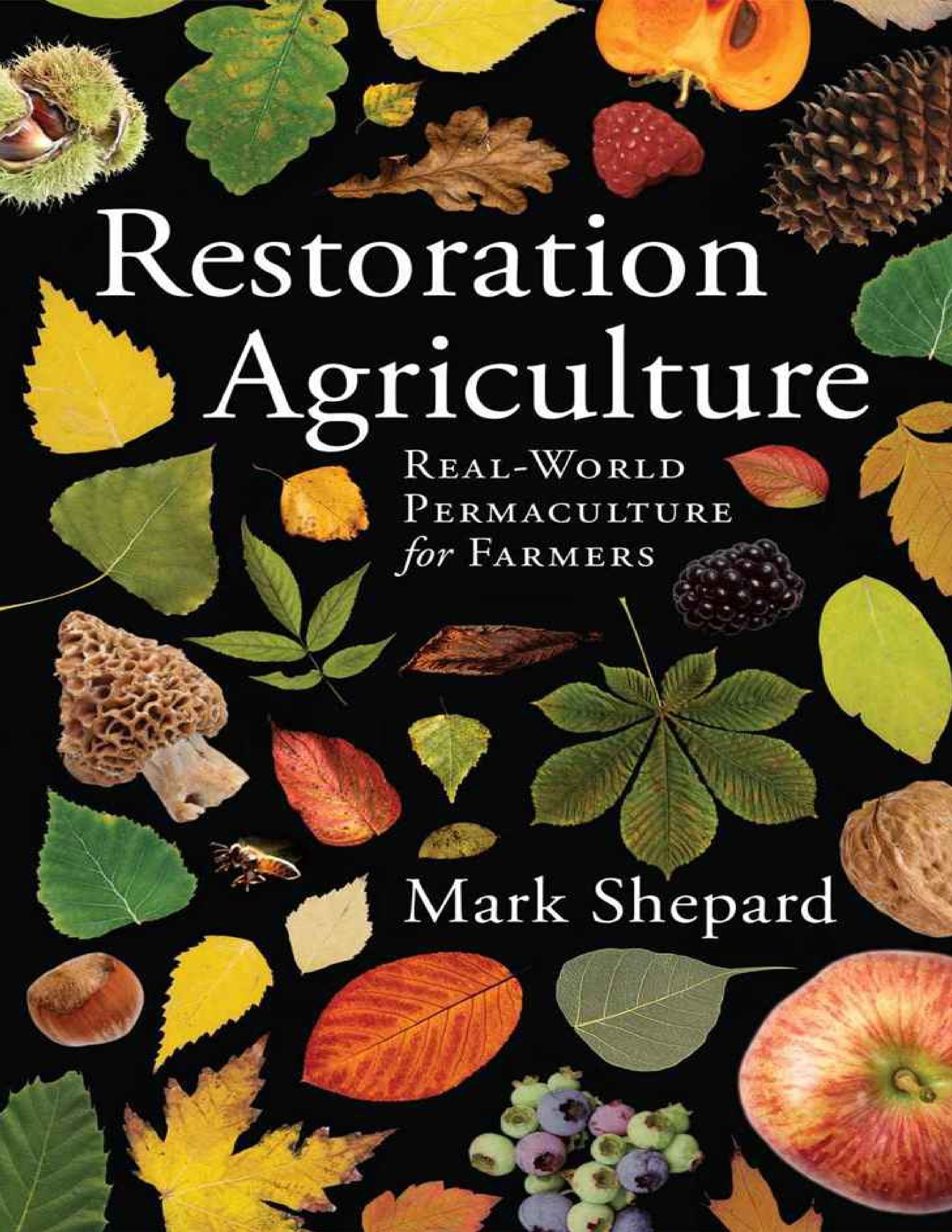
Restoration Agriculture

Real-World Permaculture *for* Farmers

Mark Shepard



ADVANCE PRAISE FOR

RESTORATION AGRICULTURE

“This book, written from real experience of working with the land and referencing real results of experience over time, will be invaluable and is destined to be a permaculture classic. This will be a reference book of great value for anyone interested in using permaculture design in a farming operation and valued by future generations.”

Geoff Lawton, managing director, Permaculture Research Institute of Australia

“In *Restoration Agriculture*, Mark Shepard convincingly makes the case for no-tillage, perennial agriculture. He draws inspiration from J. Russell Smith, Bill Mollison, Masanobu Fukuoka, his father, his grandfather, his neighbors and others who showed him that trees are the key to productive and sustainable agricultural systems. Shepard shares his practical knowledge and hard-won wisdom gleaned from years of experience growing up on a farm in central Massachusetts and later transforming a barren overgrazed landscape in western Wisconsin into a richly productive polyculture. The discussions include rotational livestock management, beekeeping, soil and water management, plant breeding, turning a profit on a small farm, and many others. This book is well organized with lots of delightful and informative personal anecdotes.”

Larry Korn, translator of The One Straw Revolution *and* Sowing Seeds in the Desert *and student of Masanobu Fukuoka*

“What a great story and a fun read … a wonderful history of man’s intervention. It’s not just the ‘reasons’ we need to change land management, it’s the ‘model’ to follow … a call to action.”

Gary Zimmer, president, Midwestern Bio-Ag

“I’ve never been a big fan of permaculture, that is, until encountering Mark Shepard and his work. *Restoration Agriculture* describes the reasons why permanent agriculture is needed, the ecological systems behind farm-scale permaculture, and the step-by-step of how to get there. His message is reality-based, down-to earth, and a call for new pioneers!”

Faye Jones, executive director, Midwest Organic and Sustainable Education Service (MOSES)

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Real-World Permaculture *for* Farmers

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by Mark Shepard

ACRES U.S.A. *Austin, Texas*

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Contents

Acknowledgements

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It would have been impossible on several levels for you to read this book if it wasn't for my Mom and my Dad. Aside from the obvious, they provided me with an incredibly dynamic way of interacting with the world. My Mom was a displaced Vermont farm girl who taught her children Yankee thrift and ingenuity, how to garden, and more importantly how to cook, can, freeze, pickle, dehydrate and jam just about everything that is edible (and some things that turned out *not* to be edible!). My Dad was a displaced Maine woodsman who instilled in his three sons a love of nature, a desire for constant learning, plant identification, and how to piece together a ramshackle tool with little more than bubble gum, duct tape and a generous application of WD-40, and to love the physical exertions of living a rural life. His never-ending planting of food trees, and his (unintentional) neglect of those trees helped me to see perennial plants in a different way than the main stream would.

The forest and the farm are part of who I am and they have become one in restoration agriculture.

Indirect inspiration came from many directions, of course, but most significantly J. Russell Smith, Masanobu Fukuoka and Bill Mollison. I may never get to meet Bill Mollison in person, and even if I do I don't know whether I'd like him or not, but Bill has begun a revolution on this planet in founding the international permaculture movement. Because of his work and charisma, millions of people worldwide have dedicated themselves to earth care, people care and equity. The world *is* and will be a better place because of Bill Mollison. If nothing else, millions now live lives of meaning and purpose within the wreckage of the industrial, materialistic global economy that has left them behind.

More directly I would like to thank all of those who have coached me through the years directly and indirectly and have helped me to come to the point where I would write all this down. To all of the workshop participants, course students, consulting clients and to folks who have come on tours of New Forest Farm, I thank you for helping me to understand that I actually do have something of value to share, and thank you for helping me to hone my message so as to be able to communicate it (I hope!) clearly enough for non-experts to understand.

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One person deserves special recognition here who has been largely behind the scenes at New Forest Farm except at the beginning; Rand Burkert. In a sweaty sauna at 2 a.m. at a permaculture design course in Colorado in 1993, he and I decided to give our thoughts about Permanent Agriculture a form, and to put them into practice. With the initial down-payment from Rand, the land for New Forest Farm was purchased, for which I am forever grateful. Namaste, my friend!

Finally (aside from those whom I have forgotten or intentionally ignored) I would like to thank my immediate family: Erik (who took most of the photographs in this book) and Daniel for growing up so apparently well-adjusted while living with a Dad who, for so many years, could have been considered seriously strange. You two have experienced something that very few people on this planet have. You have seen hundreds of acres of bare dirt and pastures transformed into an abundant food-producing ecological paradise. I hope now that you can see the wisdom of restoration agriculture and its power to change the world. I hope that you will help others to do the same, and will help to convince them how easy the transition can be. You two are the first generation of temperate “mid-succession” restoration agriculture farm managers. I know how to transition from annual crops to perennials, but how will we manage the system for the next 50, 100 or 200 years when I’m gone? You and the next generations will be the ones to learn how. At least we’ve provided you with some resources to work with.

Last on this list, but definitely not least, I have to acknowledge Jen, my best friend, lifemate, lover and companion through thick and through thin. “Wife” is such a small and shallow word for something that is as vast as the entire universe. Thank you for your patience, your forgiveness, your understanding, your encouragement and all of what it is that constitutes LOVE. I may not have a “nice job” and a Porsche; my grubby Carhartts and long sleeve white shirts may have holes in them, but I love you. All of what I do, this book included, points to the fact that I love you, and to the fact that there is some sort of grand mystery unfolding in all of our lives. Behind the outer appearances of this material world, there is an invisible pattern, being or “field.” There are invisible forces finding fulfillment in the visible drama that is life on earth. I stand with the “grand unfolding” and will strive to do my part to take care of The Garden.

FOREWORD

Hope for a Hot Planet

> Nature includes us … We are in it and are a part of it …
>
> If it does not thrive, we cannot thrive.
>
> *Wendell Berry*

STALKS of shriveled corn in Iowa. Colorado residents trying to stay cool in 115-degree heat. Farmers in 1,369 counties across 31 states holding out for disaster aid. The record-breaking heat of 2012 is a hot, dry taste of global warming-induced weather: unpredictable and extreme.

I read farmer Mark Shepard's visionary book with this summer's weather front-page news. In the context of our new climate reality, I am reminded how urgently we must rethink how we farm — and what an important tool this book is for doing just that.

I got my own peek at Mark's vision several years ago when I visited his 106-acre farm, nestled in the verdant valleys of western Wisconsin. That summer the state was hit with its own extreme weather event — powerful rainstorms had devastated farmland and left the state footing a bill for millions of dollars in flood relief. By the time I pulled onto the dirt road curving up to Mark's farm, I'd driven by enough flooded fields to have a knot in my stomach: I assumed Mark had faced the same fate. Imagine my surprise when I parked in front of his wind-powered cider house to find Mark and a farm intern joking around, grinning from ear-to-ear. These were not the faces of farmers in despair. While New Forest Farm had been pelted with the same rain that had crushed neighbors across the road and left dark brown gullies in its wake, Mark's fields were relatively undamaged. In fact, a few of his crops had never been better.

How did Mark prosper while his neighbors suffered? I was eager to know, because the answer, I believed, could hold a key for rethinking farming in a climate-unstable world. The answer, as you'll discover in these pages, is a fascinating vision for recasting our relationship with nature and the land. As Mark shares in this book, it's a vision built on the inspiration found in a lineage of ecological farmers, including J. Russell Smith (*Tree Crops: A Permanent Agriculture*), Masanobu Fukuoka (*One-Straw Revolution*), and the originators of permaculture, including Australia's Bill Mollison. And it's a vision Mark has tested on his own fields often with incredible results.

Restoration agriculture, as Mark calls it, is a vision of agriculture that taps into the inherent abundance in nature. Consider the sun. As Mark writes, "Sunlight is the ultimate energy source of all agricultural systems." Crops are merely vessels of stored sunlight — as Mark puts it, farmers and ranchers are in the "solar energy collection" business. The American corn and soy farmer is doing lousy business. A monoculture field — planted with just one annual crop the way the vast majority of American farmland is — captures the least possible sunlight a field could.

Restoration agriculture does the opposite: It maximizes the amount of sunlight captured. Mark gives us a glimpse when he says, imagine a piece of paper as an acre of farmland. This flat paper is like a monoculture field; it captures an acre worth of sunlight. But take another sheet of paper, and another and another. Fold them into tents of triangles, large and small, and lay them on the same 8½ x 11 footprint. Place them over and under each other — just as crops grow in nature, some thriving under the canopy of trees or the shade of bushes. Do so and you're tapping the abundant sunlight for all those crops now thriving. Do so and you're quadrupling, quintupling, or more, the surface area!

Go to Mark's farm and you see this solar energy collection business at work: the chestnut, oak, black walnut and hickory trees growing tall above the hazelnuts; down close to the ground the raspberries and blackberries. And that's just in one spot on the farm.

Restoration agriculture asks a lot of us — not only to rethink our relationship to the sun, but to recast the relationship between farmer and insect, too. Of the 1.1 billion pounds of active ingredient pesticide used on American farmland every year, much of them are used to deal with the weeds, nematodes, fungus and insects that routinely go after our main commodity crops.

But what if we saw insects not as nuisances to eradicate, but as essential members of a flourishing farm? If you're a chemical farmer, as soon as you get an economically harmful threshold of a pest, you spray some chemical or another.

But if you let the population run naturally, you start getting new populations of insects who arrive to eat, and thrive, on those original so-called pests.

“Eventually you find a certain stability,” says Mark. That’s why he likes to call himself a population ecologist. Mark is not in the bug-killing business. Go to his farm and you sense it immediately: New Forest Farm is alive with buzzing bees, fluttering butterflies, predatory insects, soldier and dung beetles.

In the pages of this book, you’ll learn more about Mark’s vision of agriculture — and the potential it holds to feed us well in a resource-compromised future.

By latest count, this summer broke 2,312 temperature records across the United States. The U.S. Department of Agriculture downgraded the bushels of corn coming off an acre by 12 percent. And Arctic ice melted faster than even many of the most dire scientific estimates had predicted.

This is indeed a remade planet; how will we feed ourselves here? That question should be on everyone’s minds and Shepard’s answers should be on everyone’s lips.

Anna Lappé
Brooklyn, New York
August 2012

INTRODUCTION

Food, Annual Crops & the Fate of Civilization

HUMAN beings eat food. This may sound like a silly statement to make right at the start because this fact is so obviously true to our existence that it's a given. However, it is because this statement is such a "second nature" occurrence that humankind has become blind to most of the processes by which we obtain our food. Although the requirement for food is a given for people to live, it is *not* a given that we all have sufficient food for health and well-being. It is also *not* a given that we have access to the kind of food that promotes health and well-being. One of the interesting and eye-opening realities about industrialized nations today is that the major causes of disease are too much food, and too much of the wrong kinds of food, not a lack of food.

How our food is produced is too often overlooked in the quest to get it into our mouths. In the majority of cases around the globe today, most people derive the bulk of their calories as a direct result of "annual" agriculture. The majority of the carbohydrates, proteins and oils that feed humanity are derived from annual plants; plants that grow for one season. These grow fast and produce a prodigious quantity of seeds, then die. The rice in our bowl, the wheat in our bread, our breakfast cereals, noodles in our soup, corn in our tortillas are all the seeds from annual plants. The grains, which are annual grasses, are the high carbohydrate "energy" foods in our diet.

The legumes, (beans, peas, lentils, and soy, for example), are the high-protein counterparts to the grains. Together, grains and legumes can constitute a complete human ration with enough of the body building materials that are needed to be healthy, to grow and have enough energy to be active and fit.

The oils in our diet are essential as well because they provide concentrated calories, but mostly because they are essential for carrying the fat-soluble vitamins that would otherwise be unavailable to us with a grain and legume diet. Most of our oils also come from annual crops. Corn oil, sunflower oil, canola oil, safflower oil and others, are all annual crops that are grown for one season, with their seeds harvested and pressed for oil. "Presscake" from the oil extraction process is a concentrated protein source which is used in energy bars and supplements, but mostly it is used as feed for livestock.

Annual crops, by their nature, require exposed soil to grow. In the natural scheme of things, annual plants are some of the first plants to colonize a site after a disturbance. Perhaps a flood has left some silt on a floodplain, or perhaps a landslide has left an exposed bank of earth. Fire, animal trampling and wallowing, catastrophic wind events, or erosion, all expose bare earth to the elements. No matter where on earth one may be, nature is constantly at work doing its best to cover the exposed earth with vegetation. Mount St. Helens in Skamania County in Washington state erupted catastrophically in 1980 creating an area of 230 square miles of exposed rock and volcanic debris. A mere 30 years later nature has reclaimed the blast area and covered most of it with a diversity of plant life. The first plants to colonize the areas of exposed soil, are typically annual plants.

Annual plants are characterized by several distinguishing features that have made them a very useful choice as foodstuffs. First is their annual nature. A person can throw some seeds on a patch of exposed soil and within a few months they will be able to harvest an abundance of high-energy seeds. A second distinguishing feature of annual plants is that the seeds tend to store incredibly well. Wheat, rice and corn all can be stored for years and will still sprout when given the proper light, moisture, soil and temperature conditions for growth. When seeds will no longer germinate (are no longer viable) because they have lost critical internal moisture, their carbohydrates and proteins are still useable as food. Annual plants are unique because they are typically opportunists. They will grow in a wide range of habitats in a wide range of soil and moisture conditions, all of which are useful characteristics for food plants.

Since the annual plants are the staple foods that we eat, and necessity drives us to continue to eat, it is easy to assume that "this is the way things have to be" and that "this is the way things have always been." Neither of these statements are true. In fact, in the history of humankind, reliance upon a diet of annual plant seeds for food is a relatively new phenomenon. Human cultures have only relied upon annual plant seeds as their staple food crops for around 10,000 years, which is coincidently the time that is commonly referred to as the dawn of "civilization." Our reliance upon annual crops has come to define "civilization." Annual crops have been the crops that produced in such rapid abundance that much of the population could be "liberated" from the task of food acquisition. The abundant yield of annual plants allowed for some people to specialize as the farmers, freeing up others to become builders, crafts and trades people. Grains could be easily stored and delivered to one location enabling the growth of larger, permanent settlements. Cities are a direct result of annual agriculture.

The main characteristic of the annual plant that is one of its strengths as a food plant, is also its biggest weakness. The annual plant only lives for one growing season. The plant growing fast for a single season culminates its life with an even faster death. Once the seeds have ripened, the plant dies. This characteristic means that the crop must be planted again the next year. Planting an annual seed also requires disturbing the soil. These two factors of annual plants are the cause of a perpetual treadmill of endless toil for humans, their beasts of burden, their machinery and the entire social and economic system that keeps it all going. Plowing, planting, weeding, harvesting, and processing are tasks that occur every year and have occurred every year since the dawn of civilization. With the adoption of annual crops as the staple foods in our diet, humankind has indeed lived the biblical curse,

> By the sweat of your brow you will eat your food until you return to the ground, since from it you were taken; for dust you are and to dust you will return.
>
> *Genesis 3:19*

In addition to the curse of ceaseless labor, the adoption of annual plants as staple food crops have carried with them another curse. Every human society that has relied on annual crops as staple foods in their diet has collapsed. Every single one. Every human society from the temperate zone to the tropics that has relied on annuals to feed itself, is now gone. And the rich, abundant ecosystems where their temporary societies once flourished have been rendered into dust.

The complexities of how each one of these societies has disappeared are too detailed and numerous to list here. Religion, politics, war, disease, economic inequity, and invasion have all played a role in the various collapsed societies, but the one thing they have all had in common is the reliance on annual crops as their food. How could this be a cause of collapse?

Remember that annual plants require exposed soil to grow. In order to grow annual plants, one must eradicate the perennial vegetative cover first in order to expose the soil for the planting of annual seeds. In many locations this means plowing up a perennial grassland in order to plant wheat or corn. In other places it means first eradicating a forest, then plowing the soil to plant annual crops. The growing of annual crops requires the eradication of an intact, perennial ecosystem in order to grow seeds. Tilling the soil exposes it to the elements. Exposed soil blows away in the wind. Its organic matter and minerals are oxidized by the sun rendering them useless for plant fertility needs. Tilling dries out the soil helping to stimulate drought conditions. Tilled soil is exposed to the rain and when uncovered washes away in muddy streams with every storm. Little by little precious fertile soil vanishes until all that remains is the bleached skeleton of the planet.

In any one year these soil losses may not be noticeable. You or I can still grow a wheat crop this year even though we lost some soil last year. The reduction in soil fertility and depth of our topsoil may not be noticeable even in one lifetime, but over decades and centuries the cumulative loss of topsoil means a loss of nutrition for the people living off that land. Loss of nutrition also goes with decreased yields. Decreased yields and nutrition lead to hunger, disease, social strife and eventually collapse. Mesopotamia, Egypt, Persia, India, China, Greece, Rome, North Africa, Central and South America are all scattered with the ruins of collapsed civilizations. These were cultures that relied upon annual crops as their staple foods. Cultures that had systematically eradicated their own healthy, life-supporting perennial ecosystems in order to grow a handful of hard, dry seeds.

Our own modern culture is on the same trajectory as these ancient civilizations. Our fossil-fueled farm equipment and our chemical fertilizers have allowed us to do the work of destroying ecosystems faster than any other culture to date. In less than 400 years, the North American continent has changed from a "wilderness" of health, vitality and abundance to a near ecological corpse. Vast herds of bison are all but extinct. Passenger pigeons, once abundant in flocks that would take three days to fly overhead *are* extinct, as are the mastodons, mammoths, giant armadillos, ground sloths, giraffes, and North American camels. Rivers that once teemed with billions of pounds of salmon and twelve-foot-long sturgeon, and ocean fisheries teeming with life at all levels of the food chain, have all been degraded to the point where government officials tell us that eating more than one or two servings per week will put us at risk of mercury poisoning. And that poisonous fish carries a hefty price tag at the store, too.

Our culture, worldwide, has the power to utterly destroy the entire life support system upon which it depends. The simple act of eating is the keystone of this fact. By relying on annual plants for our staple foods we, by the billions, are causing hundreds of millions of acres of land to be plowed or sprayed with herbicides in order to receive the seeds of annual grains and legumes. Hundreds of millions of acres of forest, savanna and prairie have been eradicated already and more is cleared each year, to make way for annual plants. At this scale, ecosystem destruction has immense consequences. Hydrological cycles in the soil and on the land have been altered. With less moisture being transpired into the atmosphere by perennial vegetation, rainfall patterns have changed. Forests and prairies no longer inhale carbon dioxide from the atmosphere to give us back life-giving oxygen. Increased atmospheric carbon dioxide precedes an increase in the number and intensity of tornadoes, floods, hurricanes, record-breaking heat, drought and is blamed for the melting of the polar ice caps.

Some people argue that the changes we have created are “natural” and “normal” fluctuations in the conditions of earth. Of those who observe the link between human activity and the health of the biosphere, some argue that we have already changed the earth’s living conditions to the point that we no longer inhabit the same planet as our parents. Many believe that it is too late for humanity to change its direction and hence to change the pattern of ecosystem destruction that threatens us all. Polluted air, poisonous groundwater, and toxic soil serve no one but the despoilers who profited from their destruction. Their comeuppance will no doubt take them by surprise as it takes the rest of us down with them.

This book is being presented as an alternative to the agriculture of eradication. This book is being presented as one of the many necessary solutions to many of the world’s problems. In addition to being an “interesting theory” this book is based on real-world practice. The systems described in this book *work!* It is absolutely possible for human beings to produce their staple foods using perennial, agricultural ecosystems that actually improve the quality of the environment. This can be done on a backyard scale, it can be done on the farm and ranch scale, and is needed on a global scale — without a minute to lose.

While producing an abundance of food for humankind, these systems remove carbon dioxide from the atmosphere, purify water, increase the depth and fertility of topsoil, provide wildlife habitat and create incredible beauty which is increasingly necessary in our “modern” world of concrete, steel, plastic and glass.

In this book I do not propose that we all go back to living in mud huts or living like pre-civilized cultures. I propose that our modern culture adopts a new approach of how we obtains our carbohydrates, proteins and oils — our staple food crops. In the chapters to follow I will explain how humankind can achieve all of the benefits of natural, perennial ecosystems. This can be done by creating agricultural ecosystems that imitate natural systems in form and function while still providing for our human needs.

> Now, we face the challenge to design and manage cropping systems that can reverse local problems of acidification, catchment-wide problems of salinization and nature conservation, global problems of population pressure and climate change, and assure food safety. The solution to this more complex challenge is made further difficult by the dramatic change in the profitability of farming that remains in continuing decline. Salary earners have largely kept pace with the increasing price of food but the returns to farming have not. Rather, those farmers that have survived have done so by expanding the scale of their operations and becoming more efficient. There is concern of insufficient investment to maintain the resource base of agriculture at a time when there is increasing concentration of profit higher in the food chain.
>
> Cropping Systems for Enduring Productivity *by David Connor, Joint Centre for Crop Innovation, Innovation University of Melbourne, Australia.*

CHAPTER 1

The Perennial Agriculture Vision

I stood on a ridge in southwest Wisconsin looking into the sharp, dry winds and watched the clouds of dust rise up in the afternoon heat above a small metallic swarm of combine harvesters. As far as the eye could see the landscape was the same — parched, compacted soil, lifeless as pavement with row upon endless row of corn stubble. To the horizon in the west, to the north, and to the east, nothing could be seen but barren, dusty, corn stubble. Aside from the combines, the scene was as lifeless as the moon. In fact it could have been on the moon with the same driver of the spacecraft safely ensconced in a climate-controlled life support machine, complete with GPS satellite guidance system and cell phone communication. The only birds I saw in this barren, dusty "moonscape" were turkey vultures circling high overhead, possibly hoping that the combine had spit out a crushed rat, one of the few creatures able to thrive in a desert of corn.

Here I was standing in the midwestern United States, the self-proclaimed breadbasket of the world, and what did I see? Instead of a landscape teeming with life and overflowing with bounty, I saw dust and stubble. Here where there once was life in abundance, springs gushing out from every hillside, passenger pigeons in flocks so large they blotted out the sun, beaver so thick in every stream that the valleys were a crazy-quilt of their handiwork, there was now only #2 yellow dent corn, bristly tan corn stubble, and the hard packed crust of what was once some of the most fertile soil on earth.

As a child I had been taught that the story of America was the story of progress. Once upon a time our ancestors came to this land and wrestled an existence from the cruel taskmaster called the "wilderness." They lived lives of squalor and sacrificed much in their lives so that we might live "better" than they did and so that we might enjoy more material things. My European ancestors cleared the great eastern forests of their previous inhabitants as best they could (both animal and human), burned the stumps off and began to plow. Then they marched from the shores of the Atlantic driven not by promise, as we have been told in our history books, but because they had devastated their resource base. By the early 1800s eighty percent of the New England states had been shorn of their primeval forests. The thin, rocky glacial soil quickly eroded exposing more rocks and in many places the bedrock itself. Even this epic wrestling against nature failed to provide for the growing populations. The American expansion westward was driven as much by want and privation as by dreams of progress and a glorious utopia.

How many millions of acres of healthy, intact ecosystems have been cleared and burned in order to plow and plant but a few annual crops?

In the Midwest, how many *millions* of acres of "useless brush" have now been cleared and burned in order to plow and plant but a few annual crops? The miles of barren cornfields before my gaze represented only a few generations of this so called “agricultural progress.”

In this area of southwest Wisconsin some families still reside on the land homesteaded by great-grandfather and they still remember the stories most often told about clearing the land, the depravations of the Great Depression and the Dust Bowl years. The Dust Bowl isn’t just history here. It’s a very recent family memory for many.

But what kind of progress was I looking at on that ridge overlooking the combines in the cornfield? The ridge was approximately half a mile from the center of Ash Ridge, Wisconsin. A neat green sign with the town name and “unincorporated” is about all that marks the location today. Only a generation ago this was a bustling community with a feed mill, post office, a store, a fix-it shop and two churches. The “town” of Ash Ridge is now home to five residents: a disabled retiree, an over-the-road truck driving couple and two commuters nearing retirement age who work in “town” 25 miles away.

Where is the progress in this? Is our progress as a society to be measured by how big our sport utility vehicles are? Or is our progress measured by the fact that we have a 72-inch widescreen plasma TV in the living room with 300 channels of programming? Is it progress to be able to buy a 40-ounce “Big Buddy” soft drink at every corner and have a Walmart store within 30 miles of every citizen?

Do we measure our progress by the number of extremely overweight Americans that there are in the country? The United States has one of the highest rates of heart disease (#13) and diabetes (#3) in the world according to the World Health Organization. Is progress measured by the fact that Americans are so unhealthy that the latest Army statistics show that 75 percent of military-age youth are ineligible to join the military because they are overweight, can’t pass entrance exams, have dropped out of high school, or had run-ins with the law? “We’ve never had this problem of young people being obese like we have today, “ said General John Shalikashvili, former chairman of the Joint Chiefs of Staff.

A mere generation ago much of agricultural America was bustling with vibrant communities, and now?

There’s a crisis running through the heart of America and clinging to its coronary arteries. It ripples out in all directions into everything we do, everything we feel and everything we think. Some may say it’s a political crisis. Some blame the most recent batch of immigrants, others blame religion (or lack thereof). In each case, the proponents of one solution over another share some very basic common traits with their opponents. These commonalities are such deeply held core beliefs that they are nearly invisible to both sides. No matter who is to blame for our current health predicament and no matter who is morally or ethically “right” when it comes to finding solutions, we all share the same crisis. Our crisis has its roots in how we get our food.

How a human being obtains his or her food has a direct and very real impact on the biological health of the planet. What you eat creates the market forces that cause farmers to grow crops to satisfy your demand. What a farmer grows and *how* those crops are grown directly affect the ecological health of the soil, plant and animal life of a place, the atmosphere, the hydrology and even the patterns of human settlement. What you eat is indirectly responsible for nearly every single crisis that humanity faces and with an economy that is global in scale today, the food choices of one individual (you or me) are compounded by the billions and change the world like no other socioeconomic juggernaut ever known. We are eating our planet away to the bare bedrock bones and changing the conditions of our home planet into something that would be unrecognizable to our great-grandparents.

Humankind has reached a phase in development where we must have the courage to uncover our blind beliefs and make the efforts to fundamentally change the face of agriculture. By fundamentally changing the face of agriculture, we change the food system. By changing our food system we change the health and well-being of the populace, and as I will point out in this book, by changing the face of agriculture we can change the ecological health of the entire planet. The "progress" that we have made as a nation has been built on a food system that has denuded continents for millennia. With the discovery of liquid crude oil, the invention of the internal combustion engine to power farm machinery and with the development of fossil fuel-derived synthetic fertilizers, the ecological destruction has shifted into overdrive.

In the short span of one human lifetime, the change in Ash Ridge, Wisconsin, rural North America and around the world has been extreme.

What you eat and how that food is grown is responsible for nearly every single crisis that humanity faces today.

In 1910, there were 6.4 million farms in the United States. The average farm size was 138 acres. Most farms were owned by the farmer and his family (back then most farmers were male). These small family farms provided a modest but healthy livelihood for its inhabitants which were typically large extended families.

Since 1910, the number of farms in the United States has plummeted from 6.4 million to less than 2.2 million in 2008. The average size of an American farm has ballooned to 461 acres. Despite the fact that half the number of American farmers are now tending seven times the landmass that my grandpa did, he or she is now earning *less* today (in inflation-adjusted dollars) than way back then.

The United States Department of Agriculture statistics very accurately track these changes. The changes began somewhat gradually and have accelerated with the increased availability of fossil fuels and the mechanization of farm equipment. The tractor is a relatively new invention in the world of agriculture. My grandfather farmed with horses. My uncles learned to farm with horses and adopted the tractor as soon as they could afford one. "Affording one" was a part of the problem. At the dawn of the age of tractors, a horse or mule-powered farm was a profitable venture. My grandfather raised a family of six children solely on the income from a 60-acre farm and helped send three of them to college. As tractors became more common, farm prices first went stagnant. Then they began to fall.

The advent of chemical nitrogen fertilizers (manufactured by a re-tooled munitions industry following World War II) had a short-lived boost on yields, but instead of improving the bottom line for American farmers they had the opposite effect. More crop meant lower prices. Fertility, which once came from livestock raised on-farm, now came in a bag from the agri-chemical company down the road. In less than one lifetime, farms went from being self-contained ecological production systems, to debt-ridden, input-dependent "agri-businesses" that soon required massive government subsidies to keep them afloat. In less than one lifetime, farms went from being biologically diverse systems that relied upon animal husbandry, crop rotation and perhaps additions of mined substances (calcium, for example) to specialized single-crop systems that were merely extensions of the chemical companies who manufactured the toxic brews to be spread on American soil.

In order to afford to buy tractors my uncles had to borrow money. In order to make payments on their tractors they had to buy more land in order to grow enough crops (at declining prices) to pay for the new equipment. More land meant more borrowing. More borrowing required a larger cashflow which called for bigger tractors which meant more borrowing and the cycle continues to this day. The seemingly inevitable upsizing of the American farm and the bleeding of the American farm economy shifted into overdrive in 1973-74 with what appeared to be caused by a wheat crop failure in the former Soviet Union.

Ken Meter, an agricultural economist at the Crossroads Resource Center in Minneapolis, Minnesota, has repeatedly shown how critical this time period was for the American farmer and the entire U.S. economy. In a report written for the Indiana State Department of Health in 2012, Meter writes:

> It was not until 1973-74 that American farmers would experience bountiful prosperity. This occurred in the aftermath of the OPEC decision to restrict oil production. This had the effect of raising the price of oil, and since most of the oil America purchased at the time came from the Middle East, our purchases funneled dollars into the hands of the oil industry there. At the time, Middle Eastern oil producers did very little to reinvest in the United States, so these dollars flowed steadily away from our shores.
>
> In an effort to bring dollars back to the U.S. economy, and to offset higher prices induced by oil costs, the White House created what they said would be a "win-win-win" solution. The government asked American farmers to produce more grain, promising them "permanent export markets abroad" if only they would ramp up production. The Soviet Union agreed to purchase considerable wheat and corn, using dollars they held in savings accounts; this was necessary because crop failures and distribution breakdowns had made many Soviet citizens hungry. According to the plan, Soviet consumers would eat better, farmers would make more money, and the treasury would recover the dollars that had been sent overseas.
>
> Many farmers remember Secretary of Agriculture Earl Butz standing in front of microphones asking them to "plant fence row to fence row." Further, he encouraged farmers to expand their operations, saying "Get big or get out of farming." Both federal and private lenders responded accordingly, encouraging farmers to take on additional debt. This analyst interviewed several farmers in the 1980s who had approached lenders asking for a loan of, say, $250,000, and were rejected because they asked for "too little." As one farmer recalled, the lender responded that he would not consider making a loan unless the farmer asked for $400,000 at minimum. Given the promise of permanent export markets, these farmers felt they had no choice but to go along.
>
> However, in 1974, the Soviet Union stopped buying massive quantities of grain, saying they had restored their own capacity to feed themselves. Suddenly, markets for grain commodities collapsed. As sales plummeted, so did farmgate prices, since there was no other buyer who could buy in quantity. Rural elevators across the Grain Belt loaded grain high onto immense coneshaped piles on their lawns, since storage was full. The "permanent export markets abroad" had been an illusion.
>
> Farm income returned to levels similar to those prior to the oil crisis, but with one big difference. Farmers now had higher debts to pay — loans they had taken on, at times under duress, thinking prices would stay high. Farmers now found they could not repay their debts. It took a decade for this to become obvious to the rest of the nation.
>
> *From the article "Hoosier Farmer? Emerging Food Systems in Indiana" by Ken Meter.*

The "get big or get out" policy very quickly led to the real estate cannibalism of rural America. A farmer who got bigger, typically bought out a neighboring farmer who, for whatever reason, decided to sell. In the 1980s, when farm real estate prices no longer rose fast enough for farmers to roll their debt forward by "riding the inflation train," the farm economy fell into a severe credit crisis. This was the outgrowth of the only two years of substantial prosperity for farmers since the early 1950s and was caused solely by the federal government. Not even farmers with the best agricultural practices were immune to this government-caused catastrophe. Net cash income for farmers fell close to zero from 1999 to 2002, and only in the past few years have producers experienced positive returns.

As this process of rolling debt forward continued, the biggest farms and the ones most able (or willing) to take on more debt got bigger. The people who farmed the smaller farms, raised families, sent their children to the local schools, went to the local houses of worship and shopped at the local stores; simply moved away. In any population, whether it is white-tailed deer, squash beetles in a cucumber field or a human community, there is a certain point when the population is no longer viable. At some point in time, and that time was not always obvious, when enough people leave a town or city, there are not enough people to sustain that town. This process has been going on since the dawn of civilization and will be discussed later in this book. As people left rural America, a "population viability" threshold was crossed and small towns and cities began to collapse. Some places, like Ash Ridge, Wisconsin collapsed to the point that the only memory of its existence is that small, green sign saying Ash Ridge (unincorporated).

In the post-World War II years, displaced farmers frequently found employment in the industries that sprang up near big cities. Some people, in fact, theorize that the depopulation of rural America in the 1900s was due to industry's desire to provide a large, desperate workforce for itself.

My grandfather left the family farm in rural Vermont in 1947. It simply wouldn't pay. Where my great-grandfather had been able to raise a family of ten on 40 acres of land, my grandfather could now no longer afford to raise and feed a family on 60 acres. He moved the family from semi-wild, rural Vermont to industrial Massachusetts where he could find work in the factories. I never got to meet my grandfather. Either one of them in fact. Both of them had died from illnesses linked to chemical exposure. One grandfather worked in a tannery. Breathing tannery chemicals eight hours a day in the years before workplace safety laws were in place, turned his lungs into shoeleather. He died at age 55. The other died of prostate cancer at a similar age.

Statistics are faceless, but the crisis that humankind faces is not. The food crisis has names and faces. It's a family crisis. It writes family stories and creates the reasons for our actions. The agricultural crisis is really an environmental crisis. This crisis embeds itself visibly and invisibly into the very fabric of our lives. The agricultural crisis is what is written indelibly into my own personal history. Where I was born and grew up, is a direct result of U.S. farm policy. The stories that I heard from my parents and grandparents were the stories of survival in tough times. The dreams that they had that were instilled into me, were born out of the crisis of annual agriculture.

When I was a youngster growing up in central Massachusetts in the 1970s, my brothers and I would play a game whenever we got into the car. That game was, "Guess what color the river is today!" I grew up on what today would be called a "hobby farm." We lived on the top of a hill that was surrounded on three sides by a wide, meandering loop of the Nashua River. In the river valley to the north of my childhood home was the birthplace of John Chapman, popularly known as Johnny Appleseed. To the south was the birthplace of Luther Burbank, plant breeder extraordinaire who developed the Russet baking potato, Shasta daisy, and the thornless prickly pear cactus. Burbank and Chapman have influenced my life to an extraordinary extent as you will see later in this book.

In my childhood years, the same river in which John Chapman fished for salmon had become the waste disposal system for the industrial mill towns upstream in southern New Hampshire and northern Massachusetts. The river would run red, green, cobalt blue, orange (the color of a "Creamsicle" ice cream treat), but never clear. The word "Nashaway" in the language of the first people who lived there meant "stream with a pebbly bottom." The Nashua River of my youth did not have a pebbly bottom. For one, the bottom of the river was only visible close to shore where the water was the most shallow. When you could actually see the bottom, it was a thick, grayish-green slime. The identity of this thick, grey slime was revealed in the springtime after a flood. When the spring floodwaters receded, the river left a coating of papier-mâché on the banks to mark the extent of the floodwaters.

Upstream several miles away were large paper finishing factories that would receive bulk rolls of paper from the Maine pulp mills where the forests were chipped, ground, chemically dissolved then re-constituted into paper. This primary paper would then be rolled up into what resembled eight foot tall rolls of toilet paper. Indeed, much of what was produced *was* toilet paper. These upstream factories would re-process this bulk paper and turn it into the "products" that we all enjoy — writing paper, wrapping paper, newsprint, napkins and more. In the 1960s and 1970s it was common practice that the leftover dye and waste water from the paper mills be simply dumped into the river. Tanneries, suppliers of shoe leather to the many shoe manufacturers in the region, also dumped their dyes and used tanning chemicals into the river. The "wastewater treatment plant," believe it or not, was a new invention then, and companies who were benefiting from the free waste disposal available to them in the form of a river, were reluctant to try this "unproven" and "expensive" new technology, the adoption of which in their minds would no doubt result in the ruin of the economy and cause a socialist takeover of the political system or whatever argument the wealthy businessmen were using at the time.

It took dozens of years, public pressure, political pressure, and even some environmental sabotage to finally get the polluting industries to install wastewater treatment plants to purify their waste, or rather to most of the time, render it less toxic to a "statistically significant degree."

The Nashua River with its red, blue, green, and stinking toxic waste stream taught me something — something more significant than anything that I was taught in school. I could say that it taught me that organizing "the people" around an issue to raise awareness and funds and to apply political and market pressure to affect change is the "American Way" and that this was proof that our political system actually works, but that wasn't the real lesson the river taught me. The real lesson that the river taught me, that I took to heart, was that nature *heals!*

Given the opportunity, there are forces in place in the natural world that are as dependable as gravity, forces that lead toward health, healing, diversity and stability in an ecosystem. The Nashua River was all but dead when I was a youngster in the 1960s, but by the time I was in high school in the 1980s the river ran clear! The sewage plant aroma of the river was replaced by a not-so-horrible smell (it still stank though!). Then after a few years of flooding and scouring, most of the papier-mâché coating the bottom had been washed "away" (where it now lies no doubt on the bottom of the Atlantic Ocean off the coast of Merrimac, New Hampshire) and the pebbles described three hundred years ago began to be visible again! Nature really does heal itself!

All that was done in the case of the Nashua River was to remove the main sources of pollution. Nothing was added to the river and no additional clean up help was rendered to it. River banks that formerly looked like an industrial wasteland soon began to sprout vegetation. Plants began to grow *in* the river and by the time I had graduated from high school people were canoeing on the river again. In the mid-1980s I saw my first fish in it.

It had a grotesque, cancerous growth behind its gills, but it was an actual *fish* and it was alive in the Nashua River!

The same resilience that I saw in the Nashua River during my youth I have seen many times since then, from clear-cut mountainsides in Maine to parking lots in Chicago, toxic waste dumps in Detroit to the sterile dusty ridge of farmland where I stood in southwest Wisconsin.

The combines finished shaving the last crew cut of corn from the hard-packed fields and were pouring their golden harvest into tractor trailers parked at the side of the field. I turned from looking at this dry, barren landscape to behold another quite different example of the power of regeneration. Turning around I found myself walking over an embankment that had been piled up from the excavation of a series of water collection swales. I was now walking in a place called New Forest Farm, where dozens of miles of water collection, distribution and retention ditches (swales) had been excavated. On the way home I walked through a young forest of pine nuts and chestnuts and passed a "pocket pond" where I spotted three different types of frogs and heard the sounds of at least five different species of frogs and toads as they sang in the newly formed spring.

