable design is site specific.
  - Energy planning begins by observing and auditing use.
  - Upgrade to energy efficiency.
  - Explore options of alternative technologies.
  - Purchase green energy from utility companies.
  - Reduce use through conservation measures.
  - Observe energy use.
  - Develop appropriate alternatives that are site specific.
  - Conserve energy through sound design and construction.
  - Minimize operating costs with conservation and efficient use of energy.
  - Incorporate renewable energy when possible.
  - Use local materials and locally appropriate design measures.
  - Vote for representatives that support alternative energy policies and pay attention to political issues surrounding renewable energy.

(Based on ATTRA Publication #IP220
"Efficient Agricultural Buildings: An Overview.")

- Building Design Elements
  - Natural lighting (as much as possible).
  - Airtight construction.
  - Adequate and proper insulation.
  - Passive solar capture.
  - Summer shading.
  - Natural ventilation.
  - Energy- efficient doors and windows.
  - Efficient heating and cooling systems.
  - Windbreaks that minimize heat loss by reducing wind chill effect.
  - Earth berms that reduce heat loss.
  - Re-used or recycled materials (when appropriate).
  - Upgrade buildings and equipment to efficiency).
  - Building heat: dual fuel, wood and biofuel.
  - Transition equipment to biodiesel and ethanol when appropriate.
  - Reduce energy use by weatherizing buildings.
  - Build soil fertility with organic matter, compost and manures to add carbon to soil.
  - Combine trips to reduce fuel consumption.

## Conservation

Energy conservation is the first step in reducing fossil fuel use. Performing an audit of your farm's energy use will help identify conservation strategies. To begin, make a list of all energy uses:

- Electrical motors (fans, pumps, refrigerators and coolers, etc.)
- Lighting
- Space heating
- Water heating
- Office equipment
- Farm equipment

Although your electric bill probably lists the total kilowatt hours (thousand watts used each hour) you use each month, a review of the energy demand for each machine, appliance, etc., can help guide your reduction of energy use. Once you have a clear picture of farm energy use, you can brainstorm strategies to reduce energy use and replace purchased energy with alternative sources.

## *Energy Strategies at Three Sisters Farm*

We have designed many energy conservation measures into our bioshelter. These include the use of windbreaks and earth berms (discussed in detail in Chapter 7), heavy insulation and passive cooling.

When we built our bioshelter in 1988, we estimated a similar-sized greenhouse would require $3,000 per year to heat, using over 4,000 gallons of fuel oil. At 2010 prices, this would be nearly $12,000 per year. By incorporating energy-saving features into our design, most of our $80,000 initial construction cost has been paid back in fuel cost savings alone.

The design of our polytunnel greenhouses eliminates the need for cooling fans in the warmer months. These two "high tunnels" are 15 feet wide and 45 feet long, providing 600 square feet of protected growing space. Because they are oriented to run east to west, are under 50 feet long, and have wide doors on each end, these tunnels are cooled passively and do not require electric fans to ventilate. During the winter season, they are sealed on the ends and protected on the north side by a stack of straw bales, thus reducing heat loss and extending the season by several weeks in the fall and spring.

Cooling costs are reduced by limiting the use of our refrigerated walk-in cooler to two days per week. We only use it for harvests prior to delivery. No inventory is kept in the cooler between harvests.

Our primary tillage equipment consists of an 8-horsepower gasoline rototiller and simple hand tools. Mulching, interplanting and weeding with hoes minimize the use of the tiller and helps protect soil structure. We do as little tilling as is practical.

## *Human Energy*

Human energy is a vital part of the permaculture farm. So, keeping the farmer healthy and able is important. Good food, interesting work and enough rest is essential. Good organization and the proper tools (and good weather) allow for production to flow smoothly without overtaxing the gardener. We have established daily and weekly cycles of tasks; a variety of tasks helps keep the mind fresh and free from daily monotony.

Much of our garden work takes place before 1 p.m. and after 4 p.m. each day. This allows for a long lunch break during the heat of the day. We generally provide our farm crew with a balanced lunch, including a lot of salad and other vegetables. The combination of good food with the mid-day break helps keep us productive and happy.

We have applied permaculture design concepts in our human energy planning as much as possible. Because of this, the tasks of tending the chickens, young seedlings and bioshelter plantings flow in an easy routine. Gardens are laid out so that those needing the most intensive management are closest to the bioshelter. Composts piles are located up slope from gardens so we do not have to haul wheelbarrows and cart loads uphill. Water storage tanks are placed so gravity can do the job of moving irrigation water down slope to the gardens. We have established harvest-day routines that everyone follows. This allows for a smooth process of harvesting, cleaning and storing produce.

## *Wood: A Renewable Resource*

Burning wood for heat does not return fossil carbon dioxide to the atmosphere and, in theory, will not increase carbon levels (on a geological timeframe). However, large-scale burning of forests to convert them to agriculture does contribute to atmospheric carbon dioxide buildup and global climate change because forests that could absorb $CO_2$ are lost. Therefore, the use of wood as a fuel requires sustainable forest management to be considered a viable fuel option. The acreage of forest in Pennsylvania has increased in recent decades as farmland is abandoned and reverts to woodlands. Many foresters are advocating sustainable forest management practices. These considerations allow the proper use of firewood to be considered sustainable in Pennsylvania.

We obtain our firewood for the bioshelter from local sawmills. We buy mostly cut slabs that are a byproduct of milling lumber. We buy firewood in summer to allow it time to dry before we need it.

Efficient use of firewood, that is, gaining the most heat and producing the least pollution, requires two things: fast burning of the wood and storing heat in thermal mass. (Thermal mass is any substance that will absorb heat and then slowly release it. It is discussed in more detail below.)

Our bioshelter has two wood stoves. A cast iron stove heats the air when outside nighttime temperatures fall below freezing and days are cloudy. This stove is adjacent to a large mass of concrete and barrels of water, which absorb some of the heat and radiate it back to the building when the stove cools down.

The key to burning this stove efficiently is to get a load of wood burning very hot to burn off the wood's gases before turning the stove to a lower setting. Closing down the stove too soon and burning wood too slowly is inefficient and creates polluting gases and flammable creosote in the chimney.

**Home Heating**

Home heating is responsible for 62 percent of the energy used in the average household in the northeastern US. The average household uses 730 gallons of fuel oil a year. At approximately 134,000 Btus per gallon, this represents nearly 98,000,000 Btus per household. According to the US Department of Energy (DOE), using this much fuel oil releases over 15,000 pounds of fossil $CO_2$ into the atmosphere. Heating the average home with propane releases nearly 14,000 pounds of fossil $CO_2$. One should note that the use of electricity to heat a home generally requires 3 Btus of fuel to create 1 Btu of home heat. Therefore, use of electricity produced in a coal-fired power plant can release three times as much $CO_2$ as a home furnace. For the average home in the northeast US, that means 45,000 pounds of $CO_2$ are released annually.

Using firewood to provide the same amount of heat releases over 19,000 pounds of $CO_2$ into the atmosphere. However, this $CO_2$ does not add to the net increase of atmospheric $CO_2$ because the carbon released has not been stored geologically for many million years. Moreover, wood is a locally available resource, is renewable in a lifetime, and is considered "biogenic" or of biological origin (as opposed to "fossil" fuels). According to the DOE's Energy Information Administration (EIA) "Under international greenhouse gas accounting methods developed by the Intergovernmental Panel on Climate Change, biogenic carbon is part of the natural carbon balance and it will not add to atmospheric concentrations of carbon dioxide. Reporters may wish to use an emission factor of zero for wood, wood waste, and other biomass fuels in which the carbon is entirely biogenic." (Data is from eia.doe.gov.)

Regardless of its origin, it is important to reduce all $CO_2$ use. By using energy-efficient wood stoves, we've reduced the amount of wood we use on the farm to about 2½ cords of hardwood. That amount of wood provides us with approximately 60,000,000 Btus and releases approximately 11,700 pounds of biogenic $CO_2$.

Our second wood stove in the bioshelter is an aluminum "Snorkel Stove" (see it at snorkel.com) submerged in a 600-gallon water tank. This is used when outside nighttime temperatures fall below 20°F. (Temperature measurements throughout this book are Fahrenheit) A fast-burning fire transfer heat directly to the water, resulting in minimal heat loss and maximum efficiency. The stove will heat the 600 gallons of water 10° per hour. This is an output of 49,860 Btus per hour. The water tank then acts as a radiator, providing heat to the building through the cold night. The warmed water is also used for irrigating plants in the bioshelter. The water flows by gravity out of the tank through weep hoses, warming the soil and encouraging plant growth.

Together the two stoves use fewer than three cords of wood each year.

## Biothermal Resource Recovery

Biothermal energy resources used at Three Sisters Farm include heat recovery from compost and the body heat of chickens. We first learned about this somewhat novel greenhouse heating system through the New Alchemy Institute. After visiting the Institute in 1988, we decided to integrate the system into our own bioshelter. We found support for the approach in other places as well. In *Permaculture One,* Mollison and Holmgren used the idea of combining a chicken house and greenhouse as an illustration of permaculture design. Anna Edey applied this idea — using poultry for supplemental heat and $CO_2$ — to her Solviva Bioshelter on Martha's Vineyard.

### *Biothermal Heat*

The capture and use of heat from a compost pile is an ancient practice. But it is not used much these days. Although it is standard greenhouse practice to encourage seed germination by supplying bottom heat to germination trays, this is usually done using electric heating pads — which, of course, rely on networks of nuclear, coal and natural gas power plants. The use of biothermal heat from compost to provide bottom heat for germinating seedlings requires only a source of compost materials, a compost bin, a pitchfork and some human labor.

(The composting process also generates $CO_2$, water vapor and ammonia gas. Chapters 9 through 11 detail the use of compost for supplemental heat and $CO_2$ enrichment in the bioshelter.)

### *Chickens in the Greenhouse*

Inspired by permaculture theory, we wanted to integrate egg-laying hens into our farm nutrient cycle and pest control strategies. The success of Anna Edey's Solviva Bioshelter encouraged us further, and we built a room for a flock of chickens in the bioshelter so we could "harvest" the chickens' body heat and $CO_2$ to aid plant growth. Following the lead of Solviva, we selected the northeast corner of the building. This location, away from the food processing side of the bioshelter, allowed for the development of an adjoining chicken yard.

The room is sealed from the rest of the bioshelter with a vapor barrier, so we can control the air exchange between the poultry room and the rest of the bioshelter. Fresh straw is placed on the poultry room floor daily to prevent odor and conserve nitrogen on the droppings. This bedding is allowed to accumulate during the winter; it becomes a source of heat and $CO_2$ when it is composted.

Our flock of 40 hens and two roosters has free access to the outdoors most of the year (except during periods of very cold weather, when they are kept inside). A compost chamber blower pulls the warm, $CO_2$-rich air out of the poultry room and sends it to rock storage areas beneath the raised growing beds which absorb the heat and act as thermal mass. Each bird produces around 720 Btus per day, so 40 birds produce about 28,000 Btus per day. It's a small amount of heat — equivalent to a gallon of fuel oil every five days, but in the three to four months of a heating season, the chickens provide enough body heat to save 20 to 25 gallons of conventional fuel.

## Solar

### *Winter Heating: The Ideal*

Just before dawn, the temperature outside is 25°; inside the bioshelter it is 50°. The day breaks bright in the cloudless sky. As the sun arcs low across the blue winter sky, its light and energy sweep through the solar building, penetrating the far corners, heating the air inside, recharging thermal mass throughout the building. Plants respond to the light and warmth, synthesizing sugar and processing nutrients, building leaf and bud.

Temperatures in the building rise slowly through the morning, from 50° to 60° by 11 a.m. The blowers are turned on to direct the extra heat so it can be stored in the rock and soil of the deep growing beds. At noon, the temperature on the second floor is 70°; by 2 p.m. it is 90° on the second floor and 75° on the first floor. At 3 p.m., as the temperature approaches 100° on the second floor, windows and a vent or two are opened to release excess heat. Soil surface temperatures rise several degrees by midday.

As the sun approaches the horizon and the temperature begins to drop, windows and vents are closed. The temperature drops slowly through the evening. By 9 p.m. the second floor is 75°; the first floor is 60°. The heat recovery blowers are turned off. By midnight, the building settles to a uniform 60°. In the pre-dawn darkness, the air temperature returns to 50° once again.

### *Winter Heating: Reality*

The reality is that perfect days are spaced out, especially here in northwestern Pennsylvania. Most discouraging is a heavily overcast day, with virtually no solar gain, followed by a clear, starry night when outdoor temperatures plummet. Many factors affect building heating and cooling. Presuming a well-built structure, one can expect heat to be lost at a calculable rate through walls, glazing and air leaks. This rate increases as the temperature outside drops. Wind chill increases heat loss by, in effect, dropping outdoor temperatures.

*Heat gain* is dependent on the amount of sunlight entering the building, especially at midday, when the angle is most direct. On slightly overcast days some light, and thus heat, is gained. Charts used to estimate solar gain in a given region generally report *average gain,* that is, the average of sunlight typical for a given month. The numbers are given as Btus per square foot. This average presumes the normal pattern of sunny days and cloudy days in a region.

When heat loss from the solar building due to cold temperatures outside exceeds heat gain from the sun, supplemental heating is required to prevent the building from getting too cold. Thermal mass can be viewed as a battery. Sunlight charges the mass. During periods of extended cold, cloudy weather the "batteries" of thermal mass run down. Supplemental heating has to maintain the temperature until the sun shines again. Because our ground temperatures average 50°, the un-insulated floor acts as a heat source when the inside temperature is below 50°.

A sunny mid-winter day will give one to two days charge to the thermal mass — no supplemental heat is needed. After that, the wood stove is burned at night. We prefer a nighttime air temperature no lower than 45°, but 50° is preferable. Without supplemental heat, our building tends to stay about 20 degrees above outside temperatures through winter. So anytime the outside air temperature is below 25°, we burn the wood stove. When the outdoor temperature is below 15° we also heat the irrigation tank to at least 100°. This radiates heat through the cold night. When it is below zero outside, we burn both stoves very hot and use a fan to circulate the warm air from near the stoves to the east and west ends of the building.

## *Understanding Solar Energy*

Passive solar design is designing to provide for the heating of a structure with direct sunlight. Active solar is the use of fans or water pumps to move the accumulated heat to storage. Good solar design begins with *passive* solar collection. Depending on climate and building design criteria, *actively* moving heat to storage can enhance building performance considerably.

The use of sunlight for heating a structure requires understanding a number of factors. These include:

### How Hot Is It? British Thermal Units, Calories and Joules

The British thermal unit (Btu) is commonly used as a measure of heat energy in the US. *Heat* is energy that moves from a warmer object or area to a cooler object or area. In the equations used to measure energy transfer, heat is symbolized by the letter "Q." The physics of heat, also known as thermodynamics, is a complex science, and exact measurements vary slightly based on initial temperatures and other variable factors. This variance is not critical to solar design. Basically, a *Btu* is the amount of heat energy required to raise the temperature of one pound of water one degree Fahrenheit. A Btu is also equivalent to approximately 253 calories. A *calorie* is the measure of the amount of energy required to raise the temperature of one gram of water one degree Celsius. Most heating systems measure the number of Btus produced per hour. So a 150,000 Btu furnace has the capacity to produce 150,000 Btus each hour.

Outside of the US, the joule is the common measure of heat energy. A *joule* can be quantified as the measure of the energy required to raise the temperature of one gram of dry air one degree Celsius. A calorie is 4.184 joules. Roughly speaking, a Btu is equivalent to 156 joules.

- Orientation of the structure for maximum light and heating
- Angle of glazing relative to angle of sun above horizon
- Average solar gain at various times of the year
- Heat loss from the building
- Heating and cooling needs of the structure
- Heat storage capacity of the thermal mass materials

Average solar gain is measured in Btus per square foot. This is a direct measurement of the heat generated when sunlight strikes a given surface. Maps and charts of average solar gain for specific locations are found in publications on solar design and are available from most state governments. The term *average* means the measure takes into consideration the area's cloudy days. So it is not a measure of actual heat expected to be gained on a sunny day, but the daily average for the time of year. We used data in "The Pennsylvania Renewable Energy Assessment" (see Resource List) for our calculations. This assessment provided the average solar gain at the summer and winter solstices and the spring and fall equinoxes. (Note: All the figures, formulas and charts mentioned in this chapter are included in the appendix at the end of this book, "Greenhouse Heat Dynamics: Figuring Solar Gain, Solar Storage, and Heat Loss.")

## *Design for Extreme Weather*

When designing a greenhouse or similar solar structure designed to let sunlight in, you need a plan that will allow you to maintain desired temperatures even during extremes of weather. This means planning for insulation, weatherization and possibly a backup heating system that will keep temperatures above freezing (at least) on the coldest day in winter. You also need a ventilation system that protects the plants and glazing system on the hottest day of summer.

### Orientation

Besides insulation, orientation to the sun is the simplest way for any building to capture and retain energy. Maximum gain is achieved by facing the long, glazed side of a greenhouse toward true south. If obstructions prevent this, make sure to include the difference in your calculations. Variation to the east or west by up to 20° reduces solar gain

## Finding the Right Direction in a Changing World

Solar south varies from magnetic south in most places. The compass alone is not an accurate tool for finding true solar south. This is because magnetic north varies from true solar north. This variation is known as *magnetic declination*. True solar south is determined by locating magnetic south and then adjusting for the compass's deviation.

The magnetic poles are the points where the earth's magnetic field passes through the planet's surface. A compass needle aligns with the lines of magnetic force connecting the northern and southern magnetic poles, therefore it points toward magnetic north and south.

As of 2008, magnetic north is located in Arctic Canada; it moves about 40 kilometers north each year. So, in any given location the difference between the physical North Pole and the magnetic north pole changes slightly each year.

To accurately plot solar south with a compass, one needs to know the current deviation between the North Pole and magnetic north for the site. NOAA's National Geophysical Data Center's website www.ngdc.noaa.gov/geomag/declination.shtml provides maps and tools for calculating the current magnetic declination for any location in the US.

At the time of this writing, in western Pennsylvania the magnetic deviation of south is about 9° west. This means that solar south is 9° west of magnetic south. So, for a greenhouse at this location, you would begin by placing a stake in the ground where the northwest corner will be located. Place a compass on the stake and sight a line leading 9° west of magnetic south. (A good compass will have 360° marked on the dial.) Place the stake along this line at the southwest corner of the building. The structure's south wall is then laid out perpendicular to this north-south baseline.

Other ways to find solar north and south include sighting a base line from the North Star at night or aligning it to the sun's position at solar noon.

by 5 percent. Variation by 30° reduces gain by 10 percent. The numbers seem small, but they can be significant relative to heat gain and plant growth, so any orientation over 30° away from true south is to be avoided. When a building is oriented 45° away from true south, solar gain is reduced by over 25 percent.

Because sustainable design is site specific, there may be locations and situations where such a variation is helpful. For example, if a location consistently has morning fog or cloud cover, orienting for the afternoon sun may provide the best gain. On steep land and in urban areas, the landform, vegetation, or surrounding buildings may restrict some solar gain in the morning or late afternoon. In these cases, the building should be oriented to receive the maximum amount of sunlight available.

When adding a greenhouse to existing buildings, careful consideration of solar restrictions should be made to determine potential performance.

## Glazing — What's Your Angle?

The angle of the glazing is relevant to the quantity of sunlight entering a greenhouse and how far it penetrates into a building. Design of the glazing system (glazing material and glazing support components) is critical to the successful functioning of a greenhouse, in terms of both solar gain and plant growth. Maximum gain of light into a building is achieved when the glazing is perpendicular to the sun. But this ideal really only occurs for a few minutes each day, at noon. What you are planning for is optimum solar gain throughout the day.

You need ask a number of questions when planning your glazing angle: What thermal performance is really desired? What is the worst-case scenario of winter snow load? What type of glazing will work the best and be affordable?

There are many options for the designer to consider, depending on production goals. Glazing may be vertical or angled or it may arch completely over the structure. For glass to be angled, it must be tempered safety glass and have an appropriate (strong) support system. The cost of such a system is out of reach for most agricultural enterprises. However, glass is well suited to use on vertical walls. For angled glazing, rigid plastics such as acrylic, polycarbonate, fiberglass-reinforced plastic, and plastic films are often better choices.

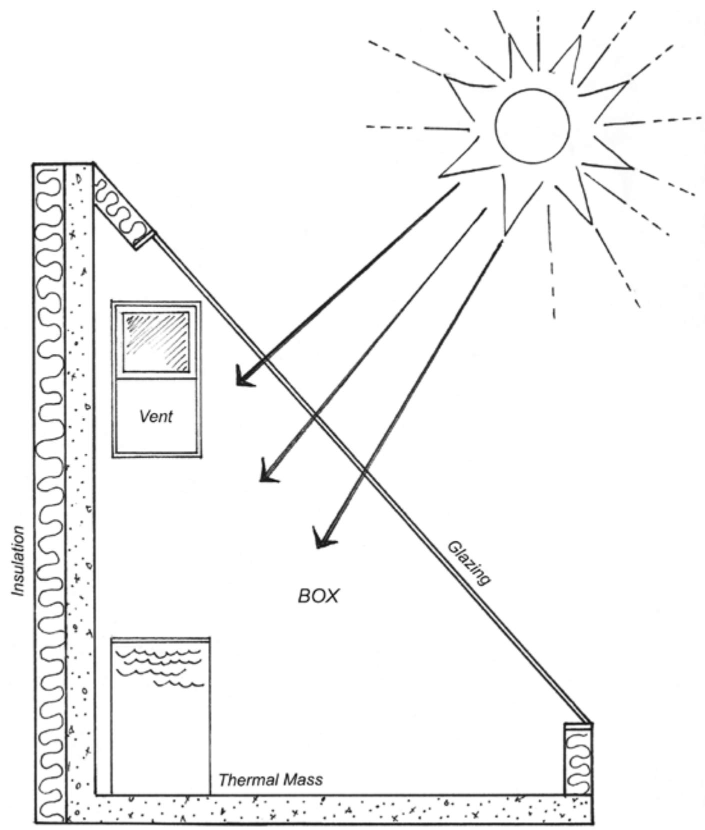
## Seasonal Sunlight

**Solar angle:** The path of the sun across the sky changes daily. The higher the latitude, the lower the sun is in the winter and summer sky. Three Sisters Farm is 42° north of the equator, so the angle of the sun above the horizon at noon is roughly 25° on December 22, 49° on March 22 and September 22, and 72° on June 22.

**Solar azimuth:** The azimuth is the angle of the sun relative to the south along the horizon, as viewed from above. In winter, these angles are smaller than in summer. Roughly speaking, in the US, the winter sun rises in the southeast and sets in the southwest. On the spring and fall equinoxes, the sun rises in the east and sets in the west; and in summer, the sun rises in the northeast and sets in the northwest. More light will enter glazed east and west walls from late spring through early fall; less will enter in winter. Because solar gain through the end walls is negligible in winter months, it is often better to reduce end wall glazing and add insulation for winter production.

### Incidental Light and Direct Light

Direct light is sunlight that shines directly into a building. Incidental light is light diffused by the clouds and sky. In Pennsylvania, clouds often cover the sky 50 percent of the time, so knowing how much incidental light is available was an important design consideration. While heat from incidental light is negligible, plants appreciate any light they can get. The choice of how much to glaze a roof is a tradeoff between the need for light (incidental and otherwise) and the need to supplement with heating or ventilation. After nearly two decades of managing the Three Sisters bioshelter, we have concluded that the extra light we would gain from a partially glazed north roof would be worth the extra cost of firewood to heat the building (glazing loses more heat than insulated roof). Our planned renovation incorporates a continuous, glazed vent in the north roof that will provide this extra light. If our bioshelter were located 40 miles south — farther away from the lake effect snow and the cloud belt — we would probably not need the adjustment.

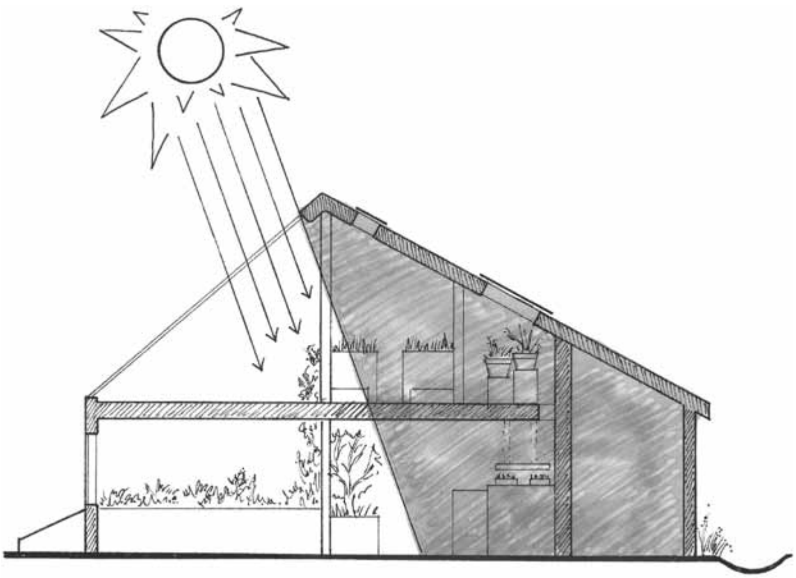


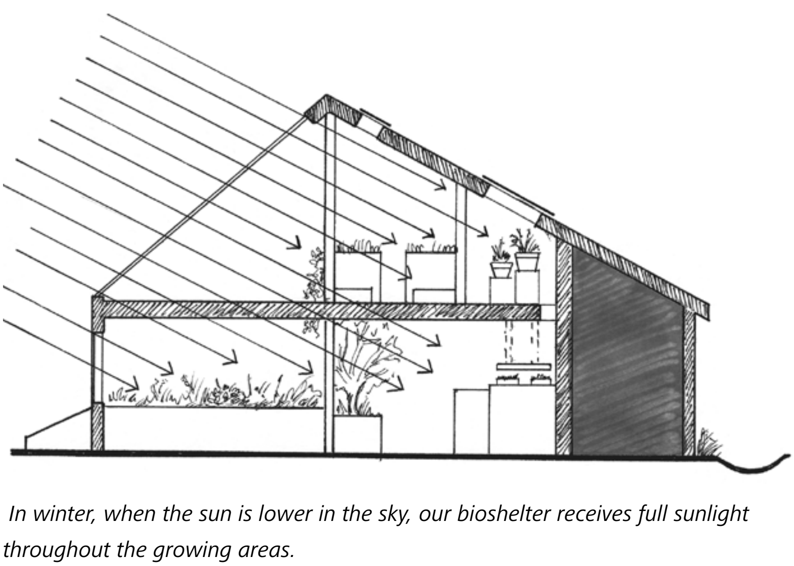

*Whether designing a solarium, greenhouse, cold frame or water heater, all include the following components: a frame structure, glazing to allow light to enter, thermal mass to capture and store heat, and ventilation. Insulation helps improve the efficiency of a solar structure.*

## *Solar Gain*

As already mentioned, a greenhouse should be oriented for maximum exposure to the sun, generally due south.

*In summer, when the sun is higher in the sky, our bioshelter is partly shaded by the north roof, keeping building cooler.*





*In winter, when the sun is lower in the sky, our bioshelter receives full sunlight throughout the growing areas.*

Glazing should be angled to maximize light penetration into the building. Each surface the sunlight strikes in the building receives energy as heat. (See appendix for formulas.) To determine a building's solar gain for a given season, multiply the square footage of glazing by Btus per square foot. In northwestern Pennsylvania, we receive an average of 1,200 Btus per square foot in December. Our bioshelter has a south-facing glazed area of 2,000 square feet. So, in December we have an average daily solar gain of 2,400,000 Btus.

### *Thermal Mass*

Thermal mass is material that acts to absorb and release heat. Different materials have different capacities to absorb and store heat (the thermal mass of the most common materials are listed in the appendix). In a sustainable greenhouse, thermal mass is used to store excess heat so it can be used later. Common storage media include water, stone, concrete, soil, wood and metal. Of these, water has the greatest capacity to absorb heat when the surrounding environment is warmer and then release it when it is cooler. Water's heat storage capacity is highest — by far — followed by wood. Soil, rock and concrete are much lower. Knowing the heat storage capacity in a greenhouse will help determine the size of the backup heating system.

## Heat Absorption Capacity

As already mentioned, a Btu is the amount of heat needed to raise a pound of water one degree. You will see water listed in solar design publications as having a "specific heat capacity" of 1.00 Btu per pound per degree Fahrenheit (Btu/lb./degree F). That sets the *relative heat absorption capacity* of a pound of water at 1.00 (relative to the heat capacity of other material).

Compared to a pound of water's heat capacity of 1.00, a pound of wood is rated at 0.33, meaning it takes about three Btus of heat to raise the temperature of wood one degree. Concrete, soil, sand, brick and stone have rates between 0.20–0.23. Steel has a heat storage capacity of 0.12. So, pound for pound, it takes almost ten times as much heat to raise the temperature of steel one degree as it does to raise a pound of water one degree.

### *Density*

The density of a material (measured as pounds per cubic foot) relates to its function as thermal mass. Water weighs 62.4 pounds per cubic foot (8.3 pounds per gallon). Concrete weighs 150 pounds per cubic foot; wood varies from 20 to 30 pounds per cubic foot; steel weighs almost 490 pounds per cubic foot. Therefore, a cubic foot of steel, while probably not cost effective, is nearly as good at storing heat as a cubic foot of water.

Concrete and stone each have about half the storage capacity of water per cubic foot. The other common heat storage media are soil, brick and sand, which have one third the heat storage capacity of water per cubic foot. However, a planter of soil, when properly moistened by daily watering, will have a higher heat storage capacity than dry soil, perhaps being twice as efficient at absorbing and releasing heat.

**Heat Storage Capacity: The Simple Explanation**

When calculating the performance of thermal mass, the density of the material (pounds per cubic foot) is multiplied by its heat absorption capacity to quantify its role in the solar heating system.

Specific heat capacity x density = heat storage
Btu/lb. per degree F x lb./cu. ft. = Btu/cu. ft. per degree F

**Example: Water**

Water weighs 62.4 pounds per cubic foot. If there is a one-degree temperature difference between surrounding air and a cubic foot of water, the water will absorb 62.4 Btus of heat. Conversely, if the air drops one degree, the cubic foot of water will release 62.4 Btus of heat.

1 x 1 degree x 62.4 = 62.4 Btus per cubic foot per degree F

### Sizing Thermal Mass

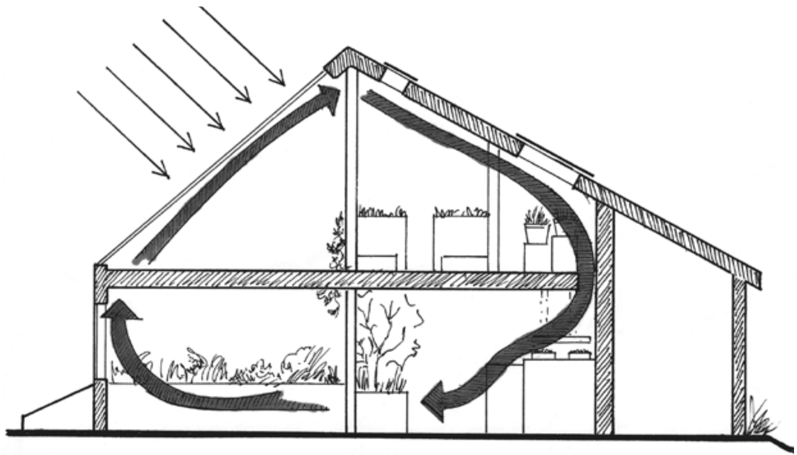
The size of the thermal mass relates to its performance. For example, if hot air is actively blown onto a bed of 3- to 5-inch diameter stones, the air circulates around the stones and is easily absorbed. But a single large stone that weighed the same as all the smaller stones put together would have less surface area to absorb and release heat; therefore, it would be slower to heat and cool. Similarly, the size of pots, planters and water containers affects their efficiency at heat absorption. Larger tanks of water, like our 600-gallon tank, provide a lot of thermal stability but are slow to absorb and release heat over a period of days and weeks. Fifty-gallon barrels of water are more reactive; they can heat up and cool down over a period of days. Smaller containers, such as five-gallon buckets warm up quickly but can release absorbed heat before the night is over.

In a greenhouse, a mix of materials — water, concrete and soil — in different configurations provides stability. Large masses keep the average temperature from falling too low; medium and small masses act to moderate daily temperatures. True to permaculture principles, greenhouse design should incorporate the ability of thermal mass to serve multiple functions in a building. Examples of multifunctional mass are concrete foundation walls (insulated on the outside), concrete soil beds, massive masonry stoves, fish tanks, planter beds, potted plants and barrels of water used to support plant tables.

Because the heat storage capacity of the water vapor is high, humid air holds more heat than dry air. So the rocks under the deep beds that help drain them also capture and release the heat because when the warm, moist air passes through the soil, it condenses on the cooler rocks, and releases this heat. It's similar to what happens when warm air in the car fogs the cooler window.

### In the Light

Location of the thermal mass in a greenhouse is important. Thermal mass is much more efficient as storage when sunlight shines directly on it. Direct sunlight on steel and plastic barrels heats the barrel, and the heat conducts through to the water. If the barrel is shaded, warm air will still warm the barrel and the water, but not as rapidly. However, while it is preferable to have mass in direct light, mass also needs to be evenly spaced around a building. And there are other factors to consider. For



*Warm air drawn from the second floor warms the first floor growing area. A thermal loop can form naturally in the well designed building, and can also be enhanced with fans or blowers.*

example, we avoided placing our 400-pound barrels on the second floor. In addition to the weight, warm moisture condensing on the cool barrels would pool on the (wooden) floor and eventually cause decay. We limit most of the mass on the second floor to large planters with controlled drainage.

Because heat rises, a building will be much warmer near the ceiling. A thermal loop of circulating air can be created by allowing an air return space along the back wall of a greenhouse. Heated air will rise to the ceiling along the glazing and cooler air will fall down the back of the building. Actively moving air from the higher levels to lower levels of a building can help capture the extra heat and direct it to storage.

Thermal mass also can help *cool* a building in the summer. The mass in a ventilated building will cool at night and absorb heat in the day, stabilizing temperature extremes.

## *Building Performance*

When the sun shines, the mass recharges. In the cool of nighttime, the heat radiates out from the mass. As already mentioned, storage capacity is the temperature increase in material from energy absorbed by the mass when the sunlight hits its surface. *Functional storage capacity* is the expected temperature range in the mass.

Calculations begin with the desired average temperature in mind. We want the soil temperature in the large planters and beds to be at least 50°, so our bioshelter temperatures need to average not less than 50° in the winter. Expected temperature range in the bioshelter is from 50° to 80°, or 30°. In other words, the base building temperature we desire is 50°, and the warmest our mass will get is about 80°.

To calculate storage capacity of a building in Btus:

- List the materials that make up the building's mass.
- Determine the total cubic foot volume of a given material.
- Consult the chart in the appendix for the material's heat storage capacity.
- Convert the volume to pounds per cubic foot using the chart's figure for the material.
- Multiply pounds by specific heat capacity of the material to get Btus per cubic foot per degree capacity.
- Multiply Btus per cubic foot by 30° functional capacity.
- Repeat for each material.
- Add together all calculations for total heat storage capacity.

### *Determining Building Heat Loss: Conduction, Convection and Infiltration*

The next calculations required for determining a building's heating needs is the amount of heat lost by the building at night and on cold, cloudy days. Heat moves at measurable rates that increase as the temperature difference between the inside and the outside increases. In a well-sealed building, energy is lost mainly by conduction through the walls and roof, and convection of heat from the building's exterior surface. This convection loss increases with temperature difference and wind speed. The other main heat loss is from *infiltration,* which is the air exchanged between the building and the outdoors through general use of doors and all those small air leaks around windowsills, frames of doors and vents. (All buildings exchange air with the outside; by sealing leaks, the amount can be reduced but not eliminated, so infiltration should always be part of the calculation.) Total heat loss from the building is conduction loss plus the infiltration loss through air exchange.

#### Conduction

Heat loss from a building depends largely on the insulation value of materials and the temperature difference between inside and outside.

Anytime it is colder outside than inside, heat will conduct through the walls, roof and floor. Conduction, or heat transfer through a material is measured as a *U value*. The *R value* is the inverse of the *U* value; it is the measure of resistance to heat transfer, or insulation value. The rate of this conduction is determined with formulas provided in the appendix.

To determine and add heat transfer values from materials, calculate:

- Total square footage of glazing (probably R-1)
- Total area of insulated walls (R-19, or better, R-30)
- Total area of insulated roof (R-30 to R-40)

The total of these areas equals conduction loss from the building per degree per hour. To clarify, heat loss is a measure of the hourly loss *and* the heat loss increase as the temperature difference between the inside and outside increases. Therefore, the calculations for building heat loss are measured "per degree per hour."

Assuming the foundation's perimeter is insulated, the un-insulated floor may also be considered as a heat loss down to 50° (at our location), but this is not a significant factor. Ground temperatures vary depending on latitude. When the inside air temperature drops below 50°, the floor becomes a heat *source*. This can be significant; in fact, it is the basis for plant survival in unheated cold frames and polytunnels. The ground temperature also helps cool the building in summer.

## Air Exchange Heat Loss

The next step in determining heating needs is to determine the average expected heat loss through normal air exchange (infiltration). Generally, it is assumed that all the air in a heavily insulated and weatherized building will change each hour. Air exchange heat loss is calculated as loss per degree of temperature difference between the inside and outside and per hour of the heating period.

See appendix for the formula used to determine the amount of heat stored in a cubic foot of air.

## Adding It Up

Calculating the total heat loss, conduction (heat loss through the building's walls, roof and glazing) plus infiltration (heat loss through air exchange with outside) gives the total Btus of energy lost per degree of difference between the inside and the outside every hour. This total is used to figure out a building's heating needs per hour and then for a 14-hour winter night, the assumed heating period.

For example if the temperature is -10°, and you want a 50° inside temperature, you multiply the heat loss per degree of difference by 60°. This gives the heating requirement in Btus per hour.

Finally, compare solar gain, storage capacity and heat requirements to estimate performance. This can (and should) be repeated for other seasons for year-round performance estimates.

### *Determine Energy Needs*

Once the heat gain and heat loss for a building is determined, you need to estimate how much supplemental heating and cooling you will need.

**Heating:** Compare the solar heat gain and the building's nighttime heat loss for the coldest expected day. For example, when the outside temperature is –10° and you want to maintain 50° inside, you need to balance heat loss from the building. First you determine the Btus lost per hour per degree from the building. Multiply this by the 14-hour winter nighttime heating period, then subtract the average daily heat gain in mid-winter. The difference is your heating needs for the worst-case night.

Example:

- Btus lost per hour: 100,000 x 14 hours = 1,400,000 Btus
- Daily solar heat gain: 800,000 Btus
- 1,400,000 minus 800,000 = 600,000 Btus of heat needed
- Dividing this number by the 14 hours you'll need the heat shows that you will need approximately 43,000 Btus per hour of supplemental heat.

A further consideration is a worst-case scenario of successive days of *no* gain due to clouds and snow. Obviously, you would need to increase supplemental heating capacity accordingly.

Although some greenhouse operations require hot water, we do not currently use hot water in the bioshelter. If we do install a hot water heater, we will use the sun to preheat the water. (We do, however, have a nifty solar shower for summer use. It consists of 300 feet of coiled plastic pipe set on top of a shower frame. Water from our well is pumped through the pipe and the sun warms the water in the pipe. With its 3-gallon-per-minute nozzle, it provides a long, hot shower in the afternoon on most summer days. We plan to upgrade this with a small holding tank to allow for evening showers as well.)

**Cooling:** The calculation of cooling needs is a similar process. Determine heat gain through glazing in the middle of June, when the days are the longest. Then determine how much volume of air needs to be moved out to keep temperatures at 90° or lower. Again, use the equation for heat storage capacity of a cubic foot of air multiplied by the cubic feet of building volume.

Deep beds and large planters will absorb heat during the day and release it at night. In the bioshelter, we generally leave the vents open 24 hours a day in the summer to aid the cooling process. On very hot summer days, we spray water on concrete planters and gravel walkways. Evaporating water absorbs heat from the mass and releases it through the ventilation system. Our bioshelter's passive cooling system draws outside air in through doors and windows on the first floor and sends it out by convection through second floor windows and vents. A large greenhouse ventilation fan turns on when temperatures exceed 95° on the second floor; this happens for about four hours each sunny day from June through early September. We plan to upgrade our passive roof ventilation system in the near future. The installation of two 30-foot by 4-foot continuous roof vents should eliminate the need for the ventilation fan.

## Photovoltaic Applications

Photovoltaic (PV) power generation offers a way to reduce demand on the electric power grid and therefore reduce the air pollution and $CO_2$ production associated with conventional electric generation. Using PV power on the farm can help reduce peak demand on the power grid, especially in summer, when electricity is most in demand.

PV-generated power on the farm is best suited when sized for and applied to specific applications rather than providing general power for the whole farm. Seasonal irrigation and livestock watering are good examples of useful applications of solar power on the farm.

### Basic Electrical Calculation

An important first step in controlling energy consumption is determining how much your equipment actually uses. The basic unit of measure for electricity is watts. Energy consumption is measured in kilowatt-hours (one kilowatt is equal to 1,000 watts). A kilowatt-hour (kWh) equals one kilowatt of electricity flowing for one hour. Ten 100-watt light bulbs, on for one hour, consume one kWh of electricity.

*Grid tied solar array at Sally's Cider Press offsets electricity used in cider sterilization.*

DARRELL FREY

*Bioshelter Viewed from pond.*

LEO GLENN

At Three Sisters Farm we use grid electricity for lighting, ventilation, water pumping and refrigeration. We have explored options for reducing purchased energy use in these areas. Planned improvements include installing larger passive greenhouse vents, building a super-insulated cooler, installing wind or solar electricity-generating systems, and using more low-energy lighting. We began with the installation of a photovoltaic irrigation system in 2004 and replacing light bulbs with compact florescent bulbs. The next phase in the application of PV to our farm will be to power the ventilation and circulation fans.

### *PV Irrigation*

The original irrigation system at Three Sisters Farm consisted of a grid-powered ¾-horsepower pump, which sent pond water to sprinklers that watered newly planted crops. We also used a submersible well pump to water crops closer to harvest and for crops inside the bioshelter.

During the first 14 years of farm operation at Three Sisters Farm, using pond water to irrigate newly planted crops used an estimated 1,449 kWh per year. This estimate is based on an average of 35 hours per week of irrigation for 30 weeks of growing season, calculated as follows:

12 amp x 115 volt pump = 1,380 watts per hour x 35 hours irrigation per week = 48.3 kWh per week x 30 weeks = 1,449 kWh.

One kilowatt hour represents approximately 3,412 Btus of heat per hour. It takes an average of three Btus of fuel to make one Btu of electricity. Therefore, the original irrigation pump at Three Sisters Farm required approximately 14,832,000 Btus of fuel each year.

A kWh represents an average of 300 grams of coal. So, saving 1,449 kWh of electricity is comparable to saving of 958 pounds of coal.

In 2004, we replaced the ¾-horsepower pump with a PV system. System components include a 125-watt PV panel, a panel mounting system, a linear current booster to regulate electricity flow, a medium-flow 12-volt pump, two 1,000-gallon water storage tanks, and miscellaneous fittings and connectors for water lines.

Our 125-watt PV system powers a small, 3-gallon-per-minute pump. This system does not require batteries. While the sun shines, the system fills the irrigation tanks. Water is allowed to overflow the tank and is directed through a series of small pools and channels back to the pond or to crops as needed. Stored water is used mornings and evenings to water crops as needed. The system is sized to match irrigation use at the farm. The pump irrigates crops directly with a sprinkler as needed. This irrigation system is secure from power disruptions and substantially reduced farm energy usage from the power grid.

## *Other Energy Systems*

There are many options to explore for increased energy efficiency. Innovative ways to conserve energy, produce energy, and eliminate energy use are awaiting our ingenuity. The full description and debate of the merits of various energy sources is beyond the scope of this book. But several topics are relevant to the immediate discussion of energy use on the farm.

Burning corn for fuel does not seem reasonable to me. In some bioregions, biofuels (from plant oils and ethanol) could and should be an important part of the sustainable future. But they can only be part of the sustainable energy equation when they can be made profitably and without the use of

*Solar irrigation system at Three Sisters Farm.*

LEO GLENN

petroleum. Large-scale production of biofuels to feed a wasteful lifestyle will only serve to raise food prices and degrade the larger environment. However, biofuel production *on a local scale* can cycle byproducts back to the land and be sensibly used to supplement livestock feed.

**Methane:** Methane digesters can be an important on-farm tool for both manure management and energy production. Methane gas is produced by anaerobic bacteria when water and organic materials are fermented in airtight tanks. The gas can then be used for fuel. Digesters are mainly suited to farms with livestock that are confined daily, such as dairy farms. They require engineered design, careful construction and a high amount of maintenance. Systems need to be scaled to the amount of manure available.

A wise farmer once told me that many dairy farm methane-production systems are based on the use of high-pressure water to wash manure into storage pits. His argument was that good compost materials are being mixed with clean water to create a problem: liquid manure lagoons. Because lagoon storage pits are a potential source of ground water pollution, and liquid manure application can result in excess nitrogen entering streams, state governments are pushing methane energy production as a way to handle what is essentially mismanagement of farm byproducts. However, with the right resources and expertise, heat and electricity from farm-produced methane can be sustainable. Some cheese factories, for example, produce methane from whey to generate heat and electricity that they use to power their operations. The choice between composting and methane production is a matter of scale, need, equipment and management capability.

**Geothermal:** Geothermal systems are referred to as *geoexchange* by the DOE to differentiate them from energy harvested from geysers and hot springs. A geothermal system uses electricity to circulate air or liquid that has been warmed by the earth through a heat pump to concentrate the heat energy for space heating. Geothermal systems require a specific volume of piping in the ground or amount of water pumped to heat a given space. A geothermal energy system may not be cost effective to heat a greenhouse that has high heat loss. However, geothermal systems are a cost effective and efficient way to heat well-insulated buildings and should be considered when viable. Geothermal can also provide cooling in summer by taking heat from a building and putting it back into the ground. For both heating and cooling, geothermal systems are most efficient when used in buildings designed to conserve energy use.

**Wind and Water:** Wind power and micro-hydroelectric systems are site specific. Small-scale hydroelectric production can be a good energy producer, but only if you have the right conditions and configuration of running water. When sufficient wind is available at the right times, wind-generated electricity and water pumping can be cost effective. But wind is capricious and may not be there when you want it. Battery systems or grid-tied systems are generally needed to make electricity generated from wind reliable.

Farm-scale energy systems can be tied together in innovative ways. For example, photovoltaic systems can run the agitators needed to promote methane digestion; they can run heat pumps for geothermal energy; or they can power components of other systems. Methane can be used to heat water already preheated in solar water tanks. Compost heat can warm soil for season extension. In Chinese-style pressure methane digesters, effluent exits through a pond built over the digester chamber. Duckweeds, water hyacinths, watercress and algae thrive in the nutrient-rich water and can be fed back into the digester or used as livestock feed or fertilizer. Such a system was designed and built in the early 1980s by Robert Hamburg of Orma, West Virginia (the Omega-Alpha Recycling System). He combined a digester, greenhouse and ponds into a symbiotically integrated organic recycling system providing methane gas, plants, and fertilizer. His methane tank was set on a south-facing slope. A greenhouse attached to the south side of the digester tank stabilized the digester temperatures to help assure year-round production. In turn, the digester tank provided thermal mass to stabilize the greenhouse environment. (For more information, visit omega-alpharecycling.com/index.html.)

Management of resources to make better use of biological and other natural energy sources is our challenge for the 21$^{st}$ century. The need to reduce fossil fuel use should be a concern of all inhabitants of the earth. In this regard, it is imperative that citizens of the US lead the way in the application of sustainable technologies.

Our recognition of these issues and a call to action was clear when we first visualized Three Sisters Farm over 20 years ago. As we have developed the farm — and as we plan future development — the conservation of energy and the use of sustainable energy technologies have been primary design goals.

Chapter 6

# Beyond Integrated Pest Control: Insects, Disease, Weeds and Other Pests

*The organiculturalist must realize that in him is placed a sacred trust, the task of producing food that will impart health to the people who consume it. As a patriotic duty he assumes an obligation to preserve the fertility of the soil, a precious heritage he must pass on, undefiled and even enriched, to subsequent generations.*

— J.I. Rodale "The Organiculturist's Creed," *Organic Gardening Magazine,* January, 1948

Managing a permaculture farm begins with organic farming practices and expands on them by integrating habitat into the farm and garden landscape. Ecological design is an ongoing process. This chapter explores disease and pest control from an ecological perspective. I begin with a discussion of soil management as the basis of healthy ecosystems. This is followed by discussions of plant disease, beneficial insect ecology and control options for a wide range of pests.

## Organic Methods

Whether or not a farm is *certified* organic, using recognized organic standards as a guide helps a farm's management to produce safe and healthful products. Organic pest control practices and material used in farm activities are defined by the USDA's National Organic Program (NOP). The national organic standards fill at least 400 pages. The NOP was established by The Organic Foods Production Act of 1990, and was a part of the 1990 US Farm Bill. The act authorized the secretary of agriculture to appoint the National Organic Standards Board (NOSB).

The 15-member board is made up of farmers and growers from four regions of the US; its members also include food processors, retailers, consumer advocates, scientists, environmentalists and organic certifiers. The board's mission is to assist the USDA in developing standards for organic production and to advise the USDA on implementing the national organic program.

Farm managers and workers should be familiar with the NOP standards that apply to farm crops and livestock. Because new practices and materials continue to be developed and organic markets are expanding, the standards change over time. The farmer is responsible for keeping up with current standards. Membership in a certification organization is the best way for a farmer to stay updated.

Materials for crop production, pest control, soil improvement, and animal feed are either *allowed, restricted,* or *prohibited* under organic standards. Associated standards also govern organic food processing. The Organic Materials Review Institute (OMRI) publishes the *OMRI Generic Materials List,* which lists 900 materials that are allowed, restricted, or prohibited.

Restricted materials may be used with certain precautions and prohibitions. Rotenone is an example of a restricted product. Once a staple organic insecticide because it is derived from plants (a botanical insecticide) and breaks down in a few days, rotenone is now restricted because it is toxic to earthworms, fish, insects, and mammals, including people. We do not use rotenone at Three Sisters Farm.

The shortcoming of the NOP is that the intent is to assure the public that organic products and their production meet *minimum* standards. Such minimum standards are indeed necessary to assure the integrity of the term *organic,* but they do not in themselves promote excellence. Organic farming and gardening, which began as a way to promote the health and vitality of the food system and the environment, is in danger of becoming simply a minimal threshold to cross into a more lucrative market.

## *Soil Management*

The development and continuous care of healthy soil is a primary concern of the organic farmer. This is done through management of manure and composted farm waste and the use of green manure crops and mineral fertilizers to create a healthy nutrient cycle that will build the soil. Crop rotation is a primary strategy to maintain fertility and reduce pests and disease. Tillage methods that preserve soil structure and nutrients are encouraged. Author Ray Wolf described biodiversity as "a natural balance in the ecosystem." Biodiversity is a vital component of the farm for natural pest and disease control.

Mineral fertility is a primary concern for the market garden. The mineral nutrients phosphorus, potassium, nitrogen, carbon, magnesium, silica and oxygen are the main components of plants by volume and weight. Trace minerals, including calcium, iron, zinc, copper, manganese, chlorine, molybdenum, boron and sulfur are used by plants as biocatalysts. They are required in minute quantities for many metabolic processes including photosynthesis, growth, flower and seed formation, and disease resistance. Trace mineral deficiency can be identified through soil tests; it can also be observed directly in defects in plant growth, such as misshapen or discolored leaves. The chemistry of trace minerals is complex. Many minerals can be toxic when overabundant, and too much of some can limit the availability of others. For this reason, organic methods rely on unrefined rock minerals and biological sources of trace minerals. The nutrients in unrefined mineral products are made available as needed by the natural reactions of plants, fungi, and soil chemistry.

Biological sources of plant nutrients include manures, composted organic matter, accumulator plants, fish emulsion and seaweed. Again, the natural action of soil and plant chemistry releases minerals held in the soil and organic matter. Thus the standard organic dictum: Feed the soil, not the plants.

## Whole-systems Planning

Permaculture builds on organic practices by attempting to design the integration of farm components into a whole system. Farm watershed management, use of accumulator plants, and integration of animals into the system promote on-farm nutrient cycles. This view of the permaculture farm as a whole — an integrated system — is strongly influenced by biodynamic agriculture. Rudolf Steiner's writings (and the work of others who contributed to the development of biodynamic methods) stress the view of the farm as an organism. The health and vitality of the farm and its products are the result of the total health of the farm system. The ideal biodynamic farm is self-contained, with minimal off-farm inputs.

Small-scale farms, especially in suburban and urban areas, are more dependent on off-farm inputs. Organic materials for compost, animal feed, hay and mulch may all need to be imported from elsewhere. Organic standards and practices help guide the use and management of off-farm resources.

### *Promoting Health*

Health is something we can easily perceive. In many ways, our innate sense of natural beauty gives us the ability to recognize healthy landscapes. When a plant is healthy, we can see it: good color; strong, firm stems; a balance in proportion of leaves and flowers; and an overall appearance of vitality. A walk through the garden early on a summer evening, after a late afternoon rainstorm, when the rainbow has faded and the air is still, will reveal plants at their peak. The air is fresh and aromatic, the insects are calm, leaves are spread wide and are full of moisture. Flowers fluoresce as the sun sets. The smell of moist soil attracts robins and other birds hunting bugs in the garden paths. Sitting on a bench in the garden to rest a while, the evident health of the landscape has a therapeutic effect on the gardener as well.

Conversely, we can also recognize what is not healthy. Plants weakened and stunted by nutrient deficiency, competition with other plants, disease, insects, or drought are readily apparent.

The same general combination of factors that promote health in people and animals also promotes plant health. Good nutrition, clean water, the right amount of stress at the right time and a proper environment are all required for strong and productive plant growth. The new axiom in permaculture is that nutrient-dense soil produces nutrient-dense food. Plants need access to a steady supply of moisture, nutrients, proper pH, and, often, an association with soil bacteria and fungi. They also need a certain amount of air circulation, both for respiration and for building strong stems and root systems. The need for strengthening by stress is analogous to the need for adolescents to have sufficient exercise to build a skeleton strong enough to carry them through their next 60 to 80 years.

Unfortunately for gardeners, many other creatures also recognize and seek out a healthful food source. While insect pests are attracted to weak and stressed plants, that is not the whole story. No matter how healthy our soil or how well we manage plant growth to promote productivity and vigor, some living being will want to share our harvest. A tenet of ecology is that anytime a resource is available, somebody will use it. Spilled grain attracts mice and rats. Unprotected gardens attract woodchucks and rabbits. Plants attract aphids, slugs, flea beetles, thrips, whiteflies, and so on. So gardeners must defend their plants.

Ridding a farm of any living being presents a problem for a permaculture farmer who is also concerned with the health of the entire farm landscape. But using design and management to exploit the natural workings of an ecosystem can provide solutions. Control of pests begins with an understanding of a pest's habitat, life cycle, and the predators and diseases that affect them — and, in effect, using that understanding against them. For example, a particular pest may be minimized by reducing their available habitat or promoting their natural predators.

Masanobu Fukuoka, a Japanese pioneer in natural farming methods, has said, in his seminal book *One Straw Revolution,* that a different pest and predator relationship manifests each year. We have found this to be true, so pest control is an unfolding process of learning and adjusting. For example, spiders are abundant some years, and frogs and toads another. As weather conditions and field conditions vary, so do the dynamics of the farm ecosystem. As ecological farmers, we promote biodiversity and attempt to develop an awareness of the ongoing dynamics on the farm.

*Spring peeper.*

Darrell Frey

## *Environmental Stress*

Crop plants need to be suited to the soil and climate to be productive and healthy, and the pH of the soil needs to be suitable for the crop. Without these basic needs being met, plants are much less likely to flourish when they are stressed.

Weather is, of course, an important and variable environmental factor. A cool, wet fall can send a tomato or potato blight through a bioregion, causing a quick decline in yields in September. Hot, dry summers can cause lettuce to bolt faster than usual. Seed germination is greatly dependent on soil temperatures. Many seeds planted too early, in cool soils, will rot away rather than grow. (This is the main reason that seeds are sold with fungicidal treatment.) But cooler fall soils *are required* for the germination of self-seeded chickweed, chervil and mache.

After the shelter of a greenhouse and grow lights, full sun and wind can quickly damage plants. *Hardening off* is the process of gradually exposing seedlings to the outdoor environment before placing them into the soil. Protected seedling frames provide a transition for seedlings by protecting them from the wind and moderating the sunlight they receive. Use of row covers, polytunnels, cold frames and greenhouses for crop production mitigate some of the environmental stresses to crops by creating sheltered microclimates.

Water — either too much or too little — can damage or kill plants. New transplants and germinating seedlings are especially vulnerable to water stress. It is important to keep soil moist, but drained, until plants have established an adequate root system.

In a time of changing climate and variable weather, a wise farmer will grow multiple crops. A great year for cabbages and greens may be marginal for tomatoes and peppers. The next year, the situation may reverse. Growing many different crops for a CSA or a produce-subscription enterprise helps reduce the effects of extreme weather.

## *The Good Earth*

Understanding your soil type and quality is the first step to promoting plant health. Just observing which plants are growing in an area can indicate whether the soil is acid or alkaline, wet or well-drained, fertile or deficient in nutrients. These observations can help you better allocate your soil testing budget by identifying the locations that require testing.

When the pH is low, plants that prefer acid soils such as docks and sorrels will grow. Wet and poorly drained soils will harbor milkweeds, Joe Pye weed, ironweed, smartweed, goldenrods and asters. We rely on field guides and the biodynamic classic *Weeds and What They Tell* by Ehrenfried Pfeiffer to help us understand our annual observations.

Do not be hasty in assuming that the presence of a particular plant always indicates a specific condition. We have good stands of sheep sorrel and milkweed in our well-tended gardens. That doesn't mean our soil is too acidic. But if widespread, or several indicator plants are present, you can make general deductions. Spring walks around the farm can reveal changing conditions.


Darrell Frey

*Gray tree frog at Three Sisters Farm.*

Our woodland had a thin soil covered with mosses, ground pine, sheep sorrel and young wild blueberries. This indicated to us that years of heavy farming and grazing had eroded the soil and allowed calcium to wash away, leaving a poor, acid soil behind. Rich, balanced soil is also easy to read. Walking around our farm in the spring when green manure is growing fast, it is obvious which of our gardens have had the most improvement. The thickest growth is in the gardens we have used the most: the Pond Garden, and the South and East gardens (Zones 1 and 2). The Zone 3 gardens have had less compost over the past 20 years — and it is apparent to the observant gardener.

## Ecological Pest Control

Ecological pest control involves understanding the life cycle of the pest or disease and finding key points in the organism's life cycle to disrupt the spread of the problem. In a natural system, what we call pests are part of the natural balance. When they affect our ability to produce a marketable crop, we seek controls. Pest populations are controlled by predators, parasites and diseases. Finding the right natural control, and the best time to use it, helps keep pest problems minimal. Some crops may not be suitable in a given season or even in a given area due to pest pressure. On our farm, the prevalence of cucumber wilt (carried by cucumber beetles) makes it difficult for us to grow marketable cucumbers and squashes. Resistant varieties are our best option.

Not all pest damage is bad. A few nibbles can induce a plant's natural defenses and result in an increase of beneficial phytochemicals in the crop. The key question is whether a pest or disease is causing economic damage by reducing yields or marketability of the crop.

Many pests and diseases certainly do kill or stunt crops, but pests and disease are often a problem more for humans than the crop. Flea beetles can destroy young eggplant seedlings but only do cosmetic damage to arugula. Minor insect feeding on leaves may actually stimulate plants to grow stronger, but it is difficult to sell arugula with holes in the leaves. The scale of the problem also determines the response. A few flea beetles on potatoes may not be a problem, but in a dry year when leaf growth is slower, flea beetles can stunt early growth and reduce yields.

## *Control Methods*

### Using Insect Disease Against Them

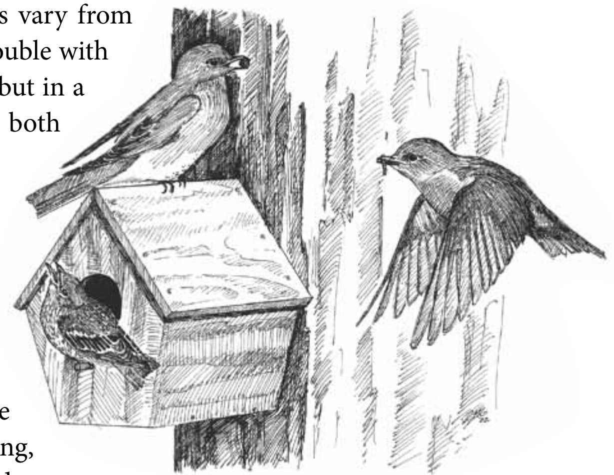
Insect diseases are becoming important tools in pest control. *Bacillus thuringiensis* (BT) is used to control many types of caterpillars. (BT should be used with care to avoid non-target species.) Milky spore disease kills the larvae of Japanese beetles in the ground. *Beauveria bassiana* is one of a number of fungal diseases that kill insects. (It is discussed in detail later in this chapter, in "Insects in the Bioshelter.")

Botanical insecticides are often used — with restrictions — in organic crop production. Pyrethrum, rotenone, sabadilla, and neem tree oil are some examples. (These products all require precautions to protect the farmer who uses them.) They are of biological origin, so they break down in sunlight and in the soil. But they may persist longer in the greenhouse. We know organic farmers who rely on botanical insecticides, but we do not use them at Three Sisters Farm because we feel they affect beneficial insects.

Pheromone traps are useful for control of some insects. These traps emit subtle chemicals to attract insects. Insects are lead to believe they will find a mate, only to be trapped (sort of a "sting operation"). Care must be taken not to *attract* pests. They are best located away from the plants you want to protect. While Japanese beetle traps are very effective, we have found they work best for us when the neighbor puts them in their yard.

Pheromone traps are also used for monitoring and control of orchard pests. Monitoring the numbers of trapped pests helps determine when more controls are needed.

We have found that the dynamics of insect pests vary from year to year and farm to farm. We have never had trouble with bean beetles or Colorado potato beetles at the farm, but in a garden at our home, just five miles away, they were both present in high numbers.



Bluebirds and other songbirds provide important insect pest control.

### Songbirds as Insect Control

The role of songbirds in the farm ecosystem is of vital importance in pest control. Each species of songbird has a role to play. The goldfinches eat thistle seeds, the Baltimore orioles patrol the orchard for caterpillars and the indigo buntings gather grasshoppers in the meadow. When they are raising their young in the spring, birds will gather an amazing amount of insects as food.

Certainly, birds also eat our fruit. Blueberries, especially, need protection from birds. The mulberries also attract a lot of birds competing with us for fruit. But on balance, we cannot do without the service songbirds provide. The aesthetic value of birds in the landscape alone is incentive enough for us to encourage them to visit our gardens and fields.

The book *American Wildlife and Plants: A Guide to Wildlife Food Habits* provides a wealth of data on the foods each type of bird and mammal eats in the US. The book is an important tool when designing a bird-friendly landscape.

Again, diversity is key. A varied landscape of meadows, shrubs, trees, hedgerows, gardens and buildings can provide nest sites and forage for numerous species. Adding a pond and lots of birdhouses further increases their presence.

LEO GLENN

*American Goldfinch nest at Three Sisters Farm.*

## Insects on the Farm

### *Bees and Wasps*

When we observe the many varieties of insects visiting the flowers on our farm, we are astounded at their diversity. The order Hymenoptera, which includes wasps and bees as well as ants, is especially well represented on the farm. Bees and wasps are important predators in the insect world. They come in countless varieties, ranging from nearly invisible parasitic wasps to big, furry bees. Bumblebees and their furry kin may be all black, black with white stripes, black with yellow stripes,

**Bees and Wasps at Three Sisters Farm**

- Honeybee, *Apis mellifera*
- Orchard bees, *Osmia* spp.
- Eastern carpenter bee, *Xylocopa virginica*
- American bumblebee, *Bombus pennsylvanicus*
- Paper wasps, *Polistes* spp.
- Potter wasps, *Eumenes fraternus*
- Eastern yellow jacket, *Vespula maculifrons*
- Braconid wasp, *Apanteles* spp.
- Green metallic bees, *Augochlora* spp.
- Ground dwelling hornets
- Furry bees/tiny wasps (undetermined species)
- Other unidentified wasps and bees

or yellow with bands of black; some are tiny and some are quite large. Furry bees come in many shades, as do metallic bees. Wasps come in even greater variety. They can be shiny blue-black, brown and yellow, have narrow waists, or be full-bodied. Some have hair-like ovipositors longer than their bodies. Miniature wasps may be shades of black or brown, with red, white or yellow patterns and markings. Paper wasps are the most abundant. They can be found nesting in the polytunnel framing and practically any spot sheltered from the rain. Mud daubers are also abundant, though less so than the paper wasps.

Where the vast majority of these reside in the farm landscape is an ongoing mystery. Ground-dwelling hornets and bees are usually discovered by painful accident, while working in garden beds or shoveling aged compost. Other bees and wasps must find lodging in undiscovered hideaways in trees, shrubs, meadows, and the odd crevasse in a building. When we do identify a beneficial insect's residence, we try to preserve it. Since the fine spring day I observed tiny metallic bees emerging from a nest in the pith of the previous fall's tansy stem, we are more careful when pruning dead plant stalks. We leave a foot or two of stalk in a tansy patch, rather than trimming to the ground. Now, instead of using pithy plant stems to aerate the bottom of a compost pile, we often toss them along the edge of the tree line to provide the bees with more places to live.

Practically all wasps and bees are beneficial. In addition to pollinating plants, most wasps and hornets are predatory. Depending on the species, they may gather spiders, caterpillars, crickets and other insects. The wasps paralyze their prey, attach one of their own eggs to it and place it in a cell of a nest. The larval wasp consumes the live insect, starting with the non-vital parts.

Chalcid, braconid and ichneumon wasps, and the aphelinid whitefly predator wasp, *Encarsia formosa,* are parasitic wasps that deposit their eggs inside the bodies of other insects.

The 2,000 species of chalcid wasp in North America include the parasite of the tomato hornworm. Chalcids are among the smallest known insects, as small as .008 inches. They may lay their eggs in the *eggs* of other insects. Some species are hyperparasites, parasitizing other parasitic insects.

Braconid species number around 1,700 in North America. They lay eggs inside many types of insects and caterpillars, including aphids.

Braconids are commonly found anywhere aphids are found. They are especially active in the bioshelter. They came in on their own the first year we began to garden indoors. They have been present ever since, as have their host, the aphid. Infected aphids are easily recognized; they become mummified and are a shiny bronze color.

Ichneumons are the most abundant species in North America, with over 3,000 species. Most are internal parasites of other insects, as evidenced by their often-prominent ovipositors. They bore into wood and use the ovipositor to deposit their eggs in wood-eating larvae.

Some wasps' larvae feed mostly on plants, including the over 600 species of gall wasp, *Cynipid* spp. Gall wasps secrete hormones into a plant to induce gall formation. The developing larvae then live inside the gall, eating the gall walls. Gall wasps are primarily parasites of oak trees, but some species form their galls on roses, willow, daisies and other plants.

### *Other Beneficial Insects*

A syrphid fly larva (family Syrphidae) will eat up to 400 aphids between hatching and pupating about ten days later. Most of the 900 species in North America resemble bees and wasps. The larvae resemble slender green slugs, with lovely yellow markings on their back; they can be seen searching for their prey on the underside of leaves. The adults hover and dart quickly, seeking nectar to fuel their flights.

Ladybugs, members of the Coccinellidae family, come in variations of red, yellow and orange, many with black spots. Both adults and larvae are predatory, consuming aphids, mites and other soft-bodied insects. A common species, the convergent ladybug, *Hippodamia convergens,* will live for several months and lay up to five hundred eggs. These orange eggs are usually in clusters of one to two dozen. Upon hatching, the larvae begin to hunt aphids, consuming many dozen before pupating. Adults winter over in leaves, under tree bark and in crevasses of building. Native ladybugs, such as the nine-spotted ladybug, have been heavily endangered by competition with non-native species.

Fireflies, including *Photinus pyralis, Photinus scintillans* and *Photuris pennsylvanica,* certainly enchant a summer evening with their aerial dance and flashing display. While the adults do not appear to eat anything, their larvae spend late summer through fall preying on slugs, snails and insects. (Firefly larvae, sometimes known as glow worms, are also luminous.) After resting through the winter in leaf litter and underground, they again feed on their prey for a few weeks before transforming into adults.

Praying mantis, *Mantis religiosa,* is a native of Europe introduced to North America early in the 20th century. After hatching from their brown, foam egg case in late spring, these voracious predators consume their kin. The fittest then proceed to patrol the landscape for prey, which includes caterpillars, moths, butterflies, bees and flies. Sitting perfectly still, praying mantis wait near leaf and flower, capturing and devouring any insect that comes within reach of their lightning-fast clutches.

Green lacewing, *Chrysopa* spp., larvae are predators of aphids, mites, caterpillars, and other soft insects and insect eggs. North America has dozens of species of these lovely lacy green insects. We have purchased green lacewing larvae for release in the bioshelter twice. Green lacewings, active in late spring and summer, lay their eggs on a silken stalk, which the books will tell you is done to prevent cannibalism as they hatch. But in the bioshelter, they have always disappeared, presumably having consumed one another.

Brown lacewing larvae, *Hemerobius* spp., also prey on aphids, scale, mites and other soft insects. While plainer than their green cousins, the dozen or so species of brown lacewings are important predators in the garden and the orchard. Both green and brown lacewings are attracted to bright lights at night. Because of this, we try to limit our use of outdoor lighting to avoid distracting all insects from their natural routines.

*Green lacewing, a predator of aphids, thrips and whiteflies, on bronze fennel.*

DARRELL FREY

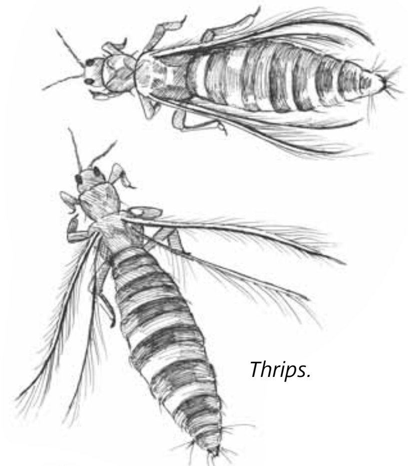
Minute pirate bugs, *Orius* spp., are an often-overlooked predator, because of their size, just 1/8 inch long. They have an easily recognized brown and tan diamond-patterned body. Nymphs and adults feed on a wide range of prey, including caterpillars, thrips, mites, aphids, and their eggs. Like a pirate, they stab their prey with a sword-like beak, after which they suck out the prey's juices. Minute pirate bugs are most abundant in a diverse garden landscape. They are attracted to legumes, corn and pollen-producing composite flowers. From these they move about, following their prey.

Dragonflies and damselflies, both of the order Odonata, are busy predators throughout their lives. More than 1,000 species are found in the Upper Midwest of North America alone. All spend their nymph stage as aquatic predators, devouring mosquito and other larvae in ponds and other standing water. Adults of damselflies and dragonflies range far from the water in search of prey. Dragonflies catch flies and mosquitoes in flight. Damselflies are known to eat almost any insect they find.