Birds flew in and around the branches of the trees: bluebirds, phoebes, meadowlarks, shrikes, swallows, kingbirds, and the common "LBBs" (short for little brown birds!). Butterflies flitted in the breeze, grasshoppers, crickets and a host of other insects chirped and trilled in a delicious cacophony that made me smile. The place where I was walking was *alive.* The earth beneath my feet was firm in the dry autumn heat, but softer than the pavement I had experienced in the cornfield. In addition to all of this, I was surrounded by *food!* The hazelnut shrubs I passed had already been harvested, as had the cherries, mulberries, kiwis and pears. Apples in a bounty of red and gold were being harvested into pallet bins while the nearby chestnuts finished ripening, awaiting their turn for harvest. Several steers grazed on the abundant grass and pigs snuffled about under the hazelnut bushes looking for dropped precious gems. I was walking through a working, food-producing farm. A farm that was *alive* with soft, rich soil, water, and an abundance of plant and animal life, including frogs! This place, New Forest Farm, had been a bare-dirt cornfield a mere fifteen years prior, but it had been transformed! It had been actively healed and restored to a state of greater productivity.

In an incredibly short period of time, we can restore and heal our farmland. We can re-create some of the abundance that our ancestors saw when they first moved to this continent. Instead of just stopping the insult, like in the case of the Nashua River, we can become active participants in the transformative, restoration process. We can do it while still farming and producing food. As we heal our farmland we can heal our planet. And when we heal our farmland we heal ourselves and our families.

Here though, is where a distinction must be made. Fifteen years ago this "working farm" (well, technically it *wasn't* working economically and that was why it was abandoned), produced roughly the 160 bushels of corn per acre that can be expected in these parts on the rough, hilly "highly erodible" (as the USDA calls it) land. Prior to the corn farm being abandoned in the early 1990s, it was a net contributor to the American food supply. Anyone who has eaten today will tell you how important food is to our well-being. Anyone who has *not* eaten today knows this painfully even more so. If we are to restore health and natural fertility to our agricultural lands, we must do so while continuing to provide food for ourselves and to the world. This book describes how we can accomplish vitally needed ecological restoration while simultaneously producing food.

Here is also where a second distinction must be made. What is being demonstrated at New Forest Farm is the production of staple food crops — the bulk calories, carbohydrates, proteins and oils in our diet that come from farm-scale production systems. There are many who claim that it is possible for individuals to grow all of their food in a small, suburban lot. At best I have found that these are people who have produced a significant portion of their annual consumption of vegetables in their suburban lot (and some with a large percentage of their own fruits and berries), but nowhere has there ever been an example of someone producing their own *food* in a suburban or urban situation.

Rice, corn, the wheat in our bread and pasta, beans, lentils, chickpeas, and dozens of other legumes and grains make up our staple food crops. These are the calories that keep our bodies metabolizing, the proteins that make up our muscles and feed the livestock that we raise for meat. We are *all* dependent upon the large-scale production of staple food crops for our sustenance. The Oxford Dictionaries definition of a farm is, “An area of land and its buildings used for growing crops and rearing animals.” We all need farms. Even the most devoted grow-it-yourselfer sometimes eats rice and beans grown on farms.

Given the lack of real examples of backyard systems where a family can grow all of their own food, (not just fruits and vegetables), and since we obtain the majority of our staple food crops from farms anyway, we need to turn our attention to the process of obtaining our staple foods from fully functional, perennial ecological farming systems.

How can we as a nation feed the majority of our population that lives in cities where most people don’t even *have* a front yard? Our families need food. Staple food crops are currently grown on farms. If the American farm is in a crisis, doesn’t that mean that our food supply is at risk? How can we produce the staple food crops that feed the world using sustainable, ecological systems that don’t pollute, that build soil rather than destroy it, that are once again biologically based systems and that are not totally dependent upon fossil fuel imports from far away? What are we to do?

CHAPTER 2

Our Present Reality

THE question, “What are we to do?” may seem like a theoretical one to many. In fact, published works abound these days that are just that. A highly credentialed author researches extensively, writes a book, then launches a speaking and teaching career where hands are wrung, bad guys are blamed and simple, easily palatable steps are given to eager audiences with the underlying assumption that they would be offended if asked to made a fundamental change rather than just something simple like changing their light bulbs.

This book is different. It is a deep, personal look at the “hand wringing” issues of today’s real world. It is the story of a radical transformation of agriculture as we know it based on the laboratory of life of the author and his family. This book is infused with the personal motivations and personal biases (both known and unknown) of the author. It is a story of the transformation of humankind’s relationship with the natural world through the production of food, as learned in the microcosm of one life, rippling outward through family, friends and neighbors into the world. Since this message can only be written from this perspective and has taken place in the “real world,” there are some foundational experiences that should be noted.

In October, 1973, the Oil Producing and Exporting Countries (OPEC) cut off the supply of crude oil to the United States. As an elementary school student this was at first merely another meaningless story on the TV news. It had nothing to do with Little League baseball practice schedules or riding bikes with neighborhood friends. My parents, being somewhat forward thinking for their day, went out and bought a top-end, efficient wood stove for supplemental household heat to reduce their expenditures on heating oil. Since we lived on a 10-acre “hobby farm” in the suburbs, and had access to an abundance of firewood, I spent an increasing amount of time in the woods hauling and stacking wood to keep us warm. My parents also bought a new, fuel-efficient car with twice the miles per gallon as the average car of the day.

I didn’t really like the new car, mostly because of its size. I was a big kid for my age and so were my two brothers. Where we formerly had a large family-sized station wagon with ample room to sprawl, the three of us now had to cram into the back seat of a Volkswagen with my youngest brother’s toddler seat taking up most of the room. I knew that my parents had gotten the smaller, more fuel-efficient car because of the oil embargo, but somehow the very real connection between what was happening on the news and what was happening in my individual life, hadn’t been made for me yet. The Middle East was a story on the news and an oil embargo meant little to me.

This began to change somewhat when “suddenly” (at least to me it seemed sudden) gasoline became rationed! In the state of Massachusetts, motorists were allowed to buy gasoline only on the days determined by the numbers on their license plates. License plates ending with an even number were allowed to fuel up on certain days of the week, odd numbers on other days of the week. This was the first stage of the rationing. As the oil embargo dragged on and the fuel supplies tightened, further restrictions were put into place when motorists were only allowed to buy ten gallons of gasoline at a time.

Within a very short period of time, life began to revolve around getting gas for the car. We needed the car to drive to the store to get groceries and my dad needed the car to get to work. Soon just getting gas became a big challenge. With everyone experiencing the shortage, the lines at the pump became longer and longer. Some days it would take over an hour to advance through the line to eventually get some gas. Sometimes drivers would sit in line for an hour only to arrive at the pump to discover that the station had run out while they were waiting. As a young boy crammed in the back seat of a Volkswagen in the hot sun with two younger brothers for far too long, you can imagine how much this cramped my style and I was now beginning to take notice.

One day, while waiting in one of the longest gas lines that we had ever experienced, the car ran out of gas. Here we were, stranded in a gas line that easily extended a quarter mile, we were out of fuel, and we had no guarantees that there would be fuel available when we reached the pump. I had somewhat of an awakening when my mom ordered me out of the car to push. Whining didn’t help. Refusing wasn’t an option and forced labor was a possibility that would quickly have been imposed if I had attempted to refuse. Mom had to steer the car and take care of my car-seat-bound youngest brother who was in all likelihood throwing Cheerios and screaming at the top of his very competent lungs. My other brother, who was eight years old, and I had to push the car. There was no way out!

A ten-year-old boy has *lots* of time to think about the root cause of his current situation when pushing a car a quarter of a mile (with questionable help from his little brother who never pulled his own weight anyways). The crying of my youngest brother and a seriously stressed-out mother only added to the intensity of the experience.

Our culture's critical dependence upon fossil fuels at that moment became incredibly *real* to me. As I grunted and huffed, sweated and cursed, rocked and pushed, my mind wrestled with the issue of fossil fuels in a very real way like it had never done before. As a family we were totally dependent on fossil fuels. My dad needed to drive the car to get to work where he would earn the money that we needed in order for us to drive to the store to get our food. Society was totally dependent upon fossil fuels as well. The grocery store depended on fossil fuels to run the trucks that brought in our food. The farms where the food was grown depended on fossil fuels to run the tractors, harvesters and (unknown to me at the time) for the fertilizers, fungicides, herbicides and pesticides. Through no fault of our own, my family was being economically and socially stressed because our steady, predictable fuel supply had been restricted. How could we as a family reduce our vulnerability to this? And, by extension, how could we as a culture limit our vulnerability to a disruption of our fuel supply? One thing that I knew, was that in order to get ourselves out of our dangerous dependency on fossil fuels, we would have to use those very same fuels in order to get ourselves to the point where we wouldn't need them anymore.

During this time my dad, always a putter-about home gardener, began to garden in earnest. My childhood experiences in the woods gathering firewood and working in the garden took on a grand seriousness that would prove to be foundational to my thinking, my career choices and in fact, my entire life.

Growing one's own food is an incredibly powerful way for a person to change the world one step at a time. It is impossible to obtain produce that is any fresher than that which is picked from the garden and immediately eaten. Freshly harvested food has colors that are the most vibrant and flavors at their peak. Vitamins and minerals have yet to oxidize and produce is the most nutritious that it will ever be. Nothing from the store can compare to garden-fresh produce. The brisk crunch of a crispy, fresh garden carrot is never better. The juice of a tomato never so cool and tasty on your tongue, or running down your elbow, as it is when freshly picked on an August afternoon.

With proper attention to soil fertility and mineral balance, it is possible to grow a significant portion of the most highly nutritious fruits and vegetables that a human being can possibly eat. After the oil embargo, our suburban backyard soon sported three apple trees, two pear trees, a dozen or so blueberry bushes in addition to nearly a half-acre under cultivation in double dug raised beds. We learned the skills of making compost from lawn waste, weeds, autumn leaves, and kitchen scraps. And for many years we kept several hives of honeybees. An old, fallen down chicken coop even found a new lease on life and became re-inhabited by a clucking, crowing flock.

At the time, my parents were considered to be quite strange by our suburban neighbors. The Hippies and back-to-the-landers of the 1960s were still held in some disregard in the "proper" New England suburbs. As a middle schooler this was quite an embarrassment for me, but what my parents were doing makes so much sense to me now! Our family was able to reduce to near-zero our reliance on expensive and hard to get heating fuel. We were able to reduce the number of trips to the grocery store, which meant a reduced likelihood of me having to push the car to the gas station.

There were some huge dissonances in my experience, however. Even though we had a garden of nearly a half-acre in size, we still needed to take trips to the grocery store. The things that we bought at the grocery store were the same over and over again — staple foods and meat. (My father would eventually stop eating beef, and for a period in my life I became a vegetarian.) The grocery list usually included rice, beans, flour, oatmeal, cornmeal, sunflower seeds, bread (if Mom wasn't baking that week), and pasta. Here we were, following the advice of the gardening gurus of the day, growing more food than everybody I knew at the time and we still weren't growing enough staple foods to provide for our needs. This bothered me. Why weren't we able to grow all of our own food when we were told that it was possible? If it *wasn't* possible, then why didn't our book and magazine authors admit as much? Why was it that Scott and Helen Nearing, the homesteading heroes of the day who claimed to be self-sufficient, spoke about how they ate raw oats, sunflower seeds, buckwheat and bulgur but happened to ignore the fact that they *weren't* self-sufficient, that they didn't grow these crops and that they actually were critically dependent upon mechanized, industrial-scale farms for their very survival? As a ten-year old I never had the courage to point out this hypocrisy. But I do now.

Another dissonance in my experience was made especially evident to me by my experiences while getting firewood. When I was working in the garden, it was exactly that *work!* There was soil to be tilled, either with a rototiller or a shovel, rake and hoe. There were seedlings to be started indoors and coddled beneath grow lights. There were compost piles to build, to turn and to apply to the garden and then mulch to add. And of course, there were always weeds to pull.

It was sunny in the garden because most of our garden plants, I was led to believe, required full sun, and besides, that's what a garden was … a sunny piece of earth where the family's vegetables were grown. Being in the sun meant hot, sweaty days getting covered with dirt. The earthy medium in which we grow our food plants may technically be called soil, but when it covers your body and becomes mud streaked with sweat I can only call it *dirt.* My apologies to those that refuse to call soil anything else.

When I was getting firewood, however, things were different. Picking up pieces of firewood that Dad had cut, hauling them out to the woods road and loading them into the back of a rusty old pickup truck was labor. It was physically strenuous, and therefore could qualify as work, but it took place in the shade. I would sweat, but I wouldn't get covered with dusty dirt. While working in the woods there were also nice convenient snacks to eat. In the early summer there were wild strawberries, raspberries and blackberries. The blueberries would ripen later in the summer. In the fall there was an abundance of wild Concord grapes, hickory nuts and butternuts to enjoy. This struck me as odd. Why was it that growing our garden produce (vegetables and small fruits) was so much *work,* and yet out here in the woods and in the border between the woods and our garden there was so much to eat, and we did nothing but harvest the bounty? There was no work involved — no starting of tender plants indoors, no transplanting, no weeding, no composting, no mulching and no watering. Nature looked after it all. Insects and diseases did exist, but they all seemed to fall into some sort of natural equilibrium through the years.

The woods provided our family with a considerable amount of food, apparently free of charge and for no more work than was required to harvest and preserve it. In springtime the woods even provided us with several gallons of the finest 100 percent pure maple syrup one could find anywhere. The garden and the forest taught me a great deal. They penetrated my thinking and over time would transform me.

While my thoughts about agriculture were being transformed from the labor-intensive annual garden toward a perennial, natural ecosystem, the industrial agriculture that supplied us with our noodles and oatmeal was continuing its transformation as well.

The size of the average farm in America continued to increase. Chemical fertilizers, the drivers of the "Green Revolution" once upon a time did indeed appear to increase crop yields, but as time went on and the soil's natural fertility became exhausted, fertilizer use increased. Pesticides, once miraculous in their ability to eradicate the insects that ate our food plants, became less and less effective and previously unknown side effects became clear. DDT, once a widely used pesticide, was discovered to have bio-accumulated in the tissues of birds. Higher up the bird food chain concentrations of DDT became so high that they caused thinning of egg shells and raptor populations, hawks and eagles, began to decline dangerously. Pests that had previously been susceptible to insecticides appeared to become tougher. What had actually happened was a genetic selection process. When a pesticide was sprayed, all of the pests that were susceptible to that chemical died like they were supposed to. That happened to be *most* pests for many years. However, by a roll of the genetic dice, some insects happened to have whatever genes were necessary to be resistant to that chemical. The chemically resistant insect would now be able to pass that trait on to its offspring. Over time the chemical resistance trait, which provided a definite survival advantage to the organism, would proliferate through the population eventually rendering the original pesticide useless against that pest.

Likewise with weeds. The National Pesticide Use Database reports that herbicide use has increased in American agriculture from zero in my grandfather's day to nearly half a billion pounds per year today. Over 440 million acres of farmland each year are the scene of advanced chemical warfare unheard of in human combat, but taken for granted in agriculture. Once again, over time the traits providing resistance to any particular herbicide will increase within the weed population requiring more and more herbicide use and eventually requiring the abandonment of the original herbicide in favor of newer ones.

Within the last ten years, chemical resistance in weeds and insects has taken a more sinister turn. When first introduced, herbicides for example, were somewhat plant specific. There were herbicides that were used before crops emerged from the ground (pre-emergent), those that killed broad-leaved plants such as dandelions and thistles, and there were herbicides that killed grass-type plants. Corn, being a grass, could be oversprayed with a broadleaf herbicide and suffer no visible damage. Soybeans (or any other legume) being a broad-leaved plant could be oversprayed with a grass-killing herbicide and survive. This worked fairly well, but still caused problems for farmers obsessed with "clean" weed-free fields. Grasses could flourish in a cornfield sprayed with a broadleaf herbicide and broad-leaved weeds could flourish in bean fields sprayed with a grass herbicide. Wouldn't it be great if *one* herbicide would kill *both* broad-leaved plants and grasses? Wouldn't it be great if that very same herbicide would *not* damage the crop in the field, but only the weeds? This was definitely smart chemistry!

The international company Monsanto was the first to come up with just such a "dream come true" herbicide. In 1996, they released the Roundup Ready soybean. This soybean is immune to the effects of the herbicide, Roundup (glyphosate). Roundup is the trademarked brand name of a systemic, broad-spectrum herbicide. The main active ingredient of Roundup (An endocrine disruptor and mutagenic chemical conveniently manufactured by Monsanto. Originally marketed as "safer than table salt!") is the isopropylamine salt of N-(phosphonomethyl)glycine.

Roundup Ready soybeans could be planted, allowed to grow, and then over-sprayed with Roundup which kills *both* broad-leaved weeds and grasses, but not the crop. How Monsanto genetically engineered the soybean to be resistant to Roundup is still technically a proprietary process, but laboratory scientists using reverse-engineering have now learned the basic outline of how this was done.

Resistance to Roundup was a trait discovered in petunias. The same simple breeding that eventually made pests resistant to pesticides could not be used to cross a petunia with a soybean, so an intermediary was chosen. *Escherichia coli,* (known as *E. coli* to most), is genetically a rather simple bacteria. There are many varieties of *E. coli,* most of which are harmless and most of which reside in the intestinal tracts of animals. Our feces are loaded with billions of *E. coli.* Some of this bacteria cause illness in their hosts and some, such as the *E. coli* O157:H7 version, can be deadly. One reason why *E. coli* is so useful to genetic manipulators, is that it is an incredibly simple organism. In addition to being genetically simple, it is also prokaryotic, which means that its DNA is not bound by a membrane and is not held within a cell nucleus. In the laboratory it was fairly simple to insert the Roundup-resistant petunia genes into an *E. coli* cell. The "petunioid" *E. coli* bacteria was then introduced into a soybean cell where it infected it, like a good bacteria should, and exchanged its genes with the host. One of the reasons why we feel ill after ingesting food contaminated with *E. coli* is that when it reproduces its DNA (the code for making proteins and enzymes) it makes proteins that are foreign to our human systems and in many cases are toxic to us. Almost miraculously, the Roundup-resistant petunia genes delivered by the *E. coli* bacteria took up residence in the soybean cell and a new transgenic organism was created — the Roundup Ready soybean. In 1996 Roundup Ready soybeans became available commercially and now there are a whole host of Roundup Ready crops from corn to canola to iceberg lettuce and alfalfa. Looking at the big picture of the ecology of planet Earth, transgenic plants are recent arrivals.

The invention of Roundup Ready soybeans caused the use of the Roundup brand of herbicide to skyrocket. Using only one herbicide was a genuine benefit to farmers. It saved them multiple trips through a field, representing a potential fuel, time and equipment savings. The UDSA reports that over 90 percent of all soybeans grown in the United States are transgenic, Roundup Ready soybeans. As is over 70 percent of all corn and 80 percent of all cotton.

Just because these new plants were different than anything seen before on planet Earth, should we have expected nature to act any differently than before? With the increased use of Roundup, weeds have become increasingly resistant to it. Previously herbicide-resistant weeds or pesticide-resistant insect populations appeared after being changed gradually through the years by "natural" selection. The pests in question were exposed to a toxin and those with a genetic resistance had an advantage and over time the genetic makeup of that population changed. A wild mustard weed may over time have become an herbicide-resistant wild mustard, but it was still a wild mustard. This is not entirely the case any more. The use of genetically modified organisms in American agriculture is creating entirely new organisms, and this is not only the crop.

That wild mustard, mentioned previously, is a brassica and is closely related to a number of our food plants (broccoli, cabbage, cauliflower, mustard and the cooking oil, canola).

Canola was the first brassica to be genetically engineered to resist the Roundup herbicide. The genes conferring Roundup resistance in this case came from a soil bacteria. Soybeans don't have a lot of wild relatives and hence don't have much risk of "soypetuniabean" genes pollinating them. Not so with canola. There are *lots* of weeds that are closely related to canola and through the totally natural process of pollination, the Roundup-resistant soil bacteria genes have escaped and entered the wild populations of canola relatives. Yellow rocket, wild mustard, wild turnip and others have begun to show genetically conferred Roundup resistance. Through pollination we have created new plants that will join in the dance of life and change through time.

More insidious than creating mutant food crops and herbicide-resistant weeds, is what we have done with plant diseases — although it hasn't "officially" shown up yet in the same way that herbicide resistance has.

A number of years ago I attended a series of commercial vegetable grower workshops. One of the workshops that I attended was on tomato production. I had gone to the class to hopefully learn something about how tomatoes grow, cultural practices, harvesting, post-harvest handling and how to manage soil fertility, but what I experienced instead was a series of presentations by "scientists-for-hire" that appeared to be little more than sales pitches for petrochemical products for sale in the next room and manufactured by the sponsoring company. The scientific method appeared to be missing from their presentations and the experiments were merely comparative analyses of this chemical vs. that chemical, with all research being done in "laboratory conditions" rather than in the real world and with experiments that had no control group (where *neither* chemical is used).

As a wholesale grower of certified-organic produce, my learning needs were not being met and I began to get restless. I did learn a few useful things about various pest and disease life cycles, so I stuck around despite the dearth of useful information. The last presentation of the day was to be a presentation on a particular variety of genetically engineered tomato. This particular tomato had been genetically engineered to be resistant to tobacco mosaic virus No. 1 (TMV 1) which, according to the speaker, was a disease of such devastating consequences that if it went unchecked would obliterate all tomatoes from the face of the earth within the next ten minutes and we'd all have to resort to alfredo sauce on our spaghetti. Or at least the speaker sounded like the situation was that urgent.

Where I grow produce in southwest Wisconsin was actually (and still is) one of the larger tobacco growing regions in the country and I knew of people who had problems with tobacco mosaic virus infecting their tomatoes, so I figured that I might be able to learn something from the information presented.

I *did* learn something that day, though not what I expected. The takehome message that the speaker was delivering to the audience was that this particular engineered tomato variety was resistant to TMV 1 and everyone should buy the seed at the sponsors booth on the trade show floor. My takehome message, however, was entirely different, and it is here that I must confess some personal history. Although professionally I am neither a mechanical engineer nor ecologist, my college education is in both fields. Since my career path did not place me within industry or academia, I have not met the professional requirements in order to call myself an engineer or ecologist. My schooling and credentials did, however, allow me to be a specialty teacher at a private high school where I taught botany, zoology and genetics. What I heard during this presentation made my stomach turn thinking about the long-term, downstream effects of this genetically engineered tomato. To understand why I was so upset, we must look at how viruses reproduce within living organisms.

A virus isn't really a living thing, or at least it doesn't act like a plant, animal or any other living organism. A virus is a rather simple affair consisting of a small and simple quantity of DNA (deoxyribonucleic acid) or RNA (ribonucleic acid), the genetic information in every living cell. This small quantity of genetic information is coated with a protective layer of proteins which in turn is sometimes coated with a layer of lipids or simple fats. Viruses are ubiquitous, existing just about everywhere you can go on land, sea or in the air. They get inside living organisms in some of the most creative ways around — from being simply breathed in, eaten or, as in the case of TMV 1, delivered in the saliva of a biting insect.

Once inside an organism, viruses are small enough that they can basically "float" around anywhere in the body. For the most part they can pass through cell membranes and go wherever the whims of biochemistry take them. Once inside a cell they reproduce themselves in one of two ways. During the DNA replication process (or the RNA replication process), which takes place in all of our cells constantly by the billions, long strands of our genetic material begin to "unzip." If you can imagine a ladder cutting itself in half lengthwise right down the middle of the rungs, you can get an idea of how this works. As the rungs of the ladder separate, the virus inserts itself into the gap and uses *your* genetic information to make another copy of itself. Some viruses simply use your ladder to make more viruses and others insert themselves right into your ladder. In both cases, your cell is momentarily genetically "not right." The cell code is interrupted by this interloper and your cell malfunctions making enzymes and proteins that are not normal and quite often toxic. These toxins are part of the reason why we get muscle aches and fevers when a particular viral population explodes in our system.

Most of the time when a virus replicates, it leaves your DNA in the same form that it entered, a small bit of genetic information in a particular arrangement. Every so often, however, measured in a chance of once every few million times, the virus happens to take some of your DNA with it. It is now a totally new form of virus that has mutated. It is because of this process that the flu virus is constantly changing and new flu vaccines need to be created every year. It is also by this process that new strains of flu (and other viruses as well) are able to change form enough to allow them to infect new hosts, as the H1N1 virus did to come to infect humans instead of just swine.

The TMV presenter showed a lot of data and numbers that afternoon, no doubt to impress the farmers in attendance that she was extremely intelligent and knew what she was talking about. Part of her presentation included explaining a chart that showed the results of the statistical analysis that she did in order to "prove" that her findings were not just a fluke, but real results. She even included a statistical analysis of the mutation rate of TMV 1. Her mathematical calculations showed that out of several million virus replications, only a handful of mutations occurred where the virus acquired new base pairs, the number of which she said was statistically insignificant.

When you are rolling dice, statistics really do apply. Your chances of rolling a 7 or an 11 at the casino are statistically known. However, when you stop rolling the dice, no more rolling occurs. Not so with a virus. Viruses are like self-rolling dice that continue to be in existence and that continue to move around, find new hosts and continue to replicate long after you've left the gambling table. What the TMV 1 virus replication numbers showed, was that by genetically engineering a tomato plant, we are actually creating new viruses that have never existed before on planet Earth. That afternoon I raised my hand and asked the question, "By inserting these new genes into the tomato (by the way, where those genes came from is proprietary information to this day) aren't you creating new viruses with potentially devastating consequences for the future?" She quickly returned to the slide that showed the statistical analysis and exclaimed "Yes, but it's statistically insignificant." I immediately replied, "That may be so, but it's *real.* You're really creating *new* viruses that have never had those engineered segments in them before!"

Her reply was, "Yes, but it's statistically insignificant."

I followed up with another question, "How can you know that one of those viruses that you created won't be *more* pathological than TMV 1?"

Her steadfast reply was, "It's statistically insignificant." I assertively stated, "Every time we plant this tomato, in *reality* we are creating new viruses the likes of which we have never seen before. All of which will go on and possibly replicate causing a compounding of tomato viruses. It's one thing to have to tolerate the natural panoply of tomato viruses that are out there and to deal with their entirely natural rates of change, it's quite another thing to intentionally *create* new forms of virus that have never existed before! This is the height of scientific irresponsibility!"

As two gentlemen in dark suits escorted me (I went willingly) from the room, the "researcher" reminded everyone that what I was talking about was statistically insignificant and she quickly went on to her next point.

When spraying insecticides on crops, not all of the insects will die (a statistically insignificant number will live, perhaps?). The ones that don't die possibly could have a genetic makeup that renders them immune to the poison being used. They could reproduce and pass this insecticide resistance on to their offspring. Continued insecticide use kills the insects that *aren't* resistant and all you have left are the pesticide-resistant insects, the superbugs. The same process applies to bacteria in livestock. Antibiotics that were perfectly effective at "controlling" disease a few decades ago are no longer effective because of developed resistance and new antibiotics need to be invented. Weeds become immune to herbicides and similarly new viruses get created.

Our modern system of agriculture that relies on annual plants, planted into an eradicated ecosystem in vast seas of uniformity, actually creates new strains of insects. Our agriculture system creates new forms of herbicide-resistant weeds. It creates genetic combinations that would not have occurred in nature that are potentially dangerous. Our modern agriculture system is actually creating weaker food plants and stronger pests and diseases. Modern agriculture has forced the breeding of plants that can only exist in weed-free environments that will only thrive when bathed in chemical fertilizers. And the pests of those plants are developing immunity to our arsenal of protective chemicals. Farmers are working longer hours and managing more acres than ever before. Farm incomes have not kept pace with the increase in farm expenses or the cost of living. Why is it that everybody seems to be working so hard at something that doesn't seem to be working all that well?

It is time to stop working in the garden and go for a walk in the woods.

CHAPTER 3

Standing on the Backs of Giants

IT certainly sounds well and good that we should stop slaving away in the garden and go for a walk in the woods. It might work individually *if we* have access to a plot of land where we can cultivate a garden and *if* we have access to natural areas nearby where we can take a stroll. Of course, both are somewhat irrelevant if we don't have enough surplus time to do anything other than survive. Both are equally irrelevant if we get our food from annual plants that by necessity require the eradication of an ecosystem in order to plant seeds. This is the case throughout much of the world.

Most human beings now live in cities. According to the United Nations, 2008 was the year when the pendulum swung with over half of all human beings living in urban areas. A mere four years later, nearly 60 percent of the entire human race now lived in cities of 250,000 or more. Most people on planet Earth live their lives surrounded by concrete, steel and stone — with the crush of humanity on all sides. Their only contact with the natural world may be with pigeons flying the streets in search of a morsel or ants emerging through cracks in the sidewalk at their feet. Like the ants, humans live lives of existential vanity working for all eternity doing apparently nothing more than working for all eternity for nothing more than working for all eternity. It was Thoreau nearly 200 years ago who rightly stated, "The mass of men lead lives of quiet desperation." And when writing about labor and leisure he said, "He has no time to be anything but a machine."

How can we provide *food* for people without destroying the life-supporting ecosystems of planet Earth? How can we continue to rely on massive, mechanized, annual crop, monocrop farms when fossil fuel costs soar and its availability decreases? How can we continue to feed ourselves when our agricultural system creates more of its own plant diseases, and breeds pests and weeds that require more deadly poisons to kill? How can we continue to feed ourselves when the wind and the rain are washing away our topsoil year after year?

With a college education behind me and an urge to figure out how to escape the rat race, all of these questions boiled in my mind. How could I as an individual escape from the drudgery and work of the garden? Or, more appropriately, escape from the annual crops treadmill? How could I break free from the bondage that culture had imposed upon me and the entire human race, from the apparently benign annual crop?

It may seem like an exaggeration to claim that the hustle and bustle of cities is caused by annual crops, but if you look closely enough you can see the striking parallels between the rapid growth of annual plants and the rapid growth of human populations. The direct parallels between the 30-, 60- and 100-fold increases in seed yield when the biblical sower casts seed on fertile ground, and the double-digit growth in earnings deemed necessary for shareholders of corporations as the economy expands infinitely upon a finite globe. Some might also see the parallels with the rapid death of the annual plant at the first sign of cold weather in the autumn or upon the shortening of day length. When resources aren't what they once were, the annual plant and the annual economy simply give up and crash. An abundance of seeds are harvested, to be measured out to the hungry population while the kings and queens of the day hoard the abundance. In the springtime, the cycle is begun again with a stimulus package of new seed, scattered upon the decay of the previous bust in a boom-bust economic cycle of annual civilization. The annual plant pattern ripples through all that we do and as we shall see in later chapters, the pattern of ecosystem destruction from the planting of annual crops for the enrichment of the few and enslavement of the masses, always ends in the collapse of that society.

What would the world be like, I thought, if we based our culture on perennial plants, rather than annuals? What if we imitated nature and designed perennial ecosystems intended to be rich, abundant habitats for humans and non-humans alike? I had no way of escaping the emerging global monoculture, so I sought to create an alternative in its midst and connect with others when I found them. Like a shoot of crabgrass sprouting in a crack in the freeway, I sought to make a change using the power of one. Here it was, a different time and in a different place, but I sought the same thing as Henry David Thoreau. In his seminal work *Walden* he wrote:

> I went to the woods because I wished to live deliberately, to front only the essential facts of life, and see if I could not learn what it had to teach, and not, when I came to die, discover that I had not lived. I did not wish to live what was not life, living is so dear; nor did I wish to practice resignation, unless it was quite necessary. I wanted to live deep and suck out all the marrow of life, to live so sturdily and Spartan-like as to put to rout all that was not life, to cut a broad swath and shave close, to drive life into a corner, and reduce it to its lowest terms, and, if it proved to be mean, why then to get the whole and genuine meanness of it, and publish its meanness to the world; or if it were sublime, to

know it by experience, and be able to give a true account of it in my next excursion.

Thoreau was definitely an inspiration to me as I sought to resolve the dilemma I faced. Thoreau, the son of a wealthy factory owner, walked away from upper-middle class society in Massachusetts to squat some land near the railroad tracks in then rural Concord, Massachusetts. His story of building his own shelter, studying nature, writing and growing his own food has been an inspiration to generations of Americans and, at least when I was in school, was intended to laud the do-it-yourself, entrepreneurial American spirit. His courage to swim upstream against the social, family and peer pressure of his day, his love of the natural world, and his self-reliance were indeed an inspiration to me, but where many of my contemporaries admired the fact that he grew beans and potatoes as well as a variety of other vegetables, I was appalled that even our great American cultural hero Henry David Thoreau had to resort to burning grasslands, flipping the sod upside-down and scratching in the dirt in order to grow his food. Of the time he spent at Walden, the greatest number of hours he spent were required to earn his calories. Here was one of the greatest American naturalists, who when placed into a natural environment, had to destroy it in order to eat. This did not sit well with me.

As I wrestled with this cosmic dissonance, I happened upon three life-changing books. All three of them were written by authors who, like me, wrestled with the course that humanity is on and all three worked within the confines of their own life to make a difference, no matter how small. Each of them were like blind men feeling one part of the elephant. They knew with an inward, perhaps not-so-silent yearning, what they were striving for, and each one of them worked tirelessly toward it for the remainder of their days. Each one of them imitated Thoreau’s pattern in that they left the familiar territory of what others expected of them, and they forged a new path.

I encountered the first book when I was an engineering student for the first time living in the big city. The college I attended was far enough away from home for me to feel free, yet close enough to return occasionally for a home-cooked meal and to do my laundry.

This first book I read that changed my thinking was an older one, originally written in 1929 by J. Russell Smith and was titled, *Tree Crops: A Permanent Agriculture.* Smith has often been described as a “practical visionary” and as a USDA geographer, he traveled the United States and the globe. In *Tree Crops* he reported on soil erosion that he had observed in China, the Middle East, North Africa and in the United States. He cited USDA documents that described the rates and extent of soil erosion across America’s breadbasket. In a later 1950 edition of *Tree Crops,* he reported on one of his travels where he related the following tale of a view from the Great Wall of China.

> The slope below the Great Wall was cut with gullies, some of which were fifty feet deep. As far as the eye could see were gullies, gullies, gullies — a gashed and gutted countryside. The little stream that once ran past the city was now a wide waste of coarse sand and gravel which the hillside gullies were bringing down faster than the little stream had been able to carry them away. Hence, the whole valley, once good farm land, had become a desert of sand and gravel, alternately wet and dry, always fruitless. It was even more worthless than the hills. Its sole harvest was now dust, picked up by the bitter winds of winter that rip across its dry surface in this land of rainy summers and dry winters.
>
> Beside me was a tree, one lone tree. That tree was locally famous because it was the only tree anywhere in that vicinity; yet its presence proved that once there had been a forest over most of that land — now treeless and waste.

Not long after his trip to China, Smith traveled to Corsica where he observed an entirely different scene. The contrast of China to Corsica is remarkably similar to the contrast of the American Corn Belt to New Forest Farm in Ash Ridge, Wisconsin. In fact it is a parallel and more. Here is what Smith wrote in *Tree Crops* of Corsica,

> Across the valley I saw a mountainside clothed in chestnut trees. The trees reached up to the place where coolness stopped their growth; they extended down the mountain to the place where it was too dry for trees. … This chestnut orchard (or forest, as one may call it) spread along the mountainside as far as the eye could see. The expanse of broad-topped, fruitful trees was interspersed with a string of villages of stone houses. The villages were connected by a good road that wound horizontally in and out along the projections and coves of the mountainside. These grafted chestnut orchards produced an annual crop of food for men, horses, cows, pigs, sheep and goats, and a by-crop of wood. Thus, for centuries, trees upon this steep slope had supported the families that lived in the Corsican villages. The mountainside was uneroded, intact, and capable of continuing indefinitely its support for the generations of men.
>
> Why are the hills of western China ruined, while the hills of Corsica are, by comparison, an enduring Eden? The answer is plain. Northern China knows only the soil-destroying agriculture of the plowed hillside. Corsica, on the contrary, has adapted agriculture to physical conditions; she practices the soil-saving tree-crops type of agriculture.

My life was changed. At the time it was in the fall of the year and my parents’ gardens overflowed with an abundance. The cool mornings warned of the winter to come and were reflected in the cool crispness of apples fresh from the trees. The September sun warmed the dark skins of grapes hanging in profusion and the sweet peach flesh preserved golden memories of summer. It was time to gather firewood for winter, and as I did so, the trees had new meaning for me. The slave labor of the hot and sweaty summer garden was immediately contrasted with Smith's descriptions of Corsica, and I knew that I had found a piece of the puzzle.

As a way to counter the loss of topsoil and to reverse the ruin caused by annual agriculture and the plow, Smith proposed what was a radical idea at the time (and unfortunately still is today!). Since some 40-60 percent of all annual grains were fed to livestock at the time, he proposed harvesting tree seeds to replace the grains being fed to the livestock. Why plow highly erodible lands to grow corn and create gullies, when chestnuts, mulberries, honey locust, walnuts, mesquite (kiawe), pecans and more could be grown?

In addition to chapters describing these useful feed-producing woody crops, Smith also included descriptions of systems that fall under the rubric of agroforestry. (These I will address in a later chapter.) *Tree Crops* was *one* piece of the puzzle that I was searching for, but like Thoreau, Smith also assumed that annual agriculture was a given. He merely wanted his oatmeal to be grown on flat ground.

The second book that caught my attention was *The One-Straw Revolution* by Masanobu Fukuoka, a Japanese natural farmer. In *Tree Crops,* Smith described simple systems such as mulberry trees planted in pastures for pigs to consume or walnuts grown in groves with cattle grazing beneath. His systems had a certain "neatness" that was typical of his era when folks believed that humanity had everything under control and progress would continue forever (with everyone aspiring to be an American). Fukuoka, in contrast, embraced the apparent randomness of nature. He believed that nature alone was perfect and that anything that humans could do would only detract from the perfection of nature. His goal was to develop "do nothing" farming (which certainly appealed to me!). He had walked away from a career in plant pathology research in order to develop his natural farming techniques and at the start he was met with disaster.

Chestnuts — grain from trees!

After Fukuoka took over the management of some of his father's carefully pruned citrus orchards, he let them grow rampant. The ensuing tangle promoted disease and insect eruptions and the entire orchard had to be destroyed. The systems that he replanted were "wild" from the start. A diversity of tree species were planted and they remained unpruned. In doing this he learned that trees that began their "orchard" lives unpruned never needed to be pruned — they thrived and produced good fruit. What was unique about his systems was that in addition to growing fruit trees, he also grew a mixture of plants as an understory planting. His plants included clover to accumulate nitrogen, but it also included an assortment of what were typical garden vegetables in Japan — daikon radish and other root crops, squash, onions and soybeans. He scattered the seeds randomly in the orchard in the theory that the plants would survive when they found the proper growing conditions. Once the plants were growing, he would let them re-seed naturally. Over time patches of naturalized vegetables could be found growing throughout his orchards.

This was nearly revelatory for me. As I gathered firewood I imagined how I would modify the forest canopy in order to let in more sunlight and what would happen if I pushed my parents vegetable garden in, under and around the trees. By looking first at the garden, and then into the woods, I was able without too much effort, to visualize what such a Fukuoka system might look like using the existing woods. I would leave all the trees standing that produced food or feed, and remove the ones that didn't. In the gaps left by the removed trees I could imagine squash, pumpkins, peppers and tomatoes. What a riot of abundance I could create. But could I produce my own *food* in such a system? Fukuoka couldn't. He also relied on annual grains with rice, of course, being the primary grain and barley being a secondary grain. Although Fukuoka relied on grains, he grew them in a radically different way than anybody else. He did not grow his rice in the typical paddy style. He grew grains organically without tillage. This was the "revolution" he referred to in his title. How he accomplished this was by pelletizing his seed in little clay balls, then broadcasting them across the field. He would plant rice into an already growing crop of barley and then he would broadcast barley into an already growing crop of rice. Weed control was accomplished during the rice part of the cycle, by flooding the field long enough to drown the weeds.

It was because Fukuoka did not plow, and it was because he returned the straw from each crop back to the field, that he was actually able to "grow" topsoil. Each year the straw layer would decompose at the soil surface in the same way that would happen naturally in a grassland, and each year additional minerals were brought to the site from the clay that coated his seed.

His system was extremely labor intensive. Although the engineer in me thinks that it would theoretically be possible to build the machinery to accomplish what he did with labor, we have no idea, really if this type of grain production could be done on a large scale; large enough to feed the cities, for example. Fukuoka's system was critically dependent on periodic flooding which, obviously, required access to huge quantities of water and obviously required rice as one of the grains. The system simply wouldn't work for oats and wheat, or beans and corn. The Fukuoka style of grain production, is only possible where it is possible to grow rice. Both his grain production system and his woody crop production system are only possible in areas with a large labor force. The randomness of his woody crop systems would rule out equipment use. So I was forced to search for more solutions. How could we grow our staple food crops in perennial ecosystems in such a way that did not require what I considered to be excessive labor?

Doing some mental pondering, I thought about combining Masanobu Fukuoka's citrus production system with J. Russell Smith's "two-story agriculture." I knew the direction that *my* Thoreauvian experiment would take. It was about the time when I thought I had a pretty good idea of how I would implement my "Masanobu-Smith-Kuoka" techniques, that a friend of mine introduced me to permaculture.

Permaculture! The word has a way of joyously bubbling off the tongue. Somehow it feels right and is easy to say. Permaculture, the word, was coined by Australian Bill Mollison and was originally meant to be a contraction of the words "permanent" and "agriculture." Like Fukuoka, Mollison was a disaffected natural resources professional working for the Division of Wildlife, the Inland Fisheries Commission and university system. When the green revolution of the chemical fertilizer, pesticide and herbicide industry hit Australia full-force, Mollison was given orders to promote its widespread adoption. Growing bulk commodities intended for the export market (which profited only the corporate coffers) was the wave of the future. In Australia, as it was in the United States, "get big or get out" was the mantra chanted to farmers. Mollison refused to comply. If feeding the world's hungry was one of the reasons why farmers were supposed to grow bloated quantities of cheap grains supported by carcinogenic chemicals, then why weren't officials promoting small-scale backyard gardening which has shown in study after study to produce more food per acre than broadscale grain farming? Why weren't techniques that could be practiced by the starving people themselves being promoted? The environmental destruction caused by large-scale agriculture's arsenal of chemical weapons and the oxidizing, erosive power of the plow were an anathema to Mollison. The downstream effects of cheap grain exports on the starving populations created dependencies upon international food aid and disempowered the already powerless. To Mollison, this was socially unconscionable. He felt that we should be teaching people how to create their own fishing poles instead of giving them fish that were tied to unjust international trade agreements. Mollison resigned his position and began one of the world's largest and most revolutionary environmental and social movements anyone has ever seen.

Beginning in the mid-1970s Bill Mollison and David Holmgren began to record their thoughts on "permanent agriculture" and what that might look like. Unlike other agricultural systems, whether biodynamic, organic or otherwise, Mollison and Holmgren were not ashamed to found their entire work on an ethical standard. Permaculture begins and is undergirded in its entirety by a triumvirate ethic, which many call the "prime directive." Permaculture is the only type of agriculture that can possibly lead to a permanent culture, and neither is possible without a foundational ethic of earth care, people care, and an equitable distribution and recirculation of resources.