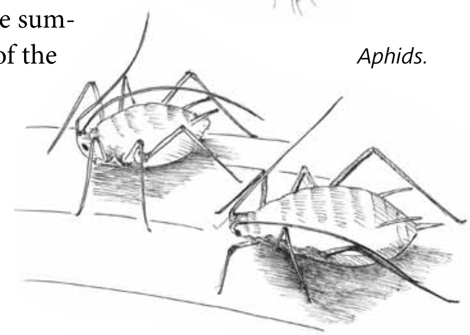
Predatory thrips, *Scolothrips* spp., are usually abundant in the summer garden, but you have to know where to look. They are one of the reasons pest thrips and spider mites are less of a problem outdoors than indoors. Predatory thrips resemble the pest thrip but are darker and have jagged or hairy sides, as opposed to the smooth-sided pest thrip. They consume many pests and their eggs, including spider mites, thrips, aphids and whitefly. Like other thrips, they are very small, about $1/20^{th}$ of an inch. We find them on daisies, where they are drawn to the pollen as an alternate food source. It is likely that any composite flower will host them.

Aphid midges, *Aphidoletes aphidimyza,* are an easily overlooked beneficial insect. Adults look like small mosquitoes. They eat the honeydew secreted by aphids, whiteflies and scale. Eggs are laid on plants near aphid colonies. Aphid midge larvae, small, red and maggot-like, are voracious predators of aphids. After consuming dozens of aphids in about two weeks, aphid midge larvae pupate in the soil. They have up to six generations a year outside. Inside the bioshelter, they begin to appear in April and continue to patrol for aphids until late October.

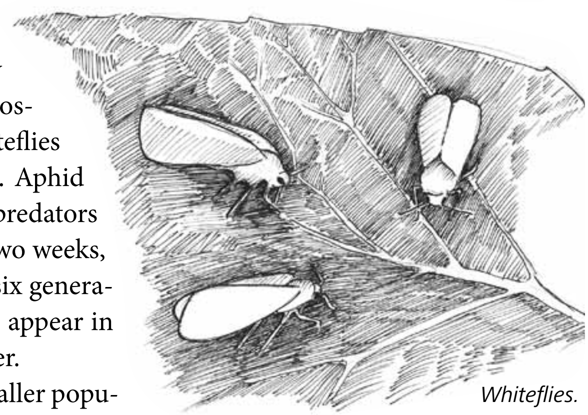
Other beneficial insects are found on our farm in smaller populations. Soldier beetles pierce and consume prey, much like a minute pirate bug. Assassin bugs, robber flies, tachnid flies and predatory mites all find a niche in the ecologically managed garden.



*Thrips.*



*Aphids.*



*Whiteflies.*

*Thrips, aphids and whiteflies are major greenhouse pests.*

## Spiders on the Farm

The diversity of spiders on a permaculture farm can rival the diversity of insects. Spiders are an important part of the farm's pest control. Those we have identified are described below, but dozens of others spin webs and crawl about everywhere on the farm. All are predators that eat some type of insect. Luckily, we do not have the black widow or (we hope) the brown recluse spider in our area. Generally, when a spider *is* forced to bite a human, the result is not much worse than a mosquito bite. Hundreds of American house spiders (*Achaearanea tepidariorum*) live inside our bioshelter. These diminutive (¼ inch) spiders string their irregular strands around the window frames, among the grow lights, and in odd corners. Small colonies of house spiders weave erratic networks of silk, which become festooned with winged aphids, fungus gnats, flies, cabbage butterflies and other insects drawn to the window's light. Because cobwebs are unsightly, we clear out older webs every now and then, especially before tours. We try to allow the spiders time to retreat to the corner, or drop to the sill. They soon return.

Crab spiders include around 200 species in North America. Rather than weave a web, they sit on a flower and wait for their prey to land. White crab spiders will sit on a white rose, yellow on a goldenrod flower, and pink on a red rose. Some species are reported to adapt to the color of the host flower. The goldenrod spider is white with lovely pink lines; it will turn yellow on a yellow flower. Other types of crab spiders are shades of green or brown, depending on their chosen habitat.

Wolf spiders (family Lycosidae) are often seen prowling for prey on the ground while carrying their egg sac. The more than 200 species are fast-moving nighttime predators of ground-dwelling insects. Like crab spiders, they do not weave webs, preferring to live in mulch, leaf litter, small tunnels, under rocks or in buildings.

Jumping spiders are common in the bioshelter and around the farm. The two most common are the pretty *Metaphidippus* spider, which is furry black with green spots on its head, and the daring jumping spider (*Phidippus audax*), which smaller and gray and black. Funnel spiders were an endless source of summer entertainment to me and my childhood friends, much to the dismay of the flies we fed into the wide funnel webs. Similar in appearance to wolf spiders, their ground-hugging webs are built in grass and weeds and alongside rocks, planters and other

### Garden spiders

- Black-and-yellow argiope, *Argiope aurantia*
- Shamrock spider, *Araneus trifolium*
- Goldenrod spider, *Misumena vatia*
- Crab spider, *Misumenoides formosipe*
- Marbled orb weaver, *Araneus marmoreus*
- Jumping spider, *Metaphidippus* spp.
- Wolf spider family, Lycosidae

### Bioshelter spiders

- Jumping spider, *Metaphidippus* spp.
- Wolf spider family, Lycosidae
- American house spider, *Achaearanea tepidariorum*

shelter. They are quick to rush out and grasp any insect that falls into their web.

More conspicuous web builders on the farm include the shamrock spider, the marbled orb weaver and the black-and-yellow argiope, or garden spider. The argiope female grows to over an inch long — plus its long legs — and builds conspicuous webs in prominent locations. The smaller, male argiope lives on the edge of a female's web and makes a zigzag line when it moves across the web. The bright yellow marbled orb weaver and the brown shamrock spider are nearly as large, up to an inch long, but with shorter legs than the argiope. They like to nest along buildings, arbors and in shrubs and brambles. All three make an egg sack in the fall. Young spiders overwinter in the sack by the hundreds and emerge in the spring. They wait until the wind is right, and then drift away on a web strand to be scattered randomly across the landscape.

*Orb weaver.*

Daddy longlegs are arachnids but are not considered true spiders. The over 200 species in North America include both predators and scavengers. Most are nocturnal hunters of small insects, but they will also eat decaying organic matter. Some are said to prey on slugs and earthworms as well as spiders and flies.

Many other spiders fill every niche on the farm, weaving webs of various sizes, cruising the underbrush, and generally hanging out waiting to catch unwary prey. Very few spiders here are poisonous, though many can give a nasty, stinging bite. All are beneficial to the farm ecosystem. In addition to catching insects, spider webs are an important material for hummingbird nest construction.

## Design for Ecological Control

With so many players "in the field," design for beneficial insect habitat is best approached with a broad strategy of providing a wide range of nectar and pollen plants throughout the growing season. Inside the bioshelter, with its reduced diversity, more specific strategies can be employed. The list of plants we use in the bioshelter and outdoor gardens gets longer as we observe insect behavior and add new flowering species. Some insect species have such short adult life spans or live in such small populations that we would only find them if we could devote all our time to observation and research. More practically, we try to provide suitable habitat and trust in nature to find a balance.

### *Plant-Insect Interaction*

The biochemical interactions between insects and plants are both mysterious and fascinating. Many insects inject plants with chemical compounds that encourage the plant to form galls or release volatile chemicals. Predatory insects are drawn to plants besieged with insect pests by chemical clues that some plants release when distressed. Similarly, male gall wasps find their mates by following chemical clues emitted by infected plants.

*The monarch caterpillar feeds only on milkweed species. Note the caterpillar in the flower.*

DARRELL FREY

The complex chemistry of plants and the interactions of plant-produced compounds with soil, insects and other plants are likely to never be fully understood. From the permaculture designer's point of view, these complex interactions are yet another reason to approach ecological design with humility and to support native diversity in our landscape.

Good garden sanitation will reduce many pest populations. (Sanitation measures include removing and composting crop residue or tilling it into the soil in a timely manner.) However, some beneficial insects overwinter under mulch and in soil. Uncultivated and fallow areas in and near gardens will act as refuge and reservoir for repopulating the garden ecosystem after cleanup and tillage. When clearing crop residue, we look for praying mantis egg cases, spider eggs sacks and dormant wasp nests. Moving these to a safe spot helps maintain populations.

As the diversity of trees and other plants increased in our tree lines and windbreaks, biodiversity increased. Certainly, the wide range of native pollinators helps keep our fruit trees, shrubs and brambles productive. The panicle and osier dogwood shrubs and viburnum species all provide forage for countless varieties of insects and many birds. The many other plants and trees each add some forage for insects and birds. Each flowering plant offers some food and shelter for insects. Leaf litter, mulch, dead fallen branches and tree bark all offer shelter and brooding places. As with most aspects of ecological design, we must acknowledge our limited information and allow for a wide range of species to fill in the gaps of our limited knowledge.

Below is a description of the beneficial habitat plants we use in our gardens, as well as those we allow to grow in the uncultivated areas between our gardens.

### *Beneficial Habitat Plants in Outdoor Gardens*

Tansy, *Phacelia tanacetifolia,* tops our list of beneficial insect habitat plants. We have established plantings of tansy near all of our gardens and in central locations between them. Doubling as a cut flower for drying, tansy never fails to host ladybugs and their larvae. Other beneficial insects on tansy leaves and flowers include soldier beetles, assassin bugs, robber flies and syrphid flies. Tansy persists where it is planted, so be careful where you establish it. It spreads easily by runners. We put it along the fence line of the South Garden and in a swale between the East and South gardens, as well on the edge of the Pond Garden and West Garden. Tansy grows at least 4 feet tall and tends to fall over in late summer and fall. Most of our patches are located where we can tie them to the fence line with cotton string. Other patches are surrounded with several stakes and tied, or simply left to fall over where they are out of the way.

Darrell Frey

*Flowering oregano is a preferred habitat for the beneficial syrphid fly.*

Mints and their relatives have found many niches on the farm. (Mints will spread and can be hard to contain, so think before you plant.) All provide nectar for honeybees, metallic bees, and small wasps. The many members of the genus *Mentha,* like most of the family Lamiaceae, produce abundant, small flowers over a long period of time. These flowers are readily accessible to even the tiniest insects. Most produce abundant nectar, as well as oils and medicinal compounds. We have established patches of various mints and other Lamiaceae throughout the farm. In the West Garden orchard, ajuga, peppermint, *Mentha x piperita var. piperita,* and spearmint, *Mentha spicata,* are planted between trees. Peppermint and water horehound, *Marrubium vulgare,* are found along the pond's edge. Permanent patches of spearmint allow us to do a weekly rotation of harvest sites. English pennyroyal, *Mentha pulegium,* has found a home in a wet swale surrounding the fire circle. American pennyroyal, *Hedeoma pulegioides,* gathered from an old farmyard, has become well established along the swale that drains the north side of the bioshelter, and around the summer kitchen. Pennyroyal hosts gatherings of tiny bees and wasps, big wasps, syrphid flies, and lots of types of ichneumon wasps.

To promote insect diversity, provide:

- diverse pollen and nectar sources in each garden
- uncultivated wildflower areas between gardens
- plant diversity in tree lines and windbreaks

Spearmint and peppermint are also planted in the farm's kitchen garden and in our polytunnel. Several patches of spearmint are tended inside the bioshelter. These are rotated every few years.

Ajuga, *Ajuga reptans* 'Atropurpurea,' or common blue bugle, flowers in late spring. While we collected it primarily for its striking purple leaves and bright blue flower spikes, it is relished by the early generations of beneficial insects.

Purple flowering oregano, *Oreganum vulgare,* is an excellent habitat plant. This spreading plant produces its clusters of dark pink blossoms from late June through fall, with a few clusters lingering until a hard frost. All summer, they are busily worked by syrphid flies, bumblebees, metallic bees and other small bees. Less aromatic than culinary oregano, this plant is mainly used as a habitat and ornamental planting; we also often include it in our herbal bouquets. Our initial planting at the door to the bioshelter kitchen has spread around the north side of the building to fill an area of about 30 square feet. Other patches are established in our other gardens among the shrubs and along the fences.

Other oreganos we grow include the aromatic Greek oregano and the ornamental culinary golden oregano. Neither of these stands out as insect habitat, mostly because we discourage flowering by regular harvest.

Motherwort, *Leonurus cardiaca,* nurtures a great diversity of tiny wasps all summer long. Honeybees love to visit the ever-rising spire of fuzzy pale lilac flowers, each a small vial of nectar. Until killed back by frost, this herbaceous perennial member of the mint family will continue to produce its lovely flowers around its slow-growing stalk. Motherwort is allowed space in the middle or on the edge of our gardens and orchards. It spreads slowly by division and possibly by seed. As the name implies, motherwort is a traditional medicinal plant for women.

Catnip, *Nepeta cataria,* like motherwort, is a medicinal plant. It too has established itself in our gardens. Growing to over 6 feet tall on the edge of our chicken yard, catnip thrives in the rich, moist soil. It flowers continuously all summer and helps give the chickens shade from the hot mid-day sun in July and August. Catnip will spread by seed, though not as aggressively as the root-running spearmint and peppermint. The clusters of white and pink flowers feed honeybees, metallic bees, bumblebees and many tiny wasps. We occasionally have allowed catnip to live in the bioshelter, but it is not a high-value, marketable culinary plant, so we only keep a few small, self-seeded plants, which are allowed to flower in summer.

Catmint, *Nepeta mussinii,* is a small, delicate relative of catnip. It grows in clusters of 6- to 8-inch-long prostrate stems with lovely leaves and blue flowers. We mainly grow catmint for our herbal bouquets. It grows well in partial shade under our kiwi arbor and in the bioshelter beneath the lemon verbena.

Anise hyssop, *Agastache foeniculum,* flowers from early summer until stopped by a heavy frost. These dark purple flower spikes attract honeybees, metallic bees and many tiny wasps. Beautiful in the landscape, delicious in tea, edible and medicinal, anise hyssop has a prominent place in our bioshelter and herb gardens. It is an herbaceous perennial, though perhaps not long lived, though it readily self-seeds. Inside the bioshelter, excess anise hyssop seedlings are cut for the spring salad mix. The fresh flowers look good and are long lasting in an herbal bouquet. Picked with care, anise hyssop will branch densely and produce flowers all summer.

Thyme's tiny florets grow in clusters and attract many wasps and bees. We grow several varieties for the herb and edible flowers. German thyme, *Thymus vulgaris,* has a very good flavor and grows upright for easy harvest. Creeping thyme, *Thymus serpyllum,* also has good flavor and flowers profusely. It grows in low, self-mulching mats. Creeping thyme lives up to its name by creeping into the yard, where it competes well with grasses. When mowed regularly, it is fragrant and soft to walk or lie on (not that we have the time to lie in the thyme). We also grow silver thyme, *Thymus vulgaris* 'Argenteus,' for bouquets, flowers and culinary use. Lemon thyme, *Thymus x citriodorus,* is established in the bioshelter and several gardens. It is known to be a mosquito repellant. We do not seem to have many mosquitoes, but we do keep some lemon thyme handy in the Zone 1 areas of the farm. A large patch in the Spiral Garden is readily accessible for workers and visitors relaxing in the kiwi arbor. We simply pick a handful of lemon thyme stems, rub them in our hands and then rub the oil on our shoulders and neck to ward off irritating mosquito attacks.

Lavender, *Lavandula angustifolia,* flowers for only a short period of time, so we harvest the flower stalks for everlasting bouquets before they fully open. When not harvested, lavender flowers over several weeks and nurtures insects in early summer, when its cousins are just beginning to flower. Bumblebees and other tiny bees are attracted to the fragrant flowers.

Cilantro, *Coriandrum sativum,* and dill, *Anethum graveolens,* both attract large numbers of tiny bees, wasps and syrphid flies. We plant them every other week through the growing season to allow a steady harvest of their leaves. Many of these plantings are allowed to flower and set seed, for both culinary use and to promote biodiversity.

Bronze fennel, *Foeniculum vulgare dulce* 'Rubrum,' is given a prominent place in our Spiral Garden and is planted in several other gardens as well. When flowering, it attracts a steady stream of small bees, syrphid flies and wasps of all sizes. Bronze fennel is a perennial. We gather the self-seeded seedlings each spring for our plant sales. Through the summer we add the dark, ferny foliage to our salad mix, stripping the narrow, anise-flavored leaves from the stalks. The two-inch-wide umbels of yellow flowers are popular as an edible dessert garnish.

Lamb's ear, *Stachys byzantina,* attracts bumblebees and tiny wasps. Grown primarily for cut flowers and dried arrangements, the silvery, furry leaves and lavender flowers are quite lovely. We grow it in several locations to promote the population of wasps.

### Wildflowers

Cultivated and unmanaged wildflowers, shrubs and vines all provide some degree of habitat and food for beneficial insects. We are still observing and learning about the dynamic relationships between plants and insects.

Queen Anne's lace, *Daucus carota,* the wild sister of the garden carrot, attracts syrphid flies, tiny bees and wasps. The delicate, flat white umbels bloom over a long season mid to late summer. They are an excellent craft material when dried. Because they are a biennial taproot, they are also important in maintaining an aerated soil.

Milkweed, *Asclepias* spp., is important summer forage for many insects. We have observed honeybees, bumblebees, butterflies, tiny wasps, small bees, wasps and hummingbirds all foraging on milkweed's fragrant pink flowers. Because milkweed is the sole food of the caterpillar of monarch butteries, we give it special privileges on the farm. Small, permanent patches of milkweed are protected from mowing on the edges of our gardens. Random milkweed plants are allowed to grow in our gardens most years. Because the first monarchs appear in early July here, we are very careful about pulling out milkweed plants after July 1. Any unwanted plant is inspected for eggs and young larvae. These are relocated to other milkweed patches as needed. Swamp milkweed has also been established in the Pond Garden and near the pond. This more delicate looking plant hosts the same insects as regular milkweed.

Wild yarrow, *Achillea millefolium,* self-seeds all over the farm and is left standing anywhere it is not in our way. Syrphid flies, metallic bees, other small bees and tiny wasps make steady use of its easily accessible flowers. Yarrow has established itself in sections of our yard as well. Mowed yarrow makes a soft, ferny carpet that spreads by underground runners, never getting a chance to flower. Some of our yard areas are thick with mowed yarrow.

Goldenrods provide important habitat for beneficial insects. With over 80 species native to North America, it is a common perennial. Canadian goldenrod, *Solidago canadensis,* is the most abundant at our farm, but at least a dozen species are found near the farm. We allow large patches of goldenrod to grow between and around our gardens. Goldenrods begin blooming in August and continue through October. They are an important honeybee forage plant, and they also support a wide range of beneficial insects. Several species are good for dried flower arrangements and cut flowers. Goldenrods are allelopaths, which means they have a capacity to suppress the germination of other plants' seeds.

Stinging nettle, *Urtica dioica,* has inconspicuous flowers but is known to host a wide range of beneficial insects. Nettles are valuable as a spring cooking green. Nettle tea, because it provides soluble nutrients, is used as a foliar spray to promote healthy plants.

Ox-eye daisy flowers, *Chrysanthemum leucanthemum,* host predatory thrips. If you look closely at the sunny yellow disc of a daisy, you can often see the tiny, slender, black insect crawling among the florets. Predatory thrips are distinguished from the smooth-bodied, plant-eating thrips by having a distinctly jagged appearance. They consume pest thrips, aphids, and other soft insects.

Asters and daisy fleabane are also common among our gardens. Daisy fleabane, *Erigeron annuus,* begins to bloom in June and can continue to flower until fall, feeding honeybees and other bees with pollen and nectar. Many asters, including the New England aster, *Aster novae-angliae,* calico, and crooked-stem asters are found in our meadows, tree line and orchard. Most flower in the fall and are important to honeybees and the last generations of bees and wasps in the fall.

Burdock, *Arctium lappa,* and bull thistles *Cirsium vulgare,* are favorites of the honeybee and bumblebee. Both are biennial tap roots and so help loosen and enrich the soil. Bull thistle is allowed space on the edge of our gardens, where it often supports large orb weaver spider webs.

### Honeybees in the Gardens

Honeybees, *Apis mellifera,* deserve special mention. Their economic importance is considerable. They pollinate tens of millions of dollars worth of fruit and vegetable crops each year. As I write, the mystery of colony collapse disorder is unsolved. This sudden die-off of many bee colonies across North America is the latest disorder to plague honeybees. The varroa mites and tracheal mites that appeared and spread through bee colonies in the last part of the 20th century have already made beekeeping a more difficult enterprise. It is likely that the colony collapse disorder is the result of multiple stresses. Together, all the challenges of beekeeping raise the cost of honey production and the cost of pollination services bees provide. They have also led to a general decline in beekeeping as a hobby.

Certainly the troubles of the honeybee confirm the need to provide food and habitat for the native pollinators. Nonetheless, the products bees provide, honey, wax, propolis (described below) and pollen make the effort to maintain bees worthwhile. Rather than provide a detailed study of beekeeping, which is the topic of many good books, here we will focus on the placement and management of bees and bee plants in the permaculture landscape.

Bees are best located away from high traffic areas. They also need regular tending to be productive. This places them in a Zone 3 management area. Some farms keep a hive or two of bees but do not tend or harvest them. This places them in Zone 4.

At Three Sisters Farm, our beehives are located along the north-west edge of the pond, well away from the main work areas. The hives are set on concrete blocks at the base of a small slope where they are somewhat protected from the prevailing wind. (We are planting a hedge of useful shrubs to the north and west of the hives to provide additional wind protection.) The hives receive full sunlight, and the additional light reflected from the pond helps warm them early in the morning. Ready access to water is important to the bees.

When beekeeping in suburban and urban areas, bees should be located where they will not bother anyone. Bee stings are a minor irritation to most people but can be deadly to those with allergies to bee toxins. Rooftops and secluded back yards are the most reasonable locations. In rural areas, bears and raccoons will break into a hive. Raccoons can be deterred by placing a heavy stone or concrete block on top of the hive. Bears may be deterred by a heavy-duty or electric fence.

### Honeybee Forage

Literally hundreds of wildflowers are foraged by bees for pollen and nectar. While most of these are only minor nectar sources, producing little if any excess honey, they are nonetheless important to the hive for building strong colonies in the spring and sustaining them between major nectar flows. Major honey plants vary with the bioregion. White clover, sweet clover and buckwheat are well known for their distinctive honey. Raspberry, blackberry, thistles, asters, goldenrod and milkweed also provide abundant bee forage. Willow, redbud, tulip poplar, catalpa, black locust, basswood, sumac, and sourwood are all important nectar-producing trees. Willow produces abundant pollen early in the year, providing an important food for the hive as it expands its population in the springtime.

We have a theory that bees collect and use a wide range of nectars and pollens to keep healthy. Just as we require a diverse diet, bees also, we suspect, need a wide range of plants to stay vigorous. The use of essential oils, including peppermint and wintergreen, rosemary and thyme, by beekeepers to kill and suppress tracheal mites and varroa mites, seems to support our pet theory. Formic acid, part of the sting of stinging nettles, also kills these mites while not harming the bees. For this reason it is good to have stinging nettle and peppermint, as well as other aromatic herbs, growing close to beehives.

Many plants should be observed for bee forage potential. For example, cowslip, *Calthus palustris,* a potherb found in sunny swamps and springs, is one of the earliest flowers each year. Whether it is worked by bees or not, I cannot say, but it flowers at a time when bees really need a good food supply. Any flowering plant might be used by bees from time to time, in any given location.

The distinction between major and minor bee forage is rarely absolute. The degree to which bees utilize a nectar source can also vary from year to year and place to place. When a minor plant is especially abundant, it can become a major source — as can a minor spring source, given an exceptionally warm, dry spring and a strong hive. A major nectar source might be a poor producer if the weather is unfavorable when it blooms. At such a time, bees will fall back on flowers they otherwise might ignore.

In our area, two species of viburnum, nannyberry (wild raisin) and arrowwood, and a shrub called ninebark, *Physocarpus opulifolius,* inhabit sunny, open wetlands and stream banks. Each alone is only minor bee forage. However, they bloom in a succession. First nannyberry (a fruit-bearing shrub that grows to 25 feet) flowers, followed by the blooms of arrowwood (a smaller shrub growing to 8 feet high) that are similar flat-topped umbels of white florets. After about a week, the arrowwood blossoms fade but the ninebark branches are loaded with lovely snowballs of florets 1½ inches in diameter for another week. These three shrubs together provide the colony with three weeks of forage, leading them to the major nectar flows in flowers of such trees as tulip, basswood and catalpa. If there is an abundance of blackberries, these shrubs may be largely ignored by the bees, who will work the high-nectar bramble blossoms instead.

Bees are attracted to flowers by color and scent. Bees see the colors blue, blue-green, yellow and ultraviolet. Strongly scented flowers generally have a lot of nectar. Pollen from a wide range of plants is gathered to raise young bees, especially in the spring. Plants also produce resins used by bees to make propolis, a glue-like substance that has been used in the production of antibiotics. Some plants also produce *extra-floral* nectars. It is believed that extra-floral nectar is secreted to attract ants. Ants then protect the plants from would-be foragers. Bees sometimes collect "honeydew" secreted by aphids. This is considered by some to make poor-grade honey due to its generally strong flavor.

Beekeeping for marketable production requires a good deal of care at the same time that the small farm requires lots of crop production.

Spring is the time to monitor hives and expand production by dividing hives. Maintenance and regular harvest after honey flows can conflict with gardening schedules. For this reason it can be difficult to do both well. Commercial-scale beekeeping should be viewed as one of the seasonal businesses that can be developed by enterprising partners on a small farm.

## Insects in the Bioshelter (and Other Creatures)

Because the bioshelter is a semi-enclosed environment, the insect dynamics are a little more complex to manage. Three of the biggest greenhouse pests — aphids, mites and thrips — are rarely a problem outdoors. In the gardens, they are kept under control because they have to contend with environmental stresses (rain, humidity, direct sunlight, etc.) and a wide range of natural predators. Inside the bioshelter, these pests can quickly expand in numbers when predator numbers are low.

Whiteflies have fewer natural predators in our area and when allowed to leave the bioshelter on infected plants, they can become a summer pest. Inside the bioshelter, they are more subject to control. When we have whiteflies on our plants, we make sure to treat them with soap spray and do a close inspection before they are taken out to the gardens.

### *Habitat Management in the Bioshelter*

Habitat management is at the heart of bioshelter management. Flowering plants that provide insect habitat are kept in the bioshelter all year: alyssum, scented geranium, blue basil, thyme, oregano, marjoram, lavender, and Johnny jump-ups are some examples. Alyssum is especially important. This low-growing plant flowers all year. It never needs deadheading, and it grows well in small planters and in the holes of the 6-inch concrete block walls that form our deep beds. Alyssum also looks good. Available in both white and violet varieties, the masses of flowers and green foliage hanging over the edge of the concrete block is quite lovely — as it provides pollen and nectar to adult parasitic wasps.

Pest control inside a bioshelter relies heavily on the greenhouse manager to keep track of populations of both

**The Cast of Characters:**

**The Bad Guys**

- aphids
- thrips
- whiteflies
- spider mites
- pill bugs
- ants
- scale insects
- slugs
- cabbage moth
- leaf miner
- spittlebugs

**The Good Guys**

- labybugs
- *Encarsia formosa*
- syrphid flies
- aphid wasps
- gall midge larvae
- spiders
- predatory thrips
- predatory mites
- ground beetles
- lacewings
- bumblebees

**Other Players are**

- toads
- tree frogs
- soil organisms

pests and their predators, and to step in with other organic control measures when necessary. Below are some of the players in the bioshelter ecosystem. Chapter 10 provides detailed discussion of bioshelter pest management.

## Insect Control Methods

### *Insecticidal soap*

Insecticidal soap is fast, easy and effective at killing insects. To work, the spray must cover the insect. Most die within a few minutes (sometimes as quickly as 30 seconds) as their cell walls dissolve. Made from potassium salts and fatty acids, insecticidal soap is non-toxic on skin contact for humans and wildlife. It can damage leaves, though, so it should be rinsed off within a day of application. It is best to apply soap spray in the evening, when whiteflies are less active.

We use distilled water for mixing the soap for application. Minerals in our water (which is hard) tend to reduce the soap's effect. When we do not have distilled water handy, we just add a little more soap than the directions call for. As with any product used on the farm, be sure that the brand you use is acceptable for organic certification. Some products contain pesticides or unnecessary additives. A small hand-held sprayer is appropriate for greenhouse use. In the gardens and for dealing with bees and wasps, it is better to have a backpack sprayer with a longer spray wand.

When bees and wasps build their homes in the wrong location, soap spray will eliminate them. It can take patience to stand near a nest long enough to spray every wasp as it enters or exits a nest, but it is preferable to applying pesticides.

Spider mites, thrips, aphids, scale, mealybugs and whiteflies are all effectively controlled with soap spray. But soap will also kill beneficial insect predators, so it is best to use soap sparingly in seasons when they are active.

### *Sticky traps and Other Methods*

Thrips and whiteflies are attracted to color, especially yellow. Coating yellow paper with a clear, sticky substance makes an effective trap. (Thrips are also attracted to light blue traps.) For many years we bought the Tangle-Trap brand of trap coating. It is a petroleum-based product, but it is approved for organic production. Coated traps remain sticky for days or weeks and so continue to trap insects for a long time.

However, sticky traps also attract insect predators, so we use these traps only when we have major infestations. In recent years, we have begun to use cooking oil as a coating for paper traps. The oil is effective only for a day, but is easier to apply than Tangle-Trap coating. Because it is only sticky for a short time, the effect on predators is less severe. We have begun to experiment with adding essential oils to the cooking oil. Lavender oil has proven extremely effective. We fold a 14-inch by 24-inch piece of paper over a clothes hanger and cover both sides with the scented oil. Infested plants are shaken with the trap held a foot or two away. Whiteflies are drawn like magic and stick to the oil.

Occasionally, we have resorted to vacuuming up pests with a portable hand-held vacuum cleaner. When a major outbreak occurs, this is an effective way to catch whiteflies and thrips.

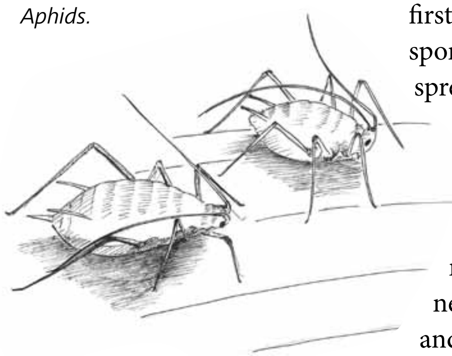
For controlling caterpillars, slugs and larger insects, picking them off by hand is sometimes the best solution. On a garden scale, though, this is impractical. Sometimes, pests can be knocked off plants with water. Aphids and other small pests infesting flats of seedling or potted plants can be rinsed off with a watering wand or rubbed off by hand.

### *Beauveria bassiana*

Our need to import predators was greatly reduced by the appearance of the insect-consuming fungus *Beauveria bassiana* in the bioshelter and surrounding gardens. This entomopathogenic fungus spends the warm months breaking down organic matter in the soil. When the air temperature cools in the fall, we find it infecting aphid colonies in the gardens. The fungus becomes active in the bioshelter in November and early December, just as the insect predators are becoming less active. With our assistance, the *Beauveria* fungus virtually eliminates aphids, whiteflies, spider mites and thrips until March, when it becomes too warm inside for the fungus to infect insects. By then, the predators are active again. In a sunny winter, the fungus is not as effective, due to higher temperatures and lower humidity.

This fungus occurs naturally in organic soils when conditions are right, that is, when the humidity is high and temperatures are cool. Every November, it first appears on aphids that are feeding on the underside of

Aphids.



low-lying leaves of tatsoi mustard, spinach and borage. Infected aphids first appear stiff and yellowish, then become white, with a bloom of spores. As the building gets cooler in December, the fungus can rapidly spread among colonies of aphids and quickly eliminate them.

*Beauveria bassiana* spores grow into the cuticle of susceptible insects, including whiteflies, thrips, aphids and spider mites. Soil-dwelling insects tend to be immune to it, but many leaf-dwelling insects succumb to various strains of this fungus and other entomopathogenic fungi. Because the spores are heavier than air, they need assistance getting to the insect host. Washing aphids off of plants and onto the soil may bring them in contact with spores. A spray application of the fungus is more effective.

*Beauveria bassiana* is available from commercial sources. It is labeled as effective for specific pests at specific humidity and temperatures. However, I suspect finding and using your own local strain is a better alternative. We collect fresh, infected aphids and place them in a clean plastic deli tray. We add a little distilled water and place them in a cool, shaded spot for a few days to spore. With proper moisture and temperature, each infected aphid will produce millions of spores. We then add more water to the trays and shake them vigorously to suspend the spores in the solution. We use a spray applicator to spray the solution onto our seedlings and infected plants. We apply the fungus on a Friday or Saturday after a harvest and plant clean-up; a cloudy cool day is preferable. Infected aphids do not readily wash off, so infested leaves need pruned off and fed to the chickens (after we have collected the specimens we want for spore culture). After one or two applications, insect populations are so reduced as to not be a problem for a while. Spring seedlings are sprayed weekly to prevent leaf-dwelling insects from colonizing.

When not infecting insects, the spores can lie dormant in the soil and also work as decomposers of decaying organic matter.

The US EPA lists *Beauveria bassiana* as non-toxic and non-infective to mammals, noting that it grows at temperatures well below human body temperature. It is approved for outdoor use and indoor use in greenhouses. However, there is a slight possibility it could cause an allergic reaction in susceptible individuals. It is best to apply the spores in solution to avoid creating excess airborne spores. A dust mask is always a reasonable protection for application of any spray. Also, follow any guidelines on commercially available strains. The EPA also warns of potential to infect honeybees. For more information, visit www.epa.gov/pesticides/biopesticides/ingredients/index.htm.

### *Predatory Mites*

We purchase predatory mites as needed to help reduce populations of thrips and two-spotted spider mites. These microscopic relatives of spiders consume the eggs, nymphs and adults of their prey. Spider mites apparently are also killed by the *Beauveria* fungus, but as the bioshelter warms in the spring, the fungus is less active.

When we see populations of spider mites in the bioshelter, we order the predatory mite *Phytoseiulus persimilis* from a commercial insectary. It is best to release these predators in late winter, when the bioshelter is neither too hot nor too cold for the predator to be active. After placing the order, we spray several applications of insecticidal soap to reduce the populations. After that, the persimilis mite is very effective in controlling the two-spotted spider mites.

We sometimes release the predatory mite *Amblyseius cucumeris* in spring to help control the population increase of thrips in the bioshelter. Thrips are especially active consumers of nasturtiums. Again, we first make several applications of soap spray to reduce populations of thrips before releasing the predator.

## Weed Control

A weed, to repeat the old saying, is just a plant in the wrong place. Many plants some gardeners consider as weeds are valuable wild edibles to us. These, of course, can get out of control and suppress the main crop. Bioshelter weeds include snapdragon and nicotiana, which both self-seed profusely.

Ehrenfried Pfeiffer, the biodynamic farmer and writer, outlines three types of biological weed management. First is planting the crop seeds thick enough to outgrow and choke out weeds. This can be a good strategy for planting lettuce in warmer months. In colder months, a dense planting can cause disease in the lettuce.

The second strategy is to plant a crop that has allelopathic properties to suppress weeds. Rye grass is a good winter crop for suppressing winter and spring weeds, and clover can suppress weeds in the summer.

The third biological weed control Pfeiffer offers is to improve the soil with compost, manure, lime and drainage. Soil improvement is an ongoing process, though, and we wonder if this really only changes the type of weeds that grow.

To Pfeiffer's measures, we add that weed control begins with seed control. Undesired weeds should not be allowed to seed. When weeds go to seed, those seeds can continue to germinate for many years. Each seed has a slightly different chemistry for breaking dormancy. Sunlight, moisture and time are all elements.

If a farm has sufficient space to produce its own mulch, weed seeds will not be as big of a problem. It's *imported* mulch and manure that will bring in weed seeds. This is where our field got its Canada thistle and probably its red dead nettle. Canada thistle is a noxious weed by legal definition. It spreads by seed and perennial roots. We strive to eradicate it by mowing and cutting it before it can flower. When patches do flower, we burn them with a torch before cutting the stalks and burning them in the fire pit. Admittedly, each weed has some virtue: Canada thistle is a wonderful bee and butterfly forage plant. But that does not make it a desirable plant.

## Disease Control

When a disease appears in the garden, the problem is often environmental. Weather, soil type, fertility, and other factors can stress plants and allow them to become diseased. A farmer should keep references on hand to identify plant disease. State plant inspectors are happy to help identify problems.