Care for the earth, its natural systems and processes is still seen by the closed-minded, selfish and ignorant, as anti-human, a luxury, and at odds with economic growth. Nothing could be further from the truth. It is the natural systems of this planet that create the air we breathe, water we drink and the food we eat. Natural systems and natural processes recycle our wastes and incorporate them into other life forms. Everything that we need as human creatures on planet Earth is totally dependent on the natural systems of the planet itself. Permaculturists understand as a given, the truth that if we don't take care of our planet and its living systems, the planet won't take care of us.

Care for people is also essential and tied directly to the first ethic. If we don't take care of human beings, if we have people who are starving, living with chronic disease, and living in constant want, we have social problems that boil over beyond those immediately affected. Social, economic and government collapse in African, Middle Eastern and Asian countries are all a direct result of inequitable distribution of resources. People in want, and people in need develop bad attitudes and have a historical record of taking up arms, and not necessarily against the cause of their problems. Prejudicial scapegoating is as common as warfare against exploiters. Warring neighbors, tribes and nations tend to be too preoccupied with their conflict to care for the planet. Our agricultural capacity is degraded during times of war. Natural vegetation gets bombed and burned, water and energy distribution infrastructures get destroyed. If we don't take care of the basic human needs of people, we get countries like Somalia, Haiti and Afghanistan. If we don't care for people, people can't care for the earth. If we don't take care of the earth, it won't take care of the people.

The third ethical pillar of permaculture is woven together and interdependent with the other two — equitable distribution of resources. Earth care and people care can only occur if the basic human needs of a population have been met. Undercompensated populations trend toward social unrest, strikes and rebellions. Deprived populations trend towards revolution. In both cases, care of the earth is far from the consciousness of most people because the "prime directive" of those that are hungry becomes providing oneself with the basic necessities of life. When economic systems are designed so that they result simultaneously in abject poverty and superfluous wealth (oftentimes existing side-by-side on the other side of a locked gate) problems arise that are destructive to the entire system, and not just to the individuals involved. It doesn't matter whether the rich or poor are conservatives or liberals, wealth and poverty separated by a gate only leads to trouble.

As Mollison and Holmgren developed their ideas about permaculture beyond a mere ethic, they studied natural patterns and indigenous or "traditional" cultures around the globe. Observation of natural patterns, they postulated, would reveal how certain processes are accomplished in the natural world. A branching, or dendritic pattern, for example, is apparently the pattern that is revealed when "resources" (energy or materials) are gathered together much as in the way small streams come together to make ever larger streams, then rivers. The water, its nutrients and mineral sediments are gathered together from the higher land elevations and sent downstream. The same branching pattern can be observed in river deltas when a single large river then divides up into smaller and smaller channels as it distributes its gathered load. Nature gathers, transports and distributes energy and material in dendritic patterns. It does so free of charge and with no expenditures of fossil fuels.

If human beings were to design our farms, gardens, homes, towns and cities after the patterns of nature, we should, in theory, be able to accomplish the same processes with the same efficiencies as nature. If we design our food production systems after natural ecosystems they should, in theory, show the same resistance to pests and diseases. They should be able to conserve and create new topsoil and they should increase in fertility, just like nature.

By studying indigenous and traditional cultures, Mollison and Holmgren hoped to learn how people actually were able to feed themselves before the advent of the modern-day food system. How did cultures survive in resource-poor environments? What cultural and social forms might exist in overlooked societies that might prove to be useful and be worthy of preservation? How might the clarity of scientific thinking be used to create a harmonious blend of the natural, the traditional, and the futuristic?

For me, permaculture was exactly that — a blending of nature, tradition and scientific knowledge in order to create an ecologically sound and socially just human culture. With permaculture we can design our own habitats, patterned after nature itself. We can re-create the vibrant abundance known by our grandparents and great-grandparents. Using permaculture design principles we can create living systems that, in Bill Mollison's own words, are "ecologically sustainable and economically profitable.” Like J. Russell Smith did, we will create these systems using perennial food crops with a strong reliance on long-lived woody crops much like the chestnut groves of Corsica. Like Masanobu Fukuoka, we will defer to nature for our patterns and guidance, because natural living systems are the most proven production systems that exist. Natural ecosystems have been thriving for eons on planet Earth and have been doing so through dozens of cycles of global warming and ice ages. Natural systems have been fully functional and promoting *life* for as long as they have been around and they have done so without the use of fossil fuel inputs, without the use of fungicides, pesticides and herbicides. They have transformed the bare, exposed rock of continental uplift, the gravel of alluvial outwash and pyroclastic debris into rich, verdant ecosystems with topsoil that increases in thickness through time. Natural processes as a longterm trend have always led toward increased species diversity and optimized population density.

Permaculture, the intentional design of perennial agricultural, social and economic systems brought a clarity of thinking to my own personal wrestling with humankind’s big problems: environmental degradation, food security, health and social justice. Permaculture helped me to unify two parts of my educational past (ecology and engineering) and to bridge gaps between seemingly opposite environments such as the garden and the forest. Permaculture helped me to draw a big circle around everything I knew or had been taught, and if there was something that didn’t fit into my understanding of the world it was my understanding that was at fault and not the world. It was the perspective that I gained while standing on the backs of giants such as J. Russell Smith, Masanobu Fukuoka and Bill Mollison, that allowed me to actually *see* a future. A future that is dramatically different than a mere projection of the present forward into time — a frightful proposition for the most part. This perspective allowed me to see a future described and written about by J. Russell Smith, a vision of beauty and pragmatism needed today as much as in his time.

> I see a million hills green with crop-yielding trees and a million neat farm houses snuggled in the hills. These beautiful tree farms hold the hills from Boston to Austin, from Atlanta to Des Moines. The hills of my vision have farming that fits them and replaces the poor pasture, the gullies, and the abandoned lands that characterize today so large a part of these hills.
>
> The unplowed lands are partially shaded by cropping trees — mulberries, persimmons, honey locust, grafted black walnut, grafted heart nut, grafted hickory, grafted oak, and other harvest-yielding trees. There is better grass than covers the hills today.
>
> The trees would produce food for both people and for foraging animals, protecting the slopes while increasing their yield.

With the vision of a rich, abundant, paradise ecosystem in our minds, let us stand tall and walk toward that future with tree seedlings at hand. The following chapters will tell how this was accomplished by one individual and how we can accomplish this across our nation and across the globe.

CHAPTER 4

Challenges Facing Agriculture

WHETHER we like it or not, the human species is facing some fairly extreme crises. These have been felt in places around the world in the years since I pushed our family car in a gas line during the oil embargo.

Even today many challenges proliferate. Rather than belabor the point and give the impression that this is just another "doom and gloom" literary exercise, I will focus here on positive change. In this book I propose a rapid successional change of our agricultural methods — as quickly as possible. In order to accomplish this rapid transformation, however, we *do* need to remind ourselves of some of the situations that we face as we undertake the task of changing the face of agriculture.

There are at least a half dozen urgencies that humankind faces that we must not and eventually cannot ignore. I mention several of them here merely as a reminder of how important our task is and to illuminate some of the conditions under which we will be working.

PEAK OIL

Crude oil, according to 99 percent of scientists is *not* a renewable resource. It is finite. It *will* run out. Whether that happens in 5, 50 or 100 years — it will run out. Running out of oil isn't the most immediate problem that our dependence on a finite resource has caused. A mere leveling off of global oil extraction coupled with an increase in demand spells trouble. Our entire global economy runs on oil right now. Anytime supplies drop and demand increases, prices skyrocket. Increased fuel costs will ripple throughout the entire economy creating potentially erratic fluctuations in the price and availability of approximately, well … everything.

Today, as we design and establish our perennial agricultural ecosystems, we have the use of relatively inexpensive fossil fuels. This may not always be the case, in fact one of the primary design criteria for our perennial agricultural system is that they produce a net surplus of useable energy. Rather than taking arable cropland and putting it into biofuel production (which, it is argued, will leave those who are economically disadvantaged short of food) we will create cropping systems that are designed to harvest the energy of the sun from niches not currently occupied by food-producing plants. Biomass researchers have shown that short-rotation woody cropping systems (SRWCS) are able to capture three to seven times the energy per acre as an annual crop field. Many of the perennial agricultural ecosystems that I will be mentioning here are, in fact, short-rotation woody cropping systems, although they are not dedicated solely toward biomass energy production. Since our ecosystems won't rely on monocrops of hyperactive willows and poplars, they most likely won't approach seven times the energy capture of an annual crop field, but that is a goal which we can all work toward.

Crude oil is a remarkably convenient medium for stored energy. It is easily extracted, transported and stored. It is relatively concentrated. Even in its unrefined form it is quite uniform and predictable. The stored energy in crude oil can be released and used in several different ways, the most familiar, of course, being combustion. It can be burned directly for heat or light, used for transportation fuel, or to run generators for electricity, and more. Energy in natural systems, however isn't so convenient. The energy captured in our ecologically designed agricultural systems comes in various forms. It will also come in a far more diluted form than crude oil. Intentionally designed agricultural ecosystems have the ability to capture the same amount of food calories per acre with the extra three to seven capture rate being used for electrical generation, the heating of buildings and transportation fuels. This will be covered in detail in later chapters.

Right now we live in an age of inexpensive fossil fuels. Their availability and costs are not known into the future, so we will be designing systems that are energy independent and net energy exporters. Former petroleum industry analyst Jan Lundberg puts it this way, "The nation and most of the rest of the world is chasing a technofix instead of adjusting to ecological/economic reality."

Restoration agriculture is a massive-scale culture-wide adjustment to ecological reality that will create a new economic and social reality.

GLOBAL CLIMATE CHANGE

There are certain measurable facts that are undeniable concerning the global climate. Carbon dioxide (CO_2) levels in the atmosphere are at the highest levels that have ever been measured since humans have begun monitoring atmospheric carbon dioxide. Globally, lake ice forms later in the fall and melts earlier in the spring all across the northern and southern latitudes. Northern polar ice is no longer attached to shore in the summer time and Antarctic ice sheets larger than several small American states have been photographed as they have broken off from the mainland or crumbled into slush. To argue whether climate change is human caused or not is about as pointless as arguing about who made the fiddle that was played while Rome burned. (The fiddle, as it happens, was not invented until several hundred years after the fall of Rome.)

Carbon dioxide levels are the highest ever recorded. It is time to make significant steps to reverse our emitted levels of atmospheric carbon. Perennial woody cropping systems by the nature of the plants involved, take carbon dioxide out of the atmosphere. That carbon dioxide is stored in long-lived plant tissues, most obvious being the wood and roots. As leaves and root hairs grow and die, they contribute their organic matter to the soil. An increase in soil organic matter from 1 percent to 4 percent may not seem like much of a change, but when measured over the 442 million plus acres of cropland in the United States, is in fact a huge quantity.

An acre of topsoil one inch deep weighs approximately 286,000 pounds. Increasing the organic matter level in this top one inch of soil from 1 percent to 4 percent would take more than 50 billion pounds of carbon dioxide out of the atmosphere. Increasing the organic matter in the top foot of soil, or in the top *ten* feet of soil as is possible under perennial woody cover, would remove astronomically high levels of carbon from the atmosphere. Plants removing carbon from the air is, in fact, how the earth's vast coal deposits were formed.

Tillage oxidizes soil organic matter and is one of the top sources of greenhouse gases. Simply by not plowing ever again, we can eliminate this source of carbon emissions.

Another simple benefit of perennial agricultural ecosystems is that soil organic matter (carbon compounds) is oxidized every time the soil is plowed (or cultivated, or disc harrowed or….) simply by *not* plowing ever again, we can eliminate this source of carbon emissions.

By fundamentally changing agriculture's relationship with energy, fossil fuel use can be reduced and eliminated in our agricultural systems. Fossil fuel-derived energy used for heating and cooling buildings will be reduced and eventually reversed. Fossil fuels used for transportation purposes will be reduced at first simply because the work of annual cropping will be gradually reduced. Every year, since annual agriculture was invented, farmers have had to prepare the seed bed (by tillage or herbicide), plant the seed, eliminate weed competition (through cultivation or herbicide), harvest the crop, then dispose of the leftover debris by chopping the stubble, baling and removing it or burning it. Each one of these processes is one more pass across the fields with motorized equipment and aside from the one time when an actual harvest is made, none of the passes across the field harvests an economic yield. A well-designed perennial agricultural ecosystem has crops and livestock and the spatial arrangement of the landscape such that the management of one element in the system is accomplished by harvesting another. Mutually ben-eficial relationships are the key to a well-designed system. Just having the right pieces to a puzzle doesn't make it fit together and function smoothly. All elements of the system are designed to work together.

In annual agriculture 20 tons of topsoil per acre per year blows away in the wind and washes away in the rain.

When the number of motorized passes across a field is decreased, less fossil fuel is used. Even better, once fuels are produced on site, no more fossil fuel imports are needed. It is possible to design farms to be net energy exporters, producing their own electricity, space and process heat, and most significantly traction fuel.

In these few simple, but dramatic ways we can reverse agriculture's effect on atmospheric carbon dioxide.

There are other natural occurrences that are also related to climate change such as stronger and more numerous hurricanes and tornados. Greater frequency and higher amplitude droughts and floods are also related to climate change and are becoming the norm. Annual cropping systems simply do not have the resilience to withstand repeated assaults from flooding and other nasty weather. Perennial, natural ecosystems on the other hand have evolved to survive many millennia of assaults and still survive. Natural ecosystems have somehow managed to survive even our recent centuries-long industrialized assault using axes and saws, plows and herbicides. We had best imitate these ecosystems if we want to survive the extremes of our new climate regime. Annual crops simply cannot cope with massive, repeated, long-lasting damage. Neither can the cultures that depend upon these crops for their sustenance.

RESOURCE SHORTAGES

Agriculture in the United States is experiencing rapid topsoil depletion and aquifer decline. In areas that do not receive enough rain to sustain agriculture, water for crop irrigation is becoming increasingly expensive, scarce and legally uncertain. Take the Ogallala Aquifer, for example. The aquifer occupies a region of water-saturated soil and bedrock that covers approximately 225,000 square miles in the Great Plains region of North America. It underlies Texas, New Mexico, Oklahoma, Kansas, Colorado, Nebraska, and parts of South Dakota and Wyoming. The depth of the aquifer from the surface of the land has been increasing over time since it was first tapped for irrigation in 1911. This means that wells need to be drilled deeper and hence are more expensive in order to reach the water. The energy required to lift that water up from the depths of the earth has also increased, as has the pump and piping size needed, all of which increases the cost to irrigate crops. The Ogallala Aquifer is a major source of water for agriculture, cities, towns and industry in the High Plains area. Withdrawal of water from the aquifer has now greatly surpassed the rate of natural recharge. (Earth shaping for water retention and aquifer recharge is addressed in a later chapter.) Some places served by the Ogallala Aquifer have already exhausted groundwater as a source of irrigation water.

Another example of dwindling precious resources is the Central Valley of California. This valley is some 450 miles long and 40 to 60 miles wide. Historically, in places it has been an arid grassland and an outright desert in others. Almost 100 percent of agricultural production in the Central Valley is irrigated. This irrigated desert supplies nearly 10 percent of the food eaten in the United States. Dozens of dams capture the runoff from the Sierra Nevada mountains, nearly eradicating the historically abundant salmon runs. So much infrastructure is in place and water is such a critical resource that the California State Water Project (SWP) was formed to govern the use of water and maintain the infrastructure. The SWP is the planet's largest public water utility. Although currently 80 percent of the water within the jurisdiction of the SWP goes towards irrigation, conflict is on the rise. Advocates for threatened aquatic life demand sufficient water flows for wildlife and the rapidly expanding urban areas all exert continued pressure on this critical resource.

Humankind at present faces a growing urgency similar to peak oil in the form of a peak water crisis. The Ogallala Aquifer or the Sierra Nevada which feeds the Central Valley in California may never run out of water completely, but limits are being reached beyond which irrigated agriculture can no longer go. Fights will become more frequent over water rights for rivers that can't sustain current population levels. Already legal and political moves are being made to drain the Great Lakes as a water supply for a thirsty western region. Whether it happens in 5, 50 or 100 years, a critical point will come in American agriculture when there just isn't enough water to go around. We must design our agricultural ecosystems with this in mind.

In order for us to redesign agriculture with clear minds, we will need to do a couple of things. For one, we must admit that these problems are real.

We must stop the endless "blame game" and the pointless debate about whether these problems are human caused or not. We must leave the blame behind and admit our accountability, individually and collectively, for the problems we face. You and I didn't personally *cause* the depletion of oil, the disruption of the global climate, or the loss of water resources, but we are part of a system that collectively contributes to these problems. Our culture as a system is a significant factor in all of these problems, and it is that system that we must change around us from the top-down, bottom-up and inside-out simultaneously.

When we are willing to admit that our agricultural system is a significant cause of these problems, we have a chance to bring a fundamental transformation to agriculture.

In addition to admitting that our agriculture has a problem and *is* a problem, we must look creatively to the future, while learning from the lessons of the past. America must learn to ignore the distractions that keep us from grappling with the most significant urgencies, not the ones that are coming, but the ones that are here now. We have no time to lose. We have no real way of knowing what cataclysms are coming next. The most important thing that we can do is to design resilient agricultural ecosystems now. What is needed are ecosystems that are designed to produce our food, fuel, animal feed, medicine and fibers, and ecosystems that can do so without the use of fossil fuel technology, those that can tolerate extremes of weather and potentially changing climates, and that can thrive without supplemental irrigation from vulnerable and increasingly expensive public utilities.

We will also need to learn to adapt. Conditions will always be changing and we must be prepared to deal with whatever shows up. We must learn to be proactive in our solutions while simultaneously reacting to the crisis "du jour" such as the global financial downturn that started in 2008 or the 2010 Gulf of Mexico oil spill. We must begin making long-term, permanent change in a world of short-term thinking. In a world impatient for a quick fix we must continue to make the long, steady progress needed toward a rich, green, abundant world, started by planting one tree at a time and repeated over and over around the world.

CHAPTER 5

Turning Things Around

SCIENTISTS like to divide the world into *"this"* and *"that."* This kind of thinking has insinuated itself into our everyday thinking and in turn affects how humankind views the world around us. Although science is based on observation, accuracy and repeatability and has brought us so many marvels and wonders, tools and toys, the scientific division of reality into separate categories whether it be the measurement of time, the description of species, or the description of habitats, does not always reflect reality. Scientists generate a concept by formulating hypotheses to be tested and either verified or denied. A concept is a human-created idea formulated to hopefully explain and to help us understand actual reality. The idea is *not* the reality just the same way that a GPS is *not* the road and a map is not the territory.

Once upon a time, human beings didn't have any concept of gravity. The very real phenomena that we now call gravity, of course existed. When a youngster 3,000 years ago jumped off a rock he or she came tumbling down like you or I would today, but there was no clear intellectual idea, no concept of what made that happen at the time.

It wasn't until the 15th or 16th century that "natural philosophers" such as Galileo began to devise experiments to test this phenomena and it wasn't until the late 1600s that Sir Isaac Newton devised the inverse-square law of universal gravitation. Galileo and earlier researchers explained that gravity was a force that sucked an object downward to the earth, whereas Newton's new theory could mathematically calculate that objects in relationship to one another exert a gravitational attraction between them, the strength of which is related to the total mass of each object. Galileo's force theories and Newton's law of universal gravitation are *concepts* used to describe the phenomena of gravity. They aren't gravity itself. Modern astrophysicists have, of course, thoroughly revised and modernized Newton's theories so that now gravity can be measured so accurately that it can be shown to occur as the bending of the space-time continuum as planetary objects whiz around through the cosmos like bowling balls, golf balls and marbles in a three-dimensional elastic fluid. No matter how accurately scientists or philosophers measure and calculate gravity and its effects, they still have no idea what gravity actually *is.* No matter what the explanation is, if a child falls out of a tree, they will go *thump* on the ground and will run off crying.

The dissection of reality into discreet little bits and the mistake of perceiving the concept as the reality, doesn't always serve us when it comes to understanding the natural world around us and definitely has not helped us to develop an ecologically sustainable agriculture.

There was a time in human history, somewhere between the late Pleistocene epoch and the early Holocene epoch when it could be argued that it was the Age of Mammals. Even that would be a concept, though and would exclude the fact that the animals ultimately depended on plants for their food and so the Age of Mammals would naturally have to have been the "age of the habitat that supported mammal abundance."

The Pleistocene epoch, according to scientists, began approximately 2.6 million years ago and was distinguished by the fact that it experienced a total of eleven major ice ages. Scientists draw a line at the end of the last ice age and call the period after this Holocene, which scientists claim began around 12,000-15,000 years ago.

Reality drew no lines between the two time periods, of course. There was merely a long period of time on planet Earth where the climate got colder, glaciers expanded, and the result was what we call an "ice age." Whenever global ice cover expanded, the living mantle of green plants that cloaked the land would get covered in snow and ice, the mountainous bones of the earth would get ground to dust and habitat for terrestrial animals would shrink dramatically. Populations of animals would decline. Some would thrive under the new conditions, others would become extinct. As the climate warmed toward the end of a glacial maximum, plant communities would begin to expand. Bare rock would become exposed and become colonized by lichens, ground rock known as glacial "drift" would become colonized by windborne seeds such as fireweed, cottonwood and willow and in other places windblown glacial dust known as loess would cloak the earth.

All of these three scenarios are but concepts we use to describe the fact that there was less ice and more available land. With more of the earth's surface exposed there were more sites available for colonization by plants. Less water locked up as ice meant more available moisture falling as rain and melting glaciers meant more rivers flowing into an expanding sea. More land and more plants meant more animals. Once again scientists' compulsions to draw discreet little lines between this time and that time, don't necessarily serve us all that well. According to geologists' timelines there was the Pleistocene epoch, then in 11,800 BCE it became the Holocene. That's not how it happened in reality, though. The transition from a glacially dominated global climate to an "interglacial period" took thousands of years. It is during those thousands of years that there was a population explosion of mammals worldwide. One of which was modern humans. We were one member in the mammal boom, and we were direct beneficiaries of the ecosystem abundance that supported that mammal boom.

Arguably, the richest, most abundant ecosystems that human beings have ever experienced were those present during the boundary years of the late Pleistocene and early Holocene epochs. Suffice to say, this was a long time ago. Planet Earth had recently begun to emerge from the latest ice age which had quite an invigorating effect on life worldwide. Anyone who has been to the toe of a glacier has seen in microcosm what occurred on a massive scale worldwide at the end of the last ice age. Glaciers pulverize everything in their path, crushing entire mountain ranges, then slowly (glacially slow) blending these "bones of the earth" while grinding them into finer and finer particles. Glaciers grind the mineral rock into such fine powders, that in many places this glacial rock dust stays in suspension in water, giving glacial lakes an otherworldly turquoise blue color.

As the glaciers of the Pleistocene retreated, or just as commonly melted right in place, they left behind billions of tons of pulverized rock. Some of these minerals were ground so fine that they blew with the wind and traveled to parts of the earth untouched by the ice itself. Other ground rock was left in place. Much of it, affected by differential melting and freezing and some of it blown by the wind, moved around like sand dunes or snow drifts. In fact one name for such glacial debris is just that — drift. Other crushed rock was left behind in tear-shaped features known as drumlins, or was transported by rivers and deposited as eskers, kames and alluvium. On a continental scale, crushed rock, gravel and sediment, was exposed to the elements and became available to be colonized by plant life. It was this mineral-rich substrate that provided the nutritional foundation to the largest abundance and diversity of terrestrial life ever known to human beings.

Abundance didn't happen overnight, however. It all took time — a long time. It's actually still going on. The debris at the toe of the Matanuska Glacier in Alaska, north of Anchorage, for example, still isn't totally vegetated, though after thousands of years the bare, lifeless drift has gone through a remarkable transformation. Like a multicolored, magical, swirling cloak, the plant and animal communities have developed over time. This dance, the advancing and retreating process of change in the plant and animal communities, is known as "ecological succession."

SUCCESSION

Ecological succession is defined as the more or less predictable and orderly changes that occur in the kinds of species that exist in a place over time. The drift at the toe of the Matanuska Glacier, for example, first became colonized by mosses, lichens and annual plants, such as the beautiful flowering fireweed that appears on river banks and sandbars all across northern North America. These hardy denizens of the exposed soil of this rugged terrain, live their lives and eventually die leaving their bodies behind to decompose and enrich the newly accumulating soil with their mineral-rich bodies.

One member of this amazing colonizing group, the lichens are a miraculous organism. They have a symbiotic relationship between two separate organisms, an algae and a fungus. They require no soil whatsoever in order to survive and will grow on the bare face of cliffs, the concrete foundation of bridges and buildings, or on the bark of trees. They're not picky. The algae photosynthesizes, creating sugars seemingly out of nothing. Using sunlight as its energy source it manufactures carbohydrate chains literally out of thin air — using carbon, hydrogen and oxygen from the atmosphere. It produces a tiny surplus of sugars that are used to feed the fungal half of itself. The fungus in turn uses the sugars as an energy source and goes about the business of slowly dissolving the minerals in the rock beneath it, and incorporating them into its body. The lichen gets its minerals from the fungus portion of itself in order to support the photosynthetic algae portion of itself. In this way, the bare rock of planet Earth is incorporated into biological organisms. These bio-available minerals now become the nutrients that will be used throughout the entire complex of life that will colonize the site through time. Slowly, the bodies of these simple plants accumulate and are decomposed by free-floating fungi and bacteria to become rudimentary soil. Nature is the ultimate recycler, and the minerals that were rock not so long ago now become available for other plants that have more exacting soil requirements.

Following lichens and mosses (the bare rock colonizers) are the rugged, annual plants. They grow fast, put down fairly elaborate root systems, and produce copious amounts of hard, durable seed. Thus, over time, mosses and lichens gradually become less prevalent and annuals, especially the annual grasses, come to dominate the site. Eventually, unless there is some sort of disturbance to set the process back in "successionary" time, annuals are eventually outgrown and overgrown by perennials. The vast perennial grasslands of the steppes and prairies are all that remain of the vast Holocene early successional grasslands.

As time goes on, these grasses too will die and contribute the organic matter of their roots and stems to the increasing thickness of a genuine topsoil layer. It is the process of ecological succession that creates soil. It is the march of plant and animal communities through time that continually add their mineral-rich bodies and excreta to the accumulating layers of soil where there was once only rock. When an area undergoing ecological succession is in the phase where soil is accumulating and increasing in thickness, that area is in a state of what is called aggradation.

In this state nutrients are accumulating, soil organic matter is increasing, the mineral availability in the soil is increasing, species diversity is increasing, and the entire system is growing toward health and abundance. Part of the richness and abundance of a successional grassland is its animals. Grazing animals have always thrived where there are grasses and broadleaved plants. It might easily be imagined that it was in the vast herds of early Holocene grassland animals, that humans found the species that were eventually bred to become domesticated livestock, but that's not entirely the case. Only the horse is a true grasslands species. Humankind's primary domesticated animals were all to be found in the next successional phase of ecosystem development.

New Forest Farm in Viola, Wisconsin in the "successional brushland" phase of succession. Crops include hazelnuts, chestnuts, raspberries, mulberries and livestock.

Anyone who has seen an abandoned lot, agricultural field or even an older highway median strip, has observed coarse, woodier plants that have come in and become established in a formerly 100 percent grassy area. Marching in are goldenrod, milkweed and thistles, along with cottonwood, willow and aspen. Many of these plants have seeds, tufted with a downy parachute, that float into the grassland and start to grow after they manage to find a patch of exposed soil. Other windblown seeds such as elm, ash, box elder and hornbeam blow into the grassland and begin to change its character. The old field will become "scruffy" with brush as woody plants, trees and shrubs begin to dominate the site. Browsing animals will keep some woody plants in check by nibbling branches, stripping their bark or snapping whole stems. Their dung becomes loaded with undigested seed (often honey locust, apples, plums or cherries) that replants the very system that fed those browsing herds.

Seeds from cane fruits such as raspberries and blackberries are excreted by fruit-eating birds — fruit being a plant's way to trick animals into dispersing their seeds for them.

It is this successional "brushland" that is the birthplace of humankind's domesticated animals, and in fact has been shown to be the original homeland of *Homo sapiens* itself. This brushland is a savanna, a rich, luxuriant grassland punctuated by drifts of brush, fruits, nuts and berries. The savanna biome, as this successional stage is called, is the terrestrial ecosystem that supports the most animal life of any other system on the planet. The savanna is the second richest biome on earth (behind tropical and sub-tropical moist broadleaf forests), but on a pound-for-pound basis more mammals can live in a savanna than anywhere else on earth. (Aquatic biomes, the oceans, lakes, rivers and especially estuaries, are the all-around top-producing biomes on the planet, and represent a future wave of restoration agriculture.)

All one needs to do is to imagine a National Geographic program on the African savanna in order to visualize the abundance of life found in early successional brushland systems as the ice age of Ragnarok faded into the mythological past.

Cows, goats, sheep, pigs, and poultry, are all domesticated savanna species. The savannas are such richly abundant systems that they even supported the largest land mammals ever to live on planet Earth, members of the family Elephantidae — mammoths, mastodons, African and Asian elephants and close to a dozen other proboscideans. Some species, such as the Woolly Mammoth, spent nearly all their time in the grasslands, rarely venturing into wooded areas, while other Elephantidae were the land managers, the "disturbance regime" that maintained the savannas of the world as an open woodland, or a brushy prairie. It was the elephants that helped to create the scenery that modern humans instinctively associate with abundance and well-being. That being a golf course-like landscape. Savannas are a community of flora and fauna, the biome that can provide the widest variety and the highest abundance of species that can be used as food for human beings.

There is more total photosynthate available for "consumers" in savanna systems, one of the many reasons why savannas support more mammals than any other biome.

If there ever was a definite line between epochs of time, one would have to draw the line between the pre-human and post-human world. Humans were born into the savanna and it was there as hunter-gatherers that they did indeed go forth and multiply. Archeological evidence has shown that everywhere that human beings went, within 1,000 years of their entering a new territory, there was a precipitous extinction of the megafauna. Through hunting pressure, habitat encroachment and possibly disease, everywhere that the modern *Homo sapiens* went, the massive herds of wildlife coincidentally disappeared. It was quite possibly the extinction of the megafauna that caused humans to stay put one year and live next to that patch of wild emmer or teocinte, the ancestors of wheat and corn. One year led to another. Seeds from the wild grain patch were saved and sown elsewhere and more grain was grown. More grain meant more food which meant more energy and larger families which soon meant more mouths to feed which necessitated more grain which necessitated slashing and burning more land, destroying the habitat around them in order to expose the bare soil to receive the seeds. The strategy of habitat destruction in order to plant annual grains, has led to geometric population growth which has led to more habitat destruction and eventual the collapse of society every time it has been employed. Perhaps it's time to employ a different strategy.

The savanna biome is the richest in animal life for several reasons. Probably the most significant reason is that it has a deep, textured structure where plants can absorb gases from a thick portion of the atmosphere and maximize the surface area exposed to the sun. From the tallest trees reaching over a hundred feet up in the air, to the smallest ground-dwelling plant, the entire biome is bathed in sunlight. Sunlight is the ultimate energy source for all agricultural systems and crops are merely vessels of stored sunlight.

Farmers and ranchers are actually in the solar energy collection business. Some grow plants, which use the sun to manufacture carbohydrates, proteins and oils. Others feed the stored solar energy in plants to animals where part of it is used in animal metabolism and some is converted into the animal products consumed by people. Since farmers and ranchers are in the business of capturing solar energy, wouldn't it make sense to utilize systems that have as large a surface area as possible in order to capture as much sunlight as they can?

Here's a demonstration to explain this point. Take a sheet of paper and lay it flat on a table. No matter how big that sheet of paper is, for this exercise let's assume that it has the surface area of one acre. As a reminder about how big an acre is, it is approximately 43,520 square feet. That would be a big square a little more than 208 feet on each side. In comparison, a football field, not counting the end zones, is slightly larger than an acre. If you were to plant one acre (or hectare for those not living in Myanmar or the United States, the only countries on the planet measuring land area in acres) of soybeans, for example, you would have a solar collector that has one acre (or hectare) of surface area exposed to the sun. Soybeans rarely get any taller than 2½ feet tall, so for the purposes of our exercise essentially the soybean farmer has one acre (or hectare) of surface area exposed to the sun.

Now take another piece of paper the same size as the first one and fold it in half, making a tent-shaped piece of folded paper. Place this triangular shape on the first piece of paper. Now take another square piece of paper and do the same thing, and now a third. Make sure that the bases of your folded paper stay on the original one acre (or hectare) piece of paper. What you have just done is to show what a three-dimensional structure does to the photosynthetic surface area exposed to the sun. Just by creating some elevated structure you can plainly see that on the same original 1-acre piece of land, you now have 3 acres (or hectares) of surface area exposed to the sun. If all things were equal (and they aren't but we'll deal with that later) you would now have three times the photosynthetic potential as the soybean field.

Since we're doing this little exercise, let's take it a little bit further. Fold a square piece of paper in half and now fold it in half again. You now have a smaller tent-shaped piece of paper. It's surface area, if we're keeping with our example, is ½ acre (or hectare). Take this small triangle and slide it underneath one of the larger ones on the original base piece of paper in front of you. Do this twice more so that each large paper "tent" has a small paper tent underneath it. If you add up the surface area of all of your paper tents, you will now see that the surface area that you have created is 4½ acres (hectares). That's four and a half times as much photosynthetic potential as a soybean field. But wait, you are probably thinking, three of the triangles are *underneath* the larger ones. The ones underneath are in the shade. Yes, they are. But different plants have the ability to thrive in different light intensities. Most annual crop plants will only thrive in the full sun. Plant corn in the shade of a forest and it will not do well at all. However, many food-producing savanna plants are adapted to living in moderate to heavy shade. Nature is designed that way. Our little paper model only shows two layers, but the layering in nature goes way beyond that, which we will address in detail later.

With layers, this increased surface area has additional benefits as well. It not only dramatically increases the surface area exposed to solar insolation, it also increases the surface area exposed to the atmosphere. This means more air is taken into the plant, more carbon dioxide is removed from that air and more oxygen is returned.

The Flemish chemist Jan Baptist van Helmont, starting in 1643, performed an experiment that many of us learned about in grade school science class. In the spring of that year, van Helmont filled a large planter barrel with a carefully measured quantity of soil and planted a willow cutting in it. For five years he tended the tree giving it plenty of water. At the end of that time he removed the tree, roots and all, and weighed it. It weighed nearly 165 lbs. To almost everybody's surprise, the soil weighed the same as it originally had. In reaching for an explanation, van Helmont theorized that the material that made up the five-year-old willow tree must have come from the water that he had added. Later experiments however, showed that the majority of the tree's body came from the atmosphere.

Most of the mass of a plant is comprised of air. Lignin and cellulose, the main structural materials in the plant body are made up of carbon, hydrogen and oxygen, all of which come from the air and not the soil. The more surface area exposed to the atmosphere, the more atmosphere that the plant can suck into its body and turn into useable products. The greater the surface area exposed to the atmosphere the greater the feedstuffs made available to human and animal alike.

The savanna biome has the largest, deepest solar-collection surface area exposed to the sunlight and the atmosphere of any biome on the planet.

Another benefit of increased surface area is that more plant surfaces are exposed to the rain. Whenever it rains, it takes a certain amount of rainfall just to wet the surface of leaves and branches. This plant surface wetting is called interception. Estimates have been made that it takes a half-inch of rain just to wet the surfaces of a modest size tree.

We're all able to experience this by standing under a tree in the rain. When a rain shower begins, we dash for cover beneath a nearby tree. Aside from the random raindrop that somehow manages to miss every single leaf on its descent, we remain dry. The leaves of the tree and its branches intercept the rain. This only seems to work for a while though, because once the leaves and branches are totally wet the rain then begins its gentle drip, drip, drip, drip onto our heads below.

The gentle drip of rain beneath the tree is yet another benefit that we get from this three-dimensional structure. On the other extreme, the pounding force of a torrential "gully washer" does just that — create gullies. The direct pounding action of raindrops on agricultural fields causes the surface soil particles to become mixed with the rain. Muddy rivulets meander downhill, gathering speed and picking up more soil as they go. Much of the "mud" in the "Muddy Mississippi" is from our agricultural topsoil rolling downstream to add its nutrient load to the Gulf of Mexico. As the fields begin to dry after the rain, the first particles to settle out of the water are the coarsest, heaviest ones. Then progressively lighter and lighter soil particles settle out until very last the finest, smallest particles settle out to coat the surface of the ground with a thin veneer of clay. Like frosting on a cake, this thin clay layer seals off air channels within the soil below. When the sunshine returns it bakes this clay layer as hard as pottery ensuring that the next rain shower meets with a soil surface as impermeable as a parking lot and the water then speeds again to the sea.

With a dense, three-dimensional structure to the ecosystem, the rainfall is intercepted. Throughfall, the rain that begins to drip and get you wet as you stand beneath the tree, falls gently and lands, not on the hard-baked pavement-like clay of an agricultural field, but on lush, green herbage and lovers who linger too long beneath the trees. Green herbage and people in turn intercept their share of rain, which runs off gently into the soft, crumbly, porous soil below. The soil under the tree is rich in organic matter and teeming with hydrophilic (water-loving) organisms that rapidly incorporate the water into their tissues. The flush of mushrooms on the forest floor after a rain is visible evidence of this wetting process. The fungi, and many other organisms, lay dry and dormant awaiting rain, and then burst forth in their moist glory, full of the new fallen rain.

Not only does the tree structure intercept rainwater, it captures snow and ice in the winter and it sweeps fog from the atmosphere much in the same way that corals and barnacles sweep nutrients from the seawater flowing around them. It is more than a mere comparison and is factually true and measurable that plants exist in a sea of atmosphere and sweep moisture and nutrients directly from it. Plants are so good at gathering moisture from the atmosphere, that there are actually woody plant communities that get nearly all their entire annual water supply from fog captured on their leaves and stems. When I walk through the chestnut polycultures at New Forest Farm and see the leaves moist with humidity, dripping their precious jewels to the ground below and causing rivulets of water to run down the cracks in the bark, I can't help but think of Luke Skywalker's Uncle Owen from the original Star Wars movie who was a "moisture farmer." Just think what he could have done with some woody plants and their three-dimensional structure to scrub moisture directly from the air.

I recently re-read a tome penned by the late Charles Walters, the founder of Acres U.S.A., entitled, *The Greatest Invention: Dung Beetles & A Cowman's Profits.* To many people this may seem like an obscure tome, and I'll admit I was somewhat unimpressed at first glance. However, one should but pause for a minute and think about how powerfully significant this lowly beetle can be, and then begin to think about the layer upon layer of life that teemed upon earth before modern man ran like a "bull through the china shop" of earth's ecosystems overharvesting or destroying entire populations of animals and plants.

The end of the last ice age was when humans first began to arrive in North America and what they found was a land teeming with an incredibly intricate web of life with every detail taken care of — including life forms dedicated to the recycling and decomposition of poop. When humans arrived in the Americas, a continent-wide, mass extinction began that included a majority of the megafauna. These animals had never experienced humans before and were unable to adapt to the hunting pressure that they experienced. When the mastodon went extinct, so did a whole chain of organisms including the mastodon-dependent parasites and birds who used mastodon hair for nests. Birds like the Oxpecker and the

North American aquatic rhinoceros (Yes, there was such an animal!), lived in symbiosis with the mastodon, feeding one another and providing one another with shelter and warnings of danger. The multitudes of living interconnections would have even included the beetles that utilized mastodon and rhinoceros dung as food and places for rearing young.

This deep, interconnected diversity is what created the deepest, most fertile soils on the entire planet — the breadbasket soils of the midwestern United States — the temperate, humid elephant savannas of North America. That same diversity is what conferred a stability to the system. If one pest or disease became a limiting factor on part of the system, other parts of the system were still healthy and whole. Through the eons, populations would ebb and flow in the dance of diversity with life feeding life and all of it enhancing the further health of the entire ecosystem.

It is this diversity, the interconnectedness and dedication to enhancing the further health of the system that is lacking in today's annual agricultural landscape and it is these missing components that we must rebuild. It is the mission and goal of restoration agriculture to address these issues by recreating healthy, intact, diverse, aggrading ecosystems that provide food, fuel, medicine and fiber for humanity and all of our fellow earth species.

CHAPTER 6

Farming in Nature's Image

As I write this, it is springtime in southwest Wisconsin. The hills and valleys of the Driftless Area are all carpeted in a lush, scruffy blanket of green foliage. In a few days it will be the summer solstice, the longest day of the year. High school and college graduation parties are scattered about the rural countryside with party balloons and Magic Marker signs pointing the way to Ashley's party or Rick's graduation. Temperatures have already warmed up to those fairly typical of Midwest summer picnics — hot and humid. Swimming pools and shady bends in the Kickapoo River foam with playful swimmers, and beach balls bounce off the backs of heads thrown by mischievous friends and sneaky little brothers looking for revenge. Puffy white clouds ply the deep blue skies, and scattered thunderstorms rumble through with their gift of rain and their terror-inspiring dark side — lightning, tornados and flash floods.

All around, the fields of corn and soybeans are showing lines of green where the new crop is rising from the rich, brown earth. All seems well in farm country.

However, right in the middle of this springtime scene of celebration and bucolic contentment something is terribly, terribly wrong. What is wrong is the very foundation of the agricultural economy of this nation (and every other nation of the world). Perhaps you picked up on the clues: just prior to summer solstice, longest day of the year, hillsides cloaked in green, the new crop rising, lines of green…

There's an old adage used in corn country that helps farmers and gardeners alike to know if they're going to get a decent corn crop (or not). In order for corn to ripen and mature in time, the plant needs to be "knee-high by the 4th of July." The Fourth of July is two weeks *after* the longest day of the year, when more sunlight is available than any other time of year, and the corn crop is only knee-high! How much sunlight can tiny, little 18-inch-tall plants capture? In addition to the corn plants being as short as a pair of rubber rain boots, the soil between rows of plants is totally bare. Whether the soil was cultivated to remove weeds or an herbicide was used, there is no plant life covering the ground. Hardly any photosynthesis is happening in the corn and none for sure on the bare soil.

Yet at the same time, the trees surrounding the farm fields and shading the neighborhood picnic have been in full leaf and clothed in green since mid-May. The edible woody crops that can be used for restoration agriculture emerge earlier in the season than most annual crops. The green leaves of the hills and valleys were photosynthesizing as much as a month or more before the corn even came up out of the ground. That extra month also just so happens to be the month with the longest days of the year.

In addition to leafing out earlier in the spring, perennial woody plants have an architectural advantage over annual plants when it comes to capturing sunlight. (Remember, a farmer is, after all, in the business of collecting solar energy.) Each year a certain percentage of a plant's diet of collected solar energy, is used to build its body. This is true of all plants. In the case of corn, it needs to build its entire structure from scratch each and every year. This is not so with perennial woody plants. Trees, shrubs and many vines and canes keep their body structure from last year and add to it in every subsequent season. By increasing their size every year, woody plants dramatically expand their photosynthetic surface area exposed to the sun (and the atmosphere). When a corn plant puts out its first little leaves in the spring, they poke out of the soil like so many pencil points. When the oak trees cloaking the hills leaf out in the spring, some of them are already a hundred feet tall. Using woody plants for our food plants gains us a month or more of extra solar energy being captured in the spring, and this confers a three-dimensional advantage not known by annual plants. Soybeans can only capture sunlight and atmosphere from two feet above the ground and corn to a maximum of eight feet. (And that corn is only going to be eight feet tall around the end of July or in August, very *late* in the summer.)

August does roll around (all too quickly in the busy life of a farmer) and by the end of the month all of the kernels of corn have been set, they've filled with carbohydrates and they now begin the process of drying down. The corn plants are in the process of decline. Photosynthesis slows dramatically until about mid-September when it is almost completely stopped. The cornfields turn from a vibrant dark blue-green to a lighter lime green, then yellow-green and eventually to brown.

In August, the trees surrounding the cornfields are *still* 100 feet tall and capturing sunlight and atmospheric gases from way up there — and they are still dark green. Their leaves have become a bit more tattered and worn from months of wind and incessant nibbling by insects, but they're still green.

In the northern tier of the Cornbelt states, woody plants have an extra month of sunlight available to them at the *end* of the season before they shut down and drop their leaves (if they drop them at all). Some trees stay green and photosynthesize longer like the oaks, and some, like the black walnut, drop their leaves sooner. In any case, woody plants are able to utilize an extra two to three months worth of sunlight before and after annuals plants are able to do this.

In the southern tier of Cornbelt states, temperatures are favorable enough that woody plants that do not shed their leaves, are able to grow year-round. Even in the regions with perennial tropical rain forests, corn still has a finite life cycle in the neighborhood of 100 days.

In addition to having a much larger surface area exposed to the sun and air, as demonstrated in our folded paper exercise (the advantage of space), woody crops have extra sunlight available to them during the course of the year, an advantage in time.

Then there's the obvious benefit … longevity. Woody plants can live a *long* time. Pines, beech, oak, chestnut, pear, basswood (linden) and hawthorn all produce edible nuts or fruit. These trees thrive in North America and are represented on the list of the 100 oldest trees in the world. One of the oldest trees of all, happens to be a chestnut tree growing out of the rock on the side of Mount Etna in Sicily. It has been producing steady crops of chestnuts year after year for more than four thousand years. There are *no* annual grain crops that will grow in the bare rock and yield season after season for 4,000 years with no human intervention. Surviving 4,000 years with no soil, no pest control, no fertilizer and living through several catastrophic volcanic eruptions, now *that's* sustainable agriculture.

At the risk of appearing repetitive, let's go over this again. Perennial woody plants live for hundreds to thousands of years, they photosynthesize earlier in the spring and later in the fall than annual crops, and they're able to capture resources (air, water, sunlight, and more) from hundreds of feet in the air. And, that's not all.

In southwestern Wisconsin, and in most of the Cornbelt of the midwestern United States, thunderstorms are the rule rather than the exception when it comes to rainfall. The Atlantic and Pacific coasts receive much of their rainfall during days long, drizzly gray showers. Not so in the Midwest. For example, during the past two weeks southwest Wisconsin has had two rainy days, which is not bad if you like fair weather. The nature of how that rainfall arrives, however, paints an entirely different story. One Saturday night a band of thunderstorms passed through the area at 2 a.m. so they disrupted nobody's day except for moms and dads who had to deal with terrified children. That Saturday it rained a total of 2½ inches in less than an hour. In some places they received even more. The second rain event happened the very next night, again around 3 a.m. In that second rain, we received 1.7 inches of rain. Rain in most of the Midwest happens in sudden, sometimes rather large deluge events. Three years ago we had a single rainfall event that dumped 10 inches of rain in less than an hour. Our local airport reported 13 inches of rain during that same one-hour storm.

When that much rain falls all at once, the effects of it are felt differently depending on what it hits. Buildings and roads, obviously are impervious to the water and up until recently most buildings and roads have been designed to concentrate all that water and make it go away. Barnyards, parking lots and ball fields are all designed to divert and concentrate water and send it to ditches, creeks and rivers.

When a pounding rain strikes the corn crop, it meets mostly exposed, bare soil. The tiny little corn plants are tough, and more often than not, they are not pounded flat by the rain, but the bare soil between rows takes a beating. The rain from a Midwest thunderstorm strikes the soil at full force and churns the surface. The soil particles are mixed and churned like mud in a blender. If the soil has enough organic matter in it from decaying plant and animal parts, it acts like a sponge and helps the rain to soak into the ground. This is one reason why increasing soil organic matter is so important. It helps soak up the rain. But even the richest organic soils on the most fertile bottomland farms get pounded in a torrential rain. The organic matter becomes separated from the mineral portion of the soil and in the mineral portion, the fine-grained minerals get separated from the coarser, heavier ones. If the rain falls faster than the soil can absorb it, runoff begins and with that runoff goes the soil. Flowing water is, of course, the most powerful erosive force on the earth, and thus begins gully and sheet erosion. In the woods the raindrops have to hit countless leaves and branches before they ever strike the ground. Their downward velocity is slowed and they strike the ground gently.

Once the rain settles down, the churned-up soil begins to settle. The first material to settle out is the heavier, coarser mineral particles, followed by finer and finer particles until the last materials to settle out are the ultra-fine clay particles.

Perhaps you've seen a puddle after it has evaporated that has a coating of slick, frosting-like clay on the topmost surface. When the puddle dries out this slick clay layer bakes in the sun and hardens just like pottery. The soil beneath this clay layer is now effectively sealed off and water is no longer able to penetrate it. Atmospheric gases can no longer be effectively exchanged either, which leads to a collapse in aerobic soil life, the very kind of soil organisms that provide the best, balanced fertilizer to the plants. What happens to the puddle is the same as what happens in annual crop fields on a scale of hundreds of millions of acres across the continent. In this way, rains pounding the midwestern United States region create a thin, impervious clay layer on top of the soil. Then, even the richest, lushest soils that are high in organic matter are not able to absorb the next rain because the rain meets this crust and runs off in a sheet.

In the deepest, darkest parts of the scruffy woods on the hills surrounding Ashley's graduation party that I mentioned earlier, there is still sunlight reaching the forest floor. Depending on the age of the trees and how close together they were planted, the trees will eventually touch branches and shade out the grasses below. Foresters call this condition a "closed canopy." Even in the deeply shaded conditions of a closed-canopy forest, there are plants growing on the ground. In fact there are multiple layers of plants from the ground all the way up to the tops of the highest trees. There are perennial and woody plants that have different tolerances for different light levels. Corn, soybeans, and in fact *all* of our staple food crop plants require full sunlight. Plant wheat in the shade of a forest and it becomes, sickly, yellow and eventually dies. If it managed to actually find enough light to stay alive, it most likely would not get light enough to produce a crop. Immediately next to that wheat plant might be a wild ginseng, blue cohosh, gooseberry, cardinal flower, or a whole host of other shade-tolerant plants that would thrive quite nicely in the low-light conditions. There are a wide variety of shade-tolerant small trees, shrubs, vines and groundcover plants that can produce an economic yield.

Since I am proposing an imitation of nature and a re-design of annual crop fields into restoration agriculture ecosystems, we will want to use plant species that have a wide range of light tolerance in our designs. Nature has provided us with a living example and the species that we can use to design crop-yielding ecosystems utilizing tall- and medium-stature trees, tall and short shrubs, canes (such as raspberries and blackberries), vines and herbaceous (non-woody) perennials. Each of these plant types have several species to choose from in either sun-loving or shade-tolerant forms. There are tall trees, medium trees, and shrubs that are sun-loving or those that are shade-tolerant.

Knowing this, we can now see that it is possible for us to design a productive ecosystem that has the multiple advantages of perennialism described earlier in this chapter.

Depending on which textbooks you read, there are a number of distinct vertical layers in a forest. For our purposes, I will describe six of them. They are in order from the tallest to the shortest: the emergent layer, the canopy layer, the understory, the shrub layer, the forest floor, and the vine layer.

The emergent layer comprises mature, exceptionally tall trees. It is so named because the trees in this layer emerge above the general level of the forest. In the eastern United States you can frequently observe white pines standing on a ridge with limbs outstretched a full third taller than the rest of the forest. East of the Rockies emergents in the temperate forests are typically widely spaced and are the exception rather than the rule. Some species of trees, such as the aforementioned white pines, may indeed be emergents in some forests (or were many years ago) because they have the ability to grow quite large. Prior to European colonization, white pines were reported to be as tall as 230 feet. When growing in an oak forest such a tree would tower above the forest below it. In a forest stand of other large pines it might very well comprise the main forest canopy layer.

Typically the tree canopy is the most photosynthetically active layer in the forest. It is usually the easiest to recognize in that it is the uppermost layer of tree foliage that you see (particularly visible from a distance), with perhaps an emergent tree standing tall above the canopy here and there. The canopy layer of a forest, in fact *all* layers of a forest, are almost ecosystems unto themselves. There are myriads of creatures, insects, birds, mollusks, mosses, lichens and fungi that exist in the canopy layer and nowhere else.

Just beneath the canopy layer, is the understory layer. In a closed canopy forest, where the branches of the canopy trees are almost touching, the understory is comprised of trees with varying degrees of shade tolerance. These may be shade-tolerant forest trees that will eventually become the canopy when the current ones die, or these may be trees that are naturally smaller than the canopy trees and exist happily in the semi-shade, never taking over as canopy trees.

In a restoration agriculture planting we could choose to plant a sun-loving tree with a smaller mature height on the sunnier south side of a planting and a shade-tolerant small tree on the shadier north side. I will address this in more detail later.

Beneath the understory layer you will find the shrub layer which, like the understory layer, is likely to be comprised of shade-tolerant plants, and here once again we can design systems with sun-loving shrubs to the south and shade-tolerant ones to the north.

The lowest layer in our three-dimensional agricultural solar collector is the groundcover layer. In a forested situation these are indeed some of the most shade-tolerant plants around. This layer has a multitude of useful plants that can be included in a restoration agriculture design, and this is the layer where most opportunities for yields occur during the growing season.

The forest floor is home to many plants that are categorized as ephemerals. Ephemeral plants are those that have a very rapid life cycle and grow, flourish and set seed in a matter of a few weeks or months. Tulips and yellow trumpet daffodils are familiar, domesticated ephemerals that most people would recognize. Watching the march of the ephemerals through the growing season is quite fascinating. Sometimes before the snow is even off the ground and well before leaves start to emerge on the trees, ephemerals begin to bloom. In the Northeast Hepatica is one of the earliest ephemerals. Look for Brodiaea on sunny woodland slopes in the West, trout lilies in the Southeast, and pasque flowers in the Midwest. Spring beauty, trillium and ramps (wild leeks) are but a few more of the well known spring ephemerals. Their entire life cycle from emergence to setting seed, withering and dying might take place before the first green is ever seen on the overhead trees. Usually, though as the season progresses subsequent waves of ephemerals emerge, bloom and set seed all the way through the season and into the fall after the last leaves have fallen to the ground. This "scheduled" plant growth can provide many opportunities for yields in a designed agricultural ecosystem.

A wild example of the many layers of productivity: aspen over crab apple over hazelnut over raspberry with gooseberries in the shade.

Crawling all over and up through this tangle of green growth are vines. Most of us are familiar with grapes, but there are more than grapes that grow on vines. Other fruiting vines include kiwis, passion fruit, the medicinal fruit called schizandra, or the ornamental berry, bittersweet.

So far I have identified six different layers: emergent, canopy, understory, shrub, forest floor and the vines. When looking at these six layers and imagining what a designed agricultural ecosystem would look like, remember that there are six layers on the sunny side of a planting and six layers on the shady side for a potential of growing twelve different crops. Also, the ephemeral nature of many plants on the ground layer add even more potential for crops.

With all of these plants growing in what is essentially the same place, you could imagine that we would be growing a considerable amount of biomass. All that you have to do is look at the forest and you can easily see the tons of plant leaves, stems, branches and trunks. All of the woody organic matter becomes food for a very significant organism in the forest ecosystem — the decomposer organisms — especially the fungi. Most fungi do not have chlorophyll in them and therefore aren't a direct part of our sunlight gathering system. However, they are important in that they are able to convert otherwise unusable woody organic matter into something useful. In the case of a designed agricultural ecosystem we will definitely focus on fungi that are edible or medicinal and therefore can produce additional income.

So, looking at the forest layers, you can see that it is possible to create a simple, three-dimensional solar collector that collects *way* more sunlight than a corn plant does and can turn the solar energy into at least thirteen different crops all while growing in the exact same size area.

While farmers spend long hours in the spring preparing the crop fields for corn and beans, using a convoy of fossil-fuel burning tractors, fertilizer spreaders, and spray rigs for chemicals, the forests on the hillsides needed none of that work. Nobody plowed the forest, fertilized it, or applied herbicides, pesticides or fungicides. All of those crop field steps represent work expended and an expense to the farmer. Quite commonly all of that work also represents the necessity of an operating loan mortgaged to the farm in order to pay the expenses until harvest time. All of the steps involved in annual agriculture, except for the harvest, are economically unproductive. For a true energy accounting you would subtract the caloric value of all that work from the caloric value of the crop and also factor this in with the dollars and cents accounting.

Meanwhile the green forested hills have required none of those inputs. They required none of the expenses of a cornfield and none of the labor. *If* anyone had interacted with the forest, it would have been to harvest. (Harvesting morel mushrooms or turkey hunting, for example.)

Once established, the input costs of a perennial restoration agriculture system approach zero. In fact an ideal design would be one where the inputs for one crop would be accomplished by the harvest of another. One simple example of this is weed control. Weed control in an annual cornfield is accomplished by herbicide application or cultivation (mechanically crumbling the soil and uprooting the weeds). Weed control for an edible woody crop system might mean rotating grazing animals through the system. The grazers would eat the grass that slows down tree growth and would conveniently fertilize the planting with their excrement. Pest control in restoration agriculture systems is the same as in natural systems. Rather than using toxic insecticides (both certified-organic as well as chemical formulations are poisonous to beneficial and detrimental insects) for pest control, the newer, richer habitat becomes a home for insectivorous birds, predatory insects, bats, amphibians, turkeys, or perhaps a flock of chickens which would rotate through the area to reduce insect populations.

Livestock provide weed control and fertilizer for the woody crop, and the woody crop provides shade and wind protection to both cattle and forage.

In the previous chapters I have described some of the reasons why restoration agriculture is needed and hopefully painted a mental picture in your imagination of what it might look like. In the following chapters I will delve into some step-by-step details of how to establish a restoration agriculture farm and how to manage it. Now, in order to more closely imitate nature and natural systems with our agriculture, we need to look a little more closely at those natural systems.

CHAPTER 7

The Steps Toward Restoration Agriculture

IDENTIFY YOUR BIOME

In order to successfully create a restoration agriculture farm, you must first have a basic understanding of what the biome is where the farm is to be established.

Simply defined, a biome is a region on planet Earth that has similar communities of plants and animals, similar rainfall patterns, and relatively similar soil types. If you were to walk around and observe the plants and animals of your region, you would get a specific list for your area. If you live in coastal Georgia, you would expect to be surrounded by certain trees and shrubs. You would expect the temperature or humidity to be one particular way in early versus late summer and to be different in the winter. If you were to be transported instantly to New Mexico, you would realize that you are in a radically different place. The change in biomes would be quite different in this case.

Biomes are identified by particular patterns and arrangements of trees, shrubs and grasses, as well as which species of those plants live there. One species of wide-spaced trees growing with grasses of another, surrounded by particular shrubs might define one biome, while another biome might have close-growing trees creating deep shade, shrubs of another kind and grasses of yet a different species. The spruce, fir and pine woods of eastern Ontario are different than the oak, hickory and pecan forests of Arkansas. Even within the same state and region the difference in biomes is fairly obvious. The spruce, white pine and fir woods of northeastern Maine are different than the sugar maple, beech and birch region of central Maine, which in turn is different than the mixed hardwoods of southern Maine.

In addition to the particular species of a place, biomes are also defined by the particular successional pathway that occurs in that region. The general concept of succession was discussed in chapter 5, but the particulars of each biome are different. Different species play out the dance of succession differently in each region. Knowing your biome is important in order for you to choose the particular species for your restoration agriculture project. Knowing your biome and knowing the individual species that take part in the successional progression of your place will give you the highest likelihood of success. Think about it. If you plant trees, shrubs, canes, vines and forage that would naturally occur in your region anyways, don't you think that they would have a greater chance of success than if you grew other plants that are not adapted to the region? Would I have much success establishing a saguaro cactus farm in the moist, snowy Upper Peninsula of Michigan instead of in sunny, warm Arizona? Would I have much success growing bananas at 8,000 feet in the Rocky Mountains of Colorado? Although we *could* manipulate the microclimate and build facilities that would enable us to grow bananas in the Rockies (and there are those who are doing this), doesn't it make a whole lot more sense to grow plants that are adapted to the Rocky Mountains instead, such as the piñon pine tree?

The change from one biome to the next is quite subtle and does not conform to any clear indication defining where one biome starts and the other ends. The transitions are gradual, and sometimes punctuated. The shapes of the trees may be different, or it may begin to feel drier. The plants that used to dominate just to the east are now only scattered here and there and other plants are beginning to dominate. The change in biomes between coastal Georgia and New Mexico are obvious and dramatic, but nature is even more subtle than that. Coastal Georgia is quite different than the hills of north Georgia which is quite different than southwest Georgia. The change can be perceived within hundreds of miles. In the mountains of New Mexico the change might even occur within a few feet. Plant communities might change dramatically with an elevation change of only a thousand feet.

FIND THE "KEY" ECONOMIC SPECIES

In most biomes, the entire character of that biome is most influenced by its trees. Trees, being the largest and longest-lived members of that particular plant community, have the longest time to affect an area. Annually they pull mineral nutrients up from deep layers in the earth and through the magic of photosynthesis combine those mineral nutrients with carbon dioxide that they inhale from the atmosphere. The atmosphere and the earth are combined to create masses of leaves that are eventually shed and dropped to the ground. Most North American broad-leaved trees drop their leaves to the ground every single year. There, leaves are acted upon by creatures seen and unseen, colonized by fungi and molds until eventually they compost completely and add their nutrients and carbon to the soil. Even the "evergreens," most needle-leaved trees and some broad-leaved trees in the South, still shed their leaves, just not all of their leaves every season. Only the oldest, least effective leaves are shed and this is often done in the spring when new growth starts.

Below ground, the trees are changing the subsurface environment in equally profound ways. The roots of trees, beginning with the tiniest of root hairs, will find their way between soil particles and into the cracks of the bedrock itself. As the years go by and the roots grow, they apply a hydraulically powered mechanical force to the soil and rocks — creating a lifting action. The roots can actually inflate and elevate the level of the soil. You can imagine that tree roots in the soil are like a biological balloon being pumped full of air from above ground. The thinnest root hairs, as they are inflated by sugars and fluids manufactured in the process of photosynthesis, snake and worm their way between soil particles in any space afforded to them (think of the tip of a balloon being pumped into popcorn). Over time, they use those very same atmospherically produced sugars to construct lignin and cellulose, vessels, stone cells, xylem, phloem and other structures. That portion of the root solidifies and firmly establishes itself in its location. Meanwhile some of the root hairs, through mechanical damage or the gnawing of a billion microscopic creatures, burst their cell walls, die in the process, and release sugars to the surrounding soil. Microscopic fungi, bacteria, nematodes and other organisms move in and dine on the sugary bounty. Each of these in turn excrete their bodily wastes which becomes fertilizer for the tree. During the years that trees exist in one place they totally change the soil conditions where they live.

Over time certain tree species come to chemically dominate a site. The surface soil created by their leaf drop and then increasingly deeper soil layers become "flavored" to that particular tree species (and any associates who can tolerate or thrive in this new condition). Some trees, like the Juglandaceae family (walnuts, hickories, pecans, etc.) ooze chemicals called juglones that are actual herbicides that kill many other plants. They don't kill *all* the plants around them, however, they just exclude the plants that aren't in their family. This change in the soil chemistry and soil life is one of the reasons why we are able to distinguish changes between biomes. If anyone has been up close to an ancient oak, you can now include soil chemistry to your understanding. The soil surrounding and underneath a 300-year-old oak tree has become "thoroughly oaked" over time. Plants that don't like oak soil will not grow there. The largest and most dominant tree species are what set the rules for the site.

IMITATE THE SYSTEM

Learn your biome. Get to know the soil types, the rainfall patterns and what kinds of trees live (or have lived pre-European settlement) in your location so that you can learn how to fit into the site in the most effective way possible. Wherever you live, and whatever biome it is, you will have greater success if you imitate what was there. It would take a several thousand page book to address every biome in North America and to design a biome-appropriate agriculture system for each region. The work of ecosystem mimicry in agriculture *should* continue and someday each biome will have its own agricultural systems in place on the ground — complete with ongoing Ph.D. level research. We are not there yet, but this book is intended to begin the discussion and stimulate more implementation and eventually the research will follow.

As mentioned before, the biome that has the widest distribution across North America, is the savanna. It was and is the biome that supports the most mammal life and is the historic biome into which we, the human family, were born as a species.

The particular form of savanna that is most widespread in North America is the oak savanna. After moving to Wisconsin to establish our restoration agriculture farm, we first consulted research material that supplied us with the general outline of what "crops" we would plant in order to genuinely restore the ecology and simultaneously produce food. In the various research papers and textbooks that we read about oak savanna ecology, we discovered some remarkable coincidences.

Over and over again in the oak savannas, the same species appeared.

This list of species (opposite) and their arrangement from taller to shorter is somewhat of a Rosetta Stone for perennial agriculture systems in North America. Here we have a natural system, the oak savanna, that is perennial, took care of itself naturally for millions of years without human intervention, and never needed expensive fossil-fuel inputs. It produces nuts and animal meat as staple foods and a wide variety of vitamins, minerals, antioxidants and more. If you were wondering about whether climate change has changed the composition of oak savannas over time, rest assured. Evidence shows that the current species that make up the North American oak savanna have ebbed and flowed through no less than four different ice ages.

OAK SAVANNA PLANTS (TALLEST TO SHORTEST)	CHARACTERISTICS
Fagaceae family (oak, chestnut, beech)	Tall, nut-bearing trees
Malus (apples) *Pre-European settlement these would all have been native crabapples.*	Medium, fruit-bearing trees
Corylus (hazelnuts)	Spreading nut-producing shrub
Prunus (cherries, plums, peaches)	Various different forms from tall trees to suckering shrubs
Rubus (raspberries, blackberries)	Cane fruit that move into grasslands
Ribes (gooseberries, currants)	Shade-tolerant small shrubs
Vitis (grapes)	Sun-loving vines
Fungi (mushrooms) *Colonizing dead wood, leaves, or other biomass.*	Shade-tolerant, moisture-loving
Poaceae family (grasses)	Primary food for grazing animals.

There were, and are, a large number of plants that are common to the oak savanna that are not included in the above list, and many of them have food, fiber, medicinal, or other marketable characteristics that would, of course, fit in well on a restoration agriculture farm. Some of the species not listed, such as the wild rose and honey locust both produce edible fruit, but neither currently have simple, easily accessible, mass markets to tap into. One of the keys to success for a restoration agriculture farm is to have recognizable, marketable products. And preferably these products have large, fairly consistent markets. My focus has been primarily food, which you will see reflected throughout all of what I present here, but many other types of products are possible from a restoration agriculture farm.

Post-ice age megafauna (mastodon, giant sloth, giraffes, giant armadillos and more) thrived on the exact same plant systems that are with us today.

The “natural” oak savannas of the late Pleistocene/early Holocene period contained exactly the same species that we see across North America today. Some of the older individual plants may have actually been witness to the wanderings of mastodon and possibly even browsed by glyptodonts (large armadillo type animals). The plant species found in a wild savanna weren’t necessarily the ones that produced the most seeds for consumption, though. Wild seedlings are more programmed toward individual survival and perpetuation of the species and this doesn’t always mean producing the most nuts or the biggest fruit for human consumption. Oaks and apples are prime examples of this. The fruit on native crabapples is small — some of them no larger than your fingernail. I've tasted fruit from hundreds of wild crabapple trees and almost without exception the fruit is very sour and often quite astringent. Being small and sour doesn't really enamor humans to wild crabapples as a food source, so it's no wonder that the native crabapple was only a minor part of the early North American diet.

Oaks exhibit a bearing characteristic known as "masting" where they have abundant, then intermittent or synchronized reproduction. Trees that reproduce this way typically have no or very few nuts for several years in a row to be followed by a year of bumper crops. This would make sense in the wild. During most years, if trees produce little or few seeds, most of them would get eaten by squirrels, mice or blue jays. This keeps the populations of nut and seed predators small. Then "suddenly" if trees produce a harvest that is so gigantic that it overwhelms the nibbler's ability to harvest all the seeds, some seeds will end up being offspring. During a mast, or bumper, year many seeds will lie on the ground where they will germinate and root into the soil, often within weeks of falling from the tree. Other overabundant seeds are buried by squirrels or lie in chipmunk caches where they sprout the next spring.

Trees with small, bitter fruit and trees that produce big nuts high in protein and oil, but only once in a while, functioned just fine for seasonally nomadic hunter-gatherers who followed their food sources around when there was plenty of wide open spaces in which to do so. Today with our suburbs, highways, privately owned real estate, and food grown on farms, these inconsistent cropping traits will not work as a significant source for human food. These are not characteristics that we want in a food crop. Agriculture, the big, important way that humanity is fed, needs to have plants that produce large crops every single season, beginning early in their lives.

With restoration agriculture we are *not* necessarily creating a savanna restoration in the purist sense of the word. Restoration work is important for the overall health and well being of the planet and should be done, but for our purposes we are not talking about restoration in the common usage of the word. Instead of restoring degraded savannas into a more historically common form, the land we are restoring is agricultural land, land that has been under the plow in some cases for centuries. What we are doing is designing an agricultural system that closely mimics the savanna in its structure (vertical structure as well as spatial distribution), the species mix (with cultivated substitutions), and in ecological function. For each individual species in the system, we will be using far more domesticated plants, plants that have been bred through the years to produce high crop yields every single year. We will substitute higher yielding varieties of the species in question and we will choose which species or varieties to plant in higher quantities, depending on the markets available to us, or because of our own personal preferences. How this would happen, is explained below.

Commercially selected cultivars of plant species can outyield their "wild" counterparts and can potentially support even more mammals than even the late Pleistocene.

Fagaceae: Oaks, Beech, Chestnuts

Earlier I wrote briefly about oaks and some of the issues that are encountered when using them as a source of staple foods for humans. Acorns are large, high-calorie nuts. They are rich in protein and minerals and 50-70 percent oil, which can be pressed and used as an industrial food processing ingredient, cooking oil, or as a fuel. Spain and Italy have an entire industry and culinary tradition in place where pigs are fattened on acorns. Their hams, salt-cured and air dried, are called jamón ibérico and prosciutto respectively. Appalachian North America also had this tradition, and after nearly disappearing the trend is actually on the increase again. Back in my great-grandfather's day, the pigs were turned loose into the woods to fatten themselves on acorns, hickories and beechnuts. The pigs would come back to the farm when the nuts were gone and they were hungry for corn. This type of forest feeding today, for the quantities of pork needed to feed millions of North Americans, would prove to be quite destructive to our remaining forests. The pigs would root up the ground, destroy forest seedlings and disrupt the natural forest in numerous ways. Turning the pigs loose in the woods to run wild and fatten up is *not* restoration agriculture. Intentionally designing and planting a slightly wooded pasture, dominated with species for hog foraging, then practicing management-intensive grazing (using hogs with nose rings to prevent rooting up the pasture) qualifies as the agroforestry practice of silvopasture (trees plus grazing livestock together). Agroforestry techniques such as silvopasture will be discussed later in this book.

More frequently these days, acorn-fed hog producers are either collecting their own feed (acorns) or buying them from acorn collectors. Think about how many tons of acorns fall unutilized on the millions of Conservation Reserve Program (CRP) acres in the United States every year. Acorn collection can even be considered a public service in places, I am sure that public works departments in many cities and towns would be more than happy to get rid of the acorns that fall in public parks. Acorns on the ground in parks are considered a public safety risk as well as a clean-up nuisance. What a different world it would be if only more people realized that acorns are incredibly nutritious food. Even better would be if we had the processing capacity to buy those unused acorns and turn them into salad oil, tortillas, granola bars or bacon.

Acorns are excellent as hog or poultry feed, but because of their irregular bearing habit a farmer would have to have a number of suppliers lined up in various regions of the country in order to ensure a steady supply. This doesn't necessarily stimulate the need to plant restoration agriculture systems, it merely creates a demand for nuts that are already out there and going unutilized.

The same would be true of another Fagaceae plant family member, and that is the beech tree. As of this writing, I know of nobody who is raising beechnut-fed pork. There is no reason why this can't be done. The same issues apply to beechnuts, however, as do acorns. Beech are masting trees, which means that they do not crop every single year and therefore one beechnut hog farmer or one beechnut butter company would have to draw from a wide region in order to ensure a regular supply.

There is, however, a Fagaceae family member that bears every single year and also bears large crops (up to and over a ton per acre), and does so beginning at a young age — that is the chestnut.

Any discussion about chestnuts in North America absolutely must include a mention of the previously grand American chestnut.

From the time of the last ice age up until the early 20th century, the American chestnut was the dominant tree in the eastern United States. Some people estimate that it comprised approximately 30 percent of all living biomass in the eastern forests. The tree has rightfully been called the "redwood of the East" and could almost have been called the "tree of life" for all of the good it provided. The older specimens approached 200 feet in height. Their wood was lightweight, strong and extremely decay resistant. The bark is extremely high in tannic acid and was used in the tanning industry for preserving leather until the 1930s. Each and every fall American chestnuts, from north Florida to central Maine and as far west as the Mississippi River, would rain down thousands of tons of small, sweet chestnuts to feed man as well as beast.

The re-emergence of the once nearly extinct American chestnut is a testament to the ability for human beings to be a force for beneficial ecosystem development.

Unlike most other tree nuts the chestnut is not a high-oil nut. Consequently chestnuts are nutritionally more similar to brown rice than they are to any other tree nut such as walnuts, almonds and acorns.

All was well until the early 1900s, with global travel on the increase, when a fungus was accidently introduced into North America. In the summer of 1904, Hermann Merkel, the chief forester for the New York Zoological Park (eventually to be named the Bronx Zoo), discovered the first known instance of what has now become known as "chestnut blight." Undergoing at least one name change from *Endothia parasitica* to *Cryphonectria parasitica*, this fungal disease originated in China and was transported to the United States on specimens of naturally immune Chinese chestnuts, spreading like a biological wildfire. Some would argue that the management practices adopted by the various states and the federal government did nothing to slow the spread of the disease and in fact may have contributed much to the American chestnut's demise.

A chestnut blight (Cryphonectria parasitica) canker in all its infectious glory.

A policy of wholesale chestnut eradication became the law beginning in 1911 in Pennsylvania, which resulted in not a single chestnut tree standing within two decades. Eradicating every chestnut tree resulted in more trees being transported than before and at a faster rate, which no doubt spread the fungus farther faster. The fact that the chestnut blight fungus harmlessly lives on oaks and will survive in the soil or as airborne spores nearly indefinitely, also accelerated the demise of the American chestnut. Looking back, the practice of eradicating every chestnut in order to prevent the spread of the blight is analogous to shooting all of the residents in a nursing home in order to prevent the spread of the flu. By eradicating the American chestnut at the hands of the logging industry's saws, there was no opportunity allowed for any tree to be known that was showing resistance. If a tree showed resistance to the blight nobody would have known, because that tree would have been cut down and added to the burn pile.

Chinese X American chestnut hybrids in bloom: The long spiky structures are the pollen-bearing catkins and the round structures at their base are the un-pollinated burr.

The American chestnut as it was may be gone forever, but chestnuts themselves are not. Even the genetics of American chestnuts remain today. More than a thousand pure, native American chestnuts survive west of the Rocky Mountains where chestnut blight has evidently not passed through yet, and the genes of the American chestnut lie embedded quite safely within European and most especially Chinese chestnut hybrids that have been created to preserve the American chestnut's genetics. The American Chestnut Foundation of Meadowview, Virginia is theoretically at a stage in chestnut breeding where they now have a Chinese and American chestnut cross that is approximately 98 percent American and only 2 percent Chinese, with the 2 percent conferring the blight resistance. These are few in numbers and are considered by the Foundation itself to be at the experimental and research stage. They also can't be relied upon to be humanity's source of renewed American chestnuts.

As I have already mentioned, the American chestnut was an extremely tall tree. It had a natural range from north Florida to central Maine. It was obviously widely adapted and had many variations and subtle differences within it. American chestnuts have been planted farther north than this natural range and have shown to be cold hardy to -50° F (USDA plant hardiness zone 2). This is not the case with the Chinese chestnut. Most Chinese chestnuts are only cold hardy down to temperatures of -20° F (USDA hardiness zone 4).

In addition to cold hardiness differences, Chinese chestnuts will tolerate less acidic soils than American chestnuts and are a smaller tree reaching heights of only 30-50 feet at maturity. Most significantly, Chinese chestnuts are virtually 100 percent resistant to chestnut blight.

These blight-resistance characteristics provide numerous opportunities for restoration agriculture growers. For those who live within USDA plant hardiness zones 4-8, Chinese chestnut is the perfect choice. They are widely available. Markets for the nuts are large, and because trees take some time to develop, it will prove to be nearly impossible for growers to saturate the huge markets which are growing even bigger. Imports to the United States stand at over 4,000 metric tons (8 million pounds) per year and these increase yearly. It would be a Herculean task to plant enough chestnuts to replace all these imports, and even if that occurred markets for chestnuts will continue to expand. As fossil fuel costs continue to increase, growing an industrial ingredient on a perennial plant (the equivalent to millions of acres of corn), will become increasingly less expensive. As planting and establishment costs become a thing of the past, the chestnut grower can potentially experience increasing returns just due to decreasing cost of production if nothing else.

Not everybody who lives within the oak savanna region, lives within the balmy climates of USDA hardiness zones 4-8. In southwest Wisconsin, where New Forest Farm has been pioneering restoration agriculture, the USDA hardiness zone map is not always clear and the actual temperature doesn't always pay attention to what the USDA map says. In 1888, for example, there was a winter with no snow and record-breaking cold. Every apple tree known to exist in these parts froze to death. During the winter of 1995-96 temperatures of -52° F were recorded in several southwestern Wisconsin towns, and those who were banking on their zone 4 perennial plants returning in the spring were severely disappointed.

Chinese chestnut may actually survive in this part of the country most years, but then along comes a “test winter” and a high percentage of them will freeze back to ground level. Out of the thousands of Chinese chestnuts that have been planted at New Forest Farm in the past 15 years, only two of them are bearing. In locations colder than zone 4, Chinese chestnut cannot be relied upon for regular, heavy crops.

Likewise, the American chestnut cannot be relied upon either. Although extremely cold hardy, American chestnuts will eventually get chestnut blight. They just will — even if there are no chestnuts in your area (or even within several hundred miles). The blight will find your American chestnuts, and the majority of trees will get the blight before they ever produce nuts. Some, however, will have nuts and others will cast pollen.

For those in climates too cold for Chinese chestnuts, hybrids (crosses) of American and Chinese chestnuts can be used. There are a number of sources for hybrid chestnuts and all of them are open-pollinated and so far none of them are patent- or royalty-protected. You can grow them, save the seed, and grow the next generation.

When growing hybrid chestnuts, you will have to understand that there will be quite a bit of variation in size, vigor, shape, blight resistance and cold hardiness. If you plant hybrid chestnuts, some of them will freeze to the ground every year and that’s alright. You’re not interested in them anyway, because they’re not cold hardy enough. Some of them will get chestnut blight and that’s alright too because you’re not interested in the ones that get blight. You’re interested in the ones that have *both* characteristics, cold hardiness *and* blight resistance. These are the ones that will survive and produce. Plant breeding made easy.

The American Chestnut Foundation is breeding specifically for blight-resistant American-type chestnuts. The restoration agriculture farmer is not such a purist. What a farmer wants most out of a crop is yield. At New Forest Farm we are looking for high-yielding chestnut trees. Straight and tall timber-form trees that resemble pure American chestnuts would be nice, but this is not essential. We’re looking to grow tons of staple food crops. If we don’t sell our chestnuts directly for human consumption, then our livestock will eat them. For higher stocking rates of livestock, you’ll want higher yielding chestnut trees.

In most oak savanna-analog restoration agriculture plantings that I am aware of, chestnut is the Fagaceae family member that is being used as the tall, central element that will eventually be the chemical and biological driver of the site. Chestnuts can be harvested mechanically by standard nut industry sweeping equipment, and basic processing companies and co-ops have sprung up in various regions of the country to complete the production cycle. Being high in carbohydrates and low in oil like the annual grains, chestnuts are the perfect staple food crop. Once dried they can be stored almost indefinitely. They can be ground into flour and made into noodles. Much like corn, they make an excellent industrial ingredient for food processing. Anywhere that a processor would use corn as an industrial ingredient (crackers, chips, cookies, high-fructose syrup, vitamin supplements and more), the chestnut can do the same. What’s more, the chestnut being a long-lived perennial will produce that industrial food ingredient year after year for millennia. Once chestnut trees are established and bearing the production cost per unit of carbohydrate energy keeps going down year after year. Annual crops, on the other hand, will always have a planting cost.

Malus (apples)

I know that using acorns for human or animal food may seem like a stretch for some, that many people have not heard of beechnuts, and chestnuts are mainly thought of at Christmastime when caroling about roasting them over an open fire. But using apples as food is an entirely different matter. Everybody is familiar with apples.

If USDA Grade A apples for eating out-of-hand are a goal of yours, then by all means learn all that you can about “orcharding” and the best of luck to you!

Can you guess what we can substitute in our restoration agriculture for wild prairie crabapples that would have grown in a natural oak savanna? Yes, we can use the common domestic apple, *Malus domestica. How* we use them in restoration agriculture can vary considerably, however.

There are many books on apple orcharding and there is no shortage of information on how to grow apples in either the chemical or the organic tradition. If having USDA Grade A apples for eating out-of-hand is a goal of yours, then learn all that you can and, if you live in the humid eastern half of North America, the best of luck to you. This is not the path that I have taken and it is not based on ecological reality. Chemical or organic, the grower of any crop — especially edible woody crops — who goes down the path of controlling pests and diseases by using inputs is fighting a losing battle. Pests and diseases that survive our poisonous attacks are the ones that have developed some sort of genetic immunity to our brews. They pass that immunity on to their offspring and eventually the entire population becomes unaffected by our sprays. A classic example of this is the “battle” against the fungal disease called apple scab (*Venturia inaequalis*). Apple scab is responsible for creating brown lesions on apple leaves and fruit, significantly affecting tree growth and yield. The fruit lesions can resemble the scab on a skinned knee, hence its name. In some years the weather conditions that are perfect for scab development (humid, cool spring weather) do not happen at the critical times in the scab fungus life cycle and infection is rare to nonexistent. In other years scab can cause the fruit to split wide open, become brown crusted, and can defoliate the entire tree. I have seen scab-susceptible varieties in abandoned orchards that were completely defoliated several seasons in a row — eventually killing the trees. Purdue University has been doing extensive research on how to fight scab and has realized that in the past 100 years of fungicide use, apple scab has evolved to the point where it is now functionally immune to all four major fungicide categories. How can we possibly grow apples if such menaces as apple scab begin to turn into the orcharding equivalent of the multi-drug antibiotic-resistant diseases found hovering around many hospitals in this modern age? It seems like the entire research establishment of the food and agriculture industry is acting to fight a battle and convince us that we should fight along with them. The organic approach is no different. Pests and diseases are still fought with sprays — but with organic growers using significantly different ones.

One particular permaculture axiom that is spoken these days, but not always understood, is that “the problem is the solution.” This applies to all crops in restoration agriculture systems as well, but especially to apples and the other fruit that we will include in the system. “Selection pressure” is a term that is used to include any cause that reduces the reproductive success of an organism that has a certain trait.

Fungicides, in the case of apple scab, reduce the reproductive success of the individual scab organisms that are susceptible to that fungicide. Some scab organisms though are resistant to that particular fungicide. They will be the only scab individuals within that population that get to reproduce, as most species can’t reproduce if they’re dead! Over time, the resistance trait spreads throughout the apple scab population until eventually the only fungal spores floating around are now resistant to the fungicide being used. The typical grower and industry response to this for the past 100 years has been to merely switch fungicides. When this happens, the process repeats itself and eventually the only survivors are now resistant to *two* fungicides. This is a no-win, losing battle. Researchers at Purdue University have now shown that a full 15 percent of the scab populations that are out there are now immune to *all* known fungicides. We have created this problem, but the same process that we used to create the problem can be used to create the solution.

In a restoration agriculture system, we begin by choosing known pest- and disease-resistant varieties. Then we will *not* spray to kill pests and diseases. In restoration agriculture systems we will use the power of sexual reproduction to breed pest- and disease-resistant food plants instead of poison-immune pests. I will deal with this in greater detail in chapter 16.

If you are skeptical that we can grow quality fruit economically without using sprays, don't worry. I won't try to convince you. But what I will do is describe the technique so you will understand where it came from and why it works.

Humans have been growing and eating the domestic apple for thousands of years. If you have ever seen the nasty, warped and caterpillar-drilled fruit that grows in an abandoned orchard, you have a visual image of why we are told that sprays are necessary. The fruit on those trees hardly looks like a good source of food. But somehow in days of yore, people actually looked at those trees and considered them to be an essential part of the human diet.

As a youngster I grew up in the apple country of Massachusetts. My childhood home was only a mile and a half from Leominster, the birthplace of John Chapman — better known as Johnny Appleseed. This area of north-central Massachusetts was home to a thriving fruit-growing industry when I was growing up. By the time I was large enough to hold an apple in my hand I was working for William Flint of Apple Lane in Lancaster. Old Mr. Flint, we called him, and evidently he must have been old because he was called Old Mr. Flint even when my father was a boy. Old Mr. Flint had managed the farm and orchards at Apple Lane since 1939. In addition to milking twenty cows by hand, he had worked at a foundry all his life. He walked slowly and was bent from years of hard labor. Old Mr. Flint grew apples for people to eat, but mostly he was a juice grower. The Veryfine juice company was founded and operated a juice plant in Littleton, Massachusetts a mere 20 miles from the Apple Lane orchard. Old Mr. Flint grew fruit for Veryfine a certain way when I was a youngster, but he told me about growing fruit in "the old days" — still fresh in his memory.

Back in the old days, he told me, there were no sprays. He had not used any sprays himself until after World War II when military surplus poisons were available cheap and manufactured at the Dow chemical plant five miles down the road.

Back then, apple trees were only minimally pruned. In late winter, he told me, the trees were pruned with spaces between the branches so that "a robin could fly through it and not touch its wings." But, he said, "if you could throw a cat through it and it couldn't catch a branch, then you cut too much." That was the only pruning advice I was ever given as he watched me from his seat on the wagon pulled behind his old red and gray Ford 9N tractor.

All trees back in the day were standard-sized trees, not the dwarfs and semi-dwarfs so common today. After a few years of dog and shotgun protection to scare away deer, so that the young trees would have a chance to start to grow, they were left unprotected and deer did the lower pruning by browsing the lowest branches to about five feet off the ground.