### *Mosaic Viruses*

There are tomato, tobacco, lettuce, and cucumber mosaic viruses. All are similar — making it hard for the average gardener to identify which one is the problem. All are spread by infected seeds or carried from plant to plant by aphids and other sucking insects or the gardener's hands when managing diseased plants. The virus can survive up to two years in infected plant residue.

Cucumber mosaic virus, especially, is carried by many weeds and their seeds. Aphids get it from infected plants and transfer it to other plants. As with many pathogens, it is likely that mosaic virus has some benefit to the aphid. The weakened plants do draw other aphids. Cucumber beetles quickly spread the disease among cucumbers and squashes. Planting resistant varieties is often the only way to prevent crop loss.

There are three times when you have a chance to control these viruses: when buying seeds; when weeding out infected plants; and when choosing how to control vector insects.

Control in the bioshelter begins with the use of mosaic-tested lettuce seeds (MT0). These seeds are tested and declared to be virus-free by the seed company. Using only mosaic-tested seeds in the greenhouse will help reduce or prevent lettuce mosaic virus.

Because mosaic virus is present in the outdoor gardens, it eventually is carried inside a greenhouse by aphids and other sucking insects. The virus may be present is a healthy looking plants and not appear until the plant is stressed. In winter, when the soil is cooler and plant defenses are low, the virus' effect appears. The misshapen leaves and stunted plants are easily recognized. Infected plants should be gathered and fed to the chickens as soon as they are found.

Many plants in the bioshelter are susceptible. Our self-seeded wild edibles, chickweed, wood sorrel, purslane, lambsquarters and amaranth can all carry cucumber mosaic virus. (Because these all self-seed, infected plants can be hidden on the floor, under planters, and in odd corners of our polyculture beds.) Our collection of ornamental oxalis is prone to mosaic virus. During the summer, plants will appear fine, but in the middle of winter the leaves will be misshapen and stunted. Self-seeded snapdragons also are a common host. When they germinate and begin to grow in the winter greenhouse, obviously infected plants are removed, and healthy looking plants are allowed to grow. It is best to remove all infected plants as they appear.

Aphids are most able to spread the virus when they begin to grow wings in the middle of winter.

### *Powdery Mildew*

Powdery mildew is often a problem in the bioshelter, primarily in the cooler months. Mildew doesn't usually overwinter outside in cold climates such as ours, but it returns with the summer rain. Outdoors, it appears in early fall on red clover, plantain, and other plants. Inside the bioshelter and cold frames it can grow as a faint white powder on the leaves of pansy, columbine, tomatoes, calendula, rosemary and a few other crops. The mildew can spread under cool, moist conditions and will kill a plant if unchecked. The first control for powdery mildew is environmental: *Do not get leaves wet when watering.* Water sitting on leaves in cool, cloudy weather will provide the conditions for powdery mildew to get established. Keeping leaves dry is not easy when watering. Poor air circulation in a closed building makes the problem worse. Also, there is a trade-off, because wetting leaves can help reduce other pests, such as whiteflies, thrips and especially spider mites. This is probably because wetting helps promote parasitic fungus and other insect disease. So a decision must be made whether to wet leaves or not. This is often a major source of disagreement between bioshelter managers at our farm. As with all agricultural practices, timing is everything. If spider mites and thrips are present and mildew is not, wetting the leaves will help control the pests.

When plants do become infected with powdery mildew, it can be cured by dusting the leaves with powdered sulfur. The sulfur will kill the mildew, but also will kill the leaf. So the treatment must be timely to save the plant. We have noticed that plants treated with the sulfur powder often grow back looking healthier; we suspect powdery mildew is related to sulfur deficiency.

### Slugs and Snails

Terrestrial mollusks, slugs and snails can be the bane of the market gardener. Continuous battle is necessary some years to control their numbers. Our worst pest is the grey field slug, *Deroceras reticulatum.* This native of Europe has followed gardeners all over the planet. We also do battle with the garden arion slug, *Arion hortensis.* This is also a European immigrant that is partly identified by its orange mucus trail. We began to see a small snail in our gardens in 2003. While not overabundant, it has spread throughout the farm. The appearance of snails can indicate an increase in available calcium, which is necessary for snail shell formation.

Slugs and snails are a favored food of fireflies. With all the thousands of fireflies we see each summer, I shudder to think how many more slugs we would have if there were no fireflies. Snakes also eat slugs, as do some songbirds.

The population of slugs in our gardens has risen and crashed several times in the past 20 years. Slugs are the worst in wet years and after mild winters. Old, damp straw and hay can harbor slugs and their eggs, so mulching with straw is often a big mistake. Slugs eat a wide range of crops and seedlings, including most salad and cooking greens.

When our children were young, we paid them a penny a piece to collect slugs. Wearing latex gloves, they picked slugs off plants by hand. Consequently, each spring, the kids had plenty of money for bike rides to the local ice cream store. Slugs come out in the early evening and can be collected in buckets of water. They are eagerly consumed by chickens. Since the children have grown, I have inherited the job of collecting both slugs and snails. Beer traps are effective and can collect dozens of slugs in a night when infestations are severe. I fill a tray half-full of beer and set it down into the soil. Slugs crawl into the beer and drown. Beer traps need to be emptied right away though, because slugs smell horrendous after they are dead a few days. It is best to feed them to the chickens each morning when they are freshly "pickled."

Diatomaceous earth, with its sharp, jagged texture, will deter slugs, but our gardens are far too large for its use to be practical. We do treat our outdoor seedling frames with diatomaceous earth. Slugs like to hide under the flats and come out at night to devour young seedlings. Between collection and the diatomaceous earth, we have been able to minimize slugs' effect on our seedlings.

In recent years, we have reduced our use of imported straw mulch and increased our use of leaf mulch. This may be responsible for the major crash of slug populations in 2006.

## Mammals

### *White-tail Deer*

The most common question we receive when presenting garden workshops is "How do you control deer?" I suggest a double fence system and a good dog. We have had almost no problem with deer on our rural farm in 20 years. I attribute this to the presence of our farm dogs and the local hunters who keep populations under control. Occasionally, a deer will sneak in to eat fallen apples, but they generally avoid us.

Many suburban communities struggle with the "Bambi phenomenon" — heavy resistance to reducing deer populations through hunting.

This is the result of an unfortunate misunderstanding of ecology. The natural processes of life require a balance of predators and their prey. Deer populations in nature are controlled by heavy predation. When we remove predators from the system, we must work to restore balance. Choosing *not* to control the population of deer and other game animals turns them into pests.

### *Groundhogs*

You say groundhog, I say woodchuck. We both mean *Marmota monax.* This wily rodent, most closely related to the squirrel, is the bane of gardeners across North America. Woodchucks can destroy a case or more of lettuce in a morning and will take a bite out of each tomato that begins to ripen. They will climb over a fence or bite a hole through chicken wire to get at your garden. The damage they can cause goes beyond the loss of crops. They can even undermine building foundations.

To control woodchucks, we must first examine their role in nature. As a strict vegetarian, they are a primary consumer in the food chain. They, themselves, are food for wolves, coyotes, dogs (and people). Young woodchucks are among the prey of foxes, owls and hawks. Their habit of digging extensive burrows does have the positive effect of bringing mineral-rich subsoil to the surface and air into the soil. When they abandon their dens, skunks, foxes, rabbits and other creatures use them for shelter. In their natural environment, woodchucks are an edge species, preferring to forage the meadow from a burrow on the forest edge; they are a key species in the ecological balance wherever they live.

Woodchucks begin to breed in their second year and can produce a litter of up to six young. They actually do arise from three or four months of hibernation in late winter and their young are born in early spring.

Spring is a good time to inventory burrows and mark their location. We like to fill in the borrow entrance and then come back to see if the burrow is active. Later in spring and summer, we are alert for new burrows as the young strike out on their own to seek new pasture. They are elusive — up early and out late — though they may forage at any time of day. They like to stand guard over their burrows and watch for intruders. The only sign you may have of their presence in the underbrush is their shrill whistle of warning as they flee to their burrow.

Our primary control method has been to have a good-sized farm dog. As discussed elsewhere, setting up predator-prey relationships on the farm is an important part of ecological design. A young and energetic dog can kill its own weight in woodchucks every week. Older dogs that have been bit once or twice will get wary and may need assistance from the farmer. As our first farm dog aged, woodchucks and rabbits began to move into our tree lines and gardens again. When he was not as good at chasing them down, we had to help. One way was to flood out the burrow with the irrigation hose. First, all exits but one are filled in. Then the hose is turned on. When the animal comes out of the burrow, the dog can catch it.

We once had two dogs, ours and a neighbor's, that developed a tag-team approach. One would guard the burrow, while the other chased the foraging woodchuck toward him.

If you have no dog, a .22 caliber bullet or two usually is sufficient to kill a woodchuck. But be aware that there may be more than one woodchuck per burrow.

You can also buy sulfur dioxide smoke bombs that will kill them by asphyxiation. If you use these, be sure to cover all other holes and then the hole with the smoke bomb. Follow all instructions and do not breathe the smoke.

Woodchucks are easily caught in a large-sized live trap. Apples are common bait. Once you have the animal in the trap, you should either kill it or take it at least ten miles away. They are particularly nasty when cornered and will bite, so use all necessary precautions when handling, or otherwise controlling them (or any wild animal). I personally do not think it is fair to give someone else my problem, but perhaps you can take it to a state game land or other place where it will not be a pest.

Once a woodchuck is dead, we usually bury it back in the hole it came from. We do have friends who find the meat of the woodchuck to be fine for roasting. It is indeed tender when the animal is young; it is similar to roast beef. They are best in July, when they weigh about five pounds. But we do not usually eat them. If you chose to add them to your diet, be sure to follow all precautions in handling wild game. Woodchucks have several musk glands that need to be removed. Woodchuck fur is too coarse to be of value, although Native Americans used their hides for leather goods.

### *Rabbits*

The Eastern cottontail, *Sylvilagus floridanus,* is the rabbit that we share the land with. They, too, are primary consumers, and are even more important to the diet of predators than the woodchuck. Rabbit populations rise and fall on a ten-year cycle, in ecological step with the populations of foxes and other predators. Rabbits can produce three new generations each year. About 25 percent of these survive to reproduce the next year. Fox, weasels, coyotes, dogs, cats, owls, hawks and snakes all prey on rabbits.

Rabbits can cause considerable damage to crops. They especially enjoy grazing on seedlings of lettuce and other greens. They can quickly girdle and kill a young fruit tree in the winter by eating the bark. Fencing for rabbits should be at least 2 feet high and bent flat to the ground at the base to prevent them digging underneath.

Rabbit control includes predation of young rabbits by the farm cat. We also hunt and eat them. During the summer month, rabbits often have warbles, a fly larva parasite that lives under a rabbit's skin, on the back of its neck. So we usually hunt them in the early spring and fall.

Rabbits can also be caught in a live trap and released off the farm. Almost as soon as one is removed from the farm, though, another moves in to take its place. The combination of hunting, fencing, and predation helps keep them from becoming too much of a problem.

### *Small Rodents*

A vole looks like a large mouse. The meadow vole, *Microtus pennsylvanicus,* is a common and constant garden pest. Voles are often mistaken for moles. Moles also burrow in lawns and gardens, but they do not eat vegetables; they prefer worms, slugs, snails and even small mice. Moles actually are beneficial because they loosen and aerate soil while patrolling for their prey. Voles also burrow through garden beds and loosen soil. But they eat our crops. They can quickly ruin a crop of potatoes, bite into ripening tomatoes and consume many root crops. They especially love mulched beds.

Voles are controlled by predators as well. Weasels and foxes hunt them. Cats and dogs will catch them when they can. Dogs can learn to locate and dig them out of the garden beds during winter months. In the summer, when dogs are excluded from the gardens, we catch them in rat traps baited with cherry tomatoes or root crops. Regular rototilling between crops also seems to discourage them.

Voles occasionally move into the bioshelter's deep beds. When we see their tunnels, we set traps to catch and eliminate them.

Various types of mice can be a problem in the garden and greenhouse. They will eat seeds and young seedlings of lettuces, peas, squash and other crops. The farm cat and natural predators, including snakes and weasels, keep down the outdoor population. Inside the bioshelter, we regularly trap them to control the population. Seeds are stored in sealed containers.

## The Farm Dog

A good dog or two is essential for farm pest control. First of all, the dog must be friendly and like children. They need to be almost a year old to really begin training. Dogs, contrary to what many people think, like to have a space of their own to hang out in. So being chained to a doghouse is not so bad from dog's point of view — so long as there is an adequate length of chain and access to fresh water. What is needed is daily exercise. Training to follow commands, including come, stop, walk, run, and sit is required. Never try to train a dog if it is not on a leash. The best reward for most dogs is a good rub behind the ears and words of praise, though dog food treats can also help with training.

The dog should be trained to walk the farm's pathways and to avoid garden beds. Daily walks around the farm's perimeter create a routine and makes the dog familiar with his territory. Dogs need to be trained to relieve themselves in appropriate places; in our case, that means along certain parts of the tree line and under the utility line, well away from foot traffic and harvest areas. Once the dog knows the property, and it is trained to stay on the farm, you can begin training it to hunt for pests. Most dogs have an instinct to kill woodchucks, chase rabbits and, sometimes, dig for moles. If the dog you are working with does not have that instinct, consider finding it another home and get another dog. Once they know the game, dogs will spend a lot of time finding a woodchuck's pathways and holes and chasing them down.

## The Farm Cat

Cats are territorial hunters. They will patrol an area of about four to five acres. Young cats will climb trees and can catch birds. But as they get older, cats seem to learn that ground-dwelling rodents are easier prey.

In the spring, they help control the population of young rabbits. Cats are necessary in a landscape to control voles, mice and young rats. Overfed cats are less likely to hunt as frequently, but this varies from cat to cat.

The ecological view of cats in the landscape is based on carrying capacity. One cat hunting on a five-acre farm is a good balance. Even the occasional bird lost to a cat may be good for the ongoing evolution of songbirds. But adding more cats can quickly overburden an ecosystem. The classic food pyramid shows the population of predators as the small triangle at the top of the food chain. Predators are by nature territorial to keep in balance with their prey populations. As food farm managers, it is important to keep the number of cats in the neighborhood to a minimum. When we do get a new cat at the farm, we always are sure to schedule a veterinarian appointment for all shots and birth prevention procedures.

Cats should not be allowed to use the garden for their litter box. We prepared a space in the tree line with sand and cat litter and encourage our cat to use these facilities. Cats can carry the protozoan parasite *Toxoplasma gondii,* which causes toxoplasmosis in humans. Cats get the parasite from eating rodents and birds. The parasite breeds in a cat's intestines for several weeks and can spread to people through contact with cat feces. The parasite can live up to 18 months on the soil. While the effects are usually mild in adults, pregnant women should avoid contact with cat feces. Toxoplasmosis can cause severe complications for a developing fetus.

## Pests and Permaculture

As with other aspects of permaculture design, ecological pest control is based on an understanding of ecological systems, continuous observation and experimentation. The diversity and balances that have developed in our five-acre field are a small step, but they are a good indication of the potential of permaculture design.

Chapter 7

# The Market Garden Farm: Management

*Apart from the character and condition of the soil, the location of the farm and the crops to be grown, two of the most important factors that influence profit and loss are the "lay" of the land and the "lay-out" of the land. Lay always refers to natural features: lay-out to the artificial ones. … Each of these has a bearing on the character of the farming to be conducted.*

— M.G. Kains, *Five Acres and Independence*

This chapter continues the study of farm design with a look at the layout of Three Sisters Farm, our crops, and other important aspects of the farm.

Our gardens are treated as separate, but interacting, elements within the farm system. Their different aspects (variously sloping to the south, west and east), microclimates and drainage patterns, as well as their locations relative to the bioshelter, determine their role in the farm management and development plan. Annual records are kept of the crops grown in every garden and are referenced when planning crop rotations. The annual garden plan takes into account each garden's history and unique character.

Each garden is composed of raised beds laid out on contour. Pathways between beds collect rainwater or can be flooded with water pumped from the pond. Wide central paths, mulched with cardboard and sawdust, allow access to the contour paths. The four main gardens have fences, birdhouses, compost areas, and irrigation hoses.

As we develop gardens, we allow uncultivated areas within or near them. These biological islands, together with herbs and flowers and other insectary plants, provide a healthy balance of predatory creatures.

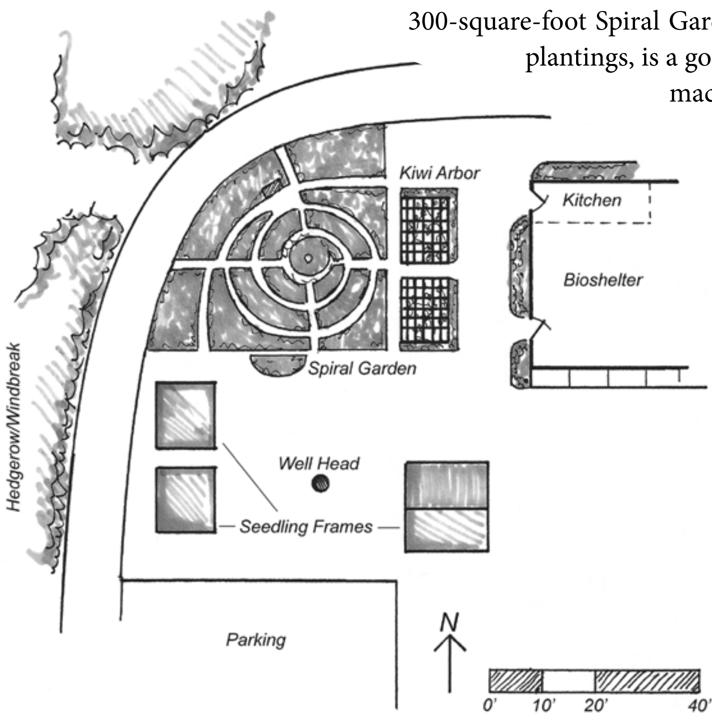
Birdhouses, rock piles and perennial plantings of fruit, nuts, berries, vines, shrubs and flowers are added each year. Plantings are placed to create windbreaks and shade zones. Large planters are used to store stones collected from the garden beds. These function as hose divots and also provide summer shelter for snakes and toads. In the spring and fall, the stones are used to hold down floating row covers.

Planting begins in the gardens closest to the bioshelter and we work outward to the other gardens as the season progresses. First, we plant the East and South gardens because they are sheltered from the winds by the bioshelter itself and slope to the southeast and south. When the weather is more stable we begin planting in the Pond Garden and Southeast Garden. Next we put summer crops in the West Garden and several smaller gardens around the farm. Culinary herbs are more likely to be planted in the gardens closer to the bioshelter, in Zones 1 and 2, where they can be better tended.

*The area immediately west of the bioshelter is a "zone one" or daily use area, where garden transplants and plants for sale are tended.*

Zone 1 Landscape:

The area within 70 feet of the bioshelter's west side, including our 300-square-foot Spiral Garden, seedling frames, kiwi arbor and other plantings, is a good demonstration of the application of permaculture design. A series of windbreaks slows and deflects ground-level wind from the west and northwest side of the bioshelter. A hardy kiwi arbor provides a shaded break room and relaxation space. The Spiral Garden allows for easy harvest of herbs and flowers, promotes biodiversity, and creates an aesthetically pleasing setting for greeting visitors. Flower and herb gardens, habitat plantings, and frames for growing and displaying seedlings are all located here for ease of watering, tending and harvest.



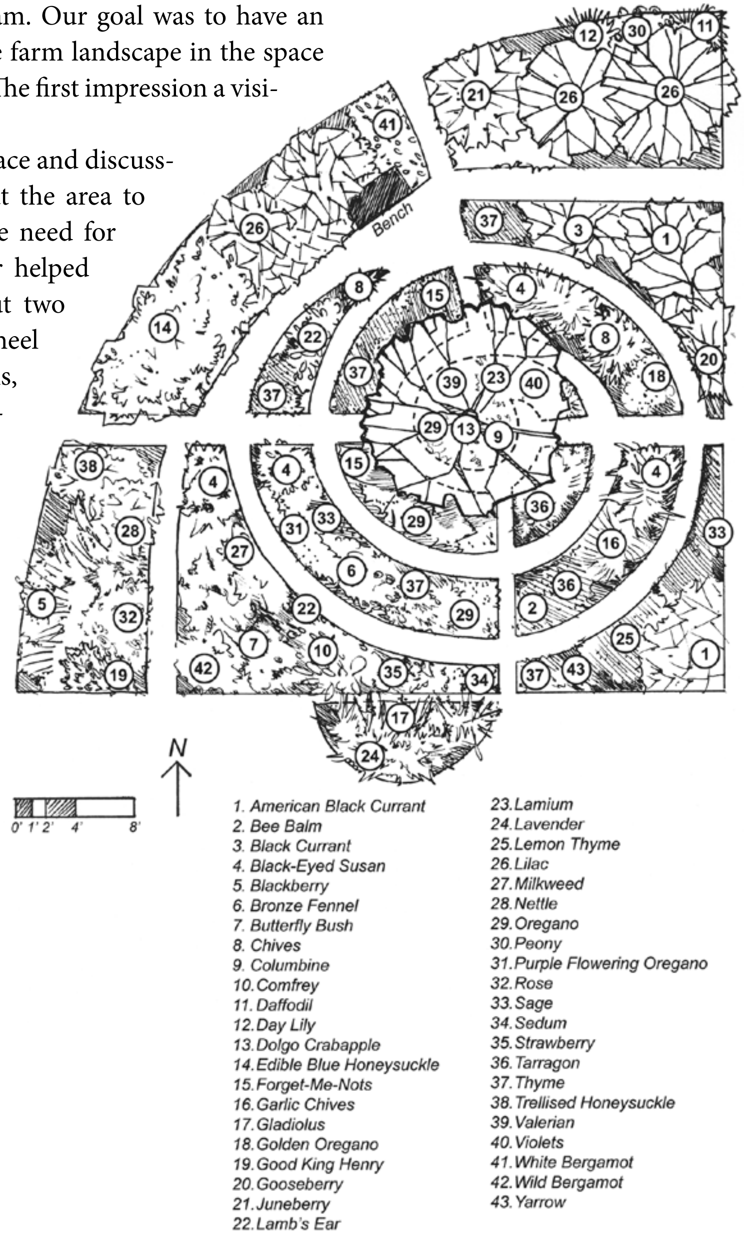

## The Spiral Garden

Designing the Spiral Garden was an important process for Linda and me. We wanted to work closely on an important project to hone our skills as a design team. Our goal was to have an inviting and functional centerpiece of the farm landscape in the space between the bioshelter and the driveway. The first impression a visitor receives can be very important.

We spent an evening looking at the space and discussing several possibilities. We sketched out the area to scale. The curve of the driveway and the need for a wide pathway adjoining the bioshelter helped define the shape and area. We drew out two possible layouts. One was a medicine wheel of concentric circles of beds and footpaths, with paths to the four directions. The second design had a path beginning directly opposite the bioshelter's kitchen door spiraling into the center, with wide beds in between. Connecting pathways to the four directions would allow easy access from all sides. The spiral design spoke to us both. It added an element of mystery — a curving path — inviting one to wander through and linger. The medicine wheel design was very nice and simple but the spiral was more interesting. (We later used the medicine wheel layout for our medicinal herb garden.)

Linda would have primary responsibility for the management of the Spiral Garden. She laid out the beds at a width she could work with and had free reign to develop the plantings.

We allowed space on the outer edge for shrubs and left enough room for an arbor between the bioshelter and the Spiral Garden. The first years of the Spiral Garden, Linda planted mostly annuals, such as basils, edible flowers




*Both ornamental and functional, the spiral garden is evolving into a forest garden as the apple tree and shrubs mature.*

and cut flowers. Every year she added more perennials; as the shrubs grew, she added an understory of herbaceous perennials. Over a period of 18 years, Linda has transformed this from a garden of annual plants to a complex, multi-level garden in the process of becoming a forest garden.

Each spring the path is hoed level and mulched with a few layers of newspaper and covered with a few inches of sawdust. The beds are cleared of grass and unwanted plants. Self-seeded herbs and flowers, such as garlic chives, bronze fennel, forget-me-nots and bee balm, are potted as needed. After thorough weeding, the beds are mulched with shredded tree bark.

The Spiral Garden is the Zone 1 garden for the bioshelter kitchen. It serves multiple functions:

- Allows quick access to small herbs for orders and harvest supplement.
- Supports a thriving biodiversity of insects, at the center of the farm.
- Adds beauty and interest to the visitor entrance.
- Creates an educational space for herb and flower identification, insect study, etc.
- Provides a quiet and beautiful sanctuary.
- Serves as a windbreak.

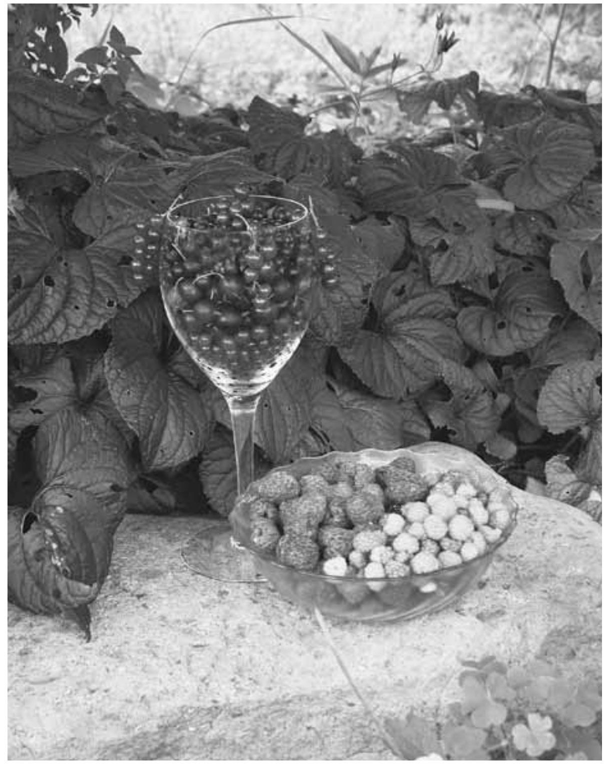
*Young Terra Frey enjoys August raspberries in the driveway windbreak.*

Catherine Paladino

### *Windbreak*

The outer edge of the Spiral Garden is planted with shrubs. The shrubs shelter the garden from wind, block dust from the adjoining driveway and create an intimate, enclosed setting. The shrubs include purple lilac, white lilac, Juneberry, edible honeysuckle, a trellised honeysuckle vine, blackberry and rugosa rose. Interplanted with these are foxglove, iris, lupine, peony, daylily, white bergamot, nettle, lamb's ear, rudbeckia, chives, and assorted groundcover plants. A stone bench in the north bed, among the Juneberry, bergamot and honeysuckle, allows one or two people to sit and observe the garden. The center bed is planted with a flowering and fruiting Dolgo crabapple with a perennial understory of valerian, columbine, violets, thyme and variegated lamium. (The Dolgo crabapples make a beautiful and deliciously tart applesauce.) Other shrubs in this garden include American black currant, black currant, and gooseberry.

Most beds in this garden have established perennial flowers and herbs interplanted with annuals each year. Plants include lemon thyme, creeping thyme, silver thyme, German thyme, dianthus, golden sage, tricolor sage, green sage, purple sage, clary sage, violets, lupine, daylily, peony, red bergamot, purple bergamot, lamb's ear, black-eyed Susan, stinging nettles, Good King Henry, garlic chives, chives, ox-eye daisy, bronze fennel, yarrow, gladiolus, iris, catmint, lavender, sheep sorrel, variegated lamium, and forget-me-not. Potted rosemary, white sage, Mexican sage, blue sage, pineapple sage, calla lily and other tender perennials are placed in this garden most years.



*Summer harvest treats, red currants, black currants, and red and golden raspberries.*

Heavy stones placed at bed corners help frame and define the beds. They also serve as hose divots to prevent us from dragging the hose over plants when we are watering.

### *Kiwi Arbor*

Between the bioshelter and the Spiral Garden, we built an arbor to support several hardy kiwi vines (*Actinidia arguta*). The arbor is actually two arbors, each 10 feet long and 6 feet wide. Eight posts, measuring 4 inches by 6 inches and 7 feet tall, are set on concrete piers. Angle bracing and rafters, made of 2-inch by 6-inch lumber, complete the framing. Trellises made of 2-inch-wide oak strips are placed on two sides of each arbor, creating an intimate setting and increasing the windbreak function of the arbor. Chairs and benches under the north half the arbor provide a lovely setting to visit with guests and enjoy the Spiral Garden.


DARRELL FREY

Hardy Kiwi.

The south half of the arbor is used to store shade-loving wildflower seedlings. The arbor is framed on the north, east and south sides with stone-edged beds. These are planted with one male and two female kiwis and a variety of herbs. Sweet woodruff and wild ginger are on the north, shaded side, and yarrow and thyme are on the sunny, south side. We also plant an annual flowering vine on the trellis. In years past, we've planted morning glory, peas and scarlet runner beans.

### *Seedling Areas*

Several covered frames and a greenhouse are located between the Spiral Garden and the parking area. These are used for holding seedlings and potted plants for the gardens and for sale. Every day, from spring through fall, the plants in the seedling frames, seedling greenhouse and under the arbor are watered from a garden hose on the west wall of the bioshelter. This hose is rolled up and kept out of traffic every day.

The earthen berm on the west side of the bioshelter is planted each year. A local red grape climbs a trellis over the main kitchen door, providing shade from the late afternoon sun as well as edible leaves and fruit. The vine is pruned each spring and puts out abundant new growth each year. Excess shoots are pruned and leaves are harvested for use in our kitchen. The rest of the berm has had a number of different plantings over the years. Lemon balm, dwarf evening primrose and an ornamental perennial geranium have persisted on the south end for 15 years. Wild oregano has grown on the north edge and around to the north end of the berm. The rest of the bed has been, at times, a strawberry bed, a couch of chamomile and thyme, and a cutting garden of rosemary and other herbs.

The north side of the bioshelter also has an earthen berm along the 20-foot-long kitchen wall. This is planted with a wildflower garden that has ostrich fern, trillium, wild ginger, sweet woodruff, wild clematis, Virginia creeper, snowdrops, wild oregano and a persistent wild blackberry. This, and a second wildflower garden on the opposite end of the bioshelter's north wall, take advantage of the shade cast by the building. The resulting microclimate is adequate for many wildflowers.

A wildflower bed on the east side is watered by a swale draining the driveway. This garden includes the purple-flowering raspberry, red currants, and a number of wildflowers: Dutchman's breeches, wild bleeding heart, trillium, black cohosh, wild columbine, Virginia waterleaf and others.

### *Tansy*

A large patch of tansy, 5 feet in diameter, promotes beneficial insects in this Zone 1 area. The patch is watered by the swale between the bioshelter's west wall and the kiwi arbor. Because tansy grows tall and has a tendency to fall over, we tie it to a fencepost for support.

### *Square-foot Beds*

Square foot gardening is a method of small-scale intensive gardening popularized by Mel Bartholomew in his book *Square Foot Gardening*. This system of gardening in wood-framed beds is good for small spaces in urban and backyard gardens. Most of our other gardens are large and sprawling and may not inform the home-scale gardener. Square-foot beds are more organized and can easily demonstrate intensive-gardening techniques. When visitors arrive, they are greeted with a simple display garden of square-foot beds. The beds are 5 feet on each side and are framed with 1- by 6-inch lumber. They are interplanted with herbs and edible flowers. One square is a "Three Sisters Garden" (with squash, beans and corn).

A pathway leads from the parking lot to the bioshelter, past the gardens and seedling frames. A small garden surrounds the water well casing in the lawn between the Spiral Garden and parking area. A small (but spreading) section of herbal lawn has developed along the south edge of the Spiral Garden. Creeping thyme and yarrow spread through and compete well with the grass. Regular mowing keeps this fragrant lawn soft. The open area between the Spiral Garden and the parking lot allows a direct view of the Spiral Garden as visitors arrive. This space serves as a staging area for farm tours; from there, we can point to most of the farm's systems and explain what we do.

Flower beds adjoin the square-foot beds and separate the parking space from the South Garden. These provide edible flowers, cut flowers and more material for herbal bouquets. The flowers provide an attractive first view of the farm.

## The South Garden

Measuring approximately 10,000 square feet, the South Garden is our prime growing area. Beds are laid out on contour running east to west. The garden gradually drops about 3 feet in elevation from the bioshelter to the south property line.

The South Garden includes the cold frames (discussed in Chapter 4) that are attached to the bioshelter. A wide path separates the cold frames and bioshelter from the South Garden. This path leads past the bioshelter, along a swale that drains the building's south roof, through the East Garden and then to the far southeast corner of the farm. A polytunnel garden is located in the northwest corner of the South Garden, near the bioshelter. The rest of the South Garden is rotated with annual crops.

*Lettuce Harvest in the south garden at Three Sisters Farm.*

TOM GETTINGS

The South Garden is the first garden planted each year and the last one to be harvested in the fall. This is because it is closest to the bioshelter, so most convenient. Also, the south-facing aspect of this garden warms the soil earlier in the spring.

Three beds in the southeast corner of the South Garden are partially shaded by a row of filberts along the property line. These beds are often planted with cool-weather crops in summer to take advantage of the cooler microclimate in the shade zone.

On a few occasions, when grasses invaded the beds on the northeast quarter of the South Garden, we fenced in that section and let the chickens forage it for a season. We left the beds fallow overwinter and then put them back into the garden rotation.

A wide path along the western side of the South Garden follows the course of a buried electric line. By locating the path over the line, we keep track of its location so the phone or electric company can find it if they ever need to.

## The East Garden

The East Garden falls gently away from the bioshelter, sloping slightly to the east and southeast. This garden is protected from wind by the bioshelter and the bale-shelter to the west and north. It is protected from the occasional east wind by a mature tree line on the east. As with the South Garden, early spring and late fall crops are planted here to take advantage of the sheltered site and easy access to irrigation.

The lower portion of the East Garden is treated as a Zone 3 area. Perennial beds of chives, mint, sheep sorrel and wild coltsfoot are all harvested from there.

TOM GETTINGS

*Linda Frey and Pam Owens harvest head lettuce.*

## The Southeast Garden

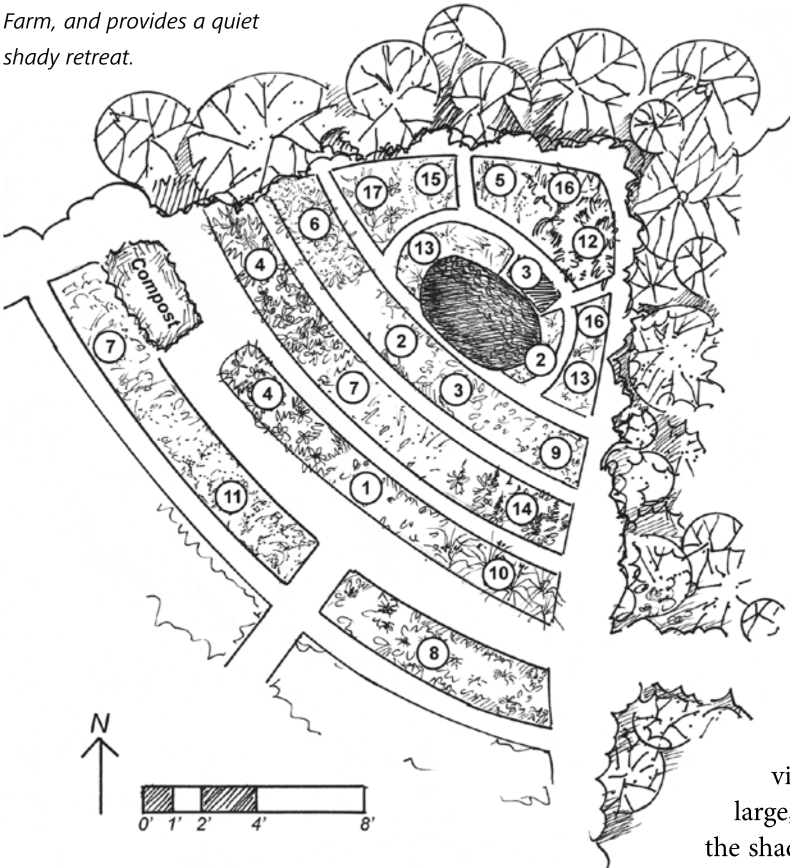
The Southeast Garden is a triangular wedge of land between the East and South gardens. Actually all three gardens are enclosed within a continuous fence, but the separate designations help us plan and manage them. The upper portion of the Southeast Garden includes a small grove of black locust trees with a comfrey understory. This area is difficult to rototill because of its small size and shape. It is fenced in to be a part of the poultry's rotational pasture. After a fall, winter or spring turn as poultry forage, the beds are shaped by hand and planted with hills of corn, beans and squash, or other mulched crops. The lower portion of the Southeast Garden borders the South Garden fence; it is planted in golden raspberries, a local variant of the black-capped raspberries that we discovered in the wild and have been propagating to increase production. The black-capped raspberry grew well on its own here, so we took note and added more, especially the golden variety.