In the spring, Old Mr. Flint's cow-calf pairs would graze in the orchard eating last autumn's fallen leaves, close cropping the fresh green grass, and giving the whole orchard a shot of fertilizer. The cattle were then rotated out of the orchard. This actually was key to the old-timer's apple scab control program. Apple leaves from the previous year, infected with a scab lesion, would lie on the orchard floor waiting until the conditions were ripe to multiply and spread. When the proper amount of heat and moisture occurred, the scab spore case would burst open when struck by a raindrop. The spores would then splash upward finding a low hanging apple bud, just opening, to land upon and infect. In the spring, having cattle eat the leaves that had fallen the previous fall, a significant portion of potential infections were eliminated. By raising the lowest branches up to a five foot height, using the free and abundant pruning services provided by the deer, the likelihood of any scab spores from fallen leaves finding a young, growing apple tip nearby would be significantly lowered. In addition to this type of plant health management, restoration agriculture systems promote adding a dense understory of marketable plants, developed to also act as spore catchers.

Old-time juice growers would wait in the fall until around 50 percent of the fruit crop fell to the ground. The first apple fruit to fall from the tree are the ones that are the most significantly damaged by pests or disease. Once half the fruit was on the ground, the remaining crop hanging on the tree was harvested. One of the responsibilities of the picker was to inspect each apple as it was harvested. If there was evidence of insect damage, the picker would simply toss the apple to the ground. This negated, for the most part, having to have a packing shed with conveyor belts and sorting tables to separate the good from the bad. In those days grading was done by human beings as the fruit was picked and only the best went into the picking bucket.

Back in the old days the majority of the fruit was pressed. Apples for home use or for fresh market sales were selected out of the stream of sound fruit during the pressing process. Remember that prior to the 20th century refrigeration did not exist at most apple orchards. The only time that anybody ever got to drink fresh apple cider was when it was coming off the press. Some was stored in the spring house, but its life as sweet apple cider (the non-alcoholic version) was measured in days. Most freshly squeezed apple juice was fermented. Apple juice fermented *with* oxygen quickly becomes infected with acetobacter bacteria which lives in the gut of fruit flies. It proliferates in the presence of oxygen and eventually turns the fresh juice into vinegar. This was perfect for the days before refrigeration because vinegar was used to pickle everything from green beans to beets.

The majority of apple juice went toward making cider (the alcoholic version). To the whole world, except for the United States and Canada (because we forced them to), cider is fermented apple juice (the alcoholic one). Alcoholic apple cider was *the* North American drink in colonial times starting from the day the first European settlers harvested the first apple. Hard cider, as the alcoholic version is popularly called these days, was a great gift to humankind. It was shelf-stable almost indefinitely and it lightened the spirit in an era of barely mechanized, subsistence agriculture.

As soon as the apples were all off the tree, the orchardist would then release the hogs to eat the ones on the ground. Imagine the joy of deliriously happy pigs eating/harvesting tons of apples. And remember that these pigs are removing additional pest and disease larvae and spores from the orchard system before being turned into bacon and chops. Pork chops are definitely my favorite form of orchard pest management.

Corylus (hazelnuts)

It is truly amazing that something like the hazelnut, which is enjoyed by so many people in so many different ways — as a stand-alone snack, crumbled on cakes or in cookies, as a flavoring in coffees, and especially as that combination made in heaven, chocolate-hazelnut spread — is so unknown as a wild plant. The American hazelnut (*Corylus americana*), and its northern and more moisture-loving cousin, the beaked hazelnut (*Corylus cornuta*), are two of the most overlooked of all the native wild plants. During the growing season they are cloaked in plain, rounded green leaves and they hide themselves well by being an anonymous green bush. Their nut clusters are sparse and generally few in the wild and hang hidden underneath the drooping branches in ones or twos.

The plant is also amazing in that it is found throughout nearly the entire range of the oak savanna biome. The humble hazelnut finds its home from the Canadian Atlantic maritime provinces in the East to east Texas and Oklahoma in the South, and up to the 8,000-foot height of the front range of the Colorado Rockies in the West and then growing just shy of Hudson's Bay in central Manitoba in the North.

Pollen-bearing catkins elongate in late winter to pollinate the female hazelnut flowers, which are nearly as small as an asterisk.

In the late Pleistocene/early Holocene era the hazelnut's abundant woody browse combined with its high-oil, high-protein nuts were staple foods for herds of mastodon as they wandered the North American savannas. Hazelnut kernels range between 50 and 75 percent oil by weight. Hazelnut oil is mostly mono- and polyunsaturated fats that are extremely high in vitamin E (just slightly less than found in almond oil). Nearly 15 percent of the hazelnut kernel is protein. Hazelnuts are an extremely high-energy, body-building food. When the oil is pressed from the kernel (and used as a delicious, nutty salad oil) the remaining meal is a protein concentrate that approaches 30 percent protein. Hazelnuts qualify as an excellent candidate for a staple food crop for the present and the future. Much as the soybean is today, the hazelnut may eventually become the ultimate biofuel feedstock for biodiesel or vegetable oil, powering our internal combustion engines. This may seem like a casual remark tossed out in conjecture, but that is not the case. In fact, the Defense Advanced Research Projects Agency (DARPA) has been funding research on biofuels feedstocks for quite some time. It was DARPA that funded research conducted by a University of Wisconsin–Superior study that showed that the American hazelnut was the perennial plant that produced the most oil per acre of any other perennial in North America. DARPA funding also paid for extensive analysis of American hazelnut oil to determine its suitability as a biofuel. It seems to me that if the Department of Defense is looking at hazelnuts as a biofuels feedstock, then that probably means that they're not messing around. The military represents a *huge* future market for hazelnuts grown in restoration agriculture systems.

American and hybrid hazelnuts produce clusters of nuts enclosed in a green, fleshy husk (envoluchre) that gets removed during processing.

There are those who are opposed to the production of edible crops for transportation fuels on the grounds that doing so takes food out of the human food chain. This may possibly be so in cases such as corn ethanol where fuel companies have become a price-competitive buyer of a finite crop of corn; a crop that is not likely to increase by much in the future, might I add, whereas new edible woody crop plantings are appearing as additional food-producing acres that have not existed before. When abandoned agricultural land, hilly terrain or marginal land is planted to restoration agriculture systems, these represent additional acres added to the current food supply. Since American hazelnuts have not been a part of the industrialized human food chain, burning their oil as fuel represents no loss of human food. Newly planted acres of hazelnuts can immediately be thought of as a multi-purpose crop.

Once harvested and dried down to the proper moisture content (around 6 percent), hazelnuts can store for years using already existing grain and nut storage technologies. From storage, the nuts can be graded by size and shell appearance and sold through the in-shell market. These are the hazelnuts (or filberts as they are also called) that you see in bulk bins or as seasonal displays at grocery stores beginning in October.

Nuts that aren't large enough, or that don't have the shell quality for the in-shell market, are sent to the processing plant. At the processing plant, the nuts are first cracked. (By weight, hazelnuts are approximately 50 percent shell.) To some this may seem like a terrible waste, but it's not. Hazelnut shells have nearly twice the BTU's of wood. They burn, in fact, as hot and much cleaner than anthracite coal. Most hazelnut processing plants use the shells for space heat, processing heat, and for heating water. Some facilities are even installing gasification technology in order to convert the solar energy stored in hazelnut shells into a vaporous gas which is then burned to generate electricity in a gas turbine. The hazelnut shell “bottom ash” from a conventional boiler and the biochar from a gasifier, are both outstanding fertilizers. Hazelnut shell ash has been shown to bind and make unavailable several heavy metals, most notably cadmium. Hazlenut shells have even been made into smokeless charcoal briquettes for backyard grilling. Thus hazelnut shells don’t represent a byproduct or waste product at all, but rather an additional value-added yield.

Once out of the shell, hazelnut kernels are sold mostly into the confectionary market, but over time as more of these long-lived perennials come into production, they can be utilized more and more as staple foods. Being high in protein, they resemble beans and other legumes except, of course, that they have three times the oil.

When hazelnuts are pressed for oil the presscake that comes out of the oilpress is a low-fat, high-protein concentrate. The hazelnut is, in essence a hazelnut flavored soybean equivalent. Who wouldn’t like that?

An additional energy cost savings is realized by the hazelnut in that the soybeans (legumes) require cooking before they are edible by humans. Not so with hazelnuts. Hazelnut protein can be consumed as is, straight from the shell or package. Hazelnut presscake protein can be used to make hazelnut milk, hazelnut tofu, even hazelnut-flavored textured vegetable protein for vegetarians looking for a unique new flavor. Plant protein that didn’t come from annual agriculture and hence didn’t destroy an intact ecosystem in order to grow and make it, is a boon. In fact, when you buy hazelnut products (or chestnut or apple or…) that were grown in restoration agriculture systems, you are creating a market demand that pays farmers to plant such systems. You can literally eat your way to a greener planet. Once upon a time this may have seemed like a fantasy, but it doesn’t take much to see that it is not. It is entirely possible to imagine a world where international cargo carriers are made of lightweight, but strong wooden tension laminate hulls and are powered by sail and solar electric engines, delivering ecosystem-grown coffee and cocoa to be blended with savanna-grown American hazelnuts.

As with chestnuts and apples, hazelnuts grown in restoration agriculture savannas obviously wouldn’t be unselected wild hazelnuts. Several universities in the United States in cooperation with First Nations, private individuals, and hazelnut grower groups, are combing the wilds of America’s north woods searching for wild hazelnut plants that regularly out-produce others. For years we have heard that the tropical rainforests of the world are more valuable as rainforests than if they’re cut down to grow soybeans to be fed to beef cattle. Well, the same is true of our North American temperate forests and savannas. They are more valuable as a source of the plant genetics that have survived the onslaught of civilization and have yet to be eradicated. They represent our preserved heritage and they hold the keys to future survival. In addition to undiscovered wild genetics, breeders, both private and institutional, have been crossing European hazelnuts with American hazelnuts and then selecting from those offspring the plants that are cold-hardy and disease tolerant. European hazelnut (*Corylus avellana*) is not cold-hardy at all, surviving only in USDA hardiness zones 5-9. The European hazelnut is not as cold hardy as the American hazelnut and is also lethally susceptible to Eastern Filbert Blight (to which the American and beaked hazelnuts are functionally immune). The European hazels, however, generally produce a larger nut and more pounds of nuts per plant. Breeders have been making steady progress toward developing compact, high-yielding bush hazelnuts that are cold-hardy and disease resistant and will thrive in zero- to low-input restoration agriculture systems.

An additional harvested product that will be produced by all of the woody crops in a restoration agriculture system is biomass. More simply put: wood. Chestnuts, apples and hazelnuts all benefit from occasional removal of some of their wood. When you consider that these species are adapted to fire and to periodic, aggressive browsing by large herbivores, you can see that pruning, coppicing, or some other periodic removal of wood can be helpful. Old or dead branches that might harbor pests or diseases would naturally be consumed by fire and the nutrients immediately returned to the soil. Charcoal and charred wood would help to chemically bind and inactivate chemical toxins. The burned plant would then respond by rapidly regrowing from below the wound, or directly from the ground. European hazelnuts in the northwest United States are commonly pruned to form single-stemmed small trees. In many parts of Europe though, hazelnuts are pruned to a form with clumps of stems. There are bush-form hazelnut growers in the American Midwest that use either technique, and there are others that use a third growing form, which is allowing the shrub to remain a shrub. Coppicing is one potential rejuvenation technique used by these bush hazelnut growers. This practice is to periodically cut the entire shrub to the ground. An entire hazelnut planting can be cut all at the same time, or alternatively, a plan can be utilized where a certain percentage of the crop is cut every year. The former method is far simpler (and potentially allows the hazelnut farmer to have a vacation year) and the latter method enables the grower to even out the nut yield over time and to have a predictable and consistent pruning workload each year. The smaller, annual coppice cuts will generate less biomass for use or sale each year, and the larger but infrequent coppice cuts will produce larger quantities for sale, which may prove to be an important factor when distances to a biomass burner may prove to be uneconomical at lower volumes. As more restoration agriculture growing regions are established, reliable supplies of woody biomass going to a centralized powerplant might be required. In cases like this, regional coppice plans will need to be established as a conversation between growers and the facilities utilizing the woodchips. In a worst-case scenario, which really isn't all that bad, coppice wood from hazelnut or chestnut or prunings from any of them can simply be laid on the ground and chipped with a flail-chopper during the same pass as the grower prepares for harvest. In the latter case there is essentially no nutrient loss during the coppice process and soil organic matter is increased.

Periodic coppicing of hazelnuts doesn't appear to have any harmful effects whatsoever. There are hazelnut growing regions near Barcelona, Spain where the same hazelnut plants have been in production and regularly coppiced since Roman times 1,600 years ago. Now *that's* sustainable!

Rubus and Ribes

Raspberries, blackberries, and their hybrids (Rubus sp.), as well as red currants, white currants, black currants, gooseberries and their hybrids (Ribes sp.), like apples, are somewhat of a solved problem in restoration agriculture systems. There are dozens up to hundreds of varieties of each that exist for nearly every soil type from the warmer regions to cold.

The Rubus plant group are cane fruits and require full sun in order to survive. Ribes are small bushes, rarely over knee height, that will thrive in partial to deep shade, but they only produce decent fruit crops when in medium to full sun. Both Rubus and Ribes plant groups are harvested commercially with a straddle-harvester. Conveniently, the same harvester can be used to harvest raspberries, blackberries, currants, gooseberries, hazelnuts and grapes in restoration agriculture systems. In order to produce the quantities of nuts and fruit needed to be used as staple food crops, machine harvesting will be required. In order to utilize harvest machinery, though, proper considerations will have to be made toward the design and layout of a restoration agriculture farm. This will be covered in more detail in a later chapter.

Ribes (gooseberries in this photo) on the left and Rubus (blackberries in this photo) on the right are two examples of crop producing plants that happily live with very little care in perennial woody polycultures.

Although much of the breeding work has already been done with the small fruits, very little research has been done in the techniques of low-input farming that will be required if these crops are to ever be elevated above the status of snack, flavor or filling.

Staple food crops are almost by definition crops that are grown on a massive scale, hundreds of millions of acres worldwide, with a very high yield-to-input ratio. The majority of the annual grain crops that currently serve as humanity's staple foods appear to fit that bill, however two major factors hide the true costs. The availability of inexpensive fossil fuels, which the industrialized nations currently enjoy, has created a false sense of what the input energy per output ratios really are. A more accurate accounting would be to look at traditional rice culture in China and India where staple food grains are grown for billions of people by the backbreaking labor of millions. Even if this more accurate accounting were used, it would not take into account the degradation of the ecosystems. Annual crops degrade the soil. Nutrients and soil particles themselves blow away in the wind and wash away with the rain. Mechanized agriculture in North America has simply done this more efficiently. It has only taken 100 years to destroy a similar amount of topsoil in the breadbasket of North America growing annual crops as the Chinese have destroyed in 4,000 years using hand tools. If high yields and efficiency are the goals of our agriculture, then North America is certainly in the lead.

Vitis (grapes)

Grapes are one of humankind's first cultivated crops. Today the selection of Vitis varieties is not in short supply, neither are the uses for grapes, from juice, wine and vinegar, to fresh fruit and raisins, grape seed oil, grape leaves for medicine and food wrappers, and the vines for ornaments and craft projects on rainy days. Grape culture, likewise has gone through very little change since ancient times as well. It has always seemed strange to me to see people building trellises for their grapes and then training and pruning the vines — all to get a handful of fruit. Likewise it has amazed me to see thousands of acres of grapes grown like this in California, Michigan, New York and other regions where viticulture appears to be undergoing a renaissance. Why is it that we erect trellises out of perishable materials like wooden fence posts and steel wire when we know that the minute we put up such a trellis it begins to fall apart? I've seen grape trellises fall apart in as little as 5 years and I've seen some that look like they've been around for 25 or 30 years.

Modern grape culture reminds me of the story of the 20-something bride entertaining her in-laws for the first time by baking a roast. Before putting the roast into the pan, she sliced the smaller end off the cut of meat and then put it in the roasting pan next to the larger one. Her new family thought this to be rather strange, and secretly queried their son as to why she did this. When his parents weren't around to embarrass the love of his life, he asked her why she cut the end of the roast off. She replied, matter-of-factly "because that's how Mom did it." At a later dinner event at *his* in-laws this time, he observed his wife's mother prepare a roast in the same way. The small end of the roast was cut off and laid beside the larger piece. With care, both were put in the oven. Fortunately for the young man, he happened to be sitting next to the family matriarch, so he decided to ask her why this was done. Grandmother was obviously the oldest and wisest and certainly when she had passed down knowledge that had survived three generations, it must be important! He turned to Grandmother and asked the question, "Why does your family cut the little end of the roast off and put it in the pan beside the bigger piece?" Grandmother, with blue eyes twinkling and obviously entertained by the question, replied, "The reason why I did it, was because when my husband and I were first married we didn't have a pan that was big enough to hold the whole roast!" Grape growers in this country build trellises for their grape vines because that is how they did it back in the old country. Back in the old country they have been doing it for as long as anybody can remember since a thousand years before Odysseus.

My puzzlement with grape trellises first arose from my own childhood observations of grapes growing in the garden out back and those out in the woods. My dad's grape vines in the garden were growing on trellises that were built to last. He had purchased a concrete mixer his first year out of high school with which he mixed and poured enough concrete to build a service station back in the heyday of big cars with bat wings over the tail lights. When I was little, he resurrected the cement mixer and with a little work he proceeded to pour himself two, eight-foot-tall, reinforced concrete trellis posts that he said were going to last until he was a hundred years old. For some reason, it took him the better part of a summer (or two) to lug the posts over to where he wanted to plant his grape vines, erect them and string the trellis wire. The following spring after he got them installed, he strung galvanized high-tensile fence wire between the crosspieces he had fastened in place. He then planted a grape vine every four feet.

The grapes were planted into moist, fertile soil and very soon he had monster vines crawling all over his trellis. The next winter he was often to be seen outdoors pruning his grape vines. For several years, the bounty of his grape harvest was a source of pride. My mother made jams and jellies, she canned juice, and my dad even made several large batches of wine, none of which proved to taste very good, but evidently produced the effect he desired.

After three or four years, the humid New England weather and the heavy grape crops snapped the high-tensile wire which had corroded almost completely through. While Dad figured out how to resurrect the trellis wire and simultaneously lift the heavy vines, the concrete pillars began to lean and the grape vines went looking for other places to climb. The grape vines eventually found my grandmother's clothesline (which was next to my mom's … I still don't understand why they had separate clotheslines!) and the adjacent pear tree. My grandmother (Dad's mom) forced my dad to fight the vines off her clothesline, which took some doing, and they delightfully ran rampant all over the pear tree.

Finally at the end of the summer, the two leaning towers of Pisa, as I imagined them to be, fell over with a thump and began their slow descent into the sod.

All during this saga, and ever since the dawn of time, grapes, like those on the edge of our woods, and grapes that have escaped from cultivation, have contentedly sprawled their way over, around, and on trees. They have happily attached themselves to a sturdy, all-natural tree trellis that continues to grow and get stronger every year rather than decay, snap and go thump on the lawn.

Currently grapes are grown on a massive scale worldwide. How can the cost of production be reduced and volume increased? Training grapes up and onto trees (such as apples) in an edible woody crop system is one way to eliminate trellising costs. This also helps to reduce pruning labor costs.

Most apple trees are pruned annually. The same applies to grapes. A landowner with 10 acres of apples and 10 acres of grapes has 20 acres worth of pruning to do. Someone who has 10 acres worth of grapes and 10 acres worth of apples growing as a combined system on the same 10 acres, essentially prunes the vineyard and the orchard in a single pass, saving time and money.

At New Forest Farm the fruit tree/grape vine "vineyorchard" is pruned annually. The tree fruits at New Forest Farm are primarily grown for juice production. Pruning is minimal, as described previously, and is primarily done to increase sunlight penetration and air flow for disease management and proper fruit ripening. In addition to this, branches below eight feet are only allowed to grow linearly within the fruit tree row. Branches that grow into the alley space are removed. Trees are essentially trained to an espalier form without using trellis wires or walls. This allows trees to be planted closer together in the orchard for more total trees per acre.

A grape vine is planted immediately next to each fruit tree. The grape vine is then allowed to grow up the fruit tree and is trellised on the lower branches. In order to get a good grape crop that ripens well, the apple foliage is pruned in such a way as to allow sunlight to reach the grapes. The total mass of the grape vine is reduced to a weight that does not break the fruit tree branches and vine tendrils are removed so that they don't girdle the branch. Aside from the lower fruit tree branches being espaliered below the eight foot height, the fruit tree is pruned to a "cat and the robin" branch density. Grape vines are pruned in the normal way for good fruit production. Altogether, pruning the tree fruit and the grapes as a single system is less time consuming than pruning an orchard and a vineyard separately.

Although there may be a trellis cost reduction and a pruning cost reduction in growing these two together, there might not be a harvest cost reduction. There are many orchards that currently use sway-type straddle harvesters for mechanical harvesting of grapes. With the current abundant availability of low-cost fossil fuels these growers probably already enjoy the lowest per-pound harvest costs they could get. The same mechanical harvester that is used to pick grapes can also be used to harvest hazelnuts, raspberries, blackberries, currants and gooseberries. If such a harvester is available for use, it might actually make sense for a grower to use trellises. I currently don't know of any grape polyculture growers who are mechanically harvesting their grapes. It's possible, I'm certain, for some creative grower somewhere to come up with some planting configuration that would allow for mechanical harvesting in a grape-on-fruit-tree system. Here is an opportunity for creative work for all of those interested in developing a fruit and grape polyculture system that can be mechanically harvested and engineering students looking to invent a revolutionary new machine.

For grape growers who currently hand harvest their grapes, grapes on fruit trees represent no increased harvest cost. Hand harvesters experience trellis cost savings (having never to have to replace trellises) and pruning cost savings.

Prunus

The Prunus group is a broadly diverse genus of woody plants that includes cherries, plums and peaches. They range from a widely adapted, tall tree such as the American black cherry (*Prunus serotina*), all the way down to small, bush-form plants such as the beach plum. Apricots, peaches and nectarines are also in the Prunus plant family. Included are some super cold-hardy plants such as the Manchurian apricot, American plum and pin cherry. There are forms that spread by root suckers and others that only spread by seed.

Pyrus species (pears) are in the Rosacea family, are closely related to apples and can be used in their place.

Although all of the Prunus produce fruit, not all of them are palatable. Sugar, maple syrup and honey can help sweeten some, but many others are best suited for use as an animal feed. Wild birds, of course, will help themselves to many fruit in season, but despite the efforts of our wild avian friends much of the plentiful fruit still falls to the ground. Pastured swine and pastured poultry will gladly consume all of this free fruit.

The versatility of the Prunus group allow them to be used in a variety of creative applications and regions. A grower in Georgia would obviously be able to sell fresh peaches whereas a grower in Wisconsin might "hog down" his black cherry crop. Growers in Nebraska up to the Dakotas would be able to machine harvest hardy beach plum and those even farther north could harvest Nanking cherry from their shrubs using the same harvest equipment.

All in all Prunus plants are a many faceted, useful plant in restoration agriculture systems.

Fungi

Biological systems in the phase of aggradation are in the process of accumulating a surplus of carbon on the site. This happens when plants bring in carbon dioxide from the air and use that carbon dioxide to manufacture two of the most ubiquitous carbon composites on planet Earth: lignin and cellulose. Lignin and cellulose in combination with other compounds are used to make the roots, stems, branches and leaves of trees. Annually leaves fall to the ground and are decomposed by a multitude of organisms. Periodically branches and eventually whole trunks of trees return to the earth. Literally millions of different decomposer organisms chew, eat, digest and chemically dissolve leaves and wood to release the energy stored in the chemical bonds between carbon molecules. The heavy-lifters in this category are the fungi. Whether a restoration agriculture farmer chooses to deliberately harvest the decay cycle or not, the fungi will show up. Fungal spores by the billions are free-floating in the atmosphere and daily land on surfaces where they simply do not grow. Every once in a while a spore of the right kind will miraculously land on the proper substrate and begin to flourish. I've worked with a landowner in Saskatchewan, Canada who has a 40-acre woodlot comprised of drought- and cold-hardy woody plants such as burr oak, Colorado blue spruce, lodgepole pine and Siberian peashrub. Branches and trunks fall to the ground and quickly become covered with lichens and mosses and eventually become colonized with fungi. In the spring there is a flush of mushrooms on the logs and growing up from the mossy forest floor. I know that this sounds like a totally ordinary description of a natural forest. What is so remarkable about this particular "forest," is that it is *not* a typical forest. Planting for this 40 acres of trees was started back in 1905 and is surrounded by hundreds of thousands of empty acres of annual crops, mostly canola. There is not a tree to be found within 500 miles of this 40-acre forest. The nearest "forest" to this place is an entire province away to the west in the Rocky Mountains of Alberta. How then, did the forest fungi show up? No matter where you locate your restoration agriculture farm, if you can get trees to grow, fungi will show up! They are free-floating on the wind and can survive for dozens if not hundreds of years totally dormant, waiting for the right conditions.

The 40 acres in Saskatchewan was planted by a tree enthusiast. When he began his project in 1905, foresters and farmers were not entirely aware of the benefits of mycorrhizal fungi. Mycorrhizal fungi are fungi that colonize the roots of most terrestrial plants. Plant roots by themselves take water and nutrients in from the liquid solutions found between soil particles. They are only so effective, though. Mycorrhizal fungi join in a beneficial (symbiotic) relationship with tree roots. Some fungi encase tree roots in a blanket of mycelium (the basic fungus body). Other fungi insert themselves into the spaces between tree root cells. The mycorrhizae expand from the tree roots out into the soil. In a manner similar to the algae/fungi relationship in lichens, the fungus chelates (dissolves and takes into its body) minerals from the rock particles and makes them available to the tree. The tree leaks sugars into the fungus keeping it happy. It is estimated that mycorrhizal fungi expand a tree's ability to capture nutrients and moisture from the soil by a factor of 100 to 1,000 times, in part because they so dramatically increase the absorptive surface area of tree roots.

Fungi are the magical soil-building bridge that turns inedible wood into a gastronomic delight. Farming the decomposition cycle!

When planting an edible woody crop system, tree roots or transplanting water can be pre-inoculated with mycorrhizal fungi. This will help trees to get established, especially if they are planted in former annual crop land where fungi are scarce and where bacteria dominate. This can be done by simply tossing a handful of soil from a healthy system into the hole of a newly planted tree. Duff (fallen plant debris) from beneath oak trees will be loaded with fungi appropriate to oaks. Duff from beneath hazelnut bushes is the same. Additionally, the soil surface can be sprayed with compost teas made from the leaves of the species in question. All of this will help to inoculate the site with beneficial fungi.

In addition to the mycorrhizal fungi, decay fungi are an important component of a healthily functioning system. Like the mycorrhizal fungi, decay fungi will eventually show up. Rather than merely waiting for this to happen, a grower can establish marketable fungi and harvest the fruits. There are numerous culinary and medicinal fungi that can be established on wood "waste" from a restoration agriculture system. Branches and logs can be inoculated with shiitake, maitake, reishi, oyster, wood ear, and numerous other valuable fungi. Branches too small to use for log-grown fungi can be chipped and used as a substrate for mushrooms like winecaps and stropharia. Fungi that thrive on chestnut wood are different than those that thrive on apple wood which are different still from those that thrive on chipped hazelnut wood.

One of the miracles of fungi is the fact that 100 pounds of wood can turn into nearly 130 pounds of high-protein mushroom bodies. After several years of producing mushrooms the substrate — whether it is logs, stumps or chips — crumbles softly into the soil and the remaining fungi becomes food for the rest of the soil food web. Thus the cycle is complete. Carbon dioxide is taken from the air and turned into tree bodies. The tree bodies become food for mushrooms which then feed nematodes and worms, bacteria and other soil life which excrete nutrient-rich feces that becomes fertilizer for the tree. Once again we are reminded that by recreating whole, healthy ecosystems we can restore the ecological functions of soil building, carbon sequestration and nutrient cycling while producing clean, healthy foods, fuels, medicines and fibers for human beings.

LIVESTOCK

Entire books have been written about the topic of raising livestock and no doubt dozens more will. So here I will not go into the details of animal husbandry, but I will describe the general pattern of raising livestock.

The general pattern of livestock management that I will describe here will have to start with a mental image. Once again I will refer to the same mental image that was described in chapter 5 and that is of the African savanna as shown in various National Geographic television specials. This is the archetypal image from which I would like to tease out the details. Can you see the elephants, giraffes, zebra, wildebeest, Cape buffalo, warthogs, dozens of species of gazelle, lions, cheetahs, hyenas and more? Don't forget huge flocks of birds parading on the ground, moving from tree to tree and filling the air with song.

This mental image is all that we need as a starting point in order to create our restoration agriculture animal system. Some of you may even actually have a land base large enough to sustainably graze elephants, as well as the interest to do so, and have access to a source of an initial herd. There is actually quite a bit of interest in using North American ranches as a way to preserve endangered African, Indian and Southeast Asian megafauna in a semi-natural setting. The Rewilding Institute and other organizations such as the Non-Traditional Farmers and Ranchers Coalition have proposed this.

This is all well and good and quite possibly essential for the preservation of endangered species, but this is not exactly what we are proposing here. Restoration agriculture is *not* setting aside vast tracks of land for the restoration of pure savannas and the rescue of endangered species. Restoration agriculture is farming in nature's image to produce the food, fuels and fibers that feed the world. Instead of elephants, giraffes and warthogs, we use commonly known livestock. Cattle, hogs, turkeys, sheep, geese and chickens are all excellent livestock choices for a restoration agriculture farm. In chapter 9 I will describe how a diverse polyculture of animal species can be used as a highly productive compliment to an edible woody crop polyculture. (Although I would still like to have a couple of elephants on the farm.)

CHAPTER 8

Other Biomes

OAK savanna is the terrestrial biome with the widest distribution of any biome in North America. For this reason we have used it as the primary model for a restoration agriculture farm. No matter where you live in North America, some variant of an oak savanna biome can be imitated and farmed successfully. There are, however, places where the oak savanna is not necessarily the best first choice.

No matter where one goes on planet Earth, there are families of plants and their associated animals that grow and thrive together in virtuous relationships with zero external inputs. In every biome on this planet, except for Antarctica, human beings have lived healthy, happy lives. They have experienced love and affection, they have laughed, they have played. They have developed cultures that were rich in art, song and spiritual tradition, and they have done so with technologies no more advanced than sticks and stones. This should prove to us (the "advanced" moderns) that we too can live and thrive just about anywhere on this planet, provided that we do not degrade the resource and thereby degrade the ability of that place to sustain us. As Permaculturists are proving in desert and mountain sites around the world, a little bit of human care using permaculture design and restoration agriculture principles can actually increase that place's ability to sustain us. Gardens of Eden are being grown in the Dead Sea Valley, on the bare rocks in Jordan, and in the desert scrub of Africa and India, the American Southwest and Central America.

As ecosystem optimizers, restoration agriculture farmers help to increase the photosynthetic productivity of a site while simultaneously growing staple food crops and restoring ecosystem services. The opposite of this is the course that dominant human cultures have taken — one of resource extraction, ecosystem degradation and eventual desertification. The Olduvai Gorge in Tanzania, Africa, is the birthplace of the human race. Parts of Tanzania have been occupied by human beings literally for millions of years. In those millions of years, human beings have extracted their sustenance from the ecosystem and degraded that system's ability to support human life. North America has only been occupied by humans for several thousands of years, and yet our mechanized, industrialized methods give us a massively leveraged ability to impact our place.

Restoration agriculture enthusiasts and researchers are involved in the lifelong process of designing and creating staple food producing ecosystems in many different biomes across the planet. Some day there will be examples of productive restoration agriculture farms in every biome on every continent and in every climate. For now, however I'll just list a few North American biomes and the plant families that can provide an ecological model for a restoration agriculture farm. Remember, staple food production is a primary goal of restoration agriculture. Since these systems are intentionally designed and highly managed, they qualify as permaculture, and because they are modeled after naturally occurring plant communities they qualify as ecological restoration. Since they produce staple food crops they qualify as agriculture, hence the name restoration agriculture.

TEMPERATE RIPARIAN ZONES

River valley floodplains are home to some of the richest soils in North America. Even before the advent of annual agriculture, they received sediments deposited from upstream erosion during flood events. Since these sites are located in the river bottoms, groundwater is fairly close to the surface making these sites extremely drought tolerant. Anyone who has traveled through the plains states of the United States and prairie provinces of Canada has seen cottonwoods, willows and other woody plants lining the riverbanks and filling valleys with green. In the humid east, these sites host some of the largest diversity of animal life in North America and provide nesting sites for some of the most critically endangered birds such as the probably (hopefully?) not yet extinct ivory-billed woodpecker and the colorful prothonotary warbler. When such riparian sites remained in an open-canopied condition, grasses thrived there like nowhere else. The river valleys, such as the Ohio, were exactly such places. The grasses grew so high that they towered over the heads of horses. The reports of these places by pioneer explorers attest to the abundance of these sites.

Riparian zones are subject to periodic flooding. Unlike water-saturated floodplains (such as the cattail wetlands mentioned in chapter 13), the riparian zones referred to here have moist and fairly well-drained soil. The species adapted to this can tolerate being submerged for short lengths of time, but they don't really appreciate waterlogged soil that becomes anaerobic. Sites like these are perfect locations for the plant family associated with trees in the Juglandaceae family (the walnuts and pecans).

THE RIPARIAN ZONE

- Juglandaceae: pecan, black walnut, Persian walnut — *Tall, nut-bearing trees*
- Rosaceae: (*Prunus*) cherries, plums, peaches — *Various different forms from tall trees to suckering shrubs*
- Others: pawpaw, nannyberry, mayhaw — *Shade-tolerant, fruit-bearing shrubs*
- Raspberry
- Grape, passion fruit — *Fruit-bearing vines*
- Kiwi
- Pasture

These plant groups, of course, are regionally adapted. Pecans are not as cold-hardy as black walnuts and black walnuts are not as cold-hardy as the butternuts which also can be used in this system. Almonds are a member of the Rosaceae family and can be used in warmer regions where they will survive the winter. Many of the most common varieties of almond and Persian/ English walnuts (*Juglans regia*) are susceptible to various fungal diseases in humid eastern North America. This represents a *huge* opportunity for a restoration agriculture farmer to select disease-resistant cultivars that will survive in climates other than the central valley of California!

The black walnut has a limited range in Canada, but more cold-hardy varieties can quickly be discovered by enterprising restoration agriculture farmers. I know of black walnut trees growing in southwest Saskatchewan where the conditions are ridiculously far from ideal for them. The walnuts in question were on the homestead of Canadian plant pioneer Adolf Heyer and they no doubt are only a few of the thousands of seedlings that were able to survive the hot, dry summers, cold arctic winters, and the dramatic daily temperature swings which are common to the Canadian prairie provinces.

Pawpaw and mayhaw are also less cold-hardy and are currently restricted to warmer climes. I personally have killed hundreds of pawpaws in search of that miraculous one or two that will survive the -40° F temperatures that occasionally settle into the nooks and crannies of southwest Wisconsin. I have one individual plant that has done exactly that and I will need another if it is to get pollinated and bear fruit. As the years go by while I "search" for the perfect Pawpaw, our walnut planting is a delightful multi-storied system of grapes trellised on walnut, with raspberries and plums planted within the row of walnuts. Cattle and hogs rotate through to harvest the greensward, pick up pest-infected fruit, and to fertilize the system with their excrement (which is quickly gobbled up and buried by dung and carrion beetles).

A southern variant of this plant grouping would be to use pecans, peaches, pawpaw, raspberry, passion fruit and livestock. A more northern variant would be black walnut, tart cherries, nannyberry, raspberries, grapes and livestock — with lush green grass growing all around. "And the green grass grew all around, the green grass grew all around."

NORTHERN PINE FOREST

The northern pine forest isn't the official name of this particular biome, but it is one that people recognize who live in these regions. My usage of "northern pine forest" covers the northern tier of states in the United States from Maine (where white pine mixed with spruce and balsam fir dominates) to northern Minnesota with its white, red and Jack pine forests. The northern pine forest region covers all of southern and eastern Canada and gradually transitions north into the subarctic boreal forest where the pines give way to spruce. Northern pine forests are also found at higher elevations in the Appalachian mountains all the way south to the Carolinas and Georgia. In this book I am not including southern pine forests which are made up of longleaf and yellow pines, since they have so many species in the habitat that differ from the northern pine plant associations and offer so many other options for co-planting.

A classic northern pine restoration agriculture system would imitate natural plant associations found in the wild and would include:

- Pinus: Korean pine, Siberian pine, Italian pine, Himalayan pine, Pinon pine — *Tall, nut-bearing pines*
- Malus: apples — *Medium height standards, semi-dwarfs or dwarfs.*
- Prunus: tart cherries, plums, Nanking bush cherry — *Various heights and forms*
- Amelanchier: serviceberry/juneberry — *Tall, fruiting shrub*

- Hazelnut — N*ut-producing shrub*
- Blueberry: highbush types (3-6 feet tall) or lowbush (ground layer) types.
- Cranberry: highbush types (3-6 feet tall) or lowbush (ground layer) types.
- Raspberry
- Grapes
- Lingonberry, strawberry, goumi, others
- Forage and animals

A northern pine restoration agriculture system is interesting in part because it seems to have its fingers in several other systems. It shares apples, hazelnuts, raspberries and cherries with the oak savanna and raspberries and grapes with temperate riparian systems. It shares pines, blueberries, lingonberries and cranberries with boreal forest systems. It also appears to be comprised of species that may not have read the current literature about what conditions certain tree species are supposed to prefer. I'm referring in this case to the occurrence of apples growing in the same place as pines. According to most agricultural literature of today, you will learn that apples prefer a calcium-rich and neutral to slightly alkaline soil. They don't really appreciate acidic soil. Well, the books and Internet are wrong. If nothing else, the entire state of Maine is a testament to the fact that apples do quite well on granite-derived, calcium-impoverished soils and in happy association with the soil-acidifying white pine and spruce. One of my favorite and inspirational places in northeastern Maine is near the town of Grand Lake Stream. At the site of an abandoned 1920s-era hunting and fishing lodge of the "grand elegant wilderness lodge" tradition, is an extensive planting of this exact system. Hundred-foot-tall white pines tower over 60-foot-tall apple trees that are bearing profusely. Beaked hazelnut and highbush blueberry have filled in beneath the deer-browsed apples along with a few serviceberries. Raspberries and blackberries protectively surround the thicket and lowbush blueberry, wild strawberry and Canada mayflower have filled in the ground layer. Present is 100 feet of food. This system is highly productive, extremely nutritious, and has had *zero* inputs for the past hundred years. That's sustainable agriculture!

BOREAL FORESTS

The boreal forest of the northernmost United States, Canada and Alaska is ecologically one of the newest and youngest biomes in North America. They have only recently emerged from the ice age. In fact, at the toes of glaciers, the planet is still emerging from the ice age. The process occurring at the toes of North America's glaciers is the process that has occurred over the tens of thousands of years since the past glacial maximum. The greater amount of time that a place has had since the last permanent ice, the more genetic complexity has been able to develop. The boreal forests are one of the first successional forest phases after glaciation and, as such, they have not had the length of time to develop the biological diversity of the more temperate regions. The palette of plants to choose from is a bit more lean in the boreal forest regions.

The boreal forests of North America are extremely impoverished when it comes to native staple food-producing woody crops. That does not mean that we can't design a restoration agriculture farm for Alaska, northern Canada and in the high altitudes of the Rocky Mountains. All that it means is that we would have to use substitute species from other continents.

In native North American boreal forests the following species occur (listed in order from tallest to shortest):

- Spruce (white, black, Engleman, red and others)
- Lodgepole pine
- White birch
- Serviceberry
- Cherry (pin cherries and various naturally dwarfed bush cherries)
- Hazelnut (seems to disappear north and west toward the Yukon Territory and Alaska)
- Highbush cranberry
- Raspberry
- Rose
- Lowbush blueberry

• Lingonberry, cranberry, bearberry, kinnikinnick, crowberry

The native North American boreal forest plant family is extremely deficient in proteins and oils. The cold temperatures and physical exertion required to live in subarctic regions necessitate sufficient fat calories and muscular proteins. Arctic cultures around the world have developed diets that are heavily reliant on animal fats and proteins. All around the north hunting and fishing is no mere pastime, but an essential part of the diet. This reliance on natural animal populations has in part led to the underdevelopment of agriculture in the north. In my opinion, this is a good thing! The last thing that the northern latitudes need is to be clear-cut, plowed and planted to a few pathetic crops of barley or oats before blowing away in the desiccating polar winds. Subsistence hunters and fishers already understand how to harvest an ecological system. They are some of the most skillful restoration agriculture farmers that I have encountered.

In order to overcome the protein and oil deficiency in the boreal plant family, two non-native species can be inserted.

Spruce or lodgepole pine can be replaced by Siberian pine (*Pinus sibirica*) or Korean Pine (*Pinus koraiensis*), and a nitrogen-fixing, bean-producing shrub, Siberian peashrub (*Caragana arborescens*) can be inserted. There are several forms of Siberian peashrub whose mature heights range from 20 feet tall to fully dwarfed shrubs barely reaching over knee height.

Siberian pine, like all of the nut pines, produces large seeds that are 50-55 percent oil and nearly 30 percent protein. Siberian pine is actually the backbone of a rapidly growing industry in the far east of Russian where it is called “cedar.” Anyone who has eaten piñons or eaten pine nut pesto knows how delicious they are. The high protein and oil concentrations make them arctic food par excellence. Pine nut oil is an incredibly delicious salad oil or dipping oil and can be used in cooking if you want to waste it that way. Early spring fireweed shoots dipped in pine nut oil will help one to forget that winter ever happened and that the mad rush of summer is upon you.

Siberian peashrub, likewise, is fairly high in oil. Being a legume and not a tree nut Siberian peashrub seed is lower in oil than pine nuts, but it is higher in protein. The seed resembles a mung bean and can be eaten like one as well. It can be cooked like any other bean, ground into flour, sprouted, roasted, or used as an animal feed or a bioenergy feedstock.

Several years ago I was invited to speak at an agroforestry conference in Saskatchewan where the premier of the province was the keynote speaker. In his presentation he spoke of the need to plant millions of acres of forest as a way to create a heretofore non-existent natural resource. My initial excitement over the idea of Saskatchewan’s politicians committing to planting millions of acres of trees began to fade as the premier started to explain. In his address he outlined how the province was going to give millions of dollars to large multinational corporations *not* to actually plant the trees, but to develop the technology to burn whole trees, to create laboratories that would produce genetically engineered hybrid poplars and willows that would be resistant to herbicides, and eventually for the machinery to mechanically plant monocrops of hybrid poplars (destined also to be machine harvested and burned whole in retrofitted coal-fired power plants). Saskatchewan’s double-digit unemployment rate at the time was mentioned several times, but nowhere did the premier actually mention hiring anybody but a few dozen well-paid engineers and lobbyists.

A later speaker then mentioned some current problems with agroforestry in Saskatchewan, one of which was the horrible, mean and nasty “invasive” Siberian peashrub! Siberian peashrub not only survives in Saskatchewan, but it kicks butt. One of the biggest problems with this plant is that it “invades” canola fields and was rapidly developing herbicide resistance. Well, hold the phone folks. A perennial shrub that produces its own nitrogen fertilizer, has large yields of high-oil and high-protein beans, produces wood that can be coppiced and burned as a biomass feedstock, can be harvested mechanically with a straddle harvester, is actually invading fields of an annual crop that also produces oil and protein but requires annual inputs of tillage, planting, herbicide, fertilizer while increasing wind and water erosion? Um, what’s the problem here?

At the conference I quickly rearranged my presentation on permaculture to include Siberian peashrub as a major industrial component of a staple food-producing, permanent crop.

One year later I was informed that research has begun at the University in Regina dealing with this plant, *Caragana arborescens*, as a harvestable protein and biomass crop.

THE SUBTROPICS

Since there are no tropical climactic zones in Canada and no true tropical zones in the continental United States except perhaps arguably parts of Florida, I will not give the tropics more than a brief mention here. The most significant point is the sheer numbers of absolutely incredible perennial plants that can be included in tropical and subtropical systems. Like any other biome there are regional variations on the theme of a species, with some tolerating seasonal monsoon saturation and the same species having variants that survive six months of drought. The tropics are the most species-diverse region on the planet and there is no shortage of material to work with. The same principles apply to designing a tropical farm as would a temperate or boreal farm: water management, earth-shaping, maintaining perennial groundcover, diverse, three-dimensional perennial woody crop plantings, and a diverse animal component.

Breadfruit, jackfruit, plantain and banana are some of the starchier staples. Nuts such as cashew, macadamia, shea, pistachio and Brazil nut are also some good protein and oil sources. The palette of species to choose from begins to get ridiculously long when you start including the hundreds of tropical fruits from citrus to tamarind, pineapple, mango, guava, pomegranate, figs, olives, avocado and the list goes on and on — and could also include cinnamon, nutmeg, pepper, lemon grass, ginger, tea, coffee and cocoa.

Most significantly, the tropics and subtropics represent an incredible repository of genetic diversity from which more temperate restoration agriculture farmers can draw. For example, very few people realize that there are bananas, figs and pomegranates growing outdoors, unprotected in Washington, D.C. These all tolerate occasional near-zero weather. If those plants can do it, there are likely to be other variants out there that will survive -10° F, -40° F, and so on. There are coffee plants that grow from near sea level to several thousand feet in elevation in the mountains. If someone were to begin a Luther Burbank-style mass selection of the highest-altitude coffee and cocoa grown from seed, it wouldn't take long at all before variants of those plants would be discovered that would tolerate growing in Texas, Oklahoma, Nebraska, Kansas and the Dakotas. Even without a changing climate this is possible, if we only commit to mass selection of site-adapted cultivars with minimal inputs. I'm looking forward to the day, probably in my retirement years, when I can settle back into my easy chair with a cup of Vermont-grown coffee while eating a Montana-grown chocolate bar with Wisconsin hazelnuts in it!

Mass selection breeding is incredibly simple. All that we need to do is to plant way too many seeds and select the plants that behave the way we want them to — pest-free and disease-free with no inputs whatsoever. With our help, we can generate the sheer number of seedlings that it will take in order to roll a genetic "Yahtzee" or two and come up with the next newest varieties that will revolutionize agriculture as we know it. The tropics are a massive gene pool from which to draw.

CHAPTER 9

Livestock & Restoration Agriculture

> Given that the several thousand years since those extinctions are but an eye-blink in geological and ecological time, it stands to reason that the New World is still reeling from the draconian loss of big animals. Therefore, it becomes reasonable to at least ponder the possibility of carefully restoring appropriate big animals to North America from Asia and Africa to see if they have beneficial impacts on truncated ecosystems and to study whether such beasts, some of which are highly imperiled in their current homes, might find secure homes where their relatives once flourished.
>
> *The Rewilding Institute*, www.rewilding.org

I had recently finished reading Paul S. Martin's book, *Twilight of the Mammoths: Ice Age Extinctions and the Rewilding of America* and I was driving the winding back roads of southwest Wisconsin thinking about the three species of elephant that used to roam these hills: woolly mammoth, mastodon and Columbian mammoth. I imagined what it would be like to see nine different species of giant sloths from the 12-foot-tall Megatherium to diminutive 4-feet-tall species weighing in at a mere several hundred pounds. I wondered what it would be like to see two species of giraffe browsing honey locust pods 20 feet up in the air and I wondered what it would be like to run over a giant armadillo lumbering along the gravel road with its humped back looking like a 3-foot-high Volkswagen bug. I came around the corner enjoying the flickering sunlight through the layers of leaves shading the road, and then I saw it — I saw the closest representation of what a pre-human Midwestern North America scene might have looked like. In a lush, green pasture before me I saw an amazing assemblage of animals.

Most noticeable were four, extremely alert Percheron work horses, three of which looked up at me as I came near their kingdom. Scattered around the horses was a herd of twenty-odd Jersey milk cattle of all ages. Farther out from the fringe of the cow/horse herd, was a very numerous, but more widely scattered flock of sheep. Here and there among the menagerie were a colorful assortment of geese, ducks and guineas. In apparent oblivion to everyone else was one of the largest boars I've ever seen in the neighborhood, and lounging in the corner of the paddock was an enormous mama hog suckling what looked like close to three hundred piglets. (There were a lot of them!)

On one fenceline stood a phalanx of portable chicken cages no doubt being moved to new pasture each day. This is the kind of animal diversity and the kind of animal polyculture that built the soils of the savannas and prairies of North America. The total weight of the animals on that pasture seemed almost unbelievable. Yet the pasture was rich and green.

To most people it seems easier to talk about a multitude of plants all growing in the same place at the same time. We see this happening all around us. Depending on where we live, we may see city lots or ditches beside the railroad tracks filled with a jumble of plants, or we may see suburban landowners as they struggle to keep the seedling trees, vines and grasses from "invading" the immaculate, green lawn in front of the house (or more than likely in the backyard and overlooked corners). Anybody who has traveled even short distances has seen abandoned lots going riot with plant life and abandoned cropland that has gone back to "brush." Not as many people, however, have much experience observing a polyculture of animal species. This topic, ecological niches, was successfully avoided during my discussion of the oak savanna biome earlier, but it cannot be avoided any more.

Whether you pronounce niches "nitch" or "neesh" it doesn't really matter to me. Call it what you will, an ecological niche is a position or role taken by an organism within its ecological community. A niche may be defined in part by what resources are available in a particular location, or it may be defined by what resources are there during a particular time of the day or season. It may even be defined as a successional phase whether it be bare black dirt, grassland, shrubland, or early or late successional forest. When I say "resources" in the definitions of an ecological niche I mean such things as food, water, shelter, reproduction sites, etc. In discussing oak savannas previously, the role of the emergent tree layer in the canopy was dominated by oaks, chestnuts or beech. A location that is 100 feet up in the air has certain resources available that aren't available down on the ground. If the biology is available to occupy that space 100 feet up, it will eventually occupy that site. Nature abhors a vacuum and will fill an empty space when it can, even if it takes a thousand or more years to do so. If we don't supply a chestnut, oak or beech for the 100-foot height niche, nature will use whatever is on hand, an ash or tulip poplar or white pine instead.

In our oak savanna model, each woody plant species (chestnut, apple, hazelnut, raspberry, currant, grape, fungi and more) occupies a specific niche in the spatial structure of the system. Be it high or low, sun-loving or shade-tolerant, self-supporting or vining, all species require the support of others. The Prunus genus has forms that are able to occupy different niches; black cherry is able to occupy either the overstory or the canopy layer while bush cherries and beach plums occupy the sun-loving shrub layer. Ecological niches in place like this are quite easy to observe. Ecological niches in time aren't as easy to observe. The previously given example of tulips and daffodils, spring ephemerals that are followed by alliums and lilies, daisies, brown-eyed Susans, Queen Anne's lace and eventually fall goldenrod and aster are not as much occupying niches in space, but locations in time within a single season.

"Time niches" are a little more challenging to detect, but when we begin to better understand succession in our bioregion we begin to realize that some niches in time are thousands of years in the making. It is easier to answer the question, "What kind of nut-bearing tree can live in Missouri and occupy the 100-foot-tall layer" than it is to think, "What kind of plant will occupy the mid-July time period 120 years from now?"

Thinking about available niches can be even more challenging when we incorporate beings that move into the calculus of both space and time. One reason why fewer people have experiences with animal polycultures is that they almost constantly change in both place and in time based on a number of factors. Even in the most inner-city location in the world, there *is* a polyculture of animals living there. Most of the time, however, we don't get to see them all at once in the same place at the same time. That is because animals, left to themselves, will move to the place where they find the most or highest quality of whatever it is that they eat at the time. If their food or drink is not where they are or if the forage is better somewhere else, they simply walk, run, trot, hop, waddle, fly or slither over there.

Another reason why many people are unfamiliar with animal polycultures is that they only see the animals that are occupying a single niche at any one point in time. One typically won't see fruit-eating birds in a McDonald's parking lot, or large graziers for that matter. The lack of fruit trees and lush green grass makes a certainty of that. A parking lot is hostile territory to a sheep or cow. We don't usually see turkey vultures unless there are dead animals around (or they're looking for dead animals), nor osprey unless there is a large body of fresh water from which to catch fish. Animals move to where the living is best. Restoration agriculture systems take into consideration niches in space and schedules in time. Time considerations for animals in restoration agriculture take into account not only changes in the plant systems during a single season, but also take into account the changes in the system through the years. Indeed, restoration agriculture is all about dynamic stability and ecological change through time. Over the course of a year, through a period of several years, and through hundreds and thousands of years of time, restoration agriculture is the process of creating a viable ecological system based on natural patterns and relationships, that is perennial, and that produces staple foods, fuels, medicines and fibers for human beings while providing an increasing number of available niches for animals both wild and domestic. Before we go through time any further let's address the vegetarian/vegan diet and animals in restoration agriculture systems.

It is entirely possible for a person to engage in restoration agriculture and not eat the carcasses of dead animals. It is also entirely possible for a person to engage in restoration agriculture and not be a herdsman, milkmaid or even a goose gaggler. Domesticated animals are an incredibly useful tool for the management of perennial polyculture systems. Simultaneous with their benefits of weed control and pest control, domestic animals provide human beings with food, clothing and other materials, additional income, and most significantly fertilization services. But, even so, domesticated animals are not absolutely necessary.

It is, however, impossible to engage in restoration agriculture or any kind of agriculture for that matter, without enlisting the aid of countless animals. Planet Earth is a living, pulsing, breathing, crawling, breeding, pooping and peeing place. Multitudes of animals, from the smallest microscopic soil organism to the largest sea mammal, are natural, normal parts of this planet. In fact the presence of healthy animal populations is an indicator that a region is a vibrant and healthy place to live.

The air that we breathe is derived from an active interaction between plants and animals. The soil in which plants grow is the same. It is impossible to grow even so much as a radish without animals being involved somehow. Animals are a part of life on this planet, and just like us, they are born and they die. As a matter of fact, in order for the 7 million acres of organic soybeans to be grown in the United States at the time of this writing, a multitude of animals had to be pushed out of their natural range and their habitat had to be destroyed. The soil in their natural range then had to be plowed or vegetation eradicated with field cultivation, and the animals exterminated when they tried to return.

Conventionally this happened on the nearly 80 million acres of soybeans nationwide.

Annual crop agriculture takes existing, functional, animal-supporting ecologies and destroys them in order to grow a limited number of human-supporting crops such as soybeans. Soybeans are responsible for the destruction of animal habitat, so if a non-animal eating diet is based on annual crops, in actuality it kills animals. In restoration agriculture, perennialism is restored. Animals, wild and domestic, now have a place to live. In restoration agriculture a multitude of ecological niches are created which animals can and do colonize. A field of soybeans has no permanent niches available for animals. Annual agriculture is hostile to animals. For a few brief weeks in the late fall or early winter some deer and crows can gather up some of the spilled soybeans, but there are no permanent populations of animals that can reside in an annual crop field.

In a restoration agriculture system niches from 100 feet up all the way down to ground level (and below!) are designed along the path toward restoration. Niches that do not exist in a corn or soybean field now become available to be colonized by animals. Whether you choose to eat meat or not, a restoration agriculture planting creates niches for more animals than any annual crop field ever can. For those who choose to not eat meat and simultaneously create new animal habitat, perennial staple foods need to be substituted for annual crops. For the vegan chestnuts and hazelnuts are one restoration agriculture answer to corn and beans. By purchasing perennial staple food crops a vegan can economically incentivize the planting of restoration agriculture systems.

For those who consciously choose to incorporate animals into their restoration agriculture system, this chapter will be a launching-off point rather than a definitive treatise. Rotational and management-intensive grazing books exist in profusion and are where one should turn for the details of how to manage one's livestock and pasture. What this book intends to do is to set the framework for one to use as a basic outline. The details need to be worked out by the individual grazier depending on their location, available markets, and personal preference, a goal being the establishment of a polyculture of animal species that provide weed control, fertility and a certain degree of pest control for the woody cropping system, as well as additional income and, of course, food.

Animal polycultures in restoration agriculture are exercises in creating carefully designed leader-follower, mob-stocked, silvopasture grazing systems. Leader-follower grazing systems are those where one animal type is let into a paddock first. Once it has eaten its preferred foods in the first paddock, it is rotated to the next paddock, and the next type of animal is turned in where the first just recently vacated. Leader-follower systems are able to out-produce other grazing systems for total animal weight gain because each animal is allowed to eat its optimal foods first. In turn, each animal eats its preferred forage first. When it is done it is moved to the next paddock and the next livestock is let into the vacated paddock. The pasture is allowed ample recovery time before the original grazing animal returns to the initial paddock. Silvopasture, an official agroforestry practice, is the intentional combining of both livestock production and woody plants. It is the intentional and intensive management of *both* the forage system *and* the woody crop. Silvopasture is *not* turning your animals loose in the woods to graze; it is intensively managing an open-canopy tree and forage system. A restoration agriculture system as described in this book is a silvopasture system on diversity hyperdrive with a goal being the optimal harvest of solar energy per acre while actually improving the site conditions.

This type of grazing takes its model from observations of animals grazing in natural savanna systems. The best examples of animal polyculture grazing available to us today are seen in Africa's Serengeti. In the wild, herds of grazing animals are food for predators: lions, leopards, cheetahs, jackals, hyenas, wild dogs and others. Pressure from predators cause the grazing prey animals to form tight groupings, to graze fairly quickly on only their preferred foods, then move on to water and greener pastures. Trampling from the grazing animals incorporates their manure into the soil and creates hoof print pits that act as miniature seed collection basins as well as miniature water collection pockets. Once a series of grazing animals passes over an area there is little food for them until the sward regrows.

All that we have to do is to begin researching Serengeti grazing animal ecology and the complex web of relationships will become apparent. We don't all need to become wildlife ecologists in order to set up a functional multispecies grazing system. It really is quite simple. We do, however, need to have a basic understanding about stocking rates and pasture management.

STOCKING RATES

Everybody who lives in grazing country has seen a pasture where there are just too many animals on the pasture. Plain and simple. The animals eat every morsel of green until even the closest cropped golf course green appears lush. Once they've eaten the pasture down to those levels, there's not enough feed for the animals and their health and nutrition suffer. Soil compaction becomes an issue because there is no longer any more root penetration to drill channels for water to percolate down into or to add fibrous carbon to the soil. Overgrazing of animals is one of the largest causes of land degradation and desertification on a global scale. Degradation from overgrazing is used by the proponents of animal confinement operations as a propaganda tool to eliminate the small grazier or rancher as competition in the food markets. As practitioners of restoration agriculture we will want to be especially aware of the anti-overgrazing bias that exists in many circles, because our goal is one of restoring health and vitality to the earth-plant-animal system, and not degradation. By being observant and by carefully managing our grazing patterns we will be able to ensure that this is so. Overstocking a pasture with one type of livestock and not rotating them to new pasture is the sure way to ruin.

That said, understocking a pasture can also lead to overgrazing. This may seem counterintuitive, but it is actually possible. Not too far down the road from Ashley's house in the Driftless Region of southwest Wisconsin, and right around the corner from the chemical cornfield, is the farm of a certified-organic, grassfed beef grazier. This grazier is very concerned about the extent of human impacts on the planet and he wants to ensure that his own personal footprint will be small. He lives in a very small, owner-built cabin off the electric grid and does so many of the things that the sustainability culture would like to urge for the masses. His concern for a small footprint reaches so far into his ethic that he is a strong opponent to overgrazing. His 13-acre pasture has a grand total of three beef steers on it. The pasture is not divided into paddocks for rotation and the animals are free to wander anywhere on the 13 acres for their food. Most references that he's read claim that 13 acres can support approximately thirteen cattle without overgrazing but he *knows* that this is incorrect. He *knows* that thirteen cows would severely overgraze 13 acres and lead to the end of the world as we know it if everyone grazed at this rate, because he is faced every day with the fact that his three cattle are overgrazing that same 13-acre area. If three cattle can overgraze 13 acres, then thirteen cattle on 13 acres would cause the next Sahara Desert and we would all blow away in the wind.

His three cattle are indeed overgrazing the 13 acres. His observation is correct. However, this is because of poor management practices rather than too many cattle. His three beef cattle on 13 acres wake up in the morning and go about their grazing day. They eat the first mouthful of their favorite forage, then move on to the next favorite mouthful. The less palatable forage gets left behind uneaten as do the unpalatable and noxious weeds. As the season progresses the cattle eat only their favorite forage while the undesirable forage, like thistles, grows stronger, more woody and less palatable, and most significantly it sets seed. Soon there are a million thistles instead of three and before long there is a pasture comprised of bare-shaven grass between old-growth forests of burdock and ragweed. By allowing the cattle to eat only their favorite forage and by not removing the unpalatable plants, three cattle have managed to destroy 13 acres of rich, abundant pasture. Thus he has proven to himself that overgrazing is a curse on the earth and that next year he may decide to have fewer cattle. Whether he decides to have fewer cattle or not, he will soon be forced to have fewer cattle because there will be very little forage left on that 13 acres for them to eat.

Overstocking can degrade pastures by removing more living plant matter than can regenerate before the next round of grazing happens. Under stocking can degrade pastures when not followed up by finish mowing or grazing with other animals in order to prevent undesirable plants from proliferating and setting seed. This is what sheep are especially good for. They will eat more coarse vegetation than cattle and they will thrive on it too. They are the "finish mower" of our animal polyculture. The rule of thumb for sheep numbers is to have the same number of sheep as there are cattle. A pasture would, of course, support more sheep than one per acre, but by the time a cow and calf, two hogs and two turkeys have gone over the pasture, it is not the same as a fresh pasture. Although the pasture will support fewer total sheep per acre when rotated with other animals than if only sheep were raised, the total number of animals, and the total amount of available forage converted into animal biomass is greater than in a single-species system.

To show how simple this can be, I will begin with a discussion of one of the simplest leader-follower systems there is, and with animals that are familiar to most of us. Those animals are cattle.

Cattle

The simplest and most researched leader-follower system is one in which only cattle are used. The system is managed according to the "first bite" theory. Cattle graze by taking a bite from the top of the most nutritious pasture according to their needs. They will then move on to the next "first bite" and so on until all of their preferred pasture has been bitten. They will then move back over the pasture and take the next bite down the stem, moving into less and less nutritious forage. In the simplest of the leader-follower systems, young calves are moved into the pasture first. They have the highest nutrient demand of any cow life stage and will take the best of the best pasture bites. After the calves have initially grazed the pasture and before they begin to move on to the "second bite" stage, they are moved into fresh pasture where they can continue to graze the most vital and nutritious feed. Lactating cows are then moved into the pasture where the calves vacated. Simple systems such as this have been shown to increase total weight gain in calves and to not reduce milk yields from the cows. The system can be refined even further.

An ideal restoration agriculture grazing system would be a multispecies, mob-stocked, leader-follower system beginning with cattle.

Calves can be grazed first. Then the cows can be divided into two classes based on their production. The heaviest milk producers can be moved into the pasture behind the calves, then the lighter producers behind the heavy producers. Dry cows can follow behind. With a leader-follower system such as this, the calves get all of the most nutritious "first bites," the cows then get all of the second and subsequent bites. This grazing system matches pasture growth. On a pasture, "first bites" are the smallest portion of available feed. This matches nicely with the calves' small size and high nutrient needs. Older cows require more bulk and dry matter in their diet and that is exactly what is available after the leaders move through. Mature, dry cows who are able to thrive quite well on dry hay alone do quite well with the coarse forage left behind by the leaders.

An ideal restoration agriculture grazing system would be a mob-stocked, leader-follower system beginning with cattle.

Hogs

Once the cattle have moved through the system, the time is right to move in the pigs. Pigs are, of course, one of the most broadly omnivorous livestock. Left to themselves, they graze a fair amount of green forage but prefer to root through the ground to eat grubs, worms and plant roots. In season, they eat dropped fruits and nuts and they have been known to dig up and eat snakes, rodents and ground-nesting birds. The "plowing" behavior of pigs can be used in the proper place and at the proper time when farmers want to disturb the soil in order to plant a new crop. Some leader-follower farmers graze their cattle first, then follow with pigs that are allowed to plow the ground and eat plants and roots until there are none left. The farmer then follows the hogs and plants a small grain crop or preferred pasture for when the cows come back on rotation. All pigs will relish rooting in the ground with their powerful, yet sensitive, snouts and it really is quite a joy to watch a pig as it lifts its head from its enthusiastic snuffling with dirt all the way up to its eyebrows. Some breeds of pigs, however, root less than others and thrive on pasture better than others. An in-depth discussion of which hog breeds thrive the best on pasture would be never ending and would offend as many "true believers" as it would enlighten others. So rather than discuss too many specifics, I'll just briefly mention a few here. In a perennial, restoration agriculture system, healthy pasture is the key. The woody polyculture is important, yes, but the health of the pasture is what drives the health of the entire system. When the forage quality is high it will support more animals. More animals provide more fertilizer, in the form of manure and urine, to the trees. A perennial woody polyculture will over time create a closed-canopy, producing so much shade that grass will not thrive. It is at this point in site development that the system has moved from a savanna system to a forest. A “food forest” is the result, but a closed canopy is not the system that produces the most food per acre. The most photosynthetically productive biome is the savanna with a deep, three-dimensional solar-collection structure. We want to maintain our woody plantings so that the grass is always greener on *our* side of the fence. Forage health results in good animal health which results in good human health. So, in order to achieve optimal productivity and optimum health in the whole system, pigs should not be allowed to diminish forage health by rooting it all up.

In addition to thriving on pasture, pigs are the ultimate cleanup tool, eating unmarketable produce and cleaning up after apple, hazelnut and chestnut harvests.

In order to do this, nose-rings are recommended — one across the columella (the fleshy part between the nostrils) and another into the tip of the snout. (Earrings and a belly button stud would look cool, too, but they don’t perform a useful function like nose rings do!)

The procedure is painful at first, and pigs always seem to squeal ten times louder than the actual pain warrants. Inserting the nose ring is best done immediately after weaning or as soon as you receive feeder pigs on the farm. Within seconds of release, the pigs stop complaining and don’t appear to experience any discomfort. Unless, of course, they try to root in the ground. Their hungry tummies quickly teach them to graze rather than root. Some breeds learn more quickly than others. Of the many different breeds of pigs that I have grazed, two stand out. Experience with other farmers has led to a third one. Red Wattle pigs appear to thrive quite well on pasture as do Berkshires and especially the Tamworths. Of the three, the Berkshires appeared to be the leanest when grassfed, and the champion in weight gain and thrift on pasture is by far the Tamworth. Berkshires take a few days to figure out how to graze well, but the Tamworths start looking for grass as soon as they’re off the nipple. When they are not ringed, Tamworths appear to do the least amount of pasture damage. I have seen un-ringed Tamworths on pasture in several states with no apparent rooting. Other hogs worth noting are the black Iberian pigs from the Basque regions of Spain. Hogs in northern and western Spain are pasture-raised and finished on acorns and chestnuts. Their darker meat becomes the famous “jamón ibérico” beloved by Spaniards and their guests. France and Italy as well have their own favorite pasture and acorn-fed hogs, and the trend is growing in North America. There is nothing quite like the flavor and texture of pork that has been grazed on pasture all summer and fattened on a diet of apple pressings, hazelnut and chestnut gleanings and acorns.

Management of pigs in a restoration agriculture system includes using them as the ultimate cleanup tool. With apples cleanup can be timed to coincide with the June drop when insect-damaged fruit falls from the tree. Pigs happily rummage through the woody polyculture and gobble up the tiny fruit with insect larvae inside. After harvest, whether of apples, chestnuts or hazelnuts, pigs are rotated through beneath the trees in order to pick up any fruit or nuts that were missed by the human harvesters who went through first.

With a “pigs following cattle” system a rule of thumb would be to have no more than two mature pigs per adult cow. Fewer than two pigs per cow works just fine. With too many pigs they’ll not have enough leftover forage to thrive, they will get hungry and begin to break through electric fences. Pigs are incredibly intelligent animals and once they learn that it only takes one zap to run through an electric fence, they will do exactly that if they are not getting enough to eat in their paddock.

Turkeys

Once the cattle have grazed off their first two bites, and after the pigs have cleaned up behind the cattle, turkeys are an excellent choice to follow. Turkeys will nibble grass and forbs and there will be some left for them, but they prefer to eat big seeds and insects. Turkeys will eat the insects attracted to the dung left behind by the larger grazers as well as any seeds that may have passed through the gut of the animals that went before. They will scratch around in the grazed and trampled debris in search of beetles, caterpillars, worms and large seeds. Many pasture “weeds” that don’t provide the best forage for cattle and pigs have large seeds. These large seeds will be gobbled up by the turkeys and ground into oblivion in the bird’s gizzard. Turkeys (and all fowl) are also a great way to introduce mineral amendments to the pasture in a low-cost manner over a period of time. To have a high-yielding pasture, whatever minerals are low can be placed in a mineral feeding box and dragged from paddock to paddock with the turkeys. Coarser-grit minerals are oftentimes less expensive than the finer particle sizes of minerals simply because less milling time went into their production. As the turkeys graze the pasture they are ingesting the spectrum of minerals available in that pasture. They will be internally deficient in whatever minerals are deficient in the pasture soil. All fowl instinctively will pick at the grit that supplies them with the missing ingredients that they need. The grit gets ground to a fine powder in their gizzard, it gets acted upon by the bird’s digestive acids and enzymes, and what isn’t used by the organism itself gets defecated onto the very pasture that needs that very mineral.

Turkeys at work grinding up mineral amendments with caterpillars, grasshoppers, slugs and more and depositing them in easily decomposed packages across the pasture. Give thanks for pest control and fertility!

Animal polycultures have been the secret in nature’s toolbox to creating the most fertile soils on the planet. The moist temperate savannas of North America, especially the American Midwest in the Ohio, Mississippi and Missouri River watersheds, are home to the planet’s deepest, most fertile topsoil. Some has been measured at nearly 200 feet thick. This fertile topsoil was created by the oak savanna plant families (and others as well) but especially with the help of the animals. Phosphorus, one of the Corn Belt’s most deficient mineral nutrients, was once brought into the region by the ton as migrating birds gobbled up Gulf of Mexico seafood and pooped their way up the Mississippi flyway leaving behind a wake of fertility. We no longer have passenger pigeons on the farm, so we now have to substitute domestic fowl and provide them with the mineral nutrients that they and the soil need.

Turkeys, especially the more intelligent, heritage breeds, are quite low maintenance and only one flock need be raised all during the summer grazing season. By the time the best grass is finished in the northern regions it will be time for the turkeys to be put in the freezer for the holiday season to come. Approximately two turkeys per hog is an adequate number.

Sheep

Imagine what the pasture looks like now. One or more waves of cattle have grazed through it first, with the calves eating the tips of the most nutritious plants, the best cows taking the second bites, lower-producing cows taking the thirds, and dry cows the fourths. Then pigs come in and clean up the leftovers, and third the turkeys pick out the seeds and eat the bugs. What's left?

Anyone who has watched this process happen, or even part of this process, will observe that the first plants to rebound after this grazing pressure are the ones that were the least preferred by cattle and not eaten by the hogs. The turkeys really aren't that much of an impact on the pasture itself, and so the green growth begins to rebound. First up from the ground are the plants, mostly biennials and perennials, that have large, fleshy roots with lots of stored energy. Other plants left behind are the ones that many graziers would call invasives, such as spotted knapweed and leafy spurge. Other plants quick to respond include dandelions, burdock, cow parsnips and thistles. With little else to eat the sheep happily graze on these broadleaf plants. Over time these weeds will become less and less prevalent in the pasture thereby providing weed control as a side benefit of the grazing system.

Chickens

Following the sheep come the chickens. Dealing with chickens in a leader-follower system can be somewhat challenging. Buying enough square-mesh portable electric fence to set up permanent paddocks for all of the chickens that you can raise is quite expensive. And moving mesh-fence paddocks every day is a lot of work and a royal nuisance. Open-bottomed, portable chicken pens are one way to deal with the issue, as are trailer-mounted, mobile chicken coops.

Dealing with chickens in a leader-follower system can be somewhat challenging, but they do eventually learn how to avoid predation and eventually become nearly care-free.

As the chickens move through the pasture following the sheep, they scratch up any remaining manure from the "leaders" ahead of them searching for insects and seeds. By the time the chickens move through the pasture there will likely be very little animal manure left to be found. It has all be eaten or carried away by dung beetles and carrion beetles or scratched apart by turkeys and chickens. With poultry included in the animal polyculture there will be very little animal mess. Chickens, whether egg layers or meat birds, are one of the simplest animals to raise and most readily purchased by direct-sales customers, although I don't know of many people raising chickens on a small scale that are actually making more than a hobby income from the enterprise. Chickens are a good starter enterprise for farm kids, and when collaborative processing and marketing ventures are undertaken, growers can do quite well.

A rule of thumb number for chickens is really not possible. If you want to use no supplemental feed, then obviously fewer chickens could be supported at the tail end of a polycultural leader-follower system. If you are going to incorporate the growing of small grains in the overall farm system, you could expect to need approximately four acres of small grain and legume production to feed 4,000 meat birds.

Geese

Geese have been included in this chapter, not because they were historically significant savanna animals, because they really weren't. They were more significant along migratory flight paths and are quite obviously, waterfowl (or supposed to be). Geese have been included here mostly because their eating habits are very similar to sheep. They happily graze broad-leaved plants and are good for following turkeys. Fencing that is set up for pigs and turkeys will also contain geese without any adjustment. Geese will also provide burglar alarm services warning the grazier that someone or something is out near the poultry. Geese are very well adapted to a perennial polyculture and can oftentimes provide a higher value income stream than sheep. Geese are oftentimes disliked for being feisty and mean, but then again so are sheep. I don't like sheep smell, whereas geese on pasture I don't mind.

Goats

Goats are a wonderful animal. They are without a doubt the animal that is able to produce high-quality meat and dairy products on the coarsest, most degraded forage. They can eat raspberry bushes, roses or poison ivy, gain weight well, produce surplus milk, cream and a kid or two each year. A goat's ability to eat almost anything is what has led to countless images in children's books and elsewhere of the bearded billy goat eating tin cans. The goat's ability to thrive on almost anything is its greatest strength — and its greatest curse. Goats can be an extremely useful tool to manage the succession of a site by browsing economically undesirable plants such as honeysuckle, multiflora roses and autumn olive.

However, goats can be the bane of a restoration agriculture farmer. After planting 10,000 hazelnut bushes at great financial and labor cost, the last thing a farmer wants is a goat to come along and murder all of them. Beware … goats are fence jumpers. If you have a charming apple orchard planted and they get it into their heads that they want to eat apple trees today — they *will* escape. Goats can jump over or go through any normal electric fence that humans can contrive. Build it higher and they'll find a way over, under or through it. A 20-foot-tall, nuclear-powered, high-tensile, 45-strand, electrified razor wire fence with a minefield in front of it is still no match for a goat with an eye for your chestnut tree.

If you are just starting out as a restoration agriculture farmer and have not quite mastered the subtleties of multispecies grazing and pasture management (I am sixteen years into my project and I still find I have *way* more to learn.), goats are best avoided. Archaeologists, anthropologists and historians have discovered evidence over and over again that goats are the last seral phase before total desertification.

Historically around the world, the preferred grazing animal of pastoralists and early agrarians have been cattle. Cattle require high-quality pasture and produce high-quality food in the form of dairy products, meat and blood from the living animal. Beef has always been the status symbol of the grazing animals. If you had cows, you were wealthy. The more cows you had, the wealthier you were. Though, too many cows kept for status or whatever reason can and do degrade pasture quality. Over time, as pastures degrade, fewer and fewer cattle can be maintained on the pasture and sheep and goats are then kept. Entire cultures have seen a shift in their diet over time from beef eaten by many, to beef as a status food only eaten by the rich and sheep eaten by the masses. As the grazing environment is degraded more and more, cattle disappear from even the ranks of the wealthy and the percentage of goats increases. As this process continues pastures fail to recover, soil erodes in the wind and rain, and societies collapse with the only survivors being a few wandering herdsmen with their skinny, starveling goats nibbling at the last few sprigs of life that cling to the bare bones of the planet.

The goat's ability to thrive on almost anything is both its greatest strength and its greatest curse.

Maintaining pasture quality is goal number one in restoration agriculture. If pasture quality is not maintained and the forage is overgrazed or incorrectly grazed, cattle and hogs give way to sheep and goats which give way to the deserts that we see in Africa, the Middle East, China, and Central and South America. When pasture quality is *not* the primary goal, goats are the final nail in the ecological coffin.

I personally do not recommend goats in a restoration agriculture system until that system is quite mature — 15 years old or more. Goats pose an unacceptable risk in the establishment phase of an edible woody cropping polyculture. If you feel that you *have* to have goats on your restoration farm, go for it. It can be done and it can be done well. Just remember … I warned you!

OTHER POTENTIAL PROBLEMS (BESIDES GOATS)

Management and fencing are probably the biggest challenges that a restoration agriculture farmer or rancher faces. This is especially the case when a farmer has changed from a rectilinear paddock system to one that is coupled to an earth shaping and water management system.

In a simple beef leader-follower system, young stock is fenced separately from the older animals. Two active paddocks worth of moveable fence need to be maintained. When pigs are added to the system, an additional strand of fence wire needs to be strung quite low and weeds need to be eliminated frequently from beneath the lower strand so the fence doesn't short and the pigs become residents in your home garden or your neighbor's cornfield. Sheep may need a third strand, or at a minimum, the fence wire will need to be moved higher or lower as the next type of livestock is moved in.

When the farm is designed in order to optimize water capture using swales or terraces on or near contour, more fence posts are needed in order to describe curves rather than straight lines. The moveable ends of paddocks are still straight lines and no change in management is needed there, but overall more fence will be required and more time will be needed to move livestock at the appropriate time into the appropriate paddock.

Multispecies grazing can possibly require additional handling facilities for loading animals for sale onto trailers. There are those who are convinced that animals cannot be trailer loaded without a species-specific squeeze chute, but this is only the case for animals that have no personal connection with their manager. When herds become larger than a certain number the animals become anonymous and no longer respond to their human companion. Multispecies grazing allows the grazier to have fewer animals of each species reducing individual anonymity. Being on friendly terms with your livestock is an incredible help. Another way to remove the need for additional handling facilities is to train the animals to load into a trailer from a young age.

Somewhere in the grazing paddock system park a livestock trailer. When the cattle are in that paddock lead the animals into the trailer where they find a tasty treat of a well-balanced feed. Simultaneous with the livestock discovering the tasty treat the herder should give out a species-specific whistle or call. As this happens periodically through the grazing season, the animals become familiar with the trailer. They see it frequently, they graze near and around it frequently, and they get a morning treat inside of it along with scratches and pats from the human. The animals become comfortable with seeing the trailer arrive and seeing it drive away. Eventually the trailer becomes associated with a positive experience. They become “Pavlov’s livestock,” conditioned to coming to the owner and loading onto a trailer at a whistle or call. The first time I called in a custom hauler to take a dozen hogs to the slaughterhouse, he asked me where my squeeze chute was. When I told him that we wouldn’t need one, he groaned and cursed and moaned “Gol Dang! You’re not one of *those*, are you?” I said, “Relax!” and gave a whistle and the pigs came thundering from around the bend. One sniff of the trailer and they let out squeals of joy. This one has *hay in it! Yippee!*

Winter is an issue for livestock production and additional housing for carryover stock may be required. Separate quarters are a good idea especially to help prevent transmission of cross-species parasites, diseases or mineral toxicity.

Mineral Toxicity

Supplemental feeding of minerals and trace elements should be carefully monitored. Cattle love their salt lick and hogs can overdose on salt. Mineral supplements for cattle and hogs may include copper and be necessary for their health, but can be toxic for sheep. Soil testing and forage testing is prudent in order to understand what your soil mineral levels actually *are* doing. Don’t lose your herd or flock to guesswork.

Parasites

Sheep and goats share the same internal parasites. (Another reason to not use goats!) As do pigs and chickens. Some parasites can subsist externally from their host animal in a form of suspended animation as dehydrated cysts. The best way to limit parasites in a multispecies livestock operation is to understand what the parasite potentials are, understand the parasite life cycles, and to *not* combine livestock with similar parasites in the same or even the following paddock. Always have a species break between one host species and the next susceptible species. Parasite problems can also be limited by maintaining a diverse pasture mix and especially a mix that includes perennial plant species that are known to be parasiticides. Some of these species are wormwood (*Artemisia absinthium*), members of the sage family in general, garlic, gentian, fennel and other strong herbs. These can be planted along main fence lines, as well as the occasional members of the walnut and hickory species (leaves and nut husks show parasiticide effects). If winter squash and pumpkins are grown on the farm, market rejects can be fed to livestock both for their carbohydrate and mineral gain as well as the antiparasitic effects of the seed skin. Lespedeza, although considered invasive in many places, is an excellent forage and has also shown to have a parasiticide effect.

Diseases

Johne’s, malignant catarrhal fever, and other livestock diseases can be managed in a similar manner as parasites. To avoid direct transfers sheep should not be grazed in a system that includes elk, deer or bison.

Like most of the parasites, livestock diseases are passed along through mouth and nose contact, and in the feces. To limit parasite and disease transmission keep cattle separate from pigs and pigs separate from the fowl and fowl separate from the sheep. Care should be taken that animals are not stressed. Clean water should be available to the animals at all times and watering tanks or troughs should be emptied and purged between species. Once again, this all comes back to pasture health. Pastures should not be grazed until the soil is exposed. Sheep, especially, will crop a pasture until the crowns of grasses are the only thing remaining. This is a surefire way to spread both parasites and diseases. Healthy pasture with long periods of recovery between grazing is the best way to maintain healthy, parasite- and disease-free livestock.

SUMMARY

Multispecies, mob-stocked, rotational grazing can lead to healthier pastures. Healthier pasture forage creates healthier soil. Healthier soil in harmonious mineral balance grows the most nutrient-dense, healthiest food to eat, whether you’re an animal grazing peacefully or a human enjoying the fruits of a healthy and abundant system.

Multiple livestock species, each with their own dietary preferences, will balance the forage plant communities and lead to pastures that recover more quickly from grazing, develop deeper root systems allowing them to recover deeply leached nutrients, and tolerate weather extremes such as excessive soil moisture or prolonged drought.

One of the goals of multispecies grazing is to utilize pasture resources more uniformly. By the time the last livestock species vacates a paddock, there should be no odd patches of ungrazed plants. Pastures recover more evenly and require less finish mowing.

In addition to being utilized more uniformly, pasture is utilized more effectively Plants that are unpalatable or even toxic to cattle, such as larkspur and leafy spurge, are eagerly consumed by sheep. This is effectively an increase in carrying capacity for the cattle next time around. Sheep (and goats … I can't believe I'm saying this!) can be used to control unwanted brushy species that will naturally want to occupy the revitalizing landscape. Restoration agriculture plantings of edible woody species provide perches for a phenomenal diversity of wild birds, many of whom came to the system with their intestines preloaded with undesirable seeds. Multispecies grazing ensures that somebody in the system somewhere likes that plant for food. Once the undesired brushy species are removed more grasses can thrive and the virtuous cycle continues.

HIGHER LIVESTOCK PRODUCTION

Total livestock production is higher when a polyculture of animal species is grazed in a leader-follower system. This is in part because of the increase in site fertility and total productivity and in part because of the different food sources used by the different animals. You may not be able to raise as many beef or sheep per acre as you used to, but the total pounds of livestock weight per acre will be greater.

ECONOMIC DIVERSIFICATION

My Uncle Bill, a lifelong farmer, once told me, "Mark, You've got to get into raising sheep." "Why is that?" I asked him. He replied, "They're the most profitable livestock I've ever raised. With sheep I only lose five or ten bucks a head!" Uncle Bill had variously been a dairyman, bull semen farmer, commodity row cropper, hog producer and beef producer. Although he had grown up on a widely diversified family farm, he had abandoned those ways during the bulk of his career. By concentrating on only one main enterprise and by pushing production to the maximum he could get away with, he had been economically bludgeoned for his fifty-year career. Yes, he had some big years, and those big ones were *big*. His downs, however, were just as big. It was in those down years that he would be forced by economic pressures to refinance and start something somewhere else. My grandfather only lost the farm once. Uncle Bill, always the overachiever, did it several times.

By diversifying the species that one grazes, market fluctuations can be evened out. Cattle, hogs, sheep and poultry all tend to have slightly different price cycles. High prices for one may offset low prices in another. Some species like geese, can have very high specialty market prices, but low total volume in sales. A multispecies, mob-stocked, rotational grazing system is the animal portion of a diversified farm products portfolio. Raising only one crop — milk or corn for example — leaves you totally at risk to that one market. Your income stream will rise and fall with that one market. In the case of most American farmers in the past sixty years, your income only falls. It is interesting to see how after a career of single-crop farming and all of the stresses it caused in his life and for the family my Uncle Bill has now officially retired and raises cattle, sheep, hogs, a gaggle of geese, and one Indian Runner referred to by his grandchildren as "snappy duck."

CHAPTER 10

Including Bees

PRIOR to the present European settlement in the Western Hemisphere (The Norse occupied Greenland for 400 years beginning in the late 900s), there were no native, colony-nesting bees on this continent. The plants in this hemisphere have existed for millions of years without honeybees. Honeybees are simply not needed in the richest, most abundantly productive ecosystem on the planet.

Honeybees are of the genus Apis and in the Apidae family. In the Western Hemisphere, bees are an entirely different family of insects (Megachilidae) and are species totally different than the honeybee (Osmia, Xylocopa, and others). North American bees are for the most part solitary insects.