Between the lower beds and the upper section of the Southeast Garden is a series of eight raised beds on contour. These beds are planted as part of the garden crop rotations.

## The Pond Garden

The Pond Garden slopes toward the southwest and borders the pond. This garden receives the force of winds from the west straight on, but it is partially protected from the prevailing northwest winds by the tree

*The wildflower garden showcases native plants grown by Three Sisters Farm, and provides a quiet shady retreat.*




1. Bee Balm
2. Cardinal Flower
3. Great Blue Lobelia
4. Green-Headed Coneflower
5. Jacob's Ladder
6. Joe Pye Weed
7. New England Aster
8. Purple Coneflower
9. Spearmint
10. Spiderwort
11. St. John's Wort
12. Staghorn Sumac
13. Swamp Milkweed
14. Wild Blue Lupine
15. Wild Columbine
16. Wood Geranium
17. Woodland Sunflower

line. The lower and eastern portion of the Pond Garden is subjected to the northwest wind due to a gap in the tree line where wet soil suppresses tree growth.

### *Native Plant Garden*

The Pond Garden includes a perennial wildflower garden at the upper, northeast corner and a developing forest garden on the edge of the tree line to the north. The contours and shape of the Pond Garden create a triangular area in the northeast corner that is too small and oddly shaped to till often. This is planted with a native plant garden. It serves both as a public space for visitors looking at the wildflowers and a private space for intimate conversation.

The windbreak planting of old farm roses to the east and the fruitful tree line to the north create a sheltered and private setting with a view of the pond and Pond Garden. A large, flat rock serves as a bench beneath the shade of a staghorn sumac grove. Under the sumac is an understory of wild columbine, woodland sunflower and New England aster. A small 6-foot by 12-foot clay-lined earthen pool collects and holds rainwater. We often keep the pool filled during dry weather with water pumped with solar power from the pond. An overflow hose from an irrigation tank keeps it recharged as needed. This pool is surrounded by water-loving plants, including spearmint, cardinal flower, and swamp milkweed. Below the pool, a series of three beds curve from east to northwest. The paths between the beds are laid out to drain the beds toward the northwest edge. The east ends of the beds are planted with plants that prefer drier soil, including lupines and Virginia spiderwort. Plants preferring damp soil, including bee balm and blue lobelia, are planted in the middle section of the beds. The wetter, northwest edge of the beds is watered by occasional overflow from the pool and rainwater falling on the paths. This section is planted with moisture-loving plants, including Joe Pye weed, green-headed coneflower and swamp milkweed.

A broad path curving around the south-most bed offers a clear view of the native plant garden. Several shorter beds, just beyond the path, are planted in sun-loving native plants, including bee balm, purple coneflower, New England aster, and the medicinal St. John's wort.

The native plant garden is weeded and then mulched with shredded bark each year. Seeds are collected for the nursery, and occasionally plants are potted for sale and replaced with new seedlings.

The main part of the Pond Garden is annual crop production beds. These beds, as with all the gardens, are laid out on contour. From the highest point at the native plant garden, to the lowest point at the southwest corner, this garden drops 5 feet in elevation.

We plant the Pond Garden in June, just after the crops in the South and East gardens are planted. Because the beds are long in this garden, they are often used for rotations of long-season crops, such as tomatoes, potatoes, squashes and sweet corn. The lower beds along the west edge of the garden are the wettest. They receive drainage from the upper beds and do not drain as well because the ground is more level.

This garden is mostly patrolled by redwing blackbirds that nest in the pond and swallows that prefer the more private birdhouses in the Zone 3 and 4 areas between the Pond Garden and the West Garden. Dragonflies and damselflies are also seen zooming about. A large patch of tansy along the lower edge of the pond and a patch of motherwort along the main central path promote beneficial insects. Leopard frogs, which breed in the pond, patrol the Pond Garden and the West Garden hunting for prey. Snapping turtles lay eggs in the beds and in the compost piles nearby.

Goldenrod dominates several thousand square feet of uncultivated land between the Pond Garden and the pond, feeding bees and other insects in late summer. As described in more detail in Chapter 9, the uncultivated space acts as a buffer zone, keeping excess nutrients from washing into the pond, and into Mill Creek. A similar space buffers the pond from the West Garden.

## The West Garden

The West Garden slopes to the east and drops about 6 feet in elevation. Between the West Garden and the pond lay several thousand square feet of uncultivated land (currently filled with goldenrod) sloping toward the pond. It is somewhat protected from the wind by a mature tree line, a young orchard bordering its west side, and the slope of the land.

### Forest Gardening

A forest garden is diverse, perennial, multi-species orchard. We have a long-term plan to develop the western portion of our farm as a sort of forest garden. Our plans are really a hybrid of a forest garden and alley cropping, which is an agricultural system that spaces tree crops wide enough to allow other crops to be grown between them. Our forest garden will group plantings in rows along contour beds.

We have been conducting trials of various fruits and berries to see which will work best in our forest garden. We have tried apple, pear, blueberries, raspberries, Juneberry, kiwi fruit, plum, currants and gooseberry. Based on these trials and customer demand, we will continue to proceed with development of the mixed species orchard, or forest garden.

We found an endorsement of our method of orchard groundcover management in the "neo-classic" on organic orchard management, *The Apple Grower.* The author, Michael Phillips, offers great advice on managing an orchard's groundcover to promote a healthy orchard. He says that individual sites and orchard management styles can and should vary. Some managers prefer to keep the ground mowed, others mulch the trees. In some of his orchards, Phillips plants patches of comfrey among his trees and allows goldenrod, selected weeds, legumes, and grasses to grow on the orchard floor. These help promote a diversity of natural predators and keep soil nutrients circulating. Mowing or scything is done close to harvest time. In our orchard, we scythe and mulch around the currants and other crops interplanted under some of the trees. Under the rest, we cut the groundcover as needed to ease the fruit harvest. This is, of course, a simplification of the discussion. We highly recommend Phillips's book as a detailed resource for orchard management.

David Jacke's two-volume *Edible Forest Gardens,* co-written with Eric Toensmeier, provides an extremely detailed study of perennials in the permaculture landscape. We developed our plan before *Edible Forest Gardens* was published, but we expect to draw heavily on both volumes as we implement and refine our plan.

The forest garden will increase farm profitability and spread the workload more evenly through the year. Fruit and other fresh products will be marketed to existing regional customers, both individual consumers and restaurants. The system will reduce the need for tillage and intensive cultivation of the soil. Perennials in permanent cover and mulch accumulate, rather than consume, carbon. Nutrient runoff and use of manure-based compost will be reduced. Instead, by-products of local sawmills — bark mulch, wood chips and saw dust — will be used for mulch and soil building.

As with the other gardens, the beds are laid out on contour to catch rain and irrigation from our pond. Our established pear and apple trees are interplanted with ☞

A gas pipeline was installed in this area before we started our farm. The path leading to and through the West Garden follows the course of the buried pipe so if the gas company ever needs to service the line, they can do so without disturbing plantings.

The West Garden is a Zone 3 and 4 area. We grow green manure there in the spring, then till it and plant the beds with crops in July. We

herbs, wild edible plants, and beneficial bird and insect habitat. Our more mature apple trees are interplanted with bush fruits, various species of currants and gooseberries. The grass is cut around the trees each June and used to mulch the bush fruit.

We are planting trees, bushes, trellised vines and other perennials in alternating rows. Semi-dwarf fruit trees, interplanted with bush fruit are alternated with shorter species, such as asparagus and raspberries.

Downslope is a bed of mulch crops, including purple vetch, red clover, alfalfa, and native grasses. Twice each year, in late May and in July, the mulch crops are cut with a scythe and used to mulch adjoining beds. The mulch crop beds are tilled and planted with annual crops as needed.

Newly planted and young trees and bushes are protected from gnawing rabbits and voles with tree guards and mulched with composted wood chips and bark, leaves, sawdust, and straw. We do this for several seasons. As the trees mature, permanent clover and grass groundcover will establish themselves. Nitrogen-fixing plants such as black locust, bayberry, bush clovers, alfalfa and red clovers will be interplanted or used as groundcovers.

Asparagus beds, to achieve maximum production, need to be heavily mulched with compost or leaves each year. Left unmulched, an asparagus patch can survive in grass for many years, but it will not be as productive. A semi-wild patch of asparagus should be mowed or scythed in the early spring and late in the fall to prevent goldenrod from overcrowding it.

As the system matures we will consider introducing ducks to the Forest Garden. Ducks can provide a valuable pest control service in the garden, and the direct application of their manure is beneficial. They also help to reduce pond weeds — and convert them to meat and eggs.

Several issues will need to be addressed when ducks are introduced. We will need to fence the other gardens and monitor and control the ducks' access to the Forest Garden when bush fruits are ripening. Predator-resistant housing will also be needed.

Research and Educational Value

Our mixed-species forest garden orchard will illustrate the value of integrating fruit production into market garden farms. Planting crops in the proper relationship to one another and to the landscape results in a healthy, profitable system. Diversifying farm crops with fruit and fruit-based, value-added products will increase the profitability of the small farm. The addition of ducks to the system adds a specialty meat product and makes use of the ducks' appetite for bugs, slugs and weeds.

Finally, the project furthers our intention to develop Three Sisters Farm as a model of diverse, small-scale intensive agriculture. The lessons we will learn about management of such a diverse system will expand the value of our farm as a learning center.


*Centennial apples, a small summer variety, are a favorite for fresh eating at Three Sisters Farm.*

occasionally contract with a neighbor to till the whole garden with a tractor and then re-shape the beds with the rototiller. The green manure is a self-seeded vetch. The plant appeared on its own, either brought in by birds or left over from a previous farmer's seeding. Over the years, we have allowed it to self-seed and spread through most of the West Garden. The vetch and other self-seeded weeds, including amaranth, grasses and lambsquarters are mowed once or twice prior to tilling. Some years, we leave the West Garden fallow and cut it several times for mulch.

An irrigation tank sits on a level area at the high point of the garden. This space, between apple trees, is planted with ajuga and tansy for beneficial insect habitat and with asparagus for harvesting.

This garden is slowly transforming into a landscape of mixed perennials that will become our "forest garden" (explained shortly). We planted apple and pear trees at the upper elevations; along the western edge of the property we are planting new rows of fruit trees and shrubs every few years. (The plans are outlined in the accompanying sidebar.) We have also planted several *Ribes* species among the apple trees: red currants, black currants and gooseberries.

The West Garden is plagued by woodchucks and rabbits. We double our patrol for them when we begin to prepare the garden in late June.

## Smaller Gardens

The Mailbox Garden is located in the far southwest corner of the farm (near the mail box). Measuring about 4,000 square feet, it is planted with annual crops in rotation. Left fallow much of the year, it serves as overflow location for main crops, potatoes, squash and sweet corn. Some years, it is fallow all year. Several apple trees border this garden on the west and south. The Mailbox Garden, like the neighboring West Garden, is subject to woodchuck and rabbit pests.

The Curve Garden is so named for a curve in the adjacent driveway and the curve of the beds on contour. This smaller garden is about 3,000 square feet. It is bordered on the south side by an uncultivated area of goldenrod, a self-planted spirea shrub and two apple trees along the driveway. A perennial patch of peppermint is encouraged in the wetter, lower bed.

## Crops and Products

Crop selection for a small-scale farm needs to be diverse enough to keep customers happy and allow for good crop rotation. But it should not be so complicated as to be unmanageable. We were inspired by the writings of Booker T. Whatley in his *Handbook on How to Make $100,000 Farming 25 Acres*. In it, Whatley describes a strategy for farm design based on a series of crops that each bring in several thousand dollars or more of income. Planting, management, and harvest schedules are arranged so they do not overlap too much. Asparagus, followed by strawberries, followed by raspberries and blueberries, followed by summer and fall apples is one example. With this combination, the workload is distributed over the growing season, and the harvest times only overlap slightly. Combined with beekeeping and value-added processing, this fruit farm would be quite manageable.

*Linda Frey tends edible flowers, lemon gem and tangerine gem marigolds.*

Catherine Paladino

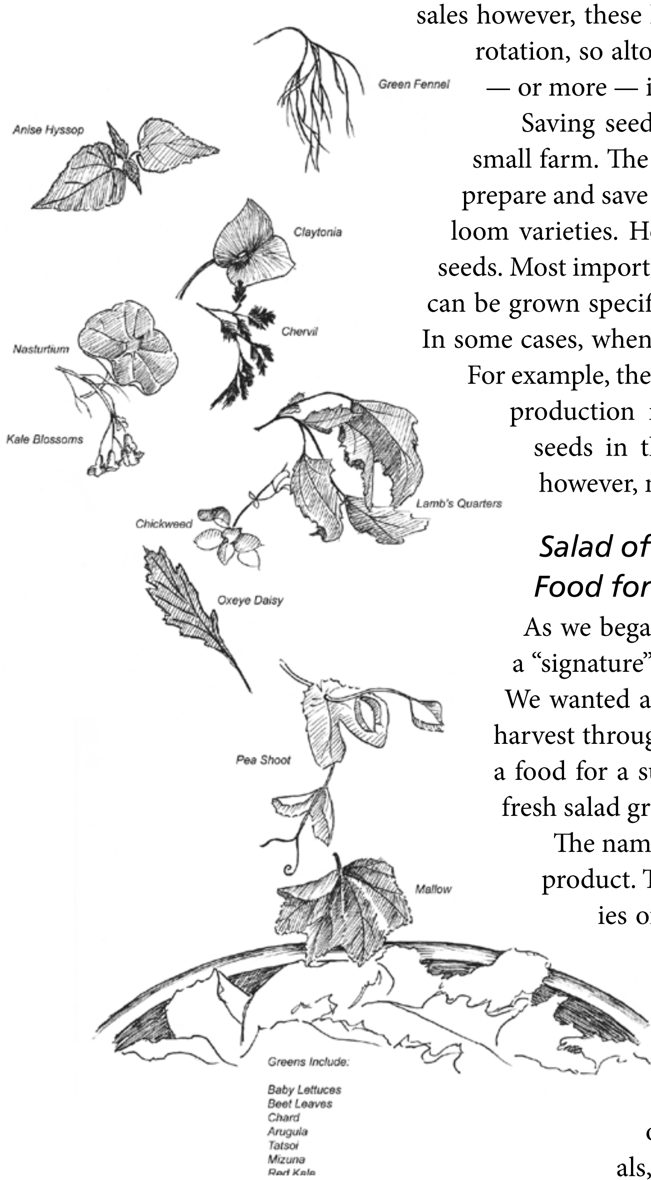
A diverse mix of crops allows for security against crop failure, and diverse enterprises spaced through the year make a lot of sense. Each main crop — herbs, flowers, salad and mixed vegetables — all bring in good profits in their season. A succession of fruits adds to crop diversity.

Edible flowers, herbs and bouquets need sales of over $1,000 a year to justify tending. Some crops are not as profitable, but must be grown to please customers. For example, a few years back, as we were getting in full swing, our sales totaled $15,000 in salad, $12,000 in head lettuce, $1,500 in edible flowers, $1,200 in basil, and $1,500 in other herbs, but for potatoes and tomatoes we made only $300 each. But we continue to grow them because customers like them.

The problem with some crops (tomatoes, peppers and eggplant, for example) is that, in our climate, they have relatively small yields for the amount of space they take up and the time they take to plant.

After only six to eight weeks of harvest, production declines. In a warmer climate with a longer growing season, tomatoes, peppers etc. would be more profitable. Season extension (discussed in Chapter 4) can help increase yields, but only for a few weeks. With subscription sales however, these lower-yield crops are a part of the vegetable crop rotation, so altogether they can bring in several thousand dollars — or more — in sales.

*A sampling of ingredients used in Salad of the Season.*




Saving seeds is probably not economically worthwhile on a small farm. The time required to isolate plants, select prime fruit, prepare and save seeds is often only worthwhile for expensive heirloom varieties. However, there are certainly other reasons to save seeds. Most important is developing locally adapted selections. Crops can be grown specifically for their seeds that can themselves be sold. In some cases, when buying seed is expensive, it pays to gather them. For example, the high cost of buying organic seeds for micro-green production makes growing the crop unprofitable. Growing seeds in the summer for winter micro-green production, however, may prove profitable.

### *Salad of the Season — Food for a Permanent Culture*

As we began to develop our market garden farm, we sought a "signature" crop that would be both healthful and profitable. We wanted a distinctive product that would provide a weekly harvest through most of the year. We wanted our product to be a food for a sustainable, permanent culture. Growing a mix of fresh salad greens and wild edibles fit the menu.

The name "Salad of the Season" describes the nature of the product. The mix changes with the seasons. Different varieties of lettuce, greens and herbs are planted to suit the growing conditions at different times of the year. Wild edibles and self-seeded crops choose their own timing.

After more than 20 years, I still take great pride in our salad mix. Fresh greens are full of life and vitality. Rich in vitamins and minerals, with a wide array of antioxidants and other micronutrients, salad greens fill a vital role in a health-promoting diet. It is a pleasure to offer our customers a diverse, seasonal blend of such good food. I feel also a sense of artistry and the satisfaction of a creative impulse. I find satisfaction in my work when the balance of ingredients looks good in the bowl and on the plate. A culinary experience can satisfy on many levels. With a good meal, other needs are nourished too.

The salad base is a mix of six to ten types of young lettuce, such as red sails, red salad bowl, green salad bowl, butter crunch, freckles romaine, speckled Bibb, Batavian endive, rouge d'hiver romaine, Paris cos romaine, and frisée endive.

Any edible leaf, bud, or flower can be added to this basic mix: cut baby greens, such as mustards, kales, mizuna, tatsoi; young pea shoots; cress; arugula; and other greens, such as nasturtium leaves and beet, spinach, and fennel tops. Inside the bioshelter, we plant and harvest the following crops weekly for the salad mix: arugula, kale, mizuna mustard, tatsoi, red mustard, pea shoots, Chinese mallow and shungiku chrysanthemum (an Asian chrysanthemum leaf).

As the seasons change, new ingredients appear. The spring salad may include violet greens and flowers, watercress, chickweed, ox-eye daisy greens, dandelion, spinach, broccoli rabe, kale florets, mache and Good King Henry.

The summer mix includes lambsquarters, amaranth, sheep sorrel, wood sorrel, purslane, anise hyssop, dock, orache, mallow, plantain, and pennycress.

By mid-summer, we can add the new dandelions that are sprouting. Late summer brings the first chickweed. Chickweed germinates in cooling soil, so it thrives in cool autumn weather. (The appearance of chickweed marks the time to plant spinach.) The sour acidity of wood sorrel, with its hint of lemon, is succeeded by similarly flavored sheep sorrel, which thrives in the cool months. Sturdy, bitter curled endive is traditionally balanced with feathery sweet chervil.

In the fall, red-veined, arrow-shaped Bordeaux spinach, smooth spinach and crinkled spinach are grown, along with chickweed, shungiku, pea shoots, various beet greens, red-ribbed dandelion, wild dandelion, red Russian kale, lacinato kale, chervil and sheep sorrel.

Fall salad may include kales, ornamental cabbage leaves, chervil, miner's lettuce, mizuna, tatsoi, spinach, chickweed and mache. Wild edible ox-eye daisy, sheep sorrel and dandelions continue to produce, so we include them as well.

The winter mix includes miner's lettuce, endive, beet greens, young chard leaves, shungiku, chickweed, chervil, salad burnet, sorrels, fennel greens, spinaches, nasturtium leaves and all the standard lettuces. We are always on the lookout for new salad greens. Many make their appearance for only a few weeks of the year.

## Maximum Nutrition

The salad mix fulfils our wish to provide our customers and ourselves with maximum nutrition. Spring tonic plants like dandelion greens, violet leaves, chickweed and watercress are relatively unselected, if at all, by breeding for specific characteristics. Being in their more natural state, wild foods may contain a broader range of phyto-chemicals, antioxidants and other healthful compounds. Most provide calcium, iron and other minerals. Many wild edibles are rich in vitamin A and C. Young sprouts of Brassicas (the family that includes cabbage and broccoli), such as kale and mustard, contain a wealth of antioxidants and other phytochemicals. Purslane contains healthful omega-3 fatty acids. Watercress is rich in minerals and contains vitamin A, $B_2$, C, D, and E. Wood sorrel is rich in vitamin A and C and is a source of potassium and phosphorus. Chickweed contains potassium, phosphorus, manganese, as well as minor mineral nutrients. Dandelion leaves, rich in vitamin A and C, also contain calcium and substantial amounts of $B_1$, sodium, potassium, and some important trace elements. It seems logical to assume that we do not yet know all the healthful compounds in these foods.

A salad mix with many fresh and raw ingredients provides a broad range of nutrients while introducing "tonic foods" into the diet. Many wild plants are traditionally known as tonics, foods that rejuvenate the body and revitalize health after a long winter. Our own theory of a sustainable diet takes the concept of tonic foods and combines it with the concept of macrobiotics. A macrobiotic diet stresses eating fresh, local foods in their proper season. It is reasonable to believe that eating a variety of fresh, live foods, in their season provides us with the most direct access to nutrients at the time we need them most.

The use of wild edibles in the salad helps increase the profitability of the farm. Although wild edibles can be tedious to harvest, seed costs are non-existent. Young "weeds" growing between planted crops can be harvested for the salad, doubling and tripling yields per area. They are then tilled in as green manure or left as groundcover. Many wild plants act as accumulators, gathering nutrients from deep in the soil. This is good for the topsoil as well as the salad bowl. Some herbs self-seed, like kale, chervil and mache. Some are perennials, like bronze fennel, salad burnet, anise hyssop and Good King Henry. Many of these double as beneficial insect habitat.

Many salad plants naturalize and adapt to the site. Brassicas, for example, cross easily with one another. We watch for interesting hybrids. One spring, we found a red mustard/Russian kale cross in our polytunnel; it made a great addition to our mix. Mache has made a permanent home in all our gardens. For many years, miner's lettuce has self-seeded in the cold frames, providing a steady winter harvest.

We have observed a lot of variation in the leaf shape of many wild edibles: we have four distinct strains of lambsquarters (magenta, white, bronze and lemon) and several less identifiable crosses. An oakleaf lambsquarters appears in several garden beds; it's a cool-soil strain that grows only a foot tall and flowers faster than other strains. Sheep sorrel leaves range from 4-inch long, narrow arrows to 1-inch, round arrows. Dandelions have a broad range of variation, from rounded lobes with few teeth to very narrow leaves with lots of sharp, pointed teeth. These variations make salad growing more interesting and help keep the product in demand with top chefs and repeat customers.

Fall through spring, we reap a good harvest of wild edibles and self-seeded greens and herbs from the bioshelter, unheated cold frames, and polytunnels. The solar-heated greenhouse beds have their own seasons: chickweed, lambsquarters and miner's lettuce are prevalent in winter; orache, amaranth and purslane emerge in the spring as soil temperatures increase.

## Precautions

*The use of wild edibles requires proper identification.* Please consult an experienced forager before eating any wild plant.

Some salad plants such as sorrels, beet greens and even spinach, while rich in nutrients, contain oxalic acid, which, in large concentrations, affects calcium absorption. Kidney failure has been associated with the excessive consumption of foods with oxalic acid and potassium oxalate. (Oxalic acid can occur as soluble oxalates of sodium or potassium or insoluble calcium oxalates.) Oxalic acid is probably not a problem unless low levels of calcium and B vitamins are combined with high intake of oxalic acids. Younger plants probably have lower levels of oxalic acid, and cooking them may help to nullify the effects. Mixing small amounts of these plants into a salad mix is a good way to enjoy and benefit from them in moderation.

Under certain conditions, such as low light and high nitrate levels in the soil, leafy greens can absorb more nitrates than they can process into plant tissue. When humans digest them, nitrates are converted to nitrites, which can be more toxic than nitrates. Nitrites replace oxygen in the hemoglobin and cause a disease called methemoglobinemia. Nitrates are also a potential source for the carcinogen nitrosamine and can cause gastroenteritis and anemia after a while. Studies have shown that nitrate accumulation can be reduced or avoided by keeping soil nitrogen low in winter gardens and harvesting near the end of a sunny day. In Pennsylvania, nitrate levels peak during cloudy weather from December through late January. Because of this, we have chosen this period as our down time. We rest, celebrate midwinter holidays and plan for the winter-spring garden. The small amount of salad we mix during this time is harvested only after periods of sunny weather. We also keep soil temperatures lower (under 50° F) during the winter solstice season to inhibit plant activity. Less active plants accumulate fewer nitrates. Growth resumes as the soil surface warms when the sun shines.

Sanitation is also a concern. We use only greenhouse-grown watercress in our mix. Thus we avoid potential health risks of parasites, waterborne contaminates and diseases. Manure must be fully composted before being used to grow raw foods such as salad greens. Customers are always advised to wash produce, whatever the source.

The Salad of the Season has evolved to be a perfect crop for our farm. With a diversity of potential ingredients, we always have a good mix, even if part of the crop fails. The seasonal variation in the salad keeps customers interested in the product. However, our determination to maintain a high-quality product limits our production capacity to about 40 pounds per week from May through November, and an average of 30 pounds per week from February through April. At the premium price we receive, our salad annually generates more than $15,000 in sales. Most important, use of what some consider a "weed" as a prime ingredient in our product demonstrates a major principle of permaculture, turning a problem into a resource.

## *Vegetables and Herbs*

Producing a wide selection of vegetables is necessary for a successful CSA or subscription sales enterprise. Our vegetable crops are detailed in Chapter 8. From a permaculture design perspective, though, our vegetable production primarily takes place in intensively managed gardens. Incorporating smart rotations and successions are all standard practices with organic gardeners. Beyond that, permaculture design emphasizes the relative location of various gardens and crops and the creation of habitat for pollinators and other beneficial creatures. Other concerns include efficient use of resources, energy and time, and the development of successful nutrient cycles between the gardens and compost piles. We are always on the lookout for new crop varieties and new organic cultural techniques. We try to adopt and maintain several varieties of heirloom vegetables. Heirloom tomatoes are especially in demand. We generally purchase heirloom seeds from the Seed Saver's Exchange (visit them at seedsavers.org/) to help support their work in preserving rare varieties of garden plants.

Herb production is an important part of our restaurant and subscription sales. Rosemary, sage, mint, chives, thyme, oregano, parsley, dill, cilantro and several varieties of basil are all in high demand. We have a lesser demand for some herbs, including French sorrel, tarragon, and chervil. But we grow them because — as with vegetables — their placement in and among the bioshelter and gardens helps promote biodiversity and productivity.

The following herbs grow best in rich, well-drained soils and full sun. In the fall, it is best to mulch rosemary plants or bring them indoors so that they can overwinter:

- salad burnet
- bronze fennel
- chives
- lemon balm
- mint
- oregano
- rosemary
- sage
- sweet woodruff
- tansy
- thyme
- lavender
- tarragon


DARRELL FREY

*Red currants, black currants, raspberries and herbal bouquets.*

### *Cut Flowers*

Cut flowers are an excellent income-producing crop. The best reference we know on organic flower production is Linda Byczynski's *The Flower Farmer,* Her detailed information on growing and marketing cut flowers is highly recommended reading. Cut flower production is one of the many enterprises we currently do on a small-scale but hope to expand. Inside the bioshelter, cut flowers are mostly the herbal bouquets described below. We also grow freesia, snapdragons, African daisies and a few other cut flowers. In our gardens, we grow iris, gladiolus, roses, foxglove, lilac, black-eyed Susan, gloriosa daisy, and purple coneflower — to name but a few. Everlasting perennials, which are useful for various crafts, include yarrow, lamb's ear, artemisia and sages.

### *The Herbal Bouquet*

Herbal bouquets add a high-value crop to the farm's offerings. An herbal bouquet is a bundle of assorted herb sprigs, edible flowers and ornamental vegetables. They are a total sensory experience, offering a mix of scents, colors, textures and tastes. There are many dozens of possible plants to include in these bouquets. Herbal bouquet production is another example of permaculture principles in action because the herbs and flowers serve multiple functions in the landscape. They promote biodiversity, which brings stability to the landscape. Seasonal succession and functional placement of the herbs and flowers are important planning elements.

Similarly, edible flowers fill a marketing, ecological and aesthetic niche on the farm. Chefs, caterers and individuals planning food events and dinners love to decorate their tables with fresh, seasonal culinary bouquets and garnish their dishes with edible leaves, flowers and stems of herbs.

A large diversity of herbs and edible garnish plants ensure a steady supply of cuttings for the bouquets. These, in turn, provide food and habitat for a wide range of beneficial insects, especially butterflies. Whether concentrated in an herb garden or used as companion plants to vegetables, these plants add beauty and interest to the garden.

Herbal bouquet favorites:

- African blue basil
- alpine strawberries
- anise hyssop
- borage
- bronze fennel
- calendula
- catmint
- chard leaves
- chive blossoms
- clary sage
- daylily
- flowering basil (cinnamon, purple, spicy globe, sweet, Thai, and others)
- flowering oregano
- garlic chives
- golden oregano
- Hopi red amaranth
- lavender
- lemon balm
- lemon verbena
- miniature roses
- nasturtium leaves and flowers
- pansy
- raspberry sprigs (with thorns removed)
- red clover
- rosemary
- sage (golden, culinary, pineapple, purple, and tri-color)
- scented geraniums sprigs and flowers
- sweet woodruff
- thyme (creeping, German, lemon and others)
- violets

A usable flower, leaf or stem is one that is edible, does not wilt quickly, and has a pleasing, but mild scent. Cilantro and dill are avoided because of their extra-distinctive scent. Chervil and fennel leaves can be used, but they will wilt if not kept in a vase of water.

## *Medicinal Plants in the Landscape*

Production of medicinal plants almost occurs spontaneously on the permaculture farm. Yellow dock, dandelion, coltsfoot, St. John's wort and yarrow all came on their own and staked claims to their niche. Aspen, willow, alder, motherwort and boneset moved in around the pond.

Slippery elm and black cherry were present in the tree lines when we started. We continue to plant medicinal plants and allow them to naturalize on the edges of the gardens. Some medicinal plants we tend in the gardens.

### Necessary Disclaimer and Some Good Advice

I am *not* prescribing or even recommending the use of particular plants as medicine. I do encourage readers to do what we do: consult several references — and perhaps your physician — to find the best remedy for what ails you.

I *do* seek to alert readers to medicinal plants' potential as a part-time enterprise on a market garden farm. Wise were the women and men who knew which plants to harvest and store for teas and tinctures for pregnancy and childbirth, for easing pain and calming the spirit. Locally sustained culture needs these wise people again.

A five-acre permaculture farm can easily provide an herbal entrepreneur with adequate plant material. I do not have the time to develop expertise as an herbalist or the investment capital to fund a start-up herbal products enterprise at our farm. I do, however, know that every neighborhood needs an herbalist — as well as a market gardener.

## *Plants as Medicines*

The term *medicinal* covers a broad range of plants and applications, including tonic plants and more specific medicinals. Tonics provide a concentrated dose of minerals and vitamins. Dandelion and yellow dock fall into this category. When mild deficiency is the root of illness, such tonics can be excellent remedies. Historically, spring tonics rejuvenated our forbearers with valuable nutrients after lean winters of stored foods. Tonic plants are rich in phytochemicals. Many of these chemicals are used by the plants to fight microbial and fungal invasion. Our current understanding of vitamins (and our growing understanding of phytochemicals) only scratches the surface of the complex interaction of plant chemistry and our bodies.

*Calendula is a medicinal plant and provides edible flowers.*

Darrell Frey

Many common plants are more specific medicinal plants — those with particular concentrations of minerals and chemical compounds that our bodies can use to fight injury, infection, illness and maintain good health. Plants produce many more chemicals than we know about. Stephen Buhner presents a view of this complexity in *The Lost Language of Plants*. Buhner gives the example of yarrow, which contains over 125 chemical compounds. The isolation of salicylin, the chemical precurser of asprin, from willow bark led to the development of aspirin, which is a powerful medicine. But natural salicylin is but one component of the total complex chemistry of willow bark. It is likely to be the *synergistic effects* of these chemicals and nutrients that provide the best, most healing medicine.

At times, we want fast-acting synthetic medicine, but we may have to pay a physical price in side effects. At other times, natural plant-based medicine may give us a more complete and long-term healing.

Making herbal teas is the easiest way to use many tonic and medicinal plants. Many can be used either fresh in season or dried for later use. Others are best preserved as tinctures and extracts. The active constituents of medicinal plants may be soluble in water, alcohol or oil. A tincture is made by soaking a plant in grain alcohol or whiskey to extract the medicinal component for storage and easy use. Oil extracts are commonly used for medicinal ointments and body oils.

*Damask rose.*

We begin collecting medicinal plants for our own use in March and April, when we gather coltsfoot blossoms. Some we dry for tea and some we use to make a tincture. We use both for colds and bronchitis. All year long, we gather the roots of dandelion and yellow dock as we prepare garden beds. These are chopped and dried in the oven for teas or made into a tincture. We also collect and dry bee balm, peppermint, spearmint, lemon balm, chamomile, lemon basil, clover blossoms, alfalfa and stinging nettles. All are used for nourishing and tonic teas.

We make herbal body oils each year. Our cabbage rose hedge provides an abundance of fragrant buds and blossoms each spring. This rose is common on old farms in our area and is probably the damask rose 'Bella Donna.' Damask roses are especially well known as a source of rose oil for making perfume. For several weeks in June, we collect the freshly opened flowers and pack them in a gallon jar with apricot kernel oil and soak them for several days. Then the oil is strained off and we soak a second batch of flowers in it. This is strained again, bottled and then stored in a cool place until needed for use as a massage oil, bath oil or general body oil. Less expensive

**Plants known to be medicinal at Three Sisters Farm**

Annuals:
- calendula
- garlic
- onion

Perennials:
- angelica
- bergamot
- boneset
- burdock
- comfrey
- dandelion
- coltsfoot
- echinacea
- lilac
- mint
- motherwort
- nettles
- pennyroyal
- rose
- St. John's wort
- valerian
- violet
- yarrow
- yellow dock

Shrubs and trees:
- basswood
- willow
- alder
- black cherry
- slippery elm

oils, such as olive oil, may work just as well as a soaking solution, but we prefer apricot kernel oil because it has good texture, is resistant to becoming rancid and has little scent of its own.

We also make oil extract with lavender, the inner bark of the birch tree, rosemary, and thyme. The procedure is the same. Each of these oils can be used to make soaps and salves.

### *Crafts*

We have dabbled in many crafts over the years. Wreaths, herbal vinegars, dried flower arrangements and herbal tea blends are all products easily made on a small farm. Combined in a gift basket with pressed flower cards, herbal oils and soaps, they have even more value.

Each season offers the opportunity for creating value-added craft products. The creative craft person can find many ways to use dried herbs and flowers for artistic creations.

Popular herbal vinegars include chive, nasturtium and tarragon. Herbal oils, for baths, massage and fragrance are made by soaking fresh herbs in oils, such as apricot kernel oil. After several days, the herbs are strained out and the oil filtered. Lavender, damask rose, rosemary and birch bark all make excellent body oils. Culinary herbal oils, made from soaking herbs in olive oil, can be made with thyme, rosemary, sage, and basils.

Herbal wreaths are made by wrapping fresh flower bouquets onto a wreath form and allowing them to dry. Any everlasting flower makes good wreaths. Some of our favorites include celosia, Queen Anne's lace, goldenrod, various sages, lavender, larkspur, annual clary sage, cinnamon basil, artemesias and sweet Annie. Wreaths can be made of single herbs or colorful combinations. Tansy flowers are good for wreaths and dried flower arrangements. Fragrant herbs and flowers can be also be dried in season for potpourris.