Like the European and Africanized honeybee *(Apis mellifera* and *Apis mellifera scutellata),* North American honeybees derive their sustenance from flowering plants. Pollen, which is analogous to the male reproductive cells of a plant, is high in the protein required by bees to build their bodies. Nectar is a liquid secreted by the analogous female portions of a flower and it has no apparent reason for existing except as a lure to attract pollinating insects. It serves no immediate physiological function for the plant itself. Nectar is high in sugars — fructose, glucose and the like — which are an extremely high-energy drink. All bees eat pollen and drink nectar for their sustenance. When bees crawl around on the anthers of a flower in order to eat pollen, or even when they bypass the pollen en route to the nectar itself, some pollen sticks to tiny bristles that cover the bee’s body. As the bee laps up the sweet nectar some of the pollen covering its body may make contact with the stigma (analogous to the vagina in female mammals) of the flower, where it will eventually travel through the style to make contact with an ovum and create a new seed.

After a drink of nectar the bee travels up out of the flower and eventually combs itself to remove the stray pollen grains from its hair. Much of the pollen is stored in specialized regions on the legs, inaccurately called pollen sacs, where it is taken back to the nest to later serve as a food source for larval bees. The pollen sacs in reality are more like strips of Velcro hooks than they are sacks, but they serve as a way to transport the pollen used for fertilizing when the bee visits the next flower (hopefully of the same species so it can be fertilized). Many species of plants cannot use their own pollen and have to receive pollen from other individuals of their same plant species in order to produce viable seed. In this way, through this miraculous functional relationship, bees pollinate flowering plants in the process of feeding themselves. There are many lessons to be learned by studying this simple, functional relationship. The flower feeds the bees, the bees pollinate the flowers to make more flowers which feed the bees. Both bee and flower are involved in a virtuous relationship that is aimed at positively affecting one another.

Over 30 percent of humanity’s food plants are pollinated by bees. From apples and cherries to tomatoes and cucumbers to squash, peas, lentils and beans — all are dependent upon bees in order to produce the food that we eat. Thus you can see that the entire human race is critically dependent upon bees for its very survival. The honey industry around the world and quite visibly in North America is big business. Once upon a time beekeepers, or apiarists, as they are called, stayed on one place. They reared their colonies of honeybees in one location and planted flowering forage crops or relied on natural populations of flowering plants to feed their bees and thereby make the honey, beeswax and propolis that were sold as products.

As the face of agriculture changed, the face of beekeeping changed as well, as both were being influenced greatly by the development of larger and faster transport and traction equipment. Larger and larger tractors, larger and faster semi-trailer trucks and the interstate highway system all combined to transform the modern honeybee industry into a highly mobile one where the primary income stream for many beekeepers no longer was honey or wax, but pollination services. As fossil fuels allowed for larger, faster and more labor-efficient equipment, farm fields became larger and larger. Fencerows and wild patches of land that may have supported a colony or two of feral honeybees were cut down. Worse than no longer having feral honeybees around, populations of wild pollinators crashed. This went largely unnoticed by most farmers dependent upon pollination because the honeybee industry stood ready at hand. Flatbed trailers loaded with pallets of honeybee hives parked on field edges and ensured adequate pollination of crops. This industry grew and became specialized rapidly in California with the boom in agriculture in the irrigated Central Valley region.

Industrialized honeybee culture has come to promote the health and vigor of the very pests and diseases that affect honeybees.

Truckloads of honeybees would follow the bloom cycle going from plums and apricots to almonds and peaches to apples and pears to strawberries, cucumbers, watermelon, squash, and tomatoes and so on as the season progressed. Mobile honey production and pollination-dependent agriculture grew specialized together to the point where you can now buy specific honey based on what crop was blooming at the time.

Not all is well, however, in the world of the honeybee, and hence not all is well in the realm of the food crops that depend upon bees for pollination. As is always observable in living systems, the more simplified a biological or ecological system becomes, the more vulnerable it becomes to perturbation by pests and diseases. The honeybee industry in North America is currently undergoing a dangerous crash. Colony Collapse Disorder, or CCD, has afflicted 50 percent or more of all honeybee colonies in North America resulting in the losses of billions of dollars of sales in honeybee products as well as yield losses in crops dependent upon bees for pollination. Coupled with this are losses of nearly 99 percent of the pre-European levels of wild pollinators mostly due to habitat loss and travel corridor fragmentation. Let's refer back to the opening sentence of this chapter and ponder it again … Prior to the present European settlement in North America, there were no native, colony-nesting bees in existence in North America. Why and how would this be?

A healthy frame with close to 2,000 honeybee larvae about to emerge.

Some light can be shed on these questions when the problem is seen through the eyes of an ecologist.

Prior to European settlement insect pollination of most flowering plants was taken care of by large and healthy populations of insects. An almost uncountable number of species of flies, beetles, wasps, butterflies and moths pollinate many flowering plants. The most effective pollinating insects of course are the bees.

Another group of flowering plants are wind-pollinated, such as the oaks, chestnuts, beech, hazelnuts, butternuts, walnuts, pecans, wild rice and corn. (These will be discussed elsewhere.)

In Europe, Africa and Asia, bees naturally formed large colonies producing their most obvious by-product — honey. Honey was used as a sweetener, of course, and mead (fermented honey wine) is the first recorded example of a fermented alcoholic beverage. The epitome of health and prosperity of a region and a culture was evident when their honeybee populations as well as their grazing animals were thriving. It is from a healthy system like this that the phrase “the land of milk and honey” was born. Any place that had rich pasturage and produced a surplus of milk while simultaneously supporting enough flowering plants to produce surplus honey was obviously a rich, healthy and intact ecosystem. High-fat, high-protein, high-calcium, fresh milk (sheep, goat *or* cow) combined with sugar, vitamins and minerals is human food par excellence. (Much of the lactose intolerance observed in the world today is a result of milk being cooked to over 180° F in order to pasteurize it. Cooked milk fats and proteins are nowhere near as digestible as fresh ones, and all of the enzymes and beneficial bacteria that pre-digest the milk are killed along with the stray harmful bacteria that might have gotten into the milk through unsanitary practices.)

None of the New World bee species formed large colonies and none of them produced surplus honey, wax or other products.

Europeans changed this in a hurry when they began to colonize the temperate and tropical regions of the Western Hemisphere. Honeybees were brought to the New World for their obvious benefits of honey production and wax for candles, which was extremely important in the years before electricity. European honeybees took to the New World and expanded with much the same vigor as their European human counterparts. *How* Europeans raised their honeybees is quite possibly the reason why colony nesting bees have been able to survive in a hemisphere that previously had not had any before.

Perhaps the Western Hemisphere has *always* been hostile to colony nesting bees. Perhaps there have *always* been fungi, bacteria, thrips, beetles, mites and other pests and diseases that have exerted a millennia-long selection pressure on Western Hemisphere bee populations and selected *against* the formation of large colonies. Perhaps the pest and disease regime in the New World was such that if you were a bee and laid too many eggs in one place, your larvae would be starved, suffocated or parasitized and your genes would not be reproduced into the future. Over the eons pests and diseases that only flared up when too many bees congregated in one place would influence the natural reproduction of bees and only the bees that laid their eggs in secluded onesies and twosies would have a chance of siring a next generation. It is entirely possible that the entire array of honeybee pests and diseases that afflict beekeepers today has always been here. How could this be?

The first recorded instances of beekeeping of European honeybees in the Western Hemisphere was back in the 1500s. By the English, French and Spanish colonial period of the 1600s honeybee colonies likely measured in the tens of thousands. Honeybees were primarily kept in inverted, woven grass baskets called skeps. Some bees were kept in sections of hollowed-out logs and others in mud and wood boxes resembling little log cabins. Sawn lumber and nails as fasteners were rare and expensive, so wooden boxes were not considered as bee houses for hundreds of years.

Every spring the beekeeper would divide his hives in order to have more total colonies and to ensure enough honey and wax come fall. The woven skep was perfect for this, since it was easily made and the grass materials needed to make them was widely abundant in newly hacked and burned homestead clearings. Early spring is the natural time for honeybees to increase the numbers of their colonies, so in this way the Europeans were actually working in harmony with nature. As the weather warms a wild profusion of pollen and nectar is abundant and honeybee populations skyrocket. As the space in the old hive becomes crowded somehow the signal arises that it is time for the old queen to lay eggs destined to become new queens. The worker bees feed the new queen larvae a special diet, and within 21 days a new queen bee is hatched. If the young queen doesn't kill her mother first, the old queen flies away taking with her a large swarm of workers. Typically the swarm would land on the branch of a tree near the original hive and stay there for a short time while specialized worker bees acting as explorers search for a new home. Once the new home is found, or once the beekeeper shakes the swarm into a new hive, the colony stays put and continues anew its life of building comb, making honey, and pollinating flowers.

By dividing colonies in the spring the beekeeper was imitating nature. So far, so good.

During the course of the summer the honeybees were left to themselves for the most part, and for some unknown reason (unknown to beekeepers today as well!) some hives would thrive and others would merely sputter along. Thriving hives work more, work faster, build more comb, make more honey, and are always seen as having extremely busy action outside the front door. After the last full flush of flowers in the fall (signaled by goldenrod and asters in the northern United States) on a cold, crisp morning with temperatures in the 40s when bees can't fly, the beekeeper would take the weakest hives and drown them. Once the bees were dead, the work of separating comb full of bee larvae from comb full of honey occurred. When separating the comb, the finest, cleanest honeycomb was cut and kept in sealed wooden boxes or clay jars and the comb honey used as a candy and gum. In the same way as today, comb honey is a sweet treat having a full rush of quick sweetness followed by hours of sweet chewing.

Honeycomb that was not completely covered over with a wax seal (bees seal their honeycomb with caps of wax when the honey is completely mature), was put into steel pots and heated. As the uncapped honeycomb was heated the wax, bee legs and bodies would float to the surface. Once all of the wax and bee parts had floated to the top, the entire pot was allowed to cool. The wax could later be lifted off the top of the cooled honey, scraped clean of bee parts and made into candles. Comb that was full of bee larvae, without any honey, was also melted down for use in candles (or wood polish, or bucket and barrel sealant, or salves and ointments, or wagon axle lubricant, and dozens of other uses). Comb full of brood (eggs and larvae) made a darker wax and didn't yield as much total wax per comb, so it was used for applications where appearance was not so critical.

Choosing to drown the weakest hives and choosing to keep the strongest ones was not scientifically taught or researched at universities at the time. Darwin would not write his troublemaking book for another hundred years or so. Saving the strongest hives and drowning the weakest ones just made good, practical sense. The strongest hives obviously had produced more honey and therefore would have more reserves to feed them through the winter when there were no flowers in the fields and forest. The strongest hives would obviously have stronger queens, which would produce stronger offspring and more offspring providing the beekeeper with more and stronger colonies in the spring. Good, strong hives of bees could be divided three or more times in the spring hedging the beekeeper's bets for success through a natural increase that makes Wall Street's returns pale in comparison.

What we know now is that this strategy of division of the strong hives in the spring and killing the weak hives in the fall is indeed a perfect strategy to improve the overall survival qualities (both genetic and behavioral) in bees. In addition to removing bees that may be genetically inferior or behaviorally disadvantaged it is entirely possible that this technique of beekeeping also killed the very pests and diseases that were responsible for half a planet being devoid of colony nesting bees. In at least two ways then, colonial-era beekeepers worked in the same selection direction as nature in order to make honeybees more fit for their environment and to limit the spread of pests and diseases that would infect colony nesting bees. The likelihood that colonial beekeepers actually lived within the same pest and disease regime that we experience today becomes more apparent as we fast-forward from colonial times to the late 1800s and the honeybee aficionado L.L. Langstroth.

The Father of American Beekeeping

Reverend Lorenzo Lorraine Langstroth (1810–1895) was an apiarist, clergyman and teacher, and is considered the father of American beekeeping. He was born in Philadelphia, Pennsylvania and as a youngster, he took an extraordinary interest in observing the habits of insects, so much that he was punished for wearing holes in the knees of his pants while learning all he could about ant life. Langstroth graduated from Yale University in 1831. After this he was pastor of various Congregational churches in Massachusetts, including the South Congregational Church in Andover, Massachusetts in 1836. In 1848, Langstroth became principal of a young ladies' school in Philadelphia. It was during this time that he took up beekeeping in part to distract himself from severe bouts of depression.

The Leaf Hive, invented in Switzerland in 1789 by Francis Huber, was a fully movable frame hive, but had solid frames that were touching and made up the "box." The combs in this hive were examined like pages in a book. Langstroth acknowledged Huber's contribution by saying, "The use of the Huber hive had satisfied me that, with proper precautions, the combs might be removed without enraging the bees, and that these insects were capable of being tamed to a surprising degree. Without knowledge of these facts, I should have regarded a hive permitting the removal of the combs as quite too dangerous for practical use." *(Langstroth on the Honey-Bee,* 1860)

Langstroth was popularly credited with discovering the "bee space," though this discovery had already been implemented in European hives. Langstroth made many other discoveries in beekeeping and contributed greatly to the industrialization of modern beekeeping. Langstroth revolutionized the beekeeping industry by using bee space in his top-opening hive. In the summer of 1851 he found that, by leaving an even, approximately bee-sized space between the top of the frames holding the honeycomb and the flat coverboard above, he was able quite easily to remove the coverboard which was normally well cemented to the frames with propolis making separation hard to achieve. He later used this discovery to make the frames themselves easily removable. If a small space was left (less than ¼ inch or 6.4 mm) the bees filled it with propolis; on the other hand, when a larger space was left (more than 3/8 inch or 9.5 mm) the bees filled it with comb.

On October 5th, 1852, Langstroth received a patent on the first movable frame beehive in America. A Philadelphia cabinetmaker, Henry Bourquin, and a fellow bee enthusiast, made Langstroth's first hives for him and by 1852 Langstroth had more than a hundred of these hives and began selling them where he could. Langstroth hives are still in common use today.

Langstroth wrote that "… the chief peculiarity in my hive was the facility with which they could be removed without enraging the bees … I could dispense with natural swarming, and yet multiply colonies with greater rapidity and certainty than by the common methods … feeble colonies could be strengthened, and those which had lost their queen furnished with the means of obtaining another. … If I suspected that anything was wrong with a hive, I could quickly ascertain its true condition and apply the proper remedies."

Langstroth also found that several communicating hive boxes can be stacked one above another and that the queen can be confined to the lowest, or brood, chamber, by means of a queen excluder. In this way, the upper chambers can be reached only by the workers and therefore contain only honeycomb. This made hive inspection and many other management practices possible and turned the art of beekeeping into a full-scale industry.

Langstroth's most revolutionary claim to fame is that he is accepted as the discoverer of what is called the "bee space." Through careful observation, measurement and experimentation, Langstroth discovered that if a space in a beehive was smaller than ¼", the worker bees would fill the space with propolis, a sticky bee excretion that hardened significantly and effectively glued the walls of the hole together. If a space, between combs, between pieces of wood, stone or straw in their home, was larger than the ⅜", they would fill it with comb, until the space was almost exactly 5⁄16" wide. This may not seem like that radical of a discovery, but it was the beginning of the process of industrializing the honeybee. With the knowledge of the bee space, a beehive could be manufactured that would have a spatially optimized amount of comb per volume of container. It also allowed for the creation of the square-cornered, cubical beehive that we are familiar with today. Within a nearly square beehive body removable frames could be inserted where the bees would make their honeycomb. When comb was full of honey the frame could be removed, the waxen caps cut off with a hot knife, and the honey spun from the frame in a centrifuge, called an extractor, designed specifically for the task. The comb could be put back into the hive and the bees could refill it. This actually was more revolutionary than it might seem for the simple fact that it takes honeybees three frames worth of honey in order to manufacture one frame worth of wax. If the bees only have to make the comb once, rather than making it over each year, three times the honey could be obtained from one hive of bees. Removable frames and mechanical extractors also allowed more total hives of bees to be kept over the winter and colonies would not have to be killed in order to get their honey. In this way, the stage was set for the buildup of pests and diseases that plague beekeepers to this day. Within a few decades of the invention of the Langstroth hive and industrial extraction technology beekeepers across the United States discovered an alarming fact — colonies of honeybees were mysteriously dying off in massive quantities. Honeybees were endangered and pollination services were at risk, and hence the food supply also.

This “sudden death” syndrome as it was called back then, coincided with the end of World War I, and fortunately for a mankind becoming increasingly reliant on petroleum-based petrochemicals there was an abundance of surplus war chemicals to apply in order to eradicate whatever was killing the bees. “Foulbrood” was a term used in the early 1900s to describe what was later discovered to be two separate species of bacterium. With the newly acquired arsenal of chemicals to help, the age of industrial beekeeping continued with pride in having conquered the equivalent of the plague. This victory over nature happened at the same time as the industrialized nations were gloating over their victories over evil monarchs and the eventual victory over the massive influenza plague of 1918. Enthusiasm and optimism were the order of the day. But, nature has never been conquered. The laws of nature are just that — immutable laws to which life on this planet is subject. The chemicals used to conquer sudden death by foulbrood didn’t quite kill all of the bad guys. The bad guys that survived were immune to the chemicals used. Over time the genes that conferred resistance to the chemicals came to dominate in the population of pests and diseases, and in another approximately 30 years came the next collapse. Colonies of honeybees were mysteriously dying by the millions. The cause was unknown, and a cure was sought. Once again it was convenient that World War II was now concluded and again an abundance of war chemistry and mind power could be aimed at the target. Once again chemicals were found to wipe the problem completely out. By this time, the petroleum and chemical industries were firmly established, and the cultural habit of successfully combating pests and diseases with the use of chemicals was entirely in place. So-called modern and efficient beekeepers annually dosed their hives with antibiotics to keep them clean from pest and disease infestation. Behind their illusory cleanliness, efficiency and success, selection pressure in the pests and diseases continued.

Honeybees can be mail-ordered and shipped overnight just about anywhere. Is there any wonder why diseases spread?

It was when I was around seven years old that my father decided to get his sons interested in beekeeping. There was a certain urgency to obtaining honeybees at that time. Can you perhaps guess why? At the time, colonies of honeybees were mysteriously dying by the millions. The cause was unknown, and a cure was sought. Sound familiar? Hobbyist beekeepers used all kinds of folk medicines and techniques to combat the latest plague to strike the honeybee, the large hive beetle. The Vietnam-era war machine once again provided the cure, or as we are beginning to see, the chemistry supplied the selection pressure to further improve the chemical resistance of the pests and diseases. Thirty years after that the pattern repeated itself again with Varroa and tracheal mites, and as of this writing the pattern is repeating itself again, this time with an apparent fungal threat that causes honeybees to just fly away and never come home again. This has happened to me. An apparently strong and vigorous hive would begin to falter and within a few short weeks there would be nothing left in the hive except for several hundred dead bees being hauled away by ants. No honey. No brood. Nothing. Just an empty, crumbling, formerly thriving bee city.

It is entirely possible that all of these pests and diseases have always been here and have always been a part of beekeeping in the Western Hemisphere. If these pests and diseases weren't a natural part of the environment, then where did they come from? Outer space? If these pests and diseases weren't here already when Europeans brought their honeybees to this continent, then either God didn't make everything in one week and waited until the 20th century to surprise us with new creations or these pests evolved because of our beekeeping practices. Did the adoption of the Langstroth hive create these "new" bee pests and diseases? Well, not necessarily, but close. The pests and diseases that plague the honeybee have always been here. The Langstroth hive played directly into their hand. The factory-style, square-walled, work-camp for honeybees allowed large populations of pests and diseases to build up until they ballooned out of control and began the collapse of honeybee colonies far and wide. The removable frame hive with permanent, year-round colonies of bees where the majority of the (possibly infected) wax was returned to the hive provided the perfect conditions for pests and diseases to thrive. Industrial beekeeping created its own problems.

This is actually the case across the board in all industrial agriculture systems. We have created the conditions under which pests and diseases thrive while almost completely ceasing the improvement of the crop's own resistance to the threats we have created.

Honeyed Cherries

To make honeyed cherries, pack a 1 pint canning jar with pitted, rinsed Montmorency cherries. Pour honey over the cherries until the jar is full. Let the honey settle for a few days, then add more honey until the jar is full and there are no air pockets in the jar. Tightly screw on a canning jar lid. Store the jar in the pantry.

Since honey is a preservative, the cherries will not spoil. They may begin to ferment slightly, but soon the fermentation is stopped as the honey penetrates the fruit. Allow several months for the cherries to be fully sweetened.

Lilac Honey

This was a favorite of mine while growing up. Pack a clean, dry baby food jar full of lilac blossoms. Pull the individual florets off the bunch and stuff them in the jar *firmly!*

Pour honey in the jar to cover the blossoms. Store the jar in the refrigerator. In a few days the lilac blossoms will no longer be packed tightly in the jar as they dramatically decrease in volume. Add more fresh lilac petals to the honey. Repeat the process until you can no longer pack more petals into the honey or until the lilacs are done blooming. Continue to store the jar in the refrigerator.

During the depths of winter, when you are longing for spring, indulge yourself in a teaspoonful. Be sure to smell it before eating. Since it has such a delicate aroma and flavor, and takes so many flowers to make, I'd recommend eating it plain or dissolving it alone in warm water. Its subtle flavors can be lost if you use it to sweeten something else.

The McIntosh apple has been used in orchards since 1839. Genetically it has not changed. It may have been perfectly adapted for life in 1839, but this is not 1839 anymore. Pest populations have changed, diseases have morphed, the weather and climate are different than 170 years ago, yet modern orchardists still attempt to allow McIntosh to live in a perfect environment, which means being surrounded by dozens of sprays from copper and sulfur to Diazinon, Sevin, Roundup and others.

The honeybee is not native to this hemisphere. Prior to its introduction flowering plants survived and thrived just fine. There were (and still are) an adequate number of species of pollinating insects that can pollinate our crops. Their populations are also threatened on a continental basis. Their threats aren't necessarily American foulbrood, Nosema and Varroa mites, because they have evolved through the eons with these insults as part of their life cycle. They are already genetically resistant and behaviorally adapted to survive living in the actual real-life environment rather than an artificial one. The biggest threat to their populations is habitat destruction and fragmentation. With modern fruit and nut orchards merely parade fields of tree soldiers all standing at attention in an herbicide, pesticide and fungicide mist, wild pollinators have a hard time finding suitable habitat. With bean, melon and tomato fields at thousands of acres in size with no brushy hedgerows between the acres, there is no place for wild pollinators to nest.

Much work *is* actually being done in the field of wild pollinator habitat preservation. Growers are being encouraged to install hedgerows between fields and along the riparian zones of stream and pond sides. University and extension publications have instructions on how to make wild pollinator nests. All of these measures are helpful steps in ensuring that wild pollinator populations don't disappear completely and that at least some potential for backup pollination services exist in case the honeybee can't chemically recover from this latest insult.

In restoration agriculture, however, instead of including wild pollinator habitat in with the cropping system, the cropping system itself *is* the wild pollinator habitat. Instead of including conservation practices along with farming, restoration agriculture *is* a conservation practice simultaneous with being the cropping system. In the restoration agriculture system at New Forest Farm, although we do keep hives of honeybees, they are far outnumbered by wild pollinators. In apple or cherry blossom season the trees are swarming with pollinator insects of all kinds while a few honeybees can be seen as well — clearly in the minority. In a maturing restoration agriculture system, honeybees are not needed for pollination at all.

But what then are we to do about the honeybee? Honey is a wonderful sweetener, a powerful medicine, and an incredible food preservative, and beeswax makes beautifully aromatic candles, modeling compound, salves and ointments — all useful products. If we choose to keep honeybees (and I do), how should we manage the colonies?

No definitive answer will be found here. I am as baffled as industrial beekeepers and researchers. I am open to trying different methods of housing such as dung-straw or clay-straw hives, topbar beehives, and using menthol cough drops to help control mites. However, I am going to follow the restoration agriculture path. I am going to go forward using the old way of breeding bees to survive in the actual conditions and I will strive to interrupt pest and disease cycles with periodic destruction of weaker hives.

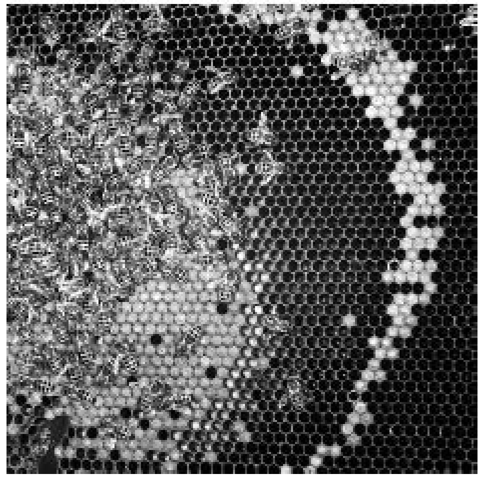
Breeding honeybees is not all that difficult. There are many non-industrial researchers that claim that artificial bee breeding is part of the problem. In industrial bee breeding, eggs are removed from the regular brood comb and placed in plastic queen cups, wide-bottomed plastic cups attached to the top bar of a frame. Several dozen queen cups can be placed on numerous crossbars placed like the rungs of a ladder across a single frame. The queen cell frame is placed back into a hive where workers feed the little larvae royal jelly, and the day before the new queens are due to emerge from their cell they are removed from the hive where they will be harvested for sale and artificially inseminated with a hypodermic needle loaded with drone bee sperm. Inseminated queens are then sold to beekeepers with a screened box full of bees.

This whole process truly borders on the bizarre and is totally divorced from the natural processes of “beehood.”

In a natural setting healthy honeybee hives will increase in size and eventually their home will become too small to contain them all. Under overcrowding stress the hive somehow gets the signal to produce a new queen. Left to her natural inclinations, the queen bee will lay an egg specifically designated to become a queen bee, most typically toward the bottom of a comb. When dividing a hive, a “replacement queen” is raised. This emergency queen starts out normally as a worker bee egg, and then the larvae begins to grow. In the cell it is oriented horizontally. As it is fed royal jelly and mysteriously changes from a worker larvae into a queen larvae it becomes too long for the worker-sized cell and bends downward. By the time day 16 goes by, it is elongated past the edge of the comb, drooped downward, and looks much like a peanut. The immature queen inside the cell is bent, her abdomen horizontal, and her thorax and head downward. In the case where a veteran queen is intentionally laying queen eggs in preparation for swarming, the egg is placed vertically from the beginning and the queen always develops vertically oriented. Many non-industrial bee researchers believe that this might actually be quite significant for honeybees. Honeybees have what can only be described as a miraculous navigational and communication ability. They live in complete darkness in their hive and somehow are able to communicate to one another about which direction to fly outside in order to find which kind of flowers are blooming. They somehow know when to raise more males, and they know when to kick the males out in the fall so that they can starve outside in the cold instead of eating honey that is reserved for winter survival of the hive.

It is thought by many that it is the queen who is sending the signals that guide the life of a hive, and indeed, if one kills the queen, the rest of the bees in the hive don’t act quite as organized when she’s gone, but somehow they know to rear a new queen. It is this type of behavior that leads many to think that the apparent intelligence of the hive is a by-product of the colony itself, an emergent property. Once a certain number of individuals are in one place at a time knowledge arises because of that fact. Whether the intelligence of a hive is a result of the queen or an emergent property of the whole colony, it is quite possible that directionality is hard-wired into a queen in her infancy as she forms in her cell. A replacement queen begins life as a worker bee and transforms from a horizontal relationship with gravity, the earth’s magnetic field, the rising and setting of the sun, to a vertical relationship. A “true,” swarm-impulse queen begins life as a queen egg and is reared solely in relationship to the vertical. Replacement queens raised from worker eggs are factually different than naturally reared swarm-impulse queens raised from queen eggs.

Note the lighter colored “pollen sac” on the honeybee’s back leg.



The pattern of capped brood in this photo shows that the queen is an older queen who is not laying eggs as effectively as a younger one would. Time to divide this hive and rear new queens.

Once an industrially reared replacement queen hatches, she is artificially inseminated by needle. How queen breeders obtain sperm from a drone is beyond me, and I don't really know if I'm interested in learning how they do it. Restraining an insect and forcing her to have machine-sex with a hypodermic needle seems like something out of an X-rated horror movie. Besides seeming creepy, this method of rearing queens is *not* selecting for the most fit queen *or* best drone. Some genetic selection and hybridization with other strains of honeybees is being done, but it is not taking place in the context of where the organisms have to live. The naturally raised "true" queen raised from a queen egg, emerges from her cell and flies from the hive on what is called her virginal flight. As she does this she is followed by every drone that knows what she's doing. As she flies along, one and only one drone is fast enough and able enough to catch up with her and mate. The actual act of insemination is still somewhat mysterious, but the end result is that the most fit queen, if she survives her rearing, (and doesn't die from foulbrood, Nosema, trachaea or Varroa mites or being killed by the jealous matriarch) mates with the absolute most fit male out of thousands who also survived the pests and diseases of the hive.

The process of dividing hives in the spring allows this process of natural sexual reproduction to take place. This process takes place in the full context of nature with all of the selection forces influencing who gets to mate with whom. It is the process by which our honeybee hives become locally adapted to the conditions at our farm.

Dividing hives also gives new colonies the opportunity to build more wax. By returning wax frames to the hive every time honey is extracted the process of building comb is drastically limited. In a natural setting honeybees go through several life stages, one of which is secreting wax and building honeycomb. Is it possible that honeybees *need* to do this? Perhaps they need to secrete the wax during a certain life stage or it builds up inside them with toxic effects.

Every year we divide our honeybee hives, once per hive, twice if the hive is incredibly strong. We extract the honey and leave enough to hopefully carry the hives through the winter. If a hive does not survive the winter, or dies from some other cause, so be it. The strong hives get divided again and the hive of the dead colony gets burned. Does this work? Done in a widespread fashion, it should. Over time, our management technique will select for honeybees that can survive along with the pests and diseases that exist all around us. As the bees survive and genetically change through the generations, so do the pests and diseases. So be it. We will be breeding honeybees *inside* of the stream of actual life on planet Earth. They will be subject to the forces, known and unknown, that exist in the real world. A plastic queen cup, artificial insemination by a needle, and a regular regime of chemical powders and liquids selects for stronger pests and diseases and honeybees dependent on artificial insemination and chemicals. We prefer to breed bees in the environment in which they will live and not in a laboratory.

CHAPTER 11

About Nutrition

ANNUAL agriculture, the kind of agriculture practiced for thousands of years, especially under industrialized, petrochemical-intensive systems, destroys ecosystems, starves over half the human race while causing disease in the other half, creates herbicide-resistant weeds, and creates pesticide-resistant insects (which spread their mutant genes throughout the natural world). But *we do need food!* The human race needs food and lots of it. United Nations research states that crop yields need to double within 40 years in order to keep up with world population growth. Despite what its detractors say the United Nations is no slouch. The people involved in its various agencies actually *are* doing their best to address real human problems and real human needs. They have ready access to the world's most credible information and their numbers are arguably some of the best around. Annual plants are humanity's staple foods: rice, wheat, corn, beans, lentils, peas, millet, chickpeas. These and other annual plants are our *food.* Again, the United Nations says that we need to double the food produced within fourty years just to break even.

So far, I have mentioned the facts that perennial woody plants leaf out sooner in the spring, stay greener in the fall, capture more total sunlight per acre, only need to be planted once, reduce or eliminate soil erosion, reduce seasonal flooding, sequester carbon, provide habitat for pest-eating organisms and other wildlife, and can be arranged into systems that closely mimic native, natural systems that have existed for millions of years while increasing the site fertility and species abundance. This is all well and good, but can we produce enough *food* this way? Can these systems produce enough total calories, enough carbohydrates, proteins and oils to feed the human race? Over and over again this issue is brought up and, in my opinion, is somewhat of a red herring. "This all sounds good, but we've got to feed the world." I agree with this sentiment and hereby turn the question back onto the asker and state that the current agricultural system is *not feeding the world!* Not only is annual agriculture *not* feeding the rapidly increasing population, it is destroying ecosystems worldwide while doing so. The current agricultural system is dependent on extraordinary labor or cheap fossil fuels or increasingly scarce mined inputs in order to not feed the world. It contributes to the greenhouse effect and the inequitable distribution of wealth worldwide while *still* not feeding the world.

That said, let's do some comparisons. Let's use a benchmark crop to start with: corn, the hubristic grandchild of the humble grass, teocinte.

CORN IS A MONSTER

Born in the highlands of Central America and bred by village-scale subsistence farmers for thousands of years, corn *(Zea mays)* is grown worldwide as an abundantly yielding, easy-to-grow staple food crop. It feeds humans and animals by the billions. Its large grain size, the fact that one corn seed planted in the earth can yield hundreds of seeds at harvest, and that it is easy to cultivate with simple hand tools, made it a sure bet as a staple crop for the thousands of years that it was a village crop. Upon its discovery by Europeans, maize has made its way to every region on the planet where the climate suits its needs. That climate happens to coincide with the great temperate savanna regions around the globe and quite significantly, the oak savannas of North America. Corn yields are impressive — massive, actually. On average, one acre of corn in the United States produces slightly over 150 bushels of the starchy, golden seeds. On the richest soils with perfect temperatures and adequate moisture, yields can exceed twice that amount. One bushel of corn weighs 56 lbs. That means that one acre of corn can produce on average 8,400 lbs. of seed or 4.2 tons of corn. At 1,665.61 calories per pound, one acre of average fertility crop land planted in corn can produce around 13.9 million calories of food energy. That's a *lot* of food.

If a person were to consume only corn, and consume 2,000 calories of food per day, that one acre of corn would feed that person for 19 years. Looking at it another way, one acre of corn can produce enough calories for nineteen people for one year. That is a pretty high caloric standard and it is this high standard that the industrial food and agriculture system would have us believe is the *whole* story. By asking us restoration agriculture farmers the question, "Can you feed the world?" what they are really asking is, can we produce 13.9 million calories of food per acre in a savanna-mimicking restoration agriculture system? If that's possible, then how is that possible? I will address the "if" here and "how" in later chapters.

The belligerent questioner — typically a stressed-out, conventional farmer growing GMO corn on forward contracts to one of the megalithic "Big Ag" multinational corporations with multi-millionaire CEOs — holding up the admittedly high bar of 13.9 million calories per acre as a standard measurement by which we claim to be raising food, may actually believe that his way of farming feeds the world or can feed the world, but we are going to stop that thought right here. Remember, right now there are billions of people worldwide living in chronic hunger. Hundreds of millions are chronically malnourished. The current system is *not* feeding the world and increased yields of the same crops alone will also not feed the world. One of the reasons for this is that monocrop systems of annual grains do not have enough *nutrition* in order to feed people. They may have enough calories to keep people alive, but they don't have enough vitamins and minerals to *feed* people and allow for at least a moderate degree of good health.

In order to be completely unbiased in this comparison, I will use USDA nutritional analyses of the foods that I will be comparing.

What the following table shows is that although corn packs a tremendous caloric wallop per acre, it hardly qualifies as nutritional food. If you were to be fed corn (as in "we need to *feed* the world"), you would very quickly develop numerous nutritional deficiency diseases. By scrolling down the table you could start with calcium deficiency which would result in tingling "pins and needles" in and around the mouth, muscle spasms, severe and easy bruising, and kidney and heart failure long before the mineral deficiency would have time to result in soft teeth and brittle bones. Interestingly enough, nutritional calcium deficiency can be caused by several other things one of which is excessive magnesium, of which corn has in excess, and a lack of vitamin D which corn has no measurable amount. Calcium deficiency can also be caused by excess phosphorus in the diet, which corn also has in abundance. Either corn has to be supplemented with a wide variety of compensating intakes, or it is actually a toxin. The bottom line — corn is really, not a food.

Annual agriculture currently is not *feeding the world and is destroying ecosystems in order to do so.*

Nutritional Analysis

VITAMINS AND MINERALS IN YELLOW CORN *(ZEA MAYS)*

MINERALS	UNITS	VALUE/10,000 GRAMS
Calcium, Ca	mg	700
Iron, Fe	mg	271
Magnesium, Mg	mg	12,700
Phosphorus, P	mg	21,000
Potassium, K	mg	27,700
Sodium, Na	mg	3,500
Zinc, Zn	mg	221
Copper, Cu	mg	31.4
Manganese, Mn	mg	48.5
Selenium, Se	mcg	1,550

VITAMINS		
Vitamin C total ascorbic acid	mg	0
Thiamin	mg	38.5
Riboflavin	mg	20.1
Niacin	mg	362.7
Pantothenic acid	mg	42.4
Vitamin B6	mg	62.2
Folate, total	mcg	1,900
Folic acid	mcg	0
Folate, food	mcg	1,900
Folate, DFE	mcg_DFE	1,900
Vitamin B12	mcg	0
Vitamin B12 added	mcg	0
Vitamin A, IU	IU	21,400
Vitamin A, RAE	mcg_RAE	1,100
Retinol	mcg	0
Vitamin E (alpha-tocopherol)	mg	49
Vitamin E, added	mg	0
Vitamin K (phylloquinone)	mcg	30

Source: USDA National Nutrient Database for Standard Reference, Release 20 (2007)

Corn has no measurable quantities of vitamin C. Insufficient vitamin C in the diet interferes with the synthesis of collagen, a necessary part of connective tissue in the human body. Vitamin C deficiency begins to be apparent with the onset of a general malaise and overwhelming fatigue, followed by the onset of spongy gums and bleeding from mucus membranes. Dark spots soon appear on the skin, often turning into open wounds, followed by jaundice, fever and death. This pathology is commonly known as scurvy and was common among sailors in the days of wooden ships when they would subsist for months on dry wheat biscuits which are also deficient in vitamin C. Vitamin C deficiency can be cured with adequate quantities of fruits and berries, especially citrus in the diet. If annual grain farmers want to feed the world they'll have to set aside some of their acreage to grow fruits and berries to compensate for the vitamin C deficiency, or corn should not be considered food.

If the hypocalcaemia (calcium deficiency) or scurvy didn't kill you first, a corn eater would have to deal with deficiencies in folic acid, vitamin B12, retinol and vitamin E. Deficiencies in any of these critical nutrients can cause a whole host of maladies which range from tremors and muscle cramps to sterility in males and, of course, to fatigue, depression and death. (Fatigue, depression and death … doesn't that the sound fun?) If the bellicose corn farmer insists that we need to grow monocrops of annual plants in order to feed the world, then he or she had better set aside some more acreage to grow enough other plants in order to supply these essential nutrients or admit that corn really isn't food.

One of the most insidious nutritional deficiencies caused by eating too much corn is not really the result of a deficiency. The nutrient in question actually *is* present in corn, but it is not bioavailable in the human digestive tract and therefore is in deficiency unless it is somehow released. That nutrient is vitamin B3 (also known as niacin). The disease caused by niacin deficiency is pellagra. The original Meso-Americans and North Americans somehow learned (or perhaps actually *were* taught by a deity) that in order to make the niacin in corn available it had to be soaked for an extensive period of time in a lime or wood-ash solution, both of which were chemically alkaline. High-calcium lime-water would fortunately also help to address corn's natural lack of calcium. Traditional corn-eating cultures neither had pellagra nor calcium deficiencies.

When European settlers adopted corn from the original Americans they generally did not adopt the wood ash or lime soaking technique and so set up the conditions where pellagra would reach almost epidemic proportions in certain regions especially Spain, Italy and the American South where corn became *the* staple grain. In order for corn to provide niacin to the human diet, it must be nixtamalized (soaked in an alkaline solution) otherwise corn really isn't a food.

In addition to being deficient in all of these vitamins and minerals, corn is low enough in protein to make a human being chronically weak and listless. In addition to being low in total protein, corn is lacking in the essential amino acid lysine. Without lysine nerve tissue cannot be properly manufactured in the body, which means that brains cannot form properly. Lysine deficiency in humans can then complete the loop by creating an inability of the body to absorb niacin which leads to niacin deficiency which leads to pellagra which leads to much weeping and gnashing of teeth, if only the teeth would gnash properly because the vitamin C deficiency has simultaneously led to scurvy and the gums have gone soft. Corn may indeed produce 13.9 million calories of carbohydrate energy per acre, and that's a lot. Also corn is incredibly useful. It can be made into chips, tortillas, cornmeal mush, grits, cornbread, and high-fructose corn syrup (HFCS). Corn is versatile in so many ways and produces a tremendous amount of empty filler to keep hungry bellies full, but it does *not* provide adequate human nutrition.

With what we know about the nutritional deficiencies of corn and what we know about the ecological devastation caused by annual grain farming we would be wise to relegate corn to the status of a niche crop that yields well but has far too many undesirable nutritional and ecological side effects to be relied upon as a staple food. Annual grains and legumes are *not* whole, complete foods. They are an energy source and can be a protein source, but must be mixed and matched properly so as to make up for their individual defects.

What we do on our farms shows up in the food system and eventually is reflected in our human bodies. Excessive reliance on high-calorie, low-nutrient foods leads to obesity, diabetes, depression, chronic fatigue, dental disease, neurological degeneration and more. This measurable fact can be seen all around us every day. Destruction of the outer ecosystem has led to the deterioration of the inner ecosystem. The depletion of flora and fauna in the exterior ecosystem in order to grow annual crops is mirrored in the rise of depleted gastrointestinal "inner" ecosystems. Increasing numbers of people are having difficulty digesting grains and require an increased reliance on supplemented probiotics. Add to that the fact that estrogen-mimicking compounds (mostly derivatives and metabolites of agricultural chemicals) are showing up in our foods at increasing levels and you have an incredibly complex web of agricultural problems, health problems, and social problems. The mainstream media, politicians and specialized medical sciences lead us to believe that these problems are separate from one another when they really aren't. The complexity of these problems and their apparent separability from agriculture and the food supply, make them appear to be intractable. We *are* what we eat and the cultural problems we see around us are a reflection of corn.

So now we find ourselves in the situation where the nutritionally deficient and physically degenerating, bellicose GMO corn farmer has repeated his charge that we savanna farmers can't feed the world. We already know that annual grain agriculture is not feeding the world, as is evidenced by famines and rescue missions worldwide, but did you know that the majority of corn produced in the United States doesn't even go to directly feed human beings?

Recent USDA reports (this is the USDA that keeps track of actual production and trends, and is in support of the current annual grain system) reveal the following:

In 2008 (the most recent data available at this time) of the 12.1 billion bushels of corn produced in the USA...

5,250 million bushels (43 percent) are used as livestock feed

3,650 million bushels (30 percent) are used to make ethanol fuel

1,850 million bushels (15 percent) are exported to other countries

943 million bushels (7.7 percent) are used as industrial ingredients including for corn starch, oil, high-fructose corn syrup (HFCS), etc.

327 million bushels (2.7 percent) are used for human consumption including for grits, corn flour, corn meal, corn chips, etc.

Viewing corn from the perspective of "total calories per acre" is deceiving and does not tell us the whole picture. In order to make a fair comparison we need to look at comparable products derived from each production method. Using the USDA statistics shown above we can easily calculate that an annual corn crop is apportioned into meat, fuel, exports, industrial ingredients, and finally human food. For this discussion I am going to assume that all exported corn will go to feed people since I have not been able to find statistics showing otherwise. That would mean that of the 13.9 million calories of corn produced per acre:

5.9 million calories go to feed animals

4.2 million calories are converted into fuel

1.07 million calories are converted into industrial ingredients

1.4 million calories are exported or used as direct human food

One of the reasons why the current annual crop agriculture system is failing to feed the world is that so much of the annual food grown never enters into the human food chain. It is obvious that the calories found in the ethanol used to fuel automobiles is energy that is not available to feed human beings. What is not so obvious is the energy loss when annual grains are fed to livestock. On average only 10 percent of any organism's food energy is converted into that creature's body. The remainder is used as fuel for the creature's metabolic processes, is dissipated as body heat, or is excreted. This phenomena has been researched and documented extremely well for hundreds of years and has led to what is called the trophic pyramid.