We keep a flower press in the bioshelter for easy access. Many flower and leaves are pressed in their season for later use in making greeting cards.

### *Plant Sales*

When we first conceived of our farm, we wanted to develop a useful plant nursery. Once a permaculture farm is established it can be replicated, to an extent, by plant propagation. We have not developed this aspect of the farm to its full potential, but we do sell some plants each spring. Because many other area greenhouses sell vegetables and flower seedlings, we decided to focus on herbs, useful perennials, pollinator plants and native wildflowers. We also have developed a market for heirloom tomato seedlings. We sell about 400 tomato plants each year. We generally offer 12-20 varieties, which might include German Pink, Black Krim, Brandywine, Cherokee Purple, Aunt Ruby's German Green, Principe Borghese, Amish Paste, Green Zebra, Jaune Flamme, Austin Red Pear, Yellow Pear, Nyagous, Giant Syrian, and Hillbilly. Sungold are also good sellers. This selection of tomato varieties includes large slicers, small slicers, canning tomatoes, drying tomatoes, small salad tomatoes, green, and purple tomatoes.

We offer for sale many of the useful plants that grow in the bioshelter and herb gardens. Scented geraniums, with their edible flowers are popular. Herb plants, especially variegated varieties, are also popular. Stevia, lemon verbena, pineapple sage, and large rosemary plants are also big sellers. We also offer insectary plants: motherwort, bronze fennel, catnip, mints, tansy, and flowering oregano. Two of our most popular plants are the prolific self-seeders: sweet woodruff and forget-me-not.

## *Native Plants*

Some wildflowers we start from seed and some we "rescue." By rescue, I mean we collect them from locations where they would otherwise be killed by road crews or utility line workers. Typically, we collect wildflowers within a few miles of our farm, along the roadsides in forested areas. The space between the road and the forest is regularly cut, and the ditches are cleaned out by the township. In these disturbed grounds, we have found many plants: purple-flowering raspberry, bergamot, Dutchman's breeches, wild bleeding hearts, red and white trilliums, wild ginger, blue and black cohosh, ramps, many types of violets, red elderberry, horsetail, jewelweed, wild phlox, wild geranium, asters, and goldenrod.

*Wood geranium.*

Spice bush, hazelnut, elderberry and a few other shrubs and wildflowers we gather on our own property from eroding stream banks and where they encroach on our driveway.

We also have several patches of ostrich fern and cinnamon fern established over 20 years ago. These spread quickly and can be thinned each year for sale. The ostrich fern is a valuable wild edible, but selling the plants is more profitable.

Seed-grown wildflowers are started in December. Seeds are sown in flats of sterile soil mix. The flat is moistened, refrigerated for a month, and then placed under grow lights in mid-January. In a few weeks, most have germinated, and they are transplanted to 60-cell 6-packs. In March and April, they are potted up for sale in 4-inch pots. Seed-grown wildflowers that we sell include New England aster, columbine, Joe Pye weed, green coneflower, purple coneflower, black-eyed Susan, woodland sunflower, bergamot, great blue lobelia, showy tick-trefoil, Virginia spiderwort, and wild lupine.

We continue to plant more native plants all over the farm each year. These add diversity to the landscape and provide seeds and plant divisions for our plant sales enterprise.

### *Honey*

Honey, beeswax and other bee products should be part of a small-scale intensive farm's product list. Our hive, however, lives untended. We have occasionally harvested some frames of honey, but we are too busy to tend them for high production. Many farms develop connections with area beekeepers, who maintain the farm's hives in trade for honey. We have found that honey production requires so much management time that it is incompatible with our intensive gardening. We simply do not have time. Bees and their role are discussed more thoroughly in Chapter 6.

## Perennials

> "There were so many things a tree could do: add color, provide shade, drop fruit, or become a children's playground, a whole sky universe to climb and hang from; an architecture of food and pleasure, that was a tree."
>
> —Ray Bradbury, *The Martian Chronicles*

After the basic infrastructure for the farm was in place in 1989, we were ready to begin placement of perennials, gardens, and season extenders. We ran a hedgerow from the north tree line south, along the edge of the driveway. This provided space for berries and roses, and it would act as wildlife habitat. The hedgerow also served as a windbreak for the compost yard and bioshelter and as a snow fence for the driveway. Plantings, from north to south, include staghorn sumac, plum trees, thornless blackberry, fragrant damask roses, and serviceberry. After a gap that allows access to the Pond Garden, the hedge continues with highbush cranberry, another rose bush, Jerusalem artichoke, iris, royalty purple raspberries, August red raspberries and four varieties of blueberries.

On the north tree line we planted Heritage, Latham and Golden raspberries, North Star cherry, Reliance peach and Heartnut.

We extended an orchard begun by our neighbor along the western edge of the property and the driveway. We planted Seckel pears and apple varieties that included Northern Spy, Liberty, Freedom, Granny Smith, Red Delicious, and several wild seedlings. We spaced them so that the full-size trees would be about 30 feet apart. We later added a second row of trees along the west edge, at the top of the West Garden. These include apple varieties Golden Russet, Yellow Transparent, and Black Oxford and Summer Crisp pear.

Other apples are planted on the south property line bordering the public parking space. These delicious small apples include Chestnut,

### Our Woodland Property

Our family home is located on a ten-acre lot near Carlton, Pennsylvania. The property is a land of much variety. Roughly a rectangle measuring 400 feet by 1,200 feet, the lot has two streams and a mix of bottomland, slopes and uplands. A seasonal stream crosses the southwest corner for about 500 feet and joins a year-round stream that also passes through the lot. The elevation rises 50 feet from the year-round stream to the upland building site. Fifty years ago, the property was part of an overworked and abandoned farm with degraded soil. The lot included two small fields and hilly pastures reverting to forest. The first trees to grow were quaking aspen on the wet slopes and wild crabapples and hawthorns in the drier areas. These trees provided shelter for many other trees to take root and grow under their protection. As the trees began to mature, native species of shrubs and understory plants suited to the site's varied aspects, soil quality and soil moisture moved in.

Today three forest systems are present and contain dozens of species of native shrubs, wildflowers, ferns, mosses and fungi, as well as many species of birds and wildlife. In the bottomland, there are riverine trees: black walnut, ash, butternut and willows; on the moist slopes grow aspen, ash, maple, tulip poplar, shagbark hickory and cucumber magnolia; on the dry upland there are cherry, maple and oaks. This forest is surprisingly diverse considering that only 50 years ago it was over-worked and abandoned pasture and field.

Centennial, and the tart Dolgo crab. (Another Dolgo crabapple is the centerpiece of the Spiral Garden.)

A row of mulberry trees is planted along the north edge of the East Garden. This acts as a windbreak for our bale-shelter polytunnel and provides shade for a compost area. Under the mulberries, common blue violet established itself. The violet flowers and leaves are harvested for our spring salad mix. After the spring harvest passes, we allow our chickens to forage the fallen mulberry fruit.

## The Farm Woodlot

Every farm benefits from having access to a woodlot. Kindling and firewood and stakes, posts and saplings for trellising are all obtained in a well-managed forest. Three Sisters Farm has access to resources from our own tree line and our woodland home property, five miles from the farm. From the tree line, we gather fallen maple and dogwood branches to use for starting winter fires. But, because the tree line is relatively young, we do not thin out saplings. Instead, we get most woodland materials from our home property. Craft materials are gathered from both our gardens and the farm landscape. Grape vines and hardy kiwi vines are used for wreaths. Bamboo is used for trellising. Aspen and willow branches and other saplings pruned from the utility line are crafted into bentwood trellises and gates. Pruned wood from our fruit trees provides the base for our spring bonfire. Black locust and honey locust trees planted 20 years ago are now yielding posts for our garden fences and trellises.

We get our garden stakes for free from a local sawmill that specializes in making survey stakes. They give away the poor-quality stakes, which are just fine for our uses. We glean some firewood from our land, but also buy some and cut some (with permission from property owners) so that we can allow our own forest to develop naturally. Locust and cedar posts are purchased for most fencing needs.

**Wood and its uses on the farm:**

- Bentwood gates: saplings of willow, hickory, birch, sassafras, aspen, ironwood, bamboo.
- Posts: cedar, black locust, post oak.
- Stakes and plant supports: hawthorn, oak, cherry, maple, bamboo.
- Trellises: willow, hickory, birch, sassafras, maple and ironwood.
- Shitake logs: white oak is best, but can also use other hardwoods that hold on to their bark for some years after inoculation.

## Managing Plant Interactions

Plants affect other plants in many ways, some beneficial and some not. Understanding these interactions is important when designing a permaculture farm.

In a forest, spring wildflowers grow and begin to flower before the leaf canopy shades the forest floor. This brief period of growth is an important part of the forest ecology. These plants reduce erosion and capture nutrients that would otherwise leach away in heavy spring rains. They grow fast, set seed, and often die back by midsummer, returning some of the nutrients to the leaf litter. While growing, the spring understory provides early-season food for native pollinators and other insects. After the trees leaf out, their shade reduces competition from grasses and thins out tree saplings, maintaining the conditions preferred by the wildflowers. Over time, the complex mix of trees, shrubs, herbaceous perennials and associated fungi, insects and animals builds the soil's store of nutrients and organic matter. Burrowing animals, fallen trees and deep-rooted plants, over time, turn and loosen the soil, keeping minerals in cycle.

In our gardens, trees and shrubs create shaded microclimates for other plants and provide structure for climbing vines. Many plants delve deep and accumulate minerals contributed to the soil by dead plants.

### A Note about Bamboo

Bamboo is an extremely useful resource on the farm. But it is a *highly invasive* perennial that is difficult to eradicate once established. Before planting bamboo, determine how it can be contained.

One method is to grow bamboo in heavy plastic planters, like a child's wading pool. We think a better approach is to establish the patch where it will meet a barrier: along a building's foundation, at the edge of a mowed area, beside a road, or at the edge of water (pond, stream, lake) or a dense forest — or any combination of these. Any of these will stop the spread of the rhizomes and act as a suitable containment strategy.

We have successfully contained bamboo between a stream and a dense forest, between a composting outhouse and a mowed path, and between the pond and a mowed path.

Dual-use bamboo is best, so pick a variety you will want to harvest for food as well as stakes. Early spring shoots encroaching into the yard can be harvested. Rhizomes spreading beyond the chosen boundaries can also be dug and cut to reduce spread. We grow yellow grove bamboo (*Phyllostachys aureosulcata*). The shoots are eaten both raw and cooked. Most winters, the wood dies back, but generally it re-grows well each year.

An enterprising farmer can get harvesting permission for an already rampant patch on a nearby property. Heavy harvest of mature canes can help limit the spread of a bamboo patch, keep a farm supplied, and make a property owner happier.

Bamboo may have unexpected uses. While harvesting a patch of bamboo near Pittsburgh, I noticed that the bamboo had overwhelmed and killed several large patches of the equally invasive, but much less useful, multiflora rose. The dense shade created by the bamboo was too much for it.

**Plant relationships:**

- Companions: symbiotic relationship with mutual benefits
- Host: one plant supports others and nutrients are shared
- Interplanted: cohabitate without competition or any obvious interaction
- Allelopathic: one plant suppresses or kills others
- Parasite: one organism lives on another with no apparent mutual benefit
- Structural: one plant supports another
- Insectary: plant provides pollen and nectar that attract pollinators

Dogwood trees perform this role in the Appalachian forest. Others, especially legumes, but also alders and *Elaeagnus* species, fix nitrogen and add it to the system. Joseph Cocannouer, in *Weeds: Guardians of the Soil,* discusses the action of deep-rooted weeds in loosening the subsoil that allows the roots of crop plants to follow them deeper to access water and minerals. Crabapple, hawthorn and aspen trees act as "nurse plants," reducing understory competition and providing the shade required for a succession of hardwood trees.

In describing the creation of complex multi-story communities of useful plants, Bill Mollison uses the concept of a *plant guild.* In this sense, a guild is a group of useful plants that benefit from close association. A guild may include a dominate tree and an understory of shrubs, vines, perennials, biennials and seeded annuals. The guild would require nitrogen-fixing legumes, accumulator plants and insectary plants for promoting pollination and pest control. A classic plant guild is the three sisters: corn, beans and squash.

Plants interact chemically in many ways with each other and with insects. In *The Lost Language of Plants,* Stephen Buhner documents the complex chemistry of plants. He says there are 10,000 alkaloids, 20,000 terpenes, and 8,000 polyphenols that are already known, and others are continually being identified. Buhner discusses how the "bioactivity" of these compounds increases when combined. David Jacke discusses the complexity of interactions between plant chemistry and the soil in *Edible Forest Gardens: Volume I.* As an emerging field, there remains much to learn about these complex interactions. As designers, we need to be conscious of the many ways plants interact — with each other, with insects and with animals — and keep alert for new discoveries.

## *Nitrogen Fixing*

In addition to the application of compost made with animal manures, cycling nitrogen into the garden is accomplished by the inclusion of plants capable of establishing a symbiotic relationship with nitrogen-fixing bacteria. For the farm, there are two primary types of plant that do this: the legumes (bean relatives); and actinorhizal species, such as alder and *Elaeagnus.* When associated with these plants, bacteria can take nitrogen from air in the soil and convert it into a form plants can use. Nitrogen fixation by these microorganisms is the primary way nitrogen enters the soil. Lightning storms can also convert nitrogen to a form usable by plants, but the extent of that contribution is difficult to assess.

Before planting, beans and peas are inoculated with powdered legume bacteria. Using inoculated beans in crop rotations every few years allows beans to replenish nitrogen in the soil. Many other legumes have found niches on our farm. White clover grows well in permanent pathways. Red clover and alsike clover self-sow in our fallow garden beds. Yellow clover has found a niche in mowed areas between gardens and along pathways, as has bird's-foot trefoil. We have included tick-trefoils in our native plant gardens. Black locust trees around the gardens and alders along the pond's edge also add nitrogen to the landscape.

Siberian pea shrubs are a valuable multipurpose, perennial legume. Like the black locust, they provide good bee and chicken forage.

*Elaeagnus* species, including buffalo berry, Autumn olive, Russian olive and goumi, have associations with nitrogen-fixing bacteria. We have not established the potentially invasive Autumn olive at the farm and have yet to introduce any other *Elaeagnus*.

**Nitrogen-fixing plants at Three Sisters Farm:**

Annuals:

- beans
- peas
- fava bean
- red clover
- white clover
- yellow clover
- alsike clover
- sweet clover
- bird's-foot trefoil
- tick-trefoils

Leguminous trees:

- black locust
- alder
- bayberry

### *Mycorrhizal Associations*

Virtually all plants form symbiotic associations with fungi. In these associations, the plants provide sugars and other products of plant chemistry to the fungus in exchange for minerals and other products of fungal chemistry. These fungi include both mushrooms and microscopic fungi. Some fungal associations are very species specific. Lady slipper orchids, for example, are difficult to propagate without their native soil. Other mycorrhizal plants can use a range of fungi. Application of commercial mycorrhizal inoculants is recommended for worn soils negatively affected by chemical farming. Well-established and organically managed soils are less likely to need inoculants. However, if in doubt, adding these valuable fungal allies is a good way to ensure a healthy landscape.

### *Accumulator Plants*

Many plants are known for their ability to gather and accumulate specific minerals from the soil. Including these plants in green manures, fallow rotations, compost piles, orchards, forest gardens, hedgerows and poultry forage yards helps maintain a balance of available minerals in the system. Robert Kourik's *Designing and Maintaining Your Edible Landscape Naturally,* and Jacke's *Edible Forest Gardens: Volume II* provide detailed lists of accumulator plants. *Phytoremediation,* the use of plants to clean soil of heavy metals, is another use of accumulator plants.

**Allelopathy Research**

Dr. Valentine Kefeli has conducted research into the allelopathic properties of staghorn sumac at Slippery Rock University's Macoskey Center for Sustainable Systems Education and Research. He soaked the sumac's leaves in water for several days and observed the effect of the extract on emerging seedlings of wheat, clover, mustard and lettuce. He found that the leaf extract acted as a strong inhibitor to seedling germination and growth. Dr. Kefeli attributes this effect to water-soluble phenolic compounds in the leaves. Similar research showed a lesser effect by sumac root extract. Other research by Dr. Kefeli has shown that these phenolic compounds eventually break down in the soil or compost pile.

## *Allelopathy*

Many plants produce chemicals called *allelochemicals,* that can inhibit the growth of other plants. Allelochemicals may be active for only a few weeks, or they can remain in soil for months or even years. These persistent chemicals are also known as *phytotoxins.* Straw mulch from oats, wheat and possibly other grains leach phytotoxins into the soil that may inhibit seed germination. This is good when using straw mulch for transplanted crops. But it may not be good if a direct-seeded crop is planted in the mulch or directly follows a mulched crop.

Goldenrod has been shown to inhibit germination. Some plants inhibit their own kind. We have observed that rosemary will not self-seed directly under or near a mature rosemary plant. Many weeds and crop plants are allelopathic, including include spotted knapweed, *ailanthus,* ragweed, and artemisias. Our observations suggest that the effect is probably more pronounced when plants grow in dense stands, as with goldenrod.

### Black Walnut

Black walnuts are a good protein source and an excellent source of health-promoting oils. However, care must be taken when planting them on the farm. The roots of the black walnut, butternut, or any Persian walnut grafted onto black walnut root stock produce a allelopathic substance known as *juglone,* that is toxic to some plants. The toxic zone extends as far as the roots spread. This can be a radius of 50 to 60 feet around the trunk of the tree — or even more for larger trees. The toxic zone will increase each year as the tree grows. Juglone toxin occurs in the leaves, bark, and wood of the black walnut, but at a lower concentration than in the roots. Juglone is poorly soluble in water and does not move very far in the soil. Black walnut sawdust and chips from tree pruning can all contain juglone. Walnut and butternut leaves can be composted because the toxin breaks down when exposed to air, water and bacteria.

Some plants will not grow well or may be killed when planted within the root zone of black walnut trees. These include tomato, potato, blackberry, apple, crabapple and most azaleas and rhododendrons. But not all plants are sensitive to juglone. Some plants known to grow under or near the trees include eastern redbud, hollyhocks, rose of Sharon, black raspberry, calendula, pansy, peach, cherry, plum, sweet woodruff, and spiderwort. Vegetables such as squashes, melons, beans, carrots, and corn can be grown near black walnuts as well. Wildflowers that cohabitate with black walnut include violet, bergamot, Virginia creeper, trillium, bloodroot, Jack-in-the-pulpit and others. The late Tom Mansell, of Aliquippa, Pennsylvania, developed a productive tree crop guild that included black walnut interplanted with pawpaw, raspberry and asparagus. His forest garden landscape was managed from the late 1940s through the 1980s and included a hedge of filberts and hazelnuts enclosing the yard, Chinese chestnuts, 20 varieties of pawpaws and 80 apple varieties grafted onto 25 trees.

### *Invasive Plants*

Great care should be taken before adding invasive exotic plants to the landscape. Thoughtlessly adding inappropriate plants to a system is contrary to the permaculture ethic of care of the earth. Each plant added to a system should be analyzed for its properties and ecological relationships and placed in a functional relationship to the rest of the landscape. Invasive plants should only be planted when and where they will be controlled.

Many of our most useful wild edibles and crops were imported from Europe and Asia. We do not want to eradicate most of them; at Three Sisters Farm we embrace them as good food for people and animals or as important parts of the farm ecosystem. But if you have done battle with Japanese knotweed or multiflora rose, you understand the need for careful consideration before adding invasive plants. Even plants we want to add to the landscape, including mints, comfrey, tansy and stinging nettles can be invasive and need to be planted where they can be controlled.

Many of our major pests and plant pathogens, including Chestnut blight, Dutch elm disease, zebra mussels, gypsy moths, honeybee mites and Japanese beetles have been imported from other, similar climates. Invasive non-native plants such as Japanese knotweed, garlic mustard, Japanese honeysuckle, multiflora rose, privet, spotted knapweed and Canada thistle are imported plants. If I were asked, I would suggest a moratorium on importation of biological materials from any other temperate climate. Enough of this continuous assault on nature! As climates change and habitats are fragmented, continued importation of biological materials will only add more diseases and pests and further stress bioregions struggling to adjust. As good stewards of the planet, we must preserve and protect as much wilderness, wildland and natural area as possible. At the same time, we must intensively cultivate and sustainably manage the land we do use. How to balance intensive cultivation with wilderness will be a continuous debate. We can only hope this debate is informed by an agreement on the need for good ecology and healthy bioregions.

### Uncle Marlin's Garlic

Many times over a period of 15 years, my Uncle Marlin gave me bunches of his garlic in the fall. I would not quite get around to planting them. We always just ate it. Then, one year, I went to see Marlin after his house had flooded from heavy rainstorms. The flood had risen to within inches of the bunches of garlic hanging in the cellar stairway. "You better plant it this year," Marlin, age 73, recommended as he gave me my yearly supply. "I am not getting any younger you know." This time I paid more attention to the story of his red Italian hard-stem garlic.

Some of my earliest memories include eating the fresh tomatoes, onions and radishes from Marlin's garden. He has maintained the same plot in his backyard since 1964. Marlin retired from the Muncy Chief Hybrid Seed Company after 43 years of breeding field corn and feed grains. He always saved seeds from his prized crops in his home garden. The garlic was a gift from the grandfather of his lifelong companion, Judy.

Born in 1902, Judy's grandfather came from a small town near Naples, Italy to seek a new life in Williamsport, Pennsylvania in the early 1920s. Poppa Piccolo was a huckster, or neighborhood produce vendor, for much of the first half of the 20th century. The origin of the garlic is not clear, but when he gave Marlin a bunch of bulbs in 1985 he told Marlin he had been growing it for over 60 years. When he passed away at age 93 in 1995, Poppa Piccolo's garlic was in good hands. Now it is in mine.

This flavorful and relatively mild garlic has been a main ingredient in the oily hot peppers canned by ☞

## *Groundcovers and Lawns*

Permaculture design seeks to mimic natural process, both to create fertility and to add diversity to a landscape. In nature, soil is protected with a covering of mulch, sod or other dense plant growth. Soil drainage, fertility, pH and amount of sunlight all affect the type of cover.

Under a canopy of trees, leaves and other organic materials accumulate in a mulch layer. The resulting leaf mold protects the soil from erosion, excess drying and temperature extremes. All the while, the mulch feeds the soil and the community it houses. In the home landscape, we mimic this process by planting grass and mulching plants with wood chips, bark mulch and leaf mold from composted yard waste.

On borders and banks and in foundations plantings, plants can replace grass and mulch. Perennial groundcovers for this purpose include useful plants like chamomile, sweet woodruff, oregano, thyme, and lemon balm, and ornamentals such as periwinkle, pachysandra and English ivy. On the north side of a building and under trees and shrubs, wild woodland plants do well. These include ferns, wild ginger,

Judy's mother for many years. The barter is simple. Marlin provides the hot "banana" peppers and garlic to Judy's mother. She sends back some jars of pickled peppers. Eating these peppers with Marlin is another vivid tradition from my youth.

I always counsel friends and students to save favorite seeds and to adopt heirloom vegetables. The list of seeds maintained at Three Sisters Farm includes purple pod soup peas, Seneca Indian pinto beans, favorite annual flowers and various tomato varieties. We budget our seed purchase dollars so we can support the efforts of The Seed Saver's Exchange and Seeds of Change. Each year we buy up to 20 varieties of heirloom tomatoes and other plants from these sources. As an advocate of varietal preservation by individual gardeners, I advise finding varieties that are suited to your local conditions and have special meaning to you.

I regret that it took so long to establish my own plot of Uncle Marlin's garlic. I was always so busy, and it was too tempting not to eat it. But the fact that Marlin's garden provided it every year made me take it for granted. After the most recent flood however, I was reminded — by the gardener himself — of the gardeners' mortality. The tradition of passing on prized crops to family and friends is an ancient part of being human. Uncle Marlin's health and vigor is excellent (no doubt due, in part, to good garlic), and he expects to continue gardening for years to come. Still, I think we both are a little happier knowing Poppa Piccolo's red Italian hard-stem garlic has found another gardener to carry on the tradition.

### Doorstep Kitchen Garden

A doorstep garden can add ultimate freshness to a kitchen. Transforming the patio and adjoining yard into a living, breathing spice rack can transform a ho-hum cook into a world-class chef. Exploring new dimensions of flavor and aroma is a journey that can begin at your doorstep.

The doorstep kitchen garden adds life to a patio, enriching the landscape with scent and color. Contrasting greens of culinary herbs, mingled with multicolored chard and flaming red hot peppers beneath trellised orange Sungold cherry tomatoes, provide a savory setting to inspire culinary excellence. When designing a kitchen garden, placement is important. Keep planters away from the grill. At the same time, the closer the plants are to the patio, the more you will use them. By interplanting herbs and vegetables in pots and beds, a broad palette will be at hand and ready for the cutting board. Each plant can be grown in as little as 1 or 2 square feet of space. These plants like rich, balanced soil and a lot of compost. Most will thrive in a sheltered location with lots of sun. A raised bed system makes harvest easier. Perennials and annuals alike can be mulched with shredded bark if the fertility of the soil is high. Weekly application of liquid seaweed and fish emulsion will ensure productivity. A simple footpath through the doorstep garden is enough to provide access to the freshest ingredients. ☞

trillium, sweet woodruff, bloodroot, bleeding hearts, Virginia bluebells and others. Currants, gooseberries, and numerous other woodland shrubs do well in shaded borders. Wild plants should be purchased as nursery-grown plants or rescued from development projects, but not transplanted from the wild. Most prefer an annual mulch of leaf mold.

Lawns can be replaced with meadow plants. When selecting them, it is best to select a regional mixture. In the northeast, meadows include goldenrod, asters, arnica, American knapweed, moth mullein, ox-eye daisy and black-eyed Susan. Annual mowing helps keep out brambles and trees and maintains a space in the “meadow stage” of succession.

Where a lawn is desired, a more natural and native lawn can be developed. A lawn ecosystem includes a variety of plants. Some of my favorite lawns are a beautiful mix of mosses, grasses and wildflowers between mature trees. Another wonderful mix is violets, veronica, dogtooth lilies and wild orchids interspersed among merging patches of native moss and planted fescue or bluegrass.

Yarrow planted thickly and mowed makes a soft carpet, as does creeping thyme. American pennyroyal and peppermint will also persist through regular mowing near downspouts and other wet spots. White

The kitchen garden begins with the culinary herbs. Potted, in planters or in beds, a great variety of herbs can be grown around the patio and kitchen doorstep. Fresh sprigs of thyme — German, creeping or lemon — are easily stripped from the stem and sprinkled on roasting root vegetables. Branches of rosemary, with their evergreen freshness, complement any meat, red or white.

Fresh trout, bass, and other whole fish can be stuffed with chopped garlic chives and shredded French sorrel, wrapped in chard and mustard leaves and grilled to moist perfection without falling apart. Salmon steaks likewise can be topped with lemony sorrel and chives.

Chicken marinated in fresh tarragon and vinegar is a dish to relish. Chicken topped with a coarse pesto of parsley and basil or cilantro will have your guests inviting themselves back for more. Give them a fresh, cold beer and grilled flatbread pizza topped with fresh chopped basil, cilantro, parsley, oregano and tomatoes — and you will have them moving in.

Do not forget to include vegetables in the kitchen garden. Small plantings of a variety of vegetables in pots and beds near the patio can supply shish kabobs of baby squash, cherry tomatoes, eggplants, peppers, scallions, snow peas, beets and even new potatoes. The creative cook can add artistry to the presentation by gracing the plate with garnishes of herb sprigs and edible flowers.

Dutch clover provides nitrogen and, if you are lucky, the occasional four-leaf clover. Creeping yellow clover is an interesting addition if you can find it. Dandelions reach deep into the soil and bring nutrients to the surface for the other plants to use. They make great playthings for children as well. Violets, blue-eyed grasses and bluets and other small plants add interest and diversity. Of course, your choice of plants to use should be guided by your climate and soil type.

A permaculture landscaping plan considers the impact of the landscape on the surrounding community. By reducing lawn space, we save energy and reduce noise and air pollution. Diversifying the landscape with native shade trees, shrubs, meadows, and groundcovers builds the health of the local environment by providing bird and insect habitat. Natural mulches and diverse plantings enhance soil fertility. The resulting landscape is natural, organic, beautiful and functional.

## Cultivation Guide for Native and Habitat Plants

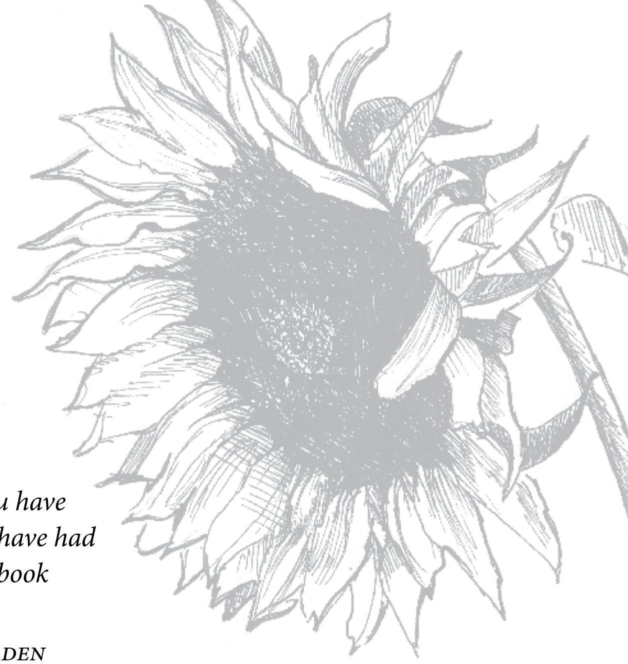
| Common Name | Botanical Name | Height | Color | Bloom Time | Moisture | Sun | Habitat |
|---|---|---|---|---|---|---|---|
| Black-eyed Susan | *Rudbeckia hirta* | 1–3′ | golden yellow | June–October | dry to moderate | full to partial | fields, prairies and open woods |
| Black cohosh | *Cimicifuga podocarpa* | 3–8′ | white | June–September | moderate to wet | partial to shade | woods with deep, loamy, moist soils |
| Blue cohosh | *Caulophyllum thalictroides* | 1–3′ | purple–brown, yellow green | April–June | moderate to wet | partial to shade | woods with deep, loamy, moist soils |
| Blue false indigo | *Baptisia australis* | 2′–5′ | blue | June–July | moderate | full to partial | thin woods and along streams |
| Common St. John's wort | *Hypericum perforatum* | 1–2.5′ | yellow | June–September | dry to moderate | full to partial | naturalized—found in fields, roadsides and waste places |
| Dutchman's breeches | *Dicentra cucullaria* | 4–12″ | white | April–May | moderate | partial to shade | rich woods — prefers to grow at the base of beech and maple trees |
| Dwarf ginseng | *Panax trifolius* | 4–8″ | dull white to pink | April–June | moderate to wet | partial to shade | moist woods and damp clearings |
| Evening primrose | *Oenothera biennis* | 2–5′ | yellow | June–September | dry to moderate | full to partial | fields and roadsides |
| Great blue lobelia | *Lobelia siphilitica* | 3–4′ | bright blue | August–September | moderate to wet | full to partial | rich lowlands, meadows and swamps |
| Green-headed cone flower | *Rudbeckia laciniata* | 1–3′ | yellow | June–October | moderate to wet | full to partial | fields, prairies and open woods |
| Hepatica | *Anemone americana* | 4–6″ | pink, lavender or white | March–June | moderate | full to partial | woods with sandy to loam soils |
| Jacob's ladder | *Polemonium van bruntiae* | 1.5–3′ | bluish–purple | May–July | moderate | partial to shade | swamps, bogs and rich woods |
| Jewelweed | *Impatiens capensis* | 2–5′ | orange and yellow | July–September | moderate to wet | partial to shade | shaded wetlands and woods |

### Cultivation Guide for Native and Habitat Plants cont.

| Common Name | Botanical Name | Height | Color | Bloom Time | Moisture | Sun | Habitat |
|---|---|---|---|---|---|---|---|
| Joe Pye weed — plain | *Eupatorium fistulosa* | 3–8′ | pinkish lavender | July–September | moderate to wet | full to partial | damp meadows, shorelines |
| Joe Pye weed — spotted | *Eupatorium maculatum* | 3–7′ | pinkish lavender | July–September | moderate to wet | full to partial | damp meadows, shorelines |
| Miterwort | *Mitella diphylla* | 8–18″ | tiny white | April–June | moderate | partial to shade | rich woods |
| New England aster | *Aster novae-angliae* | 3–7′ | bright purple | August–October | moderate | full to partial | wet thickets, meadows, and swamps |
| Ostrich ferns | *Matteuccia struthiopteris* | Up to 5′ | --------- | --------- | moderate | partial to shade | woods with moist rich soils |
| Ox-eye daisy | *Leucanthemum vulgare* | 1–3′ | white and yellow | June–August | dry to moderate | full to partial | waste places, meadows, pastures and roadsides. can spread rapidly. |
| Purple coneflower | *Echinacea purpurea* | 1–5′ | purple | June–October | dry to moderate | full to partial | dry open woods and prairies |
| Showy tick-trefoil | *Desmodium canadense* | 2–6′ | pink | July–August | moderate to wet | full to partial | moist open woods and edges of fields |
| Spring beauty | *Claytonia virginica* | 6–12″ | pink | March–May | moderate | partial | moist woods, thickets, clearing and lawns |
| Swamp milkweed | *Asclepias incarnata* | 1–4′ | pink | June–August | moderate to wet | full to partial | swamp, shorelines and thickets |
| Toothwort | *Cardamine concatenata* | 8–16″ | white or pink | April–May | wet | partial | moist low woodlands and damp thickets |
| Trillium — red | *Trillium erectum* | 1′ | burgundy | May–June | moderate | partial | woods with rich, well-drained soils |
| Trillium — white | *Trillium grandiflora* | 6–12″ | white | May–June | moderate | partial | woods with rich, well-drained soils |
| Violet | *Violaceae* | 3–5″ | lavender, white, cream | March–June | moderate to wet | partial to shade | damp woods, moist meadows, lawns and roadsides |

**Cultivation Guide for Native and Habitat Plants cont.**

| Common Name | Botanical Name | Height | Color | Bloom Time | Moisture | Sun | Habitat |
|---|---|---|---|---|---|---|---|
| Virginia bluebells | *Mertensia virginica* | 8–24″ | light blue | March–June | moderate | partial to shade | floodplains and moist woods |
| Virginia creeper | *Parthenocissus quinquefolia* | 40′ | light blue, white | Early Summer | moderate | full to shade | can spread rapidly; handling plants may cause skin irritation |
| Virginia spiderwort | *Tradescantia virginiana* | 8–24″ | blue–violet | April–July | dry to moderate | full to partial | woodland borders, thickets, meadows and roadsides |
| Wild bergamot | *Monarda fistulosa* | 2–3′ | lavender | June–September | dry to moderate | full to partial | dry fields, thickets and borders |
| Wild blue lupine | *Lupinus perennis* | 1–2′ | blue | April–July | dry | full sun | dry, open woods and fields |
| Wild blue phlox | *Phlox divaricata* | 8–12″ | blue | April–June | moderate | full to partial | rich woods and fields |
| Wild columbine | *Aquilegia canadensis* | 1–2′ | red w/ yellow | May–June | dry to moderate | full to partial | rocky, wooded or open slopes |
| Wild ginger | *Asarum canadense* | 6–12″ | red brown to green brown | April–May | moderate to wet | partial to shade | woods with rich, loamy, well drained soils |
| Wild oats | *Chasmanthium latifolium* | 2–3′ | enclosed in seed head | June–July | moderate | full sun to shade | woods with rich, loamy, well drained soils |
| Wood geranium | *Geranium maculatum* | 1–2′ | pink | May–June | moderate | full sun | woods thickets and meadows |



CHAPTER 8

# Seasons of the Garden

*Oh! The things which happened in that garden! If you have never had a garden you cannot understand, and if you have had a garden you will know that it would take a whole book to describe all that came to pass there.*

— Frances Hodgson Burnett, *The Secret Garden*

Managing an integrated agricultural landscape, with productive orchards and gardens, windbreaks and wildlife habitat, farm animals and pastures, as well as homes and bioshelters, is a complex task. Planning for a manageable pattern of activities throughout the year provides the template for a successful farm. This chapter is a study of a seasonal cycle that allows for multiple farm enterprises to thrive. It also addresses in more detail the management of gardens and the crops grown at Three Sisters Farm.

## Winter

When the wind blows hard and crystalline snow drifts over the cold frames and around the polytunnels, the farm seems dormant. Few things stir in the gray, frosty days and cold, clear nights. The tracks of rabbits and the hurried flights of small birds are the main signs of natural life. The tree line is populated by the usual crowd, black-capped chickadee, tufted titmouse, cardinal, blue jay and downy woodpecker. A Cooper's hawk makes regular assaults on the population of house finches and other small birds hiding among the dogwood twigs. Small flocks of dark-eyed junco rush about the farm, from tree line to fruit tree, foraging wild seeds. On still days, the red-tailed hawk patrols the skies above, and small groups of crows raise their call in distant fields. Beneath the snow and under the mulch and sod, moles and voles continue to tunnel. Mice tunnel under the snow and nibble seeds gathered in the fall. Woodchucks hibernate in their dens, dreaming of crisp lettuce and dog's teeth.

Extremely cold weather can freeze the tips of fruit trees and shrubs, but winter temperatures in our area mostly stay above 0°. However, in these times of changing climate, many cycles are being affected: warm winters disrupt the dormant cycles of many creatures; spring flowers sometimes begin to bloom in December; early thaws bring the frogs out early. Since just 1990, western Pennsylvania has jumped from hardiness zone 5 to zone 6. But do not go out and plant that commercial peach orchard just yet. There is not enough temperature stability in the spring and fall to count on good bloom set every year.

### *Winter Solstice*

The outdoor gardens lie dormant under the winter's snow. The beds are planted in a fall-sown cover crop of winter rye or with a mix of self-seeded "weeds." At our farm, chickweed is an especially valuable self-seeding winter cover. The evergreen, branching stems quickly form large mats to cover and protect the beds while at the same time providing valuable winter forage for songbirds. Other beds are protected with the mulch from the previous summer.

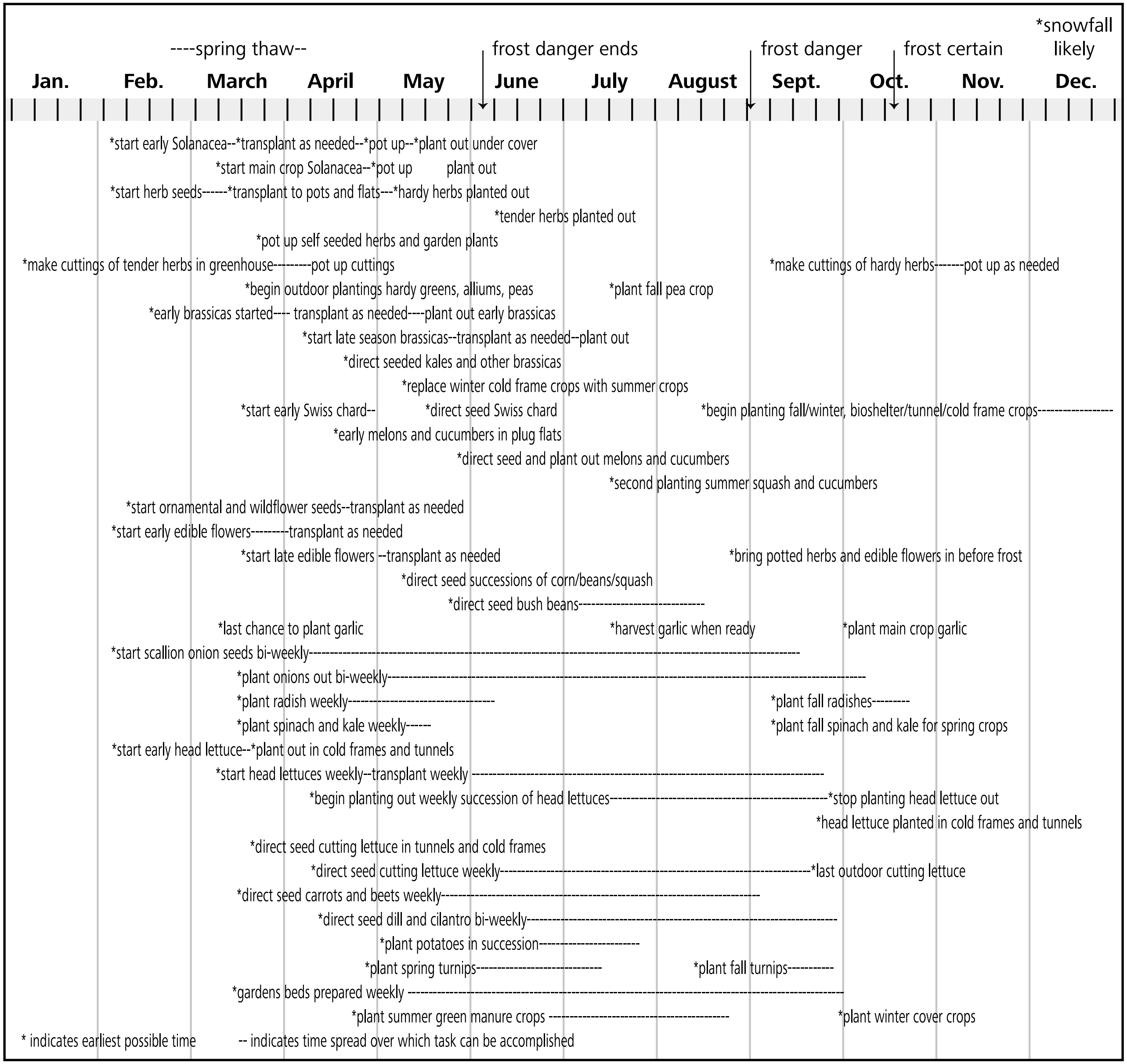
We are happy to take fresh salad and a winter bouquet from the bioshelter to our hosts for a winter solstice dinner. The winter herb bouquet is a lovely and fragrant gift. It includes fresh sprigs of scented geraniums leaves, flowering rosemary, variegated sage, flowering pineapple sage, flowering Mexican sage, nasturtium stems and flowers, thyme sprigs, flowering African blue basil, lemon verbena, flowering borage and catmint.

The solstice salad includes lettuces (red oak, buttercrunch, green romaine and red leaf), frisée, endive, spinach, baby red mustard, kyona mizuna, tatsoi, arugula, mache, chickweed, red Russian kale leaves, five-colored chard and flat leaf parsley.

Culinary herbs to select from for holiday cooking include thyme, sage, rosemary, bay, lemon verbena, marjoram, and oregano. Fresh herbal tea is made with spearmint, anise hyssop and borage.

Deep winter is the time to review the past year and plan for the year ahead. Seed catalogues are consulted for new and interesting plants.

# Three Sisters Farm Planting Schedule



Seed supplies are inventoried and sorted. Germination tests are done on seeds in storage. Sales and production records are reviewed and notes on successes and failures of specific crops and crop rotations are incorporated into the planning for the coming year. Applications for organic certification have to be made each year — just another annual farm task.

The farm plan documents the farmers' intentions for each year's garden management. A field history for each garden keeps track of soil input, including lime and other minerals, compost, green manures, and crops planted. Soil tests made the previous fall are used to plan which new amendments will be needed for the planned crops. For many reasons — weather, available labor, market variation, etc. — crops actually planted and work actually accomplished invariably differs from what was planned. Comparing the past year's plan to what was actually done is an important task.

Winter is the best time to take inventory of tools and supplies. Repairing and purchasing tools and supplies in the winter saves time and trouble later in the season. It is the best time to do equipment maintenance so everything will be ready to go when you need it. Most years, there is a need to repair and replace irrigation equipment. Hoses, sprinklers, watering wands and connectors are inspected and inventoried. Changing the oil in the tiller and lawn mower, sharpening the mower blades, and greasing moving parts are just a few of the tasks

### Germination Testing

Count out 50 to 100 seeds and place them between layers of paper towel in a shallow dish. Moisten the towels and place in a location with lighting and temperature appropriate to the species. After germination, count the successful seeds to determine the percentage of viable seed. If germination rate is low, adjust the amount of seed you plant or purchase new seed.

### Keeping up with our Customers

Customers are contacted early in the spring. A farm newsletter is sent to subscribers and other customers to remind them about our fine produce and get them thinking about the year ahead. As winter changes to spring, grocers and chefs are contacted to renew a dialogue. Usually they are looking forward to getting fresh, local produce and will have new requests and questions about our plans. Caterers and chefs plan weddings and other events many months in advance and may already have special requests. Personal visits (at a convenient time) help renew the farmer-customer relationship. This relationship benefits greatly when customers sense the farmer's enthusiasm. Most of our chefs and caterers are interested in hearing directly about what is new in the farm's crop plans, but individual produce subscribers generally do not want such a personal relationship with the farmer. We try to limit contact to the newsletter and the postcard or an email that alerts our CSA subscribers we will be back in the spring. By April 15, the year's delivery schedule and first billing is mailed to subscribers.

that should be done. Keeping a maintenance task list posted in the equipment shed helps organize these jobs.

Herb cuttings, seedlings and transplants are started on a schedule for spring plant sales and garden transplants, so potting room supplies need to be inventoried and replenished. As the spring rush of seeding and transplanting begins, it is best to be fully stocked. Plant labels, marker pens, flats, inserts and pots ordered well in advance will avoid delays later. Some material will need to be cleaned and sorted. For example, we use reuse flats, inserts and pots until they wear out. But they need to be cleaned after each use. We clean them by soaking and then rinsing them with water and hydrogen peroxide bleach; they are put outside in full sun to dry. Once dried, flats, inserts and pots are sorted by size and stored for later use.

**Winter To-do List:**

- Get some rest!
- Prune trees and shrubs
- Check and repair tools
- Stock up on supplies
- Order seeds
- Reconnect with customers
- Mulch paths and fence lines
- Plan tours and classes
- Apply for organic certification
- Prepare cold frames and seedling frames
- Turn compost

### *Tending Trees and Shrubs*

Fruit trees are pruned during the winter months. The common rule is that any month with an "R" is a good month to prune, so September through April are pruning months. Pruning in warmer months, especially in humid weather, can allow disease to infect open cuts. Fall through winter pruning allows the trees to adjust before fungal and bacterial diseases become active.

Pruning is a complex topic and is not dealt with in detail here. But, basically, we have found that the more you prune a tree, the more you will need to prune it. For example, the popular "open-vase" style of apple tree pruning requires intensive annual pruning to maintain that form. Espalier forms require even more annual maintenance. We prefer to allow our trees to develop a natural form. Once the tree is established, it is a simple task to remove a few branches from each tree to allow good light penetration and air circulation. Pruned branches are removed from beneath the trees in case they harbor pests or disease. Prunings are used for a spring celebration bonfire, cut for kindling, or used as the bottom layer of compost piles, to aid aeration of the piles.

### *First Outdoor Harvest: Late March*

The first outdoor spring harvest of wild greens is a good time to walk the farm and look closely at the condition of the gardens. Beds are inspected for problem weeds, drainage, and any cleanup needed. Mental notes are made of repairs needed to fencing and gates. Locations of plants to pot up for sale are noted, as are perennials that should be divided. Birdhouses are examined and last year's nesting sites noted. Woodchuck holes are located and monitored for activity.

The harvest begins late on a Tuesday afternoon and extends into the early evening. The evening air is full of sound. Mourning doves coo, robins, phoebe, red-winged blackbirds, and the ever-present house finch all add their songs over the background rhythm of spring peeper frogs. The spring peepers and a few other frogs with deeper voices begin their evening song in the late afternoon, urgently calling for mates as clouds move in and distant thunder rolls through the heavy, humid breeze. Several male red-winged blackbirds swoop around the pond, staking territory where the cattail will emerge. Robins scurry about, collecting last year's dried grasses to build this year's nests. Crows fly overhead, chased by smaller birds. Soon they will begin to nest in the treetops along neighboring fields and chase away the red-tailed hawks that circle overhead. The sun sets and the birds grow calm in the twilight. A great blue heron squawks as it glides toward the pond, leaving its nest for its evening forage. The frogs grow louder as the daylight fades.

Fall-planted baby carrots are pale but sweet. Last year's spinach is still frost-tinged but will recover and produce nicely. Chives are just beginning to wake up and stretch from their winter sleep. Dandelion, ox-eye daisy leaves and mache all have sprung up quickly after a week of warm weather.

Cold frames that were watered and weeded three weeks before — in the first days of weather warm enough to melt the winter snow cover — yield a plentiful harvest of salad ingredients. These include self-seeded crops: miner's lettuce, mache, chickweed, red Russian kale, dandelions, ox-eye daisy greens and chervil. Fall-planted spinach, lettuce, lacinato kale, Swiss chard, and arugula have all wintered over. A few remaining weeds, grasses, red dead nettle (*Lamium purpureum*), yellow dock and thistle are removed. Young dock leaves are used in the salad, but they grow quickly and will shade and suppress other plants. Dead nettles are edible raw, but they are a bit coarse, so we avoid them in the salad mix. Red dead nettle is also quick to set seed and is an abundant hardy winter cover in the gardens. But, being a prolific seed producer, it can be invasive, so we keep it out of our tunnels and cold frames.

Top left: *Jenkins' garden with grape arbor.*
Bottom: *Jenkins' zone one garden.*

Top right: *Orb weaver,*
Araneus marmoreus.

DARRELL FREY

CATHERINE PALADINO

DARRELL FREY

Top left: *Bioshelter and grow frames viewed from west.*

Top right: *Ladybug with larvae.*

Bottom: *Bioshelter interior plantings.*

Catherine Paladino

Catherine Paladino

Darrell Frey

Tom Gettings

Left: *Bioshelter viewed from the south east.*

Top right: *Bioshelter in the spring.*

Bottom right: *Lettuce and various wild edibles.*

Catherine Paladino

Leo Glenn

Stacy Domer

Top left: *Flower confetti cheese ball.*

Top right: *Wild columbine.*

Center right: *Bee balm edible flower, tea herb and a favorite of hummingbirds.*

Bottom: *Edible flower cake.*

Darrell Frey

Darrell Frey

Top: *Jujube Chinese date.*

Center left: *Wild crafted mushrooms, chanterelles are in high demand by chefs.*

Center right: *Fruiting shiitake mushroom logs.*

Bottom: *Sungold tomatoes in thyme.*

Top left: *Garter Snake.*

Right: *Spiral garden bench.*

EARLE BARNHART

EARLE BARNHART

EARLE BARNHART

EARLE BARNHART

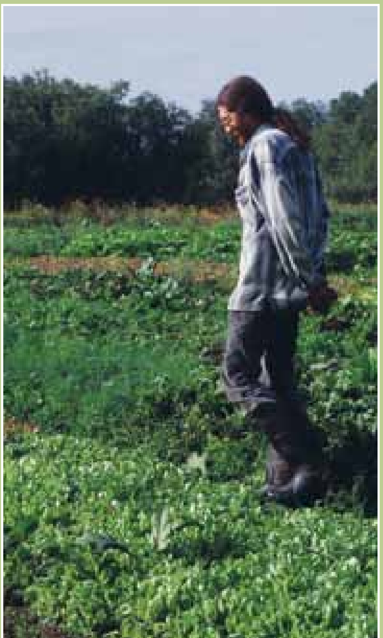
Top left: *Ark 2010 south wall exterior.*

Center left: *Ark south wall.*

Bottom left: *Thermal mass pool.*

Top right: *Ark interior.*

LEO GLENN



CATHERINE PALADINO

DARRELL FREY

Top: *Butterfly weed, a native wildflower attracts beneficial insects.*

*Bottom left: Darrell Frey in the garden.*

*Bottom right: The three sisters, corn, beans and squash.*

### *Late Winter and Early Spring Chores*

Walks around the gardens help reconnect the gardener to the land. Many tasks await the gardener in early spring. It is a good time to repair garden fences, so loose stakes, decaying posts and rusted fence are replaced. Mulching the fence lines with layered cardboard and sawdust early in the year discourages a tangle of weeds later in the season. Any row covers, garden stakes, flats or other items left in the gardens in the busy fall are gathered and put in their proper places.

Birdhouses should be cleaned of last year's nests. (When our children were young, we had a tradition of putting up several new birdhouses each Easter Sunday. Now we continue this tradition with our grandchildren.)

Perennials are tended as needed. Mulch is applied to small fruit trees and shrubs, asparagus, and other perennials. Dead canes are pruned from berries and roses. Plants we want to propagate are divided and replanted or potted. Pruning is an urgent task if not already completed.

Seedling frames and the seedling greenhouse are prepared for spring use. Flats of herbs and wildflowers that wintered over in the frames are inspected. Weeds are cleared out and the floors of the seedling frames are covered with a layer of cardboard and sawdust. Diatomaceous earth is dusted around the perimeter to discourage slugs, which love to hide under seedling flats. The seedling frames are checked for loose boards and glazing, and repaired as necessary. The seedling greenhouse shelves are cleaned and door hinges tightened.

### *Polytunnel and Bale-Shelter*

The polytunnel in the South Garden and the bale-shelter in the East Garden are important tools for our spring salad production. Each spring, we clean dead plants out of the beds, add a little compost, till, and water. Red Russian kale and spinach that winters over is left in the beds. Head lettuces or bok choy seedlings are planted on 12-inch centers in the beds and the tunnel is watered heavily. Within a week, self-seeded salad crops begin to sprout between the planted seedlings. These include kales, mache, lambsquarters, chervil, chickweed and tatsoi. The heads of lettuces are cut weekly for salad, as are the self-seeded greens. Borage and cilantro also self-sow in the tunnel. After the spring salad is harvested, some plants are left to set seed for the following year.

The overwintered kale produces flower buds for most of the summer. These are harvested weekly for our salad mix.

The bale-shelter is planted each spring and fall with direct seeded salad crops, including mizuna, mache, tatsoi, red mustard, red mallow, and spinaches.

## Bale-shelter

A bale-shelter is a low-cost, low embodied energy, micro-climate-enhanced polytunnel. Because it is insulated with straw bales fall through spring, it offers a more sheltered and more productive growing space than our other polytunnel. In our bale-shelter, lettuce, chervil, spinach, mache, kale and chickweed survive well in the winter months most years; our other tunnel tends to freeze each winter, killing all but the hardiest kale. When built in 2000, the cost for the lumber and posts was about $150, and the plastic about $75. It was built in two days by two people. It is a 700-square foot garden space that could easily keep a family in salad and other greens through all the winter months.

The bale-shelter design began as an intern project to build a low-cost greenhouse. The intern was a 50-something university professor gathering skills for his retirement. In addition to gardening, he was learning construction skills and wanted to help build a greenhouse. The project was something we would need to be able to build during his once-a-week workdays at the farm.

We needed a second polytunnel to expand our salad production in the spring and fall. We had a small budget and wanted to use natural and local materials for the frame. We were interested in experimenting with polytunnel design with the addition of an insulated north wall. Because straw is less expensive and more available in the fall than in the spring, we also needed a place to store up to a hundred bales of straw for our spring mulch.

The design is simple; it's a sort of pole building structure that is 6 feet wide and 45 feet long. Because the UV-resistant plastic comes in 100 feet rolls, a 50-foot by 24-foot length will cover two such structures, accounting for excess to fasten edges. Headers made of 2- by 8-foot lumber mounted on posts support the rafters. The endwalls have a door framed in that is big enough for a wheelbarrow and rototiller to pass through. Cedar, oak or black locust wood are used for the posts. All framing lumber is rough-cut red oak.

The north side, running east to west, has the header set on 6-foot posts, set 2 feet in the ground and spaced 6 feet apart. This makes the wall 4 feet high. The south side posts are 3 feet long, set 2 feet into the ground, with the header attached several inches above the ground; this reduces soil contact and decay. The center posts are 8 feet long, set 1 foot into the ground. The central header is made of 2- by 10-foot lumber.

Rafters made of 2- by 6-foot red oak are nailed to the headers. The south side rafters angle up from the south side header to the center header at a 45-degree angle. The north side rafters angle up from the north wall header about 60 degrees to the center header.

The rafters' edges and rough sides were hand planed so the plastic wouldn't catch and rip. The peak of the roof is cut flat and covered with small pieces of rubber roofing to protect the plastic further. Side walls are framed with 2- by 4-foot lumber for bracing. ☞

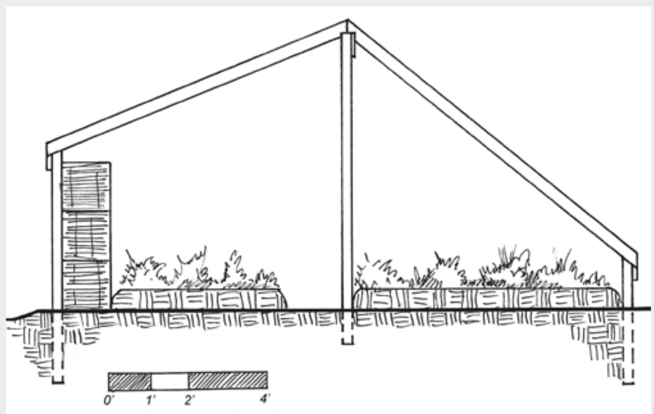
Polytunnels and cold frames are cleaned as needed of winter crop residue and fertilized with compost. Any needed repair from the winter's stress to the structures is done in early spring as well. Holes in the plastic are repaired with plastic repair tape.

All the framing and rafters are waterproofed with a mix of beeswax, turpentine and linseed oil. (The mix is discussed in more detail in Chapter 9).

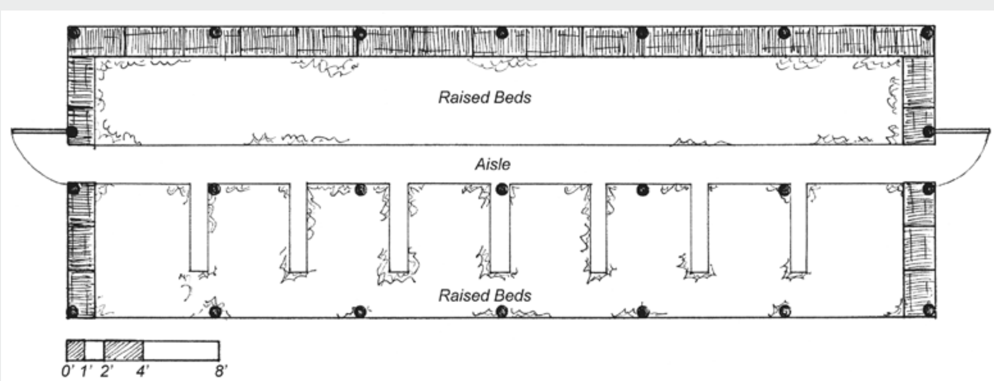
Reinforced white plastic sheeting covers the end walls. The rest of the bale-shelter is covered with 6-ml UV-resistant greenhouse plastic. The plastic on the north side extends to the ground and can be rolled up in summer.

Each fall, 45 straw bales are stacked three high along the back wall. The space under the south header is stuffed with straw to reduce airflow.

A central path provides access through the bale-shelter from east to west. The north side bed is a 4 feet wide and 45 feet long. The beds on the south are arranged in a keyhole pattern for easy access. (See top view illustration.) As of 2010, the headers and rafters are holding up fine. We need to replace the greenhouse plastic. When we do this we will replace several cedar posts, with locust posts, and we will recoat the frame with the water proofing mix.




*Bale shelter section and bale plan.*



As winter breaks and new life stirs in the soil, a few hardy plants begin to grow. Mache, chickweed and chervil that survived under the snow are reliably producing by early March.

Spring garden preparation begins as soon as beds can be worked. In wet springs, this means preparing beds with the garden fork. After the soil drains and the beds are drier, they can be prepared with the two-wheel rototiller. Only after the beds are very well drained can a tractor be brought into the garden.

Early crops to go into the ground include alliums, such as onion, leeks, chives and garlic (if not planted in the fall). Peas, radishes, hardy cooking greens and direct seeded spring salad greens can be sown up to two months before the last frost date. Spinach, chervil, miner's lettuce, peas and mache are planted early for salad greens. Growth rate will depend on how soon spring warms the soil. Generally, we try to get an early start, willing to lose a few plantings to a late hard freeze in exchange for the chance of early spring harvests. Floating row covers help prevent loss from minor freezes.

Fall-planted cover crops should be tilled in before they get more than 6 inches high. Otherwise they need to be cut with the scythe before tilling. We often use the tractor-driven rototiller to till under large areas of cover crops. Spring-planted green manure, such as field peas, rye and other cold-season cover crops, can be planted in beds reserved for summer crops.

## Spring

Spring cycles are in flux. The last frost date may be as early as May 1 now, but it can also come as late as the first week of June. More than ever, we are relying on the polytunnel, cold frames and row covers to get the crops through to certain summer.

### *Spring Propagation*

Many garden perennials are divided for propagation in the spring. Our most intensively managed gardens are located within 150 feet of the bioshelter's potting room. This Zone 1 area contains stockpiles of potting soil ingredients and watering equipment. Pots are put in a garden cart so they can be moved around as needed. Recycled potting soil and compost is mixed in a wheelbarrow. Self-seeded plants are collected and potted up. Perennial herbs and flowers are dug, divided, and potted. Care is taken to prune back dead stalks and leaves and inspect plants for any pests. As we do for indoor cuttings, plants potted from the garden are fertilized with seaweed solution to promote vigorous root growth.

Most perennial herbs benefit from being divided and replanted with fresh compost or moved to new garden beds. In our area, April through early May is the best time to do this. In 20 years, we have relocated our main beds of perennial herbs at least five times.

Every year some of our bush fruit and brambles are divided and planted in new locations around the farm. Currants, raspberries, roses and Juneberries all produce new shoots readily. These are divided and replanted while still dormant to prevent transplant shock to young leaves.

New trees are mostly planted in the spring. As stated earlier, we usually limit new tree plantings to ten or fewer. With all the other work to be done, it is difficult to keep new trees watered, mulched and protected. Planting too many is a waste of money and effort.

When planting trees and shrubs, the soil should be well prepared in advance. As the saying goes, do not put a $10 tree into a $1 hole. With current apple tree prices approaching $30, the saying is even more instructive. The soil should be dug to at least twice the width of the root ball and the bottom and sides of the hole loosened with a digging fork. This gives them room to grow outward. In heavy soils, the hole will act as a pot and the roots will fill the hole before trying to spread.

Start by digging the hole wide and deep. Keep topsoil and subsoil separate. When the hole is large enough, loosen the bottom and sides with a digging fork or pick. Next, loosen the soil for several feet all the way around the hole with a U-bar subsoiling tool (described shortly). When planting the tree, replace subsoil first, then the topsoil. Mix compost, greensand, and rock phosphate and add it to the topsoil and in a 2-foot-wide band around the tree or shrub. Then mulch with shredded wood chips. Michael Phillips, writing in *The Apple Grower,* suggests that chipped saplings make the best mulch for fruit trees because they have a higher ratio of green wood. He also recommends a gravel mulch for the first few years, especially directly around the trunk. This helps reduce hiding places for the tree-gnawing meadow vole.

Late spring is a busy time. Plant sales, garden preparation, Earth Day events, garden tours, and garden workshops are all scheduled. Plant propagation, transplanting, harvest and marketing increase with the day length. More labor is required and longer hours are the norm.

## Summer

When does summer begin? Memorial Day weekend is the official answer around here. But we know that full summer is near when robins sit on the nest and young swallows twist and turn overhead.

In recent years, we have had 80° days in early May and summers that were cool almost every night. Like the elusive springtime, summer weather, too, is changing. While hot weather is the norm, our mid-continental climate experiences both cool, wet summers and long, hot dry spells.

Many potted plants can be brought out of the bioshelter for summer. Rosemary and other herbs, ornamental sages, and hanging baskets are placed in Zone 1, in the arbor and Spiral Garden and around the pathways between the bioshelter and parking area. Here they benefit from direct sunlight, beautify the landscape, and can be watered daily. Larger planters act as hose divots around the seedling frames.

June brings intensive tilling, bed preparation and planting. The danger of frost is officially past on June 6. Long-season crops should be in their beds by the end of June. These include Solanaceaes, brassicas, basils, parsleys, sweet corn, squashes and cucumbers. Head lettuce seedlings and direct seeded salad beds are planted every week until September 21. Direct seeded summer crops that are planted every other week include beans, beets, carrots, cilantro, dill, bulb fennel and miscellaneous greens and roots.

The tunnels are either left fallow to self-seed, or planted with heat-loving crops. Peppers, basils and cherry tomatoes are planted in the tunnels as well to provide an extended fall harvest. In late spring, eggplant, cayenne peppers, Sungold tomatoes and occasionally sweet potatoes are interplanted with the remaining greens for a summer crop. Eggplants are far more productive in the tunnels and bioshelter. In the open garden, they are stunted by flea beetle damage. Flea beetles are not active under glass or plastic at our farm.

**Plant each week in summer:**

- head lettuce
- salad trays
- lettuce transplants

**Plant every other week in summer:**

- cilantro
- dill
- beans
- beets
- carrots
- fennel
- squash

**Full-season crops:**

- curled parsley
- flat parsley
- green basil
- red basil
- tomato
- pepper
- potato
- squash
- corn
- pole bean
- Swiss chard
- broccoli
- cabbage
- kale
- leeks
- onions

**Partial-Season Crops:**

- radicchio
- turnips
- spinach
- peas

The summer farm is a dynamic place. Young birds learn to fly, snakes slither among the long-season crops, cold frames and tunnels. Fish jump in the pond. Frogs and toads hop about. Butterflies and bees are busy from mid-morning until early evening.

We plan a work schedule that keeps the farm crew out of the mid-day sun. Morning and evening are the best times for most farm work, especially planting, harvesting and watering. Lunchtime lasts from around 1:00 until 2:30. After that, a rest or a swim, or indoor transplanting work is done. After 3:00, the garden work begins again. We keep sunscreen and natural insect repellant available for all workers to use.

### *Water*

Almost daily in the summer, except after rains, we irrigate new transplants and seedlings with pond water. We water mature crops with well water. In dry spells, watering can be a full-time job for one person. But we have had several recent summers when it rained hard almost daily for weeks. These trying times limited our ability to prepare beds and tend crops. We were able to get more cuttings from our salad beds, but our planting schedules suffered.

### *Value-added*

Through the summer a succession of craft items are harvested and processed. Flowers are pressed for cards and artwork. Herbs are harvested for making oils and vinegars and dried for teas and everlasting bouquets.

Excess crops are also processed weekly in the summer. Unsold basil and cilantro becomes pesto. Any not eaten right away is frozen for winter use. Tomatoes, peppers and salsa are canned. Fruit is picked and frozen. Applesauce is canned.

Weekly yard care goes on all summer. Weed trimming, and mowing are unavoidable tasks. We mow our garden's main pathways every week or two before harvest day. Other yard areas we try to mow as little as possible, but at least twice a month. Gardens are weeded and mulched again as needed in mid- and late summer.

Warm summer nights bring out the fireflies. Because bats and dragonflies keep the mosquitoes under control, we can enjoy the fireflies and summer stars unbitten. The return of the monarch butterfly in early July is a welcome occurrence. They add their orange and black wings to the dance of the tiger swallowtail, black swallowtail, hummingbird moths and other summer butterflies. We watch out for monarch caterpillars when weeding milkweed from garden beds so we can relocate them to a new home in a safe spot.

## Fall

The first changing leaves in late August and the practice flights of Canada geese remind us to begin fall plantings. Tunnels and the bioshelter are prepared for fall plantings. The last plantings of cold-hardy crops are made by September 21. After that, cold frames, tunnels and the bioshelter are planted. Spinach, mache, and cilantro are seeded in early October for a harvest the following spring. Self-seeded chickweed, lambsquarters and chervil germinate in the cooling soil.

Frost can occur as early as August 31 or as late as October 15. Any plants needing to be brought back into the bioshelter are potted up and checked for slugs, snails and insects. These include semi-hardy herbs, calla lily, and hanging baskets.

## Bioshelter Maintenance

Most maintenance jobs are done in October and November, when we have a little more time and the weather is still good.

### *Yearly Upkeep*

Every building requires annual maintenance and general upkeep. Maintaining a bioshelter includes normal tasks and repairs plus a few special considerations.

#### Weatherizing

Proper weatherization is the key to successfully utilizing solar energy as part of a building heating system. Heat loss through air infiltration can significantly reduce building performance.

Each fall, there is a checklist of weatherizing tasks to be done. Windows, doors and vents are checked for proper closure. Loose or worn weather stripping is replaced. Latches should close tightly. Doorknobs and catches are inspected and replaced if worn. As winter sets in, exhaust fan vents are closed and sealed. We usually disconnect the large gable fan motor and place a plastic cover over the vent. In early

December, when cold weather arrives, we place clear plastic covers over all the roof vents (from the inside). These we leave on until March. We take down a few at a time as the days grow longer and the building warmer. These plastic vent covers are stored for reuse each winter.

### Plumbing

Our bioshelter has a dozen plumbing fixtures; leaky faucets sometimes seem a constant. We keep extra washers and plumbing fixtures on hand. Broken and leaky faucets waste water and the energy used to pump it. Dripping water can also quickly cause wood to rot. We try to repair leaks as they occur. Exterior plumbing is drained before freezing weather can burst pipes.

Hoses also need to be repaired on occasion. Mostly they need new male ends because that end of the hose wears out from daily use.

### Painting

Interior surfaces (except floors) in the bioshelter are waterproofed with a mixture of beeswax and turpentine. We put a fresh coat on critical surfaces (near planters and growing areas) each year. Other surfaces are re-coated every other year. Interior wood floors are painted with linseed oil as needed.

Exterior surfaces are stained with a linseed oil stain. Planters, arbors, seedling-frames, bale-shelter framing and other surfaces in contact with plants are painted with the beeswax mixture. The bioshelter exterior, cold frames and roof vent frames are repainted with linseed oil stain every few years. Doorframes are repainted as needed with water-based latex paint.

### The Wood Stove

Many destructive fires begin with a dirty chimney. Chimneys need to be cleaned at the beginning of each heating season and again in late winter. Proper use of a wood stove prevents creosote buildup, but ash and soot need to be brushed out as needed. Chimney pipes should be inspected and replaced when they get worn. The single-wall steel pipes may last two to three years, but be sure to inspect them. The insulated stainless steel pipes that pass through the roof will last many years if properly cleaned each year.

### Steel Barrels

Steel barrels used as thermal mass will eventually rust. To increase their life span, they should be cleaned and painted if necessary. A good design is to cap steel barrels with flashing to prevent soil and water from collecting on the top. Barrels should be set on gravel or other well-drained surfaces to prevent the bottoms from rusting.

### Planters

We try to avoid wooden planters. They just do not hold up to rot. But plastic barrel planters sag and deform. Every year or two, we check bracing and support of the planter barrels to keep them secure.

### Window Washing

Rooftop glazing and windows should be washed each fall and perhaps again in mid-winter. Dust and dirt buildup on windows reduces incoming light and can increase condensation on the glazing, which further reduces light. Roof glazing and glass windows can be washed with warm water alone or with a small amount of mild soap. Too much soap will leave a film that can attract more dirt. We use a cloth squeegee tool with a telescoping handle. We only wash the inside surface of the roof glazing. The outside of the glazing gets washed by the rain and by snow sliding off in winter.

### Grow Lights

Florescent grow-light tubes need to be replaced after two years — at most. We date the tubes with a marker and replace them when they are too old for proper plant growth. Of course, you should replace burned-out tubes promptly.

## *Weekly and Daily Upkeep*

### Floor Sweeping

Floors need to be swept regularly. Moving flats and trays of plants inevitably leaves trails of soil mix and dirt. Working on planters and weeding also leaves dirt on floors. If not cleaned regularly, dirt collects and can absorb moisture that will rot wood surfaces.

The kitchen floor is swept daily, on harvest day or market days we sweep several times a day as needed. Countertops and sinks are cleaned and disinfected with liberal use of hydrogen peroxide bleach.

### Floor Raking

The gravel floor and dirt floor sections of the bioshelter need to be raked regularly to remove plant leaves and other residue. Raking also redistributes the gravel, making a neater surface.

### Dusting and Spider Webs

Spiders are welcome in the bioshelter. However, their old webs tend to collect dust and look messy. Periodically we clean the old spider webs from the rafters and corners of the building.

### Pest Control

Bug and pest patrol is a constant activity. We want to promote beneficial insects and minimize pests through monitoring and control.

Mice and rats will try to invade any building. Both are most likely to invade during autumn and early winter as they seek shelter from the coming cold. Vigilant trapping and building upkeep are essential to reducing or eliminating these pests. We use a number of traps and occasionally resort to organic-approved vitamin D rat poison. The poison is placed in child- and pet-proof bait stations in out-of-the-way locations in our barn.

### Firewood

Firewood is cut by midsummer each year to cure in time for fall. We try to cut or buy the following year's firewood in mid-winter. Wood is stacked on old pallets and kept covered until needed. Sticks and kindling are gathered as needed from the tree lines.

> white sun warms the soil
> seeds lie dormant in the earth
> awaiting the rain

## Managing the Permaculture Landscape

### *Tilling and Soil*

Permaculture places a lot of emphasis on no-till methods such as mulch gardening, perennial food gardens, and the creation of *no dig gardens* built up with layers of cardboard, mulch and organic matter laid on the soil surface. Each of these reduces or eliminates tillage, therefore conserving time, energy and effort. These methods rely on earthworms and other soil fauna and decomposers to process compost and mulch and distribute nutrients through the soil. Fungi become the dominant component of nutrient processing and delivery, trading minerals and other compounds with plants for sugars and other things they need.

Tillage breaks up soil structure and adds air to the soil, which increases respiration of soil microorganisms. Aerobic bacteria break down organic matter, making more nutrients available to promote plant growth, and release carbon dioxide in the process. In nature, this happens when trees uproot. Plants attuned to disturbed soils, many of which are annuals and biennials, capture this rush of nutrients. When they die, they return their nutrients to the soil surface and begin the process of succession that leads to perennial cover. This process also occurs where burrowing creatures mound soil and subsoil, where herds migrate, and along naturally eroding watercourses. Many of our vegetable crops probably originated in such disturbed soil.

John Jeavons's writings (see the Resource List) have thoroughly documented the high productivity of intensive gardening. Also called *bio-intensive gardening,* this method relies heavily on deep tillage, crop rotation and the regular application of compost. Bio-intensive gardening methods have been used by cultures around the world for millennia. Garden crops have, in a very real sense, co-evolved to suit disturbed, or more precisely, worked soil. Thus, they prefer the balance of air, moisture, drainage and organic matter of prepared raised beds.

Intensive gardens, when well managed, improve with age. The annual addition of organic matter such as green manure, compost and mulch increases the soil's capacity to hold moisture and minerals while balancing the soil's pH. Soil tests are used to monitor mineral levels. Rock minerals such as greensand, rock lime and rock phosphate are slowly released to the plants by the complex interaction of the soil's biochemical processes. These processes include passage through the digestive system of an earthworm, distribution of nutrients by mycorrhizal fungi, and chemical interaction with other minerals. After a number of years of garden soil development, minerals become ever more available to the plants.

## A Matter of Scale

My father used a spade to work the soil; my grandfather used a horse-drawn plow and disc; we use garden forks, rototillers and a tractor. Whatever the tool, the goal is the loose, well-drained and aerated soil that vegetables prefer. From an ecological point of view, though, tillage creates a disturbed environment. Digging, hoeing, turning, and discing all greatly disrupt soil structure and its flora and fauna — which can have serious consequences. For example, when immigrants brought traditional East German farming to the Great Plains prairie, they brought a farming method that relied heavily on plowing and disking. When drought and high winds came in the 1930s, millions of tons of disturbed topsoil were easily carried away in the dust storms.

When and where and how, then, do we till the soil? The answer is not straightforward. Use of tillage is a matter of scale and is site specific. Permaculture design encourages us to intensively cultivate only where we need to produce bountiful gardens and plant productive perennial landscapes; we should leave as much unmanaged wildland as we can. Our early attempts to rely on extensive mulching resulted in plagues of slugs, plentiful voles, and new weeds. Both straw and hay provide the perfect ecological niche for these pests and bring in weed seeds. Our current strategy is to rotate mulched crops with tilled crops. In any year, up to a third of our beds are mulched or fallow for part of the season. This allows for the continual addition of organic matter while also disrupting the life cycle of slugs and voles.

We limit our "involvement" when we can. Our perennial gardens are mulched only until the trees and shrubs are large enough to shade out competition on their own. When feasible, gardens are loosened and dug by hand with a garden fork to eliminate weeds — rather than using herbicides or power tools that would do more damage to soil structure.

### *Bed Making*

Beginning in late March and continuing through spring and early summer, we prepare and plant an average of 2,400 square feet of raised beds each week. The unit size of beds is generally 4 feet wide and 50 feet long, so each bed is 200 square feet. Every week, we plant at least four to six beds. We plant adjacent beds so we can water with our overhead sprinkler. We plant a mix of crops each week. At the peak planting season in June, we may need to plant 12 to 18 beds each week to establish our long-season crops.

The first step is to rototill the block of beds to be planted. Tilling incorporates organic matter and helps loosen and aerate the soil to a depth of 6 to 8 inches. We till in any green manure or prior crop residue a week before planting. Tall green manure crops may need mowing before tilling.

Before tilling, it is wise to first check for lost plant labels, plastic flat inserts, or even lost hand tools. Sticks and stones used to hold down the floating row covers the previous year also have to be searched for and removed. Usually it requires two passes with our tiller to break the ground and incorporate the green manure. New ground may require several more passes or we may need to use the tractor-driven tiller to save time and wear and tear on the small tiller — and on our bodies.

The second step is to form the pathways with a hiller, or furrower, attachment on the rototiller. Initially the pathways were laid out 60 inches apart, on contour. This is a reasonable width for working by hand, tillable by two passes of the rototiller, and also the tire width of a small tractor. Several contour lines are measured with a water level and marked with stakes. (See Chapter 4 for more detail on how to do this). We then till along the contour line with the hiller attachment. The hiller is an adjustable triangular implement that pushes soil out on both sides — sort of a double-sided plow. It makes a furrow 6 inches deep and 12 inches wide. We then use a flat shovel to widen the furrow and flatten the bottom to establish the path. Soil removed from the path is added to the beds.

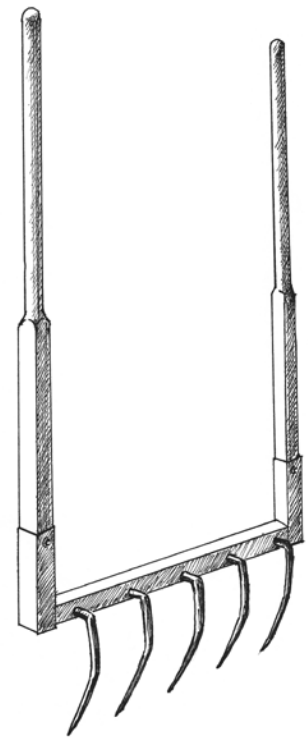
The final step is to add compost and prepare the bed for planting. After the green manure has begun to disappear thanks to the soil's various digesters and decomposers, usually in about a week (maybe two in cooler soils), compost is added, along with any necessary minerals and organic fertilizer. Beds are then tilled again.

After two passes with the tiller, the bed is raked to remove any crop residue or weed roots. Raking should not be a back-destroying chore. New gardeners rarely know how to use a rake properly. Raking raised beds is best performed standing erect and raking to one's side rather than stooping over and raking forward. To rake out roots and stones, one should begin a section with a deep pull and heavy pressure. The second and third pass over an area are progressively lighter, pulling the debris to the surface. The final shallow pass then rakes away the roots and stones, which are destined for the compost pile or the chicken yard.

If quackgrass has invaded the beds, we hand rake the roots out of the soil before adding compost. Starting with a three-pronged rake, we pull the grass roots up to the surface, then rake off the surface with a garden rake. This step is repeated as necessary to reduce the grass population.

Quackgrass is stubborn and hard to get rid of. Some hand pulling is usually required as well.

When establishing new beds, after tilling and hilling we also loosen the subsoil with a U-bar, or broad fork. This tool has a row of heavy rods on a bar and two long handles. Ours has two lengths of rods, 12 and 14 inches long. The rods are pushed into the soil by stepping on the bar. Then the handles are pushed forward and pulled back several times. The goal is to loosen the subsoil, not to turn it. Excessive strain is not needed. Most of the work is done by body weight, standing on the tines to push them in the soil, and leaning back and forth to break up the lower layer. Simply loosen a spot, and then move 6 to 8 inches forward and repeat until the bed is covered. This is not as strenuous — and not as thorough — as double digging, but it greatly improves soil aeration and drainage. This allows plants to feed from a larger soil area and will help increase the depth of the topsoil. Every three or four years, we repeat the subsoiling on most annual garden beds. The U-bar is also used in the bioshelter's deep beds to break up the hard pan that develops.



*A broadfork, or U-Bar, is used to loosen subsoil , increasing soil drainage and root penetration.*

The method of bed preparation described above has many advantages. The beds are the right width to be worked from both sides and still maximize the use of space. As the path becomes compacted with foot traffic and wheelbarrows, they become small swales. The pathways catch any hard rain that runs off and slowly drains it under the beds. The extra soil from the paths increases soil depth in the beds, which stay loose because they are not walked on. Pathways are weeded with a stirrup hoe or hand weeded or mulched.

When an entire bed is replanted in succession, we often just till once and rake the plant residue.

## Problems with Rototilling

One must be careful to not till up snakes and toads and the desirable plants. Often, we need to till around or move self-seeded plants. Excess tillage can make our soil *too* loose. The fine particles compact into a hard crust and prevent germinating seedlings from breaking the surface. The incorporation of several inches of compost in the final tilling before planting helps prevent this crusting. We manage the problem by keeping the soil moist with daily watering and covering direct seeded crops with a layer of compost and sand.

### Tending the Tiller

We have managed to keep a 1983 Horse Model 8HP Troy-Bilt rototiller running and in fair repair. This rugged machine, used for at least 100 hours each year for almost 20 years, has had the engine replaced twice, tines replaced every five or six years, and the gears rebuilt several times. The tiller came with a very useful, detailed manual that shows how to tear down and repair all key parts and keep the tiller working well.

In 2007, we purchased an 8HP BCS tiller with a sickle bar attachment. Learning to till with the new machine was a challenge. The Troy-Bilt tiller has variable speed gears that allow the operator to control how finely the soil is tilled. The BCS runs at only one speed and can make our soil too fine. We have at times used the BCS tiller to break ground and till in green manure, then used the older machine for the final tillage before planting. After adjusting to the new machine's design, we do find the BCS tiller a good tool.

We do not endorse any brand, not knowing if current models are built to the same standards. We do advise that the market gardener and small-scale farmer purchase rugged, well-built and easily serviced equipment. Make sure the manufacturer has repair parts available. It is advisable to keep spare drive belts, nuts, bolts and other small repair parts on hand. Regular maintenance of the engine, including oil changes and other lubrication, and maintenance of the tiller's controls, gears and levers should ensure a long life for a quality machine. We expect to eventually replace the tiller's engine with a diesel engine, which we could power with locally and sustainably produced biofuel.

## Planting

A key aspect of intensive gardening is employing multiple strategies to make the most of space and bed preparation time. Below are some of the strategies we have found useful:

- Plant weekly, in blocks of four to six beds for watering and harvest efficiency.
- Use transplants to reduce the amount of time crops are in the garden.
- Use corn, squash, potatoes, and perennial beds to divide blocks of transplant crops and provide wind and pest barriers.

- Have two or more beds of perennial herbs in different gardens as insurance against pests and disease.
- Centrally locate the bioshelter, compost areas, and piles of sawdust, leaves and other garden supplies.
- Make central location on high ground, so seedlings and bulk supplies move out and downhill, and produce moves uphill, back to central packing and storage.
- Space plants closely.
- Use interplanting (companion planting).
- Do succession plantings.
- Over-seed beds.
- Space plants either in close rows or staggered to maximize plants per bed.

*The three sisters, corn, beans and squash, with Hopi amaranth, at the Bioshelter.*

DARRELL FREY

## *Interplanting*

Planting details for different crops are discussed below, in "Linda's Crops," but interplanting is a somewhat different subject.

There are many combinations of crops that can be usefully interplanted. We seed radishes, which mature in a few weeks, together with spring crops, such as peas, spinach, carrots and beets. We save on space and watering because the spring crops are still getting established when the radishes are mature. This form of multi-cropping allows for a succession of yields from one planting.

Many combinations are useful. Dill is often interplanted with cabbages and broccoli to attract braconid wasps. Carrots are planted in rows between maturing head lettuces, after the first harvest of wild edibles and a thorough hoeing. Carrots and basil are interplanted in the mulch between staked tomato plants. And rows of carrots, beets, or turnips can be alternated with spinach, dill, cilantro and other short-season crops. The root crops do not compete with the leaf crops, and they mature after the leaf crops are harvested, again allowing a succession of crops from one planting.

Succession plantings without tilling are a common practice. Garlic is planted in the fall through the mulch after tomatoes are harvested. Spring crops are often planted in last year's mulch. Generally, these beds need a bit of weeding and additional mulch, but the beds are still soft and fertile. Succession planting makes the most of compost.

We often over-seed green manure into crops. White clover can be interplanted with unmulched brassicas as soon as the transplants are well established. Summer buckwheat and fall rye can be seeded as summer crops decline. Of course, we have plenty of self-seeded dynamic accumulators (a.k.a. weeds) acting as intercropped green manure as well.

### *Weeding*

Weeding the crops has a very different meaning on a permaculture farm than on a commercial farm. Weeds are often either food for us or for the chickens. They are also green manure. Many accumulate minerals from the subsoil and keep them in the nutrient cycle. Many wild edible plants are allowed to grow for use in our salad mix. This complicates bed preparation, weeding, crop rotation and harvest. The term *weed management* at Three Sisters Farm often means encouraging the useful ones. One of the first things that interns learn at Three Sisters Farm is that a weed is not necessarily a weed. So, to clarify the discussion with the workforce, I use the term *weed* to mean any plant growing where it is not wanted, and wild edible to mean useful *weeds.* (Although, even inedible weeds are useful by acting as green manure and cover crops, collecting nutrients and hosting beneficial insects.) Interns are taught that the key to managing weeds is learning when they need to be hoed or pulled to allow a planted crop to grow — and when to leave them as the crop is nearing harvest. *However,* dense and fast-growing weeds

*Radicchio and chickweed ready for harvest*

Catherine Paladino

| Genus /species | Family | Common Name | Form | Habitat | PROP. | Human Uses | Animal Uses | Functions/ Properties | Problems |
|---|---|---|---|---|---|---|---|---|---|
| *Eichhornia crassipes*^ | Pontederiaceae | water hyacinth | ph | qw, p, l, sst, d Z: 5-9 | C, S? | food: cooked flower, leaf stock young leaves | edible leaf and flower (livestock); rich in nutrients | ornamental, methane feed stock, fertilizer, water purification | invasive in warm climates; low temps will kill it |
| *Eleocharis* | Cyperaceae | spikerush | em, ph | psh, lsh | S, T | *E. tuberose* has edible root (called water chestnut) | edible seed and tuber: (water fowl) | --- | --- |
| *Epilobium angustifolium E. hirsutum* | Onagraceae | fireweed willow weed willow herb | sh | wm, sw, btl, b, lsh, psh, stb Z: 3-7 | S, T | food: leaves, shoots, rhizomes: tea | browse: seeds (sm. mammals) | ornamental, pioneer, bee forage | --- |
| *Equisetum,* spp. *E. palustre E. fluviatile E. arvense* | Equisetaceae | horsetails, scouring rush | ph | wm, sw, wm, d Z: 3-8 | D | medicinal; scours wood and metal | food: (water fowl, bear, moose, muskrat) | --- | invasive, poisonous to livestock |
| *Eupatorium perfoliatum* | Asteraceae | boneset, Joe-Pye weed | ph | wm, sw, stb Z: 3-7 | S, D | medicinal | --- | bee forage; ornamental (Joe-Pye weed) | --- |
| *Fraxinus,* spp. *F. lanceolata F. nigra F. pennsylvanica* | Oleaceae | ash: green, black, red | t | stb, lsh, sw Z: 3-7 | S | medicinal; lumber; handles; fuel; furniture; basketry (*N. nigra*) | --- | bee forage (propolis) | --- |
| *Geum rivale* | Rosaceae | water avens | ph | p, l, stb, sw, shw | --- | edible roots | --- | --- | --- |
| *Glyceria maxima* | Poaceae | reed sweet grass | em, ph Ht: 6’ | psh, lsh, sw Z: 1-7 | RH, D | thatch | winter fodder for livestock | decomposes rapidly | invasive (overshadows other em) |
| *Hydrastis canadensis* | Ranunculaceae | goldenseal | ph | mw, wm Z: 3-6 | S | medicinal | --- | --- | rare in the wild |
| *Hydrophyllum,* spp. | Hydro-phyllaceae | waterleaf, Indian salad | ph | --- | --- | edible roots and shoots | --- | --- | --- |
| *Ilex,* spp. | Aquifoliaceae | holly, *winterberry, **yaupon | sh st: 6-16’ | sw, wm, stb *Z: 3-5 **Z: 6-8 | S, C | tea (yaupon has caffeine) | browse; berries (birds) | --- | --- |
| *Impatiens capensis I. pallida* | Balsaminaceae | jewelweed | ah | shady stb, wm–wd | C | medicinal; food: cooked shoots | food (wildlife, humming-birds) | bee forage | poisonous raw |
| *Iris pseudacorus I. versicolor* | Iridaceae | yellow iris, wild iris | ph | lsh, psh, wm, m Z: 3-7 | D | medicinal; perfume | --- | ornamental; bee forage (nectar) | --- |
| *Juncus,* spp. | Juncaceae | rushes | ph | b, wm, m, sw, lsh, psh-wd Z: 2-9 | S | weaving | edible seed (waterfowl) | erosion control; wildlife cover; aq. habitat; does not clog waterways | weed in pasture |

| Genus /species | Family | Common Name | Form | Habitat | PROP. | Human Uses | Animal Uses | Functions/ Properties | Problems |
|---|---|---|---|---|---|---|---|---|---|
| *Lepidium* | Brassicaceae | peppercross, pepperweed | ah | stb, sp Z: 3-6 | S | edible leaves, seeds, stem and roots | --- | --- | --- |
| *Ledum groenlandicum L. latifolium* | Ericaceae (Heaths) | Labrador tea | sh Ht: 1-6′ | b, sw, wm, tundra Z: 1-5 | S, C | medicinal leaves (tea) | --- | --- | --- |
| *Leersia oryzoides* | Poaceae | rice cutgrass | --- | b, sw, wm, tundra Z: 1-5 | S | --- | edible seed and roots (waterfowl, birds and muskrat) | --- | invasive |
| *Lemna,* spp. # | Lemnaceae | duckweed | ph, fl | p, l, d, sst Z: 4-9 | D | food: dried plant | food (waterfowl, livestock, gamebirds) | aquatic habitat; water purification; some types thrive in low-$O_2$ water | can limit light penetration and use up nutrients; *L. minor* has been listed as invasive in N. America |
| *Lindera benzoin* | Lauraceae | spicebush, wild allspice | sh Ht: 6-15′ | wooded, sw, stb Z : 4-9 | S, C | tea; medicinal (bark, leaf, twig); spice (berry) | edible fruit (birds) | male and female plants; bee forage | --- |
| *Lobelia,* spp. | Campanulaceae | lobelia, cardinal flower | ph | stb, sw, lsh, psh | S | medicinal; edible root? | --- | ornamental | rare |
| *Lonicera*, spp. | Caprifoliaceae | honeysuckle | d vine, sh | sw, wm-wd | S, C | some varieties have edible fruit | browse; edible fruit (wildlife) | ornamental, bee forage | --- |
| *Lythrum salicaria*^ | Lythraceae or Primulaceae | purple loosestrife | d, sh | m, sw, wm, d Z : 3-7 | S, C | medicinal | edible seed (birds) | major bee forage; bird nesting habitat | very invasive; listed as a noxious weed in many states and sale may be regulated |
| *Mentha,* spp. *M. piperita M. spicata M. aquatica* | Lamiaceae | mints peppermint spearmint watermint | ph | wm, stb, sp-wd Z: 3-7 tolerates low pH | S, C | medicinal, tea oil, flavoring | Bee forage; attracts beneficial insects, repels others; peppermint contains salicylic acid; various mints contain citronella, menthol, camphor | --- | invasive; *M. perperita* will dry off livestock |

| Genus /species | Family | Common Name | Form | Habitat | PROP. | Human Uses | Animal Uses | Functions/ Properties | Problems |
|---|---|---|---|---|---|---|---|---|---|
| *Monarda,* spp. *M. didyma* | Lamiaceae | bee balm | ph | stb, d, wm, ww Z: 4-7 | S, D | medicinal, tea | nectar (hummingbirds) | bee forage | --- |
| *Myrica cerifera* | Myricaceae | bayberry, wax myrtle | sh (low thicket) Ht: 40′ | sw, m, ww, cool areas Z : 6-8 | S, D,L | medicinal (root and bark); food: berry, seed, leaf; wax | edible berry (game birds, waterfowl, other birds) | tolerate salt spray and wide soil variation | doesn't like heavy soils |
| *Najas,* spp. *N. flexilus* *N. gracillima* *N. minor#* | Najadaceae | naiads, water nymphs | sub ph Ht: 6-10″ | deep fresh water: 1-8′ | D | --- | edible tubers, nutlets, seed, foliage (waterfowl): fish forage | fish cover; associated with pond-weed and wild celery | may be invasive |
| *Nasturtium aquaticum* *N. officinale* | Brassicaceae | Watercress | ph | sp, st, shallow, cold, water, ws Z: 3–tropical | D, S | medicinal (root and leaf); edible: shoots and leaves | --- | used for wastewater treatment; rich in vit. A, B, C, iron and iodine | --- |
| *Nelumbo lutea#* | Nymphaceae | American lotus | fl, p | water 2-12′ deep Z: 5-7 tolerates changing water level | D | --- | edible seed, root and leaf (wildlife) | fish habitat, ornamental | plant in tubs to control and harvest |
| *Nitella gracilis* | Chlorophyceae | stonewort | sub | fresh water 2-10′ deep pH 5.5-6.5 | D | --- | forage (fish and water-fowl) | --- | --- |
| *Nuphar advena* *N. lutea* *N. polysepalum* | Nymphaeaceae | yellow pond-lily, spatterdock | fl, ph | l, p, sunlit, fresh water, 3-10′ deep; tolerates changing water levels | S, D | food: root and seed (nutritious flour or popped) | --- | aquatic habitat | --- |
| *Nymphaea tuberosa* *N. odorata#* | Nymphaeaceae | white water lily | fl, ph | qw, p, sst 1-8′ deep Z : 3-8 | D, D | medicinal; food: young leaf, bud, seed, roots (rich in starch, oil, protein) | edible plant (moose, muskrat, porcupine); edible seed (waterfowl) | aquatic habitat; ornamental | shades water |
| *Nymphoides peltata#* | Menyanthaceae | fringed water lily | fl, p | p, l | S, D | --- | --- | aquatic habitat; ornamental; bee forage (nectar) | shades water |
| *Nyssa sylvatica* | Cornaceae | pepperidge, blackgum, sourgum | d, t | sw, bl–wd Z: 4-7 | S | food: fruit; woodenware; rollers; crates; wheel hubs | browse, wildlife forage | bee forage, ornamental | hard to split and work |
| *Oryza sativa^* | Poaceae | rice | a grass | paddy to dry land Z: 7-8 (some varieties) Z: 6 | S | edible seed (staple), straw | edible seed | --- | --- |

| Genus /species | Family | Common Name | Form | Habitat | PROP. | Human Uses | Animal Uses | Functions/ Properties | Problems |
|---|---|---|---|---|---|---|---|---|---|
| *Onoclea sensibili* | Dryopteridaceae | sensitive fern | ph | m, wm, sw Z: 3-8 | D | food: young shoots (cooked) | fronds: turkey food | --- | --- |
| *Osmunda regalis* | Osmundaceae | royal fern | ph | m, wm, sw Z: 3-9 | D | food: young fiddleheads; cloth (fiber); medicinal | --- | --- | --- |
| *Oxydendrum arboreum* | Ericaceae | sourwood, lily-of-the-valley tree | smt, t | sw, wd | S | medicinal, handles, woodenware | --- | ornamental, bee forage | --- |
| *Peltandra virginica* | Araceae | arrow arum | ph | sw, b, stb, p, l (to 1′ deep water) Z: 4-8 | S, D | food: fruit, flower spike, dried root (up to 4 lbs) | edible seed (wood ducks and water fowl) | tolerates shade | poisonous before drying |
| *Phalaris canariensis P. arundinacea* | Poaceae | canarygrass, reed canarygrass | ph | d, m, psh, lsh | S, D | edible seed, mats, weaving, thatch | edible seed (game birds and waterfowl) | --- | clogs channels |
| *Phragmites communis P. phragmites* | Poaceae | reed grass, common reed | ph grass Ht: 6′ | d, sw, m, psh, lsh, Z: 3-8 | S, D | food: stems (sugar, flour) and young shoots, leaves, seed (cereal); thatch; paper; cellulose; insulation; weaving | grazing | erosion control, wildlife cover and habitat | low value to system; slow to decompose; invasive (replaces cattails); seeds rare |
| *Platanus occidentalis* | Platanaceae | American sycamore | t | stb, bl Z: 3-7 | S | syrup; sap (emergency water); lumber, crates; butcher block; furniture | --- | bee forage | --- |
| *Polygonum,* spp. *P. lapathifolium P. persicaria# P. muhlenbergii* | Polygonaceae | smartweeds, knotweeds | ph or ah | d, psh, lsh, m, seasonal ws Z: 3-7 | S | food: shoots, leaf, roots, medicinal dye | edible seed (waterfowl, songbirds, sm. mammals) | aquatic habitat; bee forage; rich in vit. P, C and rutin | some species weedy or invasive |
| *Polystichum acrostichoides* | Dryopteridaceae | Christmas fern | ev. ph | sw, wm, stb | D | Christmas decoration | browse (deer) | --- | --- |
| *Pontederia cordata* | Pontederiaceae | pickerel plant | em, ph Ht: 3′ | p, sst, m, rich soil Z: 2-8 | S, D | food: young leaf, fruit | edible seed (waterfowl) | fruit and seed highly nutritious, fish habitat, ornamental | invasive |
| *Populus,* spp. | Salicaceae | cottonwood, poplar, aspen | t | lsh, bl, mw Z: 2-7 | S, C | medicinal; lumber, fuel; pulpwood alcohol; food: inner bark, catkins | browse and forage | pioneer tree | --- |

| Genus /species | Family | Common Name | Form | Habitat | PROP. | Human Uses | Animal Uses | Functions/ Properties | Problems |
|---|---|---|---|---|---|---|---|---|---|
| *Potamogeton,* spp. # *P. pectinatus* *P. americanus* *P. richardsonii* | Zosteraecae or Potamogeton-aceae | pondweed, Sago pond weed | ph | sub, fl, p, sst, up to 12' Z: 3-tropics | S, D | food: tubers, stems, leaves | edible seeds and plant (waterfowl) esp. *P. pectinatus* | aquatic habitat | may be weedy or invasive |
| *Pteris pensylvanica* *P. nodulosa* | Pteridaceae | ostrich fern | ph Ht: to 6' | stb, m, wm | C | food: fiddle heads under 6" (excellent raw) | --- | --- | --- |
| *Quercus bicolor* *Q. michauxii* | Fagaceae | swamp white oak swamp chestnut oak | d, d | sw, stb | S | food: sweet acorns; lumber | edible acorns | --- | --- |
| *Ranunculus peltatus* | Ranunculaceae | water crowfoot, buttercup | fl, ph | p, l, sst | D | --- | --- | bee forage (pollen and nectar); aq. habitat | --- |
| *Rosa palustris* | Rosaceae | swamp rose | sh | sw, b, wm | S, D, C | food: fruit, flowers, shoots seed, leaf | browse | bee forage; fruit rich in vit. C, calcium, iron and phosphorus; seed rich in vit. E | --- |
| *Ruppia maritima* | Ruppiaceae | widgeon-grass | em | l, p; alkaline water | S, D | --- | edible seed (waterfowl) | --- | --- |
| *Sagittaria* ssp.^ *S. cuneata* *S. latiofolia* | Alismataceae | arrowhead, duck potato, wapato | em | p, l, sst. m, d Z : 2-9 tolerates changing water levels | S, D | food: tubers (rich in starch) | edible tubers (water fowl, muskrat, fish, good pig forage porcupine); edible seed | --- | *S. sagittifolia* L. has been listed as invasive in N. America |
| *Salicornia,* spp. | Chenopodi-aceae | glasswort pickleweed, | ph | p, l; tidal flats, alkaline, Z : 1-9 | --- | food: tender tops | edible seed, leaf, stem | thrive in salt | --- |
| *Salix,* spp. *S. discolor* *S. viminalis* *S. babylonica* | Salicaceae | willow pussy willow osier willow weeping willow | sh-t | stb, lsh' psh, m, d, wm-wd | S, C | food: leaves medicinal, charcoal, basketry | browse and forage | bee forage; erosion control; fire resistant hedge; transpiration pump (weeping) | can invade waterlines |
| *Sanbucus canadensus* | Caprifoliaceae | elder | ph | stb, lsh, psh, d, wm to wd; full sun to partial | S, C, D | food: fruit, flower; syrup taps; flutes; medicinal | edible fruit (birds and wildlife); browse, forage; insect | indicates a high water table | --- |

| Genus /species | Family | Common Name | Form | Habitat | PROP. | Human Uses | Animal Uses | Functions/ Properties | Problems |
|---|---|---|---|---|---|---|---|---|---|
| *Sanbucus canadensus* | | | | shade Z: 2-7 | | | eat buds, branches, blossoms | | |
| *Sarracenia,* spp. | Sarraceniaceae | pitcherplant | ph | b, m, wm Z: 2-9 | --- | bioshelter plant | --- | carnivorous (insects) | endangered |
| *Saxifraga* | Saxifragaceae | lettuce saxifrage, deer tongue | ph | sp, sw, m, damp slopes Z: 2-8 | --- | food: leaves (raw or cooked) rich in vitamins | browse and forage | --- | --- |
| *Scirpus,* spp. *S. fluviatilis* *S. paludosus* | Cyperaceae | bullrush | em, ph, aw Ht: 1-7' | lsh, psh, sw, m, d | S, D | food: tubers, rhizomes, seeds, pollen; thatch | edible tubers and plant (waterfowl and muskrat); edible seed | waterfowl cover, erosion control, water purification | causes silting of ponds and lakes |
| *Sparganium,* spp.^ *S. americanum* *S. eurycarpum* *S. antipodium* | Sparganiaceae | burr reed | ph | sw, m, psh, lsh, d Z : 1-7 tolerates changing water levels | S, D | food: seeds and tubers | edible seed (waterfowl, game birds, mammals); edible plant (sm. mammals) | waterfowl cover, erosion control | handling plant can cause health problems |
| *Sphagnum,* spp. *S. obtusifolium* | Sphagnaceae | sphagnum moss bog moss | ph | b, sw, m | D | medicinal; food: entire plant; peat; soil mix | --- | --- | handling plant can cause health problems |
| *Spirodela polyrrhiza* | Lemnaceae | duckmeat, duckweed | ph, (minute) fl | sw, p, l, sst Z: 5-8 | D | food: dried | edible plant (waterfowl and livestock) | water purification, aq. habitat, methane digester, fertilizer | dense growth can block light and kill sub plants |
| *Spirulina,* ssp. | Cyanophyceae | spirulina, blue-green algae | algae | p. l. sw. sst | D | food: dried and powdered | edible (fish and fowl) | rich in amino acids, vitamins and minerals | --- |
| *Symplocarpus foetidus* | Araceae | skunk cabbage | ph | sw, ww, stb Z: 2-7 | S, D | food: leaf and dried root; medicinal | --- | bee forage (earliest pollen) | foul odor |
| *Trapa,* spp. *T. natans* # | Trapaceae or Hydracaryaecae | water chestnut | fl, ph | l, p, d Z: 6-tropical | S, D | food: seed (starchy) | --- | aquatic habitat | needs high nutrient level |
| *Typha latifolia* *T. angustifolia* | Typhaceae | cattail, bullrush, reed mace | em, ph | sw, m, lsh' psh, d | S, D | food: shoots, roots, pollen spikes; weaving fiber; insulation; tinder; paper; fish bait | edible tubers (waterfowl, sm. mammals, pigs) | waterfowl and wildlife cover, water purification | invasive; silt-ing crowds out more valuable em; large quantities of leaves are poisonous to livestock |

| Genus /species | Family | Common Name | Form | Habitat | PROP. | Human Uses | Animal Uses | Functions/ Properties | Problems |
|---|---|---|---|---|---|---|---|---|---|
| *Utricularia,* spp. *U. vulgaris* *U. minor* | Lentibulariaceae | bladderwort | ph, fl and sub | alkaline, p, l, d, sst *U. minor* likes acid | S, D | --- | browse (birds and deer) | carnivorous (insects) | --- |
| *Vaccinium corymbosum* | Ericaceae | swamp blueberry | sh Ht: 6' | sw, wm | S | medicinal; food: berry | browse and forage | hedge | --- |
| *Vaccinium macrocarpon* | Ericaceae | cranberry | ev. sh Ht: 6' | b, m-dry peat, acidic soil, conifer woods | D | medicinal; food: berry | forage | --- | needs symbiotic fungus on roots |
| *Vallisneria spiralis* | Hydrocharitacea | wild celery, eel grass | sub, ph | p, l, sst, alkaline Z: 4-7 | --- | --- | edible plant and seed (water fowl) | oxygenates water, aq. habitat | --- |
| *Veratrum album* *V. viride* | Liliaceae | American hellebore | ph | sw, wm, stb Z: 2-7 | Rh, D | medicinal, insecticide, rat poison | --- | --- | --- |
| *Viburnum* *V. opulus* *V. prunifolium* | Caprifoliaceae | highbush cranberry, nannyberry | sh ht. 6-10' | sw, m, b, wm, stb | S, C | medicinal food: fruit | --- | rich in vit. C, K; erosion control; hedge | --- |
| *Wolffia,* spp. | Lemnaceae | duckweed, watermeal | ph, (minute) fl | p, l, d, sst Z : 3-9 | D | food: dried plant | edible seed: (water fowl, livestock, game birds) | succeeds azolla in late summer; aq. habitat, water purification | --- |
| *Zannichellia palustris* | Zannichelliaceae | horned pondweed | sub, ph | p, l, sst | S, D | --- | food: waterfowl | aq. habitat | --- |
| *Zizania aquatica* | Poaceae | wild rice | ah | sw, m, p, l, sst, needs currents Z: 3-9 | S | food: grain, stem base | edible seeds: (waterfowl and birds) | --- | --- |
| *Zizaniopsis miliacea* | Poaceae | giant cutgrass | ph | psh, lsh | S | food: rhizome tips, young shoots | edible seeds: (waterfowl and birds); forage | --- | --- |

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## About the Author


Darrell Frey is the latest in a long line of gardeners and farmers, from both sides of his family tree. Raised to have a deep appreciation for nature's beauty and the fruits of good labor, he found in Permaculture design a way to be close to the earth while obtaining a yield from sun and soil and rain.

Along with Linda Frey and their three children, and inspired by other gardeners and many sustainable living writers, researchers and teachers, he developed Three Sisters Farm and Bioshelter. The five-acre plot of season extenders, gardens, uncultivated areas and pond, is an ongoing research project in right livelihood and Permaculture design.

As a sustainable community development consultant, Darrell offers a wide range of services to numerous clients. When not working on a new project or tending the landscape, he enjoys time with friends and family, including five grandchildren.

For more information about Darrell Frey and Three Sisters Farm, visit Bioshelter.com.