At the bottom of the trophic pyramid of any particular system we have the producers. In ecological terms a producer is an organism that can take its sustenance directly from the environment. In a terrestrial system these organisms are the plants.

One trophic level above the producers are the organisms called primary consumers. These are organisms that cannot absorb their nutrients and energy directly from the environment and have to get them by eating producers, in this case plants. Plant-eating primary consumers are commonly called herbivores. In an annual grain production system livestock eating grain (cattle, for example) would be considered a primary consumer. Human beings eating grain directly would be primary consumers as well.

If a human being eats 10 lbs. of corn directly, approximately only one pound of that corn becomes (nutritionally deficient) human flesh and bone. The remainder is used as the energy for metabolism or is flushed down the sewer. If a cow eats 10 lbs. of corn, approximately one pound becomes cow, or in this case, beef steer.

Where the implications of the trophic pyramid become sinister is when human beings eat meat that was raised on grain. At this point the human being becomes a *secondary* consumer. Once again it is only approximately 10 percent of the energy of the previous trophic level that becomes converted into the biomass of the consumer. A human eating corn would consume 10 lbs. of corn to build one pound of human flesh. A human eating beef would consume 10 lbs. of beef to build one pound of human. This is the trophic level argument where vegans are absolutely correct. If a human eats one pound of corn-fed beef, they are actually consuming 10 lbs. worth of corn. If it takes 10 lbs. of beef to make one pound of human, that means that a corn-fed beef eating person is eating the equivalent of 100 lbs. of corn in order to gain one pound. Even that is not the whole picture. If a corn-fed beef steer has a market weight of 1,150 lbs. (that's its live weight on the hoof before it goes to slaughter) and it is of average grade (not too fat, not too skinny), it will yield approximately 715 lbs. of carcass. That's a 65 percent yield. Of that 715-lb. carcass, there will only be approximately 569 lbs. of edible human food. This edible human food includes the variety meat (liver, heart, tongue, tripe, kidneys and brains).

Now according to our trophic level calculations, in order to get 1,050 lbs. of bovine, we needed to feed it approximately 10,500 lbs. of corn. For that 10,500 lbs. of corn, all we get is a lousy 569 lbs. of meat! Live weight-to-carcass yield-to-edible meat makes the trophic loss even more extreme. Only 5.4 percent of the calories of corn become calories for human nutrition. This *is* a travesty when so many people are going hungry.

Cattle convert plants that are inedible to humans into highly nutritious complete human foods.

In order to account for the livestock portion of the 13.9 million calories per acre of corn, we will have to take that 5.9 million calories that went to livestock and discount it. If people eat grain-fed meat, they are only getting 5.4 percent of the total caloric value that they would have gotten if they had eaten the corn directly. This means that of the 5.9 million corn calories produced per acre as livestock feed, only 318,600 calories per acre become available for human consumption. This would reduce corn's effective total calories per acre from 13.9 million calories per acre to 8,318,600 calories. The bar just got lowered.

Corn to Beef

On average, how many pounds of corn make one pound of beef? Assuming an all-grain diet from backgrounding through to 1,250-pound slaughter weight, I have heard estimates ranging from 6 pounds corn/1 pound beef to 20 pounds corn/1 pound beef. Can you clarify?

You ask a really good question. There are reasons why you have heard many numbers because it depends a bit on production practices and your definition of a pound of beef. An old rule of thumb is that it requires 50 bushels of corn to finish an animal for our United States desired endpoint (USDA choice grade; USDA yield grade 2 or 3; approximately 28 percent body fat). There are 56 pounds of corn in a bushel, so you will need around 2,800 pounds of corn to produce an animal that weighs 1,250 to 1,350 pounds. This equates to 2.07 to 2.24 pounds of corn per pound of finished animal. The reason you have numbers that are much higher than that may be due to many factors. Cattle convert (pounds of feed per pounds of gain) at around 5.5 to 6.5 in the feedlot. That means you need to feed about 5.5 to 6.5 pounds of diet (assuming normal finishing diet) for an animal to gain one pound. However, they do not enter the feedlot until they already weigh 600 to 900 pounds. During that time, they consume mostly forage prior to entering the feedlot (most producers use forage because it is cheaper and a good use of fiber that would otherwise not be harvested). So, it is misleading to say that it takes six pounds of corn to make one pound of beef. The reason you may have heard 20 pounds of corn is because not all the 1,250 to 1,350 pounds of live animal is consumed (as beef anyway). Many of the alternative meats, such as liver, intestine, etc., are consumed but not as much in the United States. We utilize the entire animal, but not all for food; an example is hides for leather. Most is harvested, but for just meat cuts, the proportion of beef in the 1,250-pound animal is much lower. For example, carcasses are generally 63 to 65 percent of the 1,250 pounds, or approximately 790 pounds. Some of that carcass is fat that is not consumed, and some is bone (15 percent or so). Therefore, edible meat cuts and ground beef may be 600 pounds. So, with the example above of 50 bushels of corn fed to a finished animal, now 4.67 pounds of corn were required for each one pound of beef. If you calculate the red meat yield from this and equate that to pounds of feed per pound of red meat yield, that conversion may approach as high as 20, especially using the 6 pounds for every one pound gain.

Clearly, it does not require 7,500 pounds of corn to get 600 pounds of beef. This would be a conversion of 12.5 to 1. Most of the beef raised in the United States, and even more so globally, consume relatively small amounts of grain. Cows that produce calves almost always utilize forage diets. Forage would not be used for human food without beef cattle grazing pasture or fed harvested forages. Lastly, many feedlots utilize other by-products from human industries. For example, in Nebraska, use of corn gluten feed and distillers grains is prevalent. These industries that produce the by-products of ethanol and high-fructose corn syrup (both human products) would be devastated if they were forced to landfill or not feed these byproducts to livestock. In ethanol production from corn, approximately one-third of the corn grain ends up as cattle feed. This feed has no value to humans but makes an excellent cattle feed. In the scenarios above, we assumed no by-products were fed. We also used an average animal in the example above with 50 bushels of corn fed. That may vary from 1,000 pounds of corn per finished animal (with by-products and heavy cattle fed a short period of time) to as much as 3,500 pounds of corn per finished animal (with no by-products and feeding lighter calves to market weights). The only appropriate way to answer this is to look at all the numbers. Clearly, 20 pounds is not correct because cows are usually grazing forages, not corn, and cattle do not enter the feedlot until they are 7 to 20 months of age. Clearly, 2 is not correct if you are using only red meat yield. So, the answer to the question depends how you define "beef."

Texas AgriLIFE Extension (Texas A&M System)
Updated October 07, 2008

It is undeniably true that calories of corn converted into ethanol motor fuel are corn calories that are not available to humans. This fact is often used by activists as a bludgeon to make their point that big annual agriculture is starving the world (which they are), however, what is often left out is the fact that not all of the corn calories are extracted in the ethanol fuel manufacturing process. What is also not widely discussed is the fact that the distillers grains that remain after the fermentation process are used as a livestock feed. The majority of the carbohydrates have been removed from the grains and what is left behind is a high-protein, high-fiber animal feed that is actually more healthy for ruminants to consume than the whole corn grains. So, *some* of the corn calories actually do turn into beef and *some* of those beef calories turn into human flesh. So turning corn into ethanol is not entirely a food loss for humans.

According to research done for the USDA distillers grains have a mere 12.6 calories per pound. That means that for the fuel component of corn utilization 2,387 calories, or 99.95 percent, went out your exhaust pipe for each pound of corn produced. The calories that humans recover from ethanol distillation by eating distillers grain-fed beef, is 5.4 percent of 0.05 percent of the 4.2 million calories, or a mere 11,340 calories. This is just about enough to starve and malnourish six people for a week. The number is almost incalculably small.

When you take the trophic level discount and add it to the calories lost as fuel for vehicles, the total number of calories available for humans from one acre of corn come out to a mere 3.06 million calories. Out of 13.9 million calories produced per acre only 3.06 million calories go to feed humans. Only 22 percent of the calories in the entire U.S. corn crop is consumed as food. This is the *true* food yield of corn. If we can provide humanity with more than 3.06 million calories per acre, then restoration agriculture farmers are doing a heck of a lot better job at feeding the world than King Corn.

Let's look back for a minute to the breakdown of how the calories in an acre of corn are used:

5.9 million calories go to feed animals

4.2 million calories are converted into fuel

1.07 million calories are converted into industrial ingredients

1.4 million calories are exported or used as human food

Instead of the question, "Can we feed the world?" in a savanna analog, the question perhaps should be, "Can we produce equal or comparable amounts of foodstuffs, fuel and industrial ingredients per acre as annual agriculture?" A later, more significant question in an era of declining petroleum availability is can we produce a higher percentage of food, fuel and nutrients *out* per caloric expenditure *in.* In case you were wondering, when it comes to total calories *out* per input calories expended, annual crops don't stand a chance when compared to a living, breathing, reproducing perennial ecosystem that is perpetually self-renewing forever. Plant it once and it never needs to be planted again.

But for now, let's return to our oak savanna mimic in the next chapter.

CHAPTER 12

Nutrition & Perennial Agriculture

OUR modern oak savanna replication consists of the following plant species: chestnuts, apples, hazelnuts, raspberries, grapes, currants and forage.

Unless you are a grass juicer, a maker of grass tofu (yes, you can make tofu from lawn clippings!), and consume acres of grass, human beings cannot digest grass very well. However, animals can. The animals most suited to eating grasses are the ruminants. Our simple oak savanna mimic can be home to an integrated animal system that consists of cattle, pigs, sheep and chickens. For this nutritional analysis some of the chickens will be raised for meat and others for eggs. Some of the cattle will be used for meat and others for producing dairy products. Since I prefer to drink cow's milk rather than sheep's milk, I am only going to include cow's milk in the nutritional analysis. (Sorry sheep people, I'm just trying to save space and not addle too many brains with too much information.) Although the sheep dairy folks might initially take a little offense that I did not include sheep dairy in the nutritional analysis, and even though sheep milk may have way higher quantities of certain nutrients when compared to cow's milk, I'm not comparing sheep's milk to cow's milk. I'm comparing oak savanna mimic restoration agriculture to monocropped corn. Even my sheep dairy friends will see that by the time we get down to dairy products the evidence will be clear — an oak savanna-mimic, restoration agriculture farm produces a full and complete diet for the human being. The nutrition per acre under restoration agriculture outcompetes corn so much that it's not even funny. In order to make this system less cumbersome I am also leaving out turkeys which would work quite well in the system I have described. The system will include zero imported feed for the livestock and will be based on a very conservative number of animals that could be supported by it.

What we will need to do first is to lay out a simple, one-acre restoration agriculture farm "field." It is based on one of many systems pioneered at New Forest Farm in Wisconsin and is similar to others around the country.

This one-acre field would look something like this:

9 rows of edible woody plants with a 23-foot-wide alley between each row.

The rows would be planted as follows:

- 5 rows of chestnuts planted 12 feet apart within the row. Beneath each chestnut tree would be a row of red currants planted 2 feet apart within the row and one grape vine trellised on each chestnut tree.
- 4 of the 9 rows would be an apple and hazelnut row with apples planted every 24 feet and hazelnuts as an understory planted every 4 feet. Raspberries would be planted on the south side of the entire row every 2 feet and one grape trellised on each apple tree.

This spatial arrangement would result in a total for each acre of:

- 34 apple trees
- 86 chestnut trees
- 120 grape vines
- 208 hazelnut bushes
- 416 raspberry canes
- 520 red currant bushes

As you can plainly see, on a nutrient-by-nutrient basis, an oak savanna-mimic restoration agriculture farm growing a perennial polyculture of chestnuts, apples, hazelnuts, raspberries, grapes and currants provides superior nutrition to corn. There are only two measured nutritional elements, sodium and selenium, that are available in lower quantities in the perennial polyculture. Sodium, although it is an essential nutrient, is available far in excess in the modern diet and has been accused of being the cause of hypertension, heart attacks and strokes. Selenium, although it is essential for brain and nerve function, is a heavy metal and as such is a neurotoxin in even modest amounts. With corn being in so many of the foods we eat and comprising the base diet upon which most American livestock is fed is there any wonder why hypertension is such a large national health issue? With the deficiency of sodium naturally occurring in the "wild" human diet, is it any wonder that we developed to have such a strong desire for salt? It is an essential nutrient and it isn't readily available in a natural, plant-based diet.

The perennial polyculture as described above is nearly a perfect nutritional system for a vegan diet in North America. The system will be a home to a huge variety of birds, amphibians, pollinating insects and more, so animal habitat will be improved. Human beings can live healthy and well fed and no animals need be killed. Without livestock, however, the system would need to be mowed in order to favor the edible woody plants, so even a vegan would benefit from having some livestock in the system. For those who choose to eat the animals in their restoration agriculture system, they are lucky indeed. As the next few charts will show, with the addition of grassfed meats and especially organ meats to the above described perennial polyculture diet, all nutritional deficiencies disappear.

Nutrient Values of Polyculture Plants

		CORN	CHESTNUT	APPLE	HAZELNUT	RASPBERRY	CURRANTS	GRAPES	TOTAL NUTRIENTS
MINERALS	**UNITS**	**V/10K g***	**V/10K g**	**V/10K g**	**V/10K g**	**V/10K g**	**V/10K g**	**V/10K g**	**V/10K g**
Calcium, Ca	mg	700.00	1,800.00	600.00	11,400.00	2,500.00	5,500.00	1,400.00	23,200.00
Iron, Fe	mg	271.00	141.00	12.00	470.00	69.00	154.00	29.00	875.00
Magnesium, Mg	mg	12,700.00	8,400.00	500.00	16,300.00	2,200.00	2,400.00	500.00	30,300.00
Phosphorus, P	mg	21,000.00	9,600.00	1,100.00	29,000.00	2,900.00	5,900.00	1,000.00	49,500.00
Potassium, K	mg	27,700.00	44,700.00	10,700.00	68,000.00	15,100.00	32,200.00	19,100.00	189,800.00
Sodium, Na	mg	3,500.00	300.00	100.00	0.00	100.00	200.00	200.00	900.00
Zinc, Zn	mg	221.00	87.00	4.00	245.00	42.00	27.00	4.00	409.00
Copper, Cu	mg	31.40	36.30	2.70	172.50	9.00	8.60	4.00	233.10
Manganese, Mn	mg	48.50	160.10	3.50	617.50	67.00	25.60	71.80	945.50
Selenium, Se	mcg	1,550.00	0.00	0.00	240.00	20.00	0.00	10.00	270.00
VITAMINS	**UNITS**	**V/10K g***	**V/10K g**	**V/10K g**	**V/10K g**	**V/10K g**	**V/10K g**	**V/10K g**	**V/10K g**
Vitamin C, total ascorbic acid	mg	0.00	3,600.00	460.00	630.00	2,620.00	18,100.00	400.00	25,810.00
Thiamin	mg	38.50	16.00	1.70	64.30	3.20	5.00	9.20	99.40
Riboflavin	mg	20.10	18.00	2.60	11.30	3.80	5.00	5.70	46.40
Niacin	mg	362.70	80.00	9.10	180.00	59.80	30.00	30.00	388.90
Pantothenic acid	mg	42.40	55.50	6.10	91.80	32.90	39.80	2.40	228.50
Vitamin B6	mg	62.20	41.00	4.10	56.30	5.50	6.60	11.00	124.50
Folate, total	mcg	1,900.00	6,800.00	300.00	11,300.00	2,100.00	0.00	400.00	20,900.00
Folic acid	mcg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Folate, food	mcg	1,900.00	6,800.00	300.00	11,300.00	2,100.00	0.00	400.00	20,900.00
Folate, DFE	mcg_DFE	1,900.00	6,800.00	300.00	11,300.00	2,100.00	0.00	400.00	20,900.00
Vitamin A, IU	IU	21,400.00	20,200.00	5,400.00	2,000.00	3,300.00	23,000.00	10,000.00	63,900.00
Vitamin A, RAE	mcg_RAE	1,100.00	1,000.00	300.00	100.00	200.00	1,200.00	500.00	3,300.00
Retinol	mcg	0.00	1,000.00	0.00	0.00	0.00	0.00	0.00	1,000.00
Vitamin E (alpha-tocopherol)	mg	49.00	0.00	18.00	1,503.00	6.00	100.00	19.00	1,646.00
Vitamin E, added	mg	0.00	0.00	0.00	0.00	246.00	0.00	0.00	246.00
Vitamin K (phylloquinone)	mcg	30.00	0.00	220.00	1,420.00	780.00	0.00	1,460.00	3,880.00

*V/10K g = Value per 10,000 grams

At this point in the book readers who thrive on tables and figures will be very happy and those who can't stand looking at charts and numbers will begin to think about flipping to the next chapter. If you're about to flip to the next chapter, stick with me just a little while longer. Have a brief look at the charts and tables, but mostly just follow the narrative.

There are two major food groups that I have left out of this nutritional analysis so far. All of the foods that we've listed to this point are ecologically categorized as producers. They are all plants. They take in water, soluble soil nutrients and air and using the power of the sun, store the sun's energy as carbohydrates, proteins and oils. Much of a plant's body is made up of complex carbohydrates such as lignin and cellulose. In perennial plants this is especially true. Lignin and cellulose are indigestible to human beings. Lignin and cellulose combined are the most common organic compounds on planet Earth and are an incredible source of stored solar energy.

There are two basic types of organisms that use the stored carbon in plants as a food source. One broad category falls under the ecological classification of consumers and the others are recyclers.

Any creature that eats plants is a consumer. Human beings are consumers. Any creature that eats *only* plants can be considered a primary consumer — an herbivore. A creature that eats other consumers is ecologically called a secondary consumer. Cows are primary consumers. Wolves are secondary consumers. The consumers that I will address nutritionally are cattle, pigs, sheep and chickens. Additional animal products to be listed will be cow dairy.

The other type of organisms that use plant matter for food fall into the category of recyclers. There are quite a variety of recyclers in nature from earthworms to ants, springtails, nematodes and more. Although I could explain how worms and ants are edible and could even provide delicious recipes for you to follow, they are not recognizable as crops or even food to most North Americans at this time. Worms and ants currently have very limited culinary markets in North

America, if they have any at all. However other recyclers are widely recognized as food and have large markets, some of which are quite lucrative. I am referring to the fungi. There are a wide variety of culinary and medicinal fungi that have an important decomposition role to play in restoration agriculture, so many that I don't have the space here to get into anything other than a cursory discussion concerning them. For this nutritional analysis I will only list two mushrooms, the shiitake and the maitake. This is done not because they are the only two mushrooms that can be grown in restoration agriculture, but because one is a culinary mushroom and one is a medicinal mushroom, and we would like to have proactive medicines grown in our system in addition to more than adequate nutrition. Most significantly, shiitake and maitake are two easily grown mushrooms that have been nutritionally analyzed by the USDA using the standardized protocol that we have been following.

Meat Nutrient Summary

		BEEF TOTAL	CHICKEN TOTAL	LAMB TOTAL	PORK TOTAL	MEAT TOTAL
NUTRIENT	**UNIT**	**V/100g***	**V/100g**	**V/100g**	**V/100g**	**V/100g**
PROXIMATES						
Water	g	793.24	284.35	664.2	925.76	2,667.55
Energy	kcal	2,667	615	1,332	3,891	8,505.00
Energy	kJ	11,155	2,571	5,573	16,282	35,581.00
Protein	g	181.91	78.66	143.99	235.67	640.23
Total lipid (fat)	g	205.94	30.06	78.33	318.35	632.68
Ash	g	12.74	3.92	10.55	12.53	39.74
Carbohydrate, by difference	g	9.05	3	2.81	4.4	19.26
MINERALS						
Calcium, Ca	mg	187	43	87	215	532.00
Iron, Fe	mg	79.22	24.77	74.89	87.45	266.33
Magnesium, Mg	mg	190	78	163	184	615.00
Phosphorus, P	mg	2,858	872	2,295	2,383	8,408.00
Potassium, K	mg	3,279	1,110	2,697	3,235	10,321.00
Sodium, Na	mg	1150	256	880	1,331	3,617.00
Zinc, Zn	mg	26.91	14.45	22.24	31.04	94.64
Copper, Cu	mg	11.744	1.334	8.811	2.735	24.62
Manganese, Mn	mg	1.001	0.529	0.57	0.957	3.06
Selenium, Se	g	415	128.9	368.5	458.5	1,370.90

Fluoride, F	g	22.4	0	0	0	22.40
VITAMINS						
Vitamin C, total ascorbic acid	mg	158.2	31.1	114	118.6	421.90
Thiamin	mg	1.437	0.581	1.845	3.686	7.55
Riboflavin	mg	8.704	3.866	8.585	8.835	29.99
Niacin	mg	62.098	26.636	59.989	67.833	216.56
Pantothenic acid	mg	25.21	13.254	16.52	25.428	80.41
Vitamin B6	mg	3.417	2.205	2.4	3.52	11.54
Folate, total	g	434	1019	314	302	2,069.00
Folate, food	g	434	1019	314	302	2,069.00
Folate, DFE	mcg_DFE	434	1019	314	302	2,069.00
Choline, total	mg	707.8	253.2	69.3	244.5	1,274.80
Betaine	mg	17.5	24.6	10.2	0	52.30
Vitamin B12	g	138.15	35.26	188.79	69.01	431.21
Vitamin A, RAE	mcg_RAE	5,408	6,456	7,513	6,574	25,951.00
Retinol	g	5,381	6,450	7,513	6,574	25,918.00
Carotene, beta	g	320	56	0	0	376.00
Carotene, alpha	g	11	11	0	0	22.00
Cryptoxanthin, beta	g	13	11	0	0	24.00
Vitamin A	IU	18,488	21,603	25,017	21,889	86,997.00
Lycopene	g	37	40	0	0	77.00
Vitamin E (alpha-tocopherol)	mg	4.6	0.97	0.2	1.87	7.64
Tocopherol, gamma	mg	0.18	0.48	0	0	0.66
Tocopherol, delta	mg	0	0.03	0	0	0.03
Vitamin D (D2 + D3)	g	3	0	0.1	2.5	5.60
Vitamin D	IU	122	0	2	102	226.00
Vitamin K (phylloquinone)	g	3.1	0.8	3.6	0	7.50

**V/100 g = Value per 100 grams*

As you can now plainly see, today's oak savanna-mimic diet is a nutritionally dense, complete diet. If you were to eat only from such a system you would have all of the nutrients needed for a long and healthy life.

The astute reader will have noticed that I took a frontal assault from the conventional agriculture world and willingly tackled the most common question that is posed to sustainable farmers everywhere — can we feed the world this way? I did conveniently step to the side of the main thrust of that argument though, which was the total calories per acre. I pointed out that conventional, high-input, monocrop annual agriculture is currently not feeding the world, in part because a tremendous amount of the total corn calories per acre aren't even going to feed humans. I instead directed the conversation toward nutrition per acre. This was in no way intended to avoid answering the primary "feed the world" question. It was intended to help clarify what it is that I am talking about. When I've taken this question in a public forum I've intentionally asked the questioner to be clear about what it is we're discussing. They usually *aren't* clear about what they're talking about and for the most part are merely parroting talking points fed to them by industry groups selling inputs (fertilizers, herbicides, insecticides, fungicides, tractors and equipment). Now getting back to the total calories per acre question, how much food for humanity can we actually produce in restoration agriculture systems?

I have already shown that one acre of corn *doesn't* actually produce 13.9 million calories of human food per acre, but because of the net human food loss to fuel and the trophic loss to feed livestock the net food calories per acre of corn comes out to a mere 3.06 million. Can a restoration agriculture system produce this much food per acre?

The answer to this question is *yes*.

One way in which restoration agriculture can produce more calories per acre than annual crops is by creating overyielding polycultures. Overyielding polycultures are intentionally designed plant and animal systems that may produce lower yields per item, but the total per acre yield exceeds that which any one crop would have produced. In perennial polycultures such as the one described above there will be fewer of each element than if that element were raised in a monoculture, and because of competition effects with neighboring plants and animals, yields per plant may be less than in a monocropped system. The restoration farmer's goal is to create a system where the *total* yield is greater in a polyculture than a monoculture and hence the name "overyielding polyculture." A perennial polyculture including chestnuts may not produce the same amount of chestnuts per acre as a conventional chestnut orchard or grapes as a conventional vineyard or raspberries or hazelnuts and so on. This is not always the case, though, because many plants yield just as much in polycultures as they do in monocropped systems. The average perennial polyculture farmer is not striving to grow the most of any one crop. A perennial polyculture farmer is striving to manage and optimize an ecological *system.* The system is modeled after nature, and the system is designed to optimize its total system yield.

In previous chapters I have described a cropping system that is entirely perennial, has multiple layers of plants, and has a strong livestock component. Energy capture and energy flow in natural systems has been studied extensively and the data shows that yes, more energy is captured within a system such as this, than is captured in an annual crop field. Short rotation, woody cropping systems designed for biomass energy production have shown that perennial woody plants when coppiced (cut to the ground) regularly, can capture upwards of three times the energy per acre as an annual crop field. In some trials in New York state the energy capture was seven times that of an annual crop field. Natural savanna systems and short-rotation, woody cropping systems have proven that more energy can be captured on each acre of land than can be captured in an annual crop field. Unfortunately, there is no technical research data available as of yet showing that a savanna-analog, restoration agriculture cropping system can actually increase total *food* yields. This is merely because so few restoration agriculture systems exist and little to no research is being conducted on them. Fortunately, these exact systems as described exist on the ground and are being actively managed by an increasing number of farmers across North America. And they are springing up more and more frequently. Actual data is in the process of being collected and will be gathered by more and more researchers as time goes on.

The question still remains, "Can a designed agricultural savanna yield more calories, total vitamins and minerals per acre than an annual crop field?"

Here is a brief exercise using the system I described above, which will shed some light on the possibilities.

Here is the total caloric food yield from the plants:

PLANT TYPE (#)	YIELD X CALORIE RATING	TOTAL CALORIC YIELD
Chestnut trees (86)	1,000 lbs/ac × 1,088 Kcal/lb =	1,088,000 Kcal
Apple trees (34)	34 × 2 bu/tree x 42 lbs/bu × 235 Kcal/lb =	671,160 Kcal

Hazelnut shrubs (208)	208 × 2 lbs/plant × 2,939.2 Kcal/lb =	1,222,707.2 Kcal
Raspberry canes (416)	416 × 1-2 qts/plant × 256 Kcal/qt =	106,496 Kcal
Red currant bushes (520)	520 × 2,551 Kcal/plant (10-15 lbs/plant) =	1,326,520 Kcal
Grape vines (120)	120 × 1,528.4 Kcal/plant (5 lbs/plant) =	183,408 Kcal
Plant Total		**4,598,291.2 Kcal**

ANIMAL TYPE (#)	YIELD X CALORIE RATING	TOTAL CALORIC YIELD
Cow (1)	6-7 gal/day × 2,334.1k = Kcal/gal (8.6 lbs/gal) =	14,004.8 Kcal
Beef steer (1)	569 lbs. meat × 852 Kcal/lb =	484,788 Kcal
Pig (2)	2 × 250 lbs. × 73.6 percent = 368 lbs. × 907.2 Kcal/lb =	333,849.6 Kcal
Chicken (10)	10 × 6 lbs. × 65 percent = 39 lbs × 1007 Kcal/lb =	39,299.34 Kcal
Sheep (2)	2 × 160 lbs. × 50 percent = 160 lbs × 1231 Kcal/lb =	196,988 Kcal
Animal Total		**1,068,929.74 Kcal**
Combined plant and animal system		**5,667,220.94 Kcal**

It has been said many times that there are three kinds of untruths … lies, damned lies, and statistics. One of the problems with data and statistics is that they have to be interpreted. Another especially significant problem with statistics and data is that we are working with a long-lived, perennial system and will have somewhat different yields every year of its existence. Our system will yield less from the perennial woody crops in the early years and have greater yields in later years. In the early years the fast-growing plants, such as raspberries and currants, will have higher yields than they will in later years, and eventually plants such as raspberries and grapes will come to yield less and less as the site becomes more shady.

Another problem with statistics is how do we accurately discount yields per plant species? Without years or even decades of results from operating systems such as this one we have no real idea what the overall long-term yields will be.

From my experience grapes appear to have no net yield loss when planted in complex polycultures, and neither do currants. Raspberries do appear to yield less when competing with other plants for space, light, nutrients and with other crops like hybrid bush hazelnuts. This type of hazelnut is such a new crop east of the Rockies that no real yield data exists at this time. The research simply isn't being done. So, in order to generate the above table I used some assumptions…

Chestnuts

According to several sources, from commercial chestnut nurseries to universities and the California Department of Agriculture, I found figures that claim that chestnut yields per acre range from a low of 1,000 pounds to a high of 6,000 pounds. This wide range is due in part to the wide range of soils and climates where chestnuts are grown commercially (from Ohio to California) and the fact that the industry is so small in North America that data points are few. For our purposes I used the low end of the scale. According to several sources, the number of chestnut trees initially planted per acre is too dense in the later years, but it is the early year production that helps to keep the total crop yield numbers up. As the trees grow and begin to interfere with one another they will be removed, representing caloric value of another kind. How to account for this biomass harvest will be addressed at the end of this section.

Apples

For apple yields I once again erred on the low side of the yield spectrum using two bushels of apples per tree. An apple harvest can in all likelihood be greater than this and my experience confirms this. However for this exercise I am estimating on the low side so as to not be accused of overstating my case and to account for the fact that apples can be grown on dwarfing and semi-dwarfing rootstock which *will* actually produce fewer fruit per tree. I have personally harvested well over 100 bushels of fruit from one grand, old, poorly cared for Baldwin apple tree when I worked for Old Mr. Flint. So I know that yields of more than two bushels per tree are possible.

Hazelnuts

When it comes to hazelnuts in the system, these are the real “sleepers.” The Upper Midwest Hazelnut Development Initiative in collaboration with the universities of Wisconsin and Minnesota and other academic institutions are collaborating with growers to develop highly productive bush hazelnut cultivars that are extremely cold-hardy, disease-resistant, and contain a majority of their genes from newly discovered wild American hazelnuts. Since the breeding work is in its infancy and selection of cultivars is only just beginning, there are only two yield data reports in existence at present. One report included plants of all ages instead of only mature plants, and the data was skewed because one-year-old plants were included in the same yield analysis as fifteen-year-old plants. On top of this, most Midwestern-grown commercial hazelnuts are originally grown from seed (instead of asexually propagated cuttings), and the yield variation between plants is considerable. Some individual plants can have a ten-year track record of producing 5-8 lbs. per plant, while other plants grown from seeds end up being complete duds, producing no nuts after a decade. There are even some individual plants that have yielded more than 20 lbs. per plant.

The Hybrid Hazelnut Consortium, a collaboration between Rutgers University, University of Nebraska, Oregon State University and the Arbor Day Foundation, are introducing cold(er) hardy European hazelnut selections to the Mid-Atlantic states and Nebraska. Their program, also in its infancy, is experiencing the same erratic and inconclusive results.

So, for all practical purposes, there is no data available for bush hazelnuts in the Midwest. I chose a yield of two pounds per plant as the number, which is higher than the current, skewed data shows, but this I feel is a fairly conservative number. Looking at long-term potential we know that this number can easily be exceeded.

Hazelnuts in an oak savanna-mimicking restoration agriculture system are “sleepers” because they pack an incredible caloric wallop. For this exercise all I included was the food value and did not include the fuel value of either the shells or the pruned coppice wood, which is significant in both cases.

In our model system there are far fewer raspberries and currants planted than would ordinarily be planted per acre, and once again in both cases I estimated on the low end of the yield scale. The entire caloric calculation was done using the low yield values for those crops.

BIOMASS

Coppice wood and prunings represent a significant yield in a restoration agriculture system. At first thought it would seem that surplus wood can be used as heating fuel for the farm. At New Forest Farm we operated under that assumption for quite a few years until we realized that we were faced with a wood disposal problem. Where previously the farm had been a bare-dirt corn and bean field (and wood was a scarce resource), within ten years, wood was in abundance. Within 15 years it began to pose a challenge. How can all of this wood be utilized? In addition to heating with wood, smoking meats, and having plenty of campfires and bonfires, plans are in place to gasify the wood and use the syngas to power an electric generator. Although we have yet to build the system, our calculations show that one acre of hazelnut shells, for example, should produce nearly $90.00 worth of electricity per acre if sold to the utility company at 12.5¢ per kilowatt. Small-scale systems already exist for doing this.

One of the benefits of gasifying hazelnut shells, coppice underwood, and prunings is the production of biochar that can be used as a soil amendment.

Although New Forest Farms has a utility connection to sell electricity back to the grid, we do not yet have a gasifier installed. This book is *not* intended to be a discussion of pie-in-the-sky possibilities, but is intended to share from actual experience. So for “wood disposal” right now I will stick with home heating fuel and growing mushrooms.

When researching biomass yields in tons of wood per acre, the numbers range from 3 to 30 tons per acre depending on the woody plant species grown and the region in which they’re grown. In fertile, well-watered regions more wood will grow per season than in drier regions like Nebraska or the northern High Plains.

For our caloric yield per acre exercise, I chose one ton of biomass per acre per year. Experience has shown that this is easily the case, since hazelnut shells alone can approach several hundred pounds per acre.

A simple, delicious and potentially lucrative way to dispose of surplus wood is to convert the inedible into the edible. The way to convert inedible wood into edible wood is with fungus.

Mushroom Nutrient Summary

NUTRIENT	UNIT	HONEY TOTAL V/100g*	MAITAKE MUSHROOM TOTAL V/100g*	SHIITAKE MUSHROOM TOTAL V/100g*	TOTAL OF ALL V/100g*
Proximates					
Water	g	17.1	90.37	89.74	197.21
Energy	kcal	304	31	34	369.00
Energy	kJ	1272	130	141	1543.00
Protein	g	0.3	1.94	2.24	4.48
Total lipid (fat)	g	0	0.19	0.49	0.68
Ash	g	0.2	0.53	0.73	1.46
Carbohydrate, by difference	g	82.4	6.97	6.79	96.16
Fiber, total dietary	g	0.2	2.7	2.5	5.40
Minerals					
Calcium, Ca	mg	6	1	2	9.00
Iron, Fe	mg	0.42	0.3	0.41	1.13
Magnesium, Mg	mg	2	10	20	32.00
Phosphorus, P	mg	4	74	112	190.00
Potassium, K	mg	52	204	304	560.00
Sodium, Na	mg	4	1	9	14.00
Zinc, Zn	mg	0.22	0.75	1.03	2.00
Copper, Cu	mg	0.036	0.252	0.142	0.43
Manganese, Mn	mg	0.08	0.059	0.23	0.37
Selenium, Se	g	0.8	2.2	5.7	8.70
Fluoride, F	g	7	0	0	7.00
Vitamins					
Vitamin C, total ascorbic acid	mg	0.5	0	0	0.50
Thiamin	mg	0	0.146	0.015	0.16

Riboflavin	mg	0.038	0.242	0.217	0.50
Niacin	mg	0.121	6.585	3.877	10.58
Pantothenic acid	mg	0.068	0.27	1.5	1.84
Vitamin B6	mg	0.024	0.056	0.293	0.37
Folate, total	g	2	21	13	36.00
Folate, food	g	2	21	13	36.00
Folate, DFE	mcg_DFE	2	21		23.00
Choline, total	mg	2.2	51.1	0	53.30
Betaine	mg	1.7	0	0	1.70
Vitamin E (alpha-tocopherol)	mg	0	0.01	0	0.01
Vitamin D (D2 + D3)	g	0	28.1	0.4	28.50
Vitamin D	IU	0	1123	18	1141.00

**V/100 g = Value per 100 grams*

The mushroom nutrient table above shows the nutritional information for Maitake and Shiitake mushrooms. There are literally dozens of different mushrooms that can be grown on solid wood or wood chips. Through the magic of decomposition, mushrooms can turn that ton of woody biomass from each acre into nearly 300 lbs. of mushrooms.

There are literally hundreds of edible and medicinal mushrooms that can be incorporated into the decay cycle on a restoration agriculture farm.

Mushroom logs or wood chip beds that have yielded their full life cycle of high-value crops can become converted into a soft, soil-like material that acts as a highly absorbent biological sponge. This will be incorporated into the existing soil within one growing season. The one ton of woody biomass harvested as a by-product from our restoration agriculture system, if converted into Shiitake mushrooms, would provide an additional 34,019 calories per acre.

Again, just to mention a point made previously and using corn as an example, we take 13.9 million calories of digestible human food and make 10.03 million calories unavailable and yield only 3.06 million calories of actual human food. On our restoration agriculture farm, we take calories that are inedible to humans and make them edible. For example, the livestock convert grass, insects, slugs and snails into meat and dairy products, and the fungus turns wood into a delicacy.

The last caloric yield from our restoration agriculture example that I would like to include is rather tricky to calculate. That food is honey. I've already shared how the European honeybee is not native to this hemisphere and in a diverse, ecological system is not needed for pollination services, but they are here, they do provide pollination services, and they do produce an outstanding sweetener. Like sugar and maple syrup, honey is a powerful, high-calorie sweetener. One pound of honey has over 1,382.4 calories. One hive of honeybees located in the northern United States can easily produce over 50 lbs. of surplus honey per year. If only one hive were kept on an acre, that one hive would add an additional 69,120 calories to our system. One problem is, though, that unlike cattle or sheep honeybees will not stay on one acre. They will fly to where they can find the most abundant resource. It's estimated that one hive of honeybees can range over 8,000 acres when they make their 50 lbs. of honey. Apiarists (beekeepers) do report decreasing per-hive honey yields when they have more than 20 hives per acre.

Since the one general rule about honeybees is that there are no general rules about honeybees, I am going to choose a somewhat arbitrary and simple number of bee colonies to include in our calculation. Four. The reason why I chose this number is that four is enough hives to be worth making the investment in the basic beekeeping equipment needed such as smokers, capping knives, and an extractor. Four hives also produce enough honey at each inspection to make it worth the look even if the hives aren't full. Four hives also gives the beekeeper the ability to observe differences in strength between the hives and therefore over time begin to select for stronger queens and colonies. Having four hives on hand also gives you the ability to divide strong hives, rear extra queens if needed, and generally guarantee a reasonable amount of honey even in an "off" year. In our 17 years of experience at New Forest Farm we average approximately one 5-gallon bucket of honey per hive. Each 5-gallon bucket is slightly over 50 lbs. of honey, so for this exercise I will estimate 50 lbs. of honey per hive for an additional 276,480 calories per year.

Adding all of the calories per acre totals together:

Plant Polyculture:	4,598,291.2
Animal Polyculture:	1,068,929.74
Honey and Mushrooms:	310,499.00
Total Human Food Calories:	**5,977,719.96 per acre**

The oak savanna mimic, restoration agriculture system produces more than twice the number of edible human calories per acre as an average acre of corn.

The restoration agriculture system produces more than twice the human calories per acre as an acre of corn; it is perennial and never needs to be planted again. It prevents erosion, creates soil, and can be managed with no fossil fuel inputs. This means that its total net caloric gain is almost infinitely greater than an average acre of genetically modified, #2 yellow dent corn grown in America. The nutrient difference per acre is nearly incalculable.

THE CASE OF THE HOLSTEIN STEERS

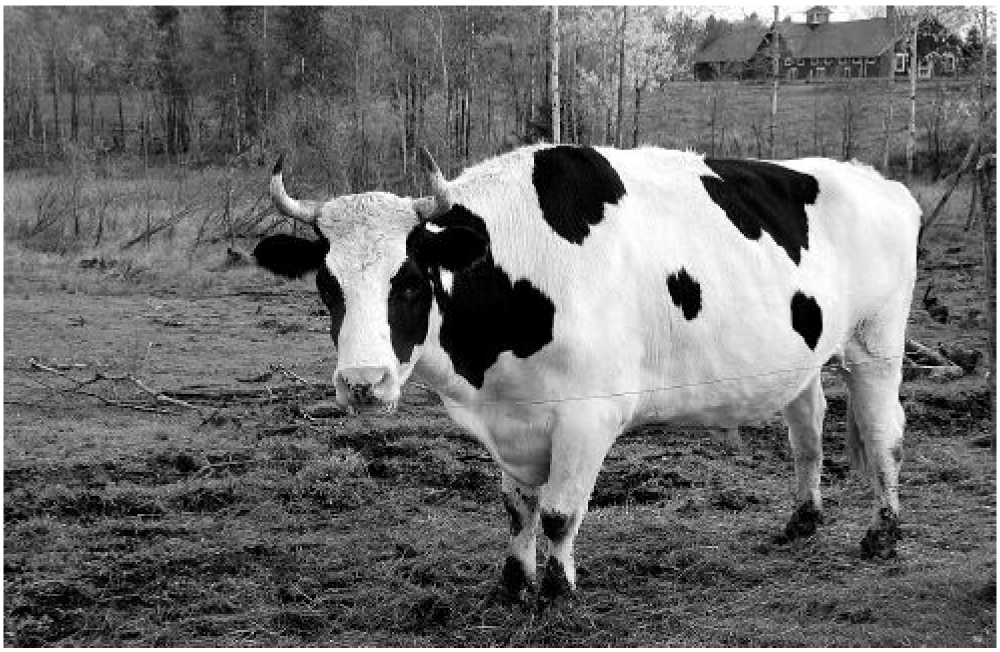
On a 90-acre hillside field adjacent to New Forest Farm in southwest Wisconsin, graze twelve Holstein steers. When these steers approach 800 lbs. in weight, they will be sold and sent to a feedlot where they will be fattened on a diet dominated by corn and soybeans (the majority of which in the United States are genetically modified). The 90 acres of land is steep and the soil is thin — most of it having long since washed down the Mississippi River and flowed out to clog the Gulf of Mexico. The bedrock skeleton of the earth itself protrudes like the bone from a compound fracture. The slopes are too steep for a tractor to drive upon safely, but once upon a time this land was plowed by horses.

Nationwide there are literally hundreds of millions of acres of land that are extremely steep, highly erodible and underutilized. If they were to be cropped, their shallow, droughty and nutrient-poor soils would produce lower-than-average yields. When the age of horses moved on to the tractor in my Grandfather's day, this particular field was used as a pasture for a handful of steers. It still is today.

If we examine these twelve steers we will find that the total calories available from them falls far short of the total calories of corn that could be produced on one acre of your average farmland. If each steer has a weight of 800 lbs.

when they're shipped off to the feedlot, that means that this 90-acre field only produced 9,600 lbs. of animal. The edible portion of those steers (approximately 62.2 percent of a beef steer is edible to humans) would only add up to 5,971.2 lbs. of meat per 90 acres of land. USDA semi-lean ground beef averages about 1,000 calories per pound, making the total caloric yield from this 90-acre field a miniscule 5.9 million calories, or a pathetic 65,000 calories per acre. Here is where the mighty giant corn falls flat on its face. Corn can't even be grown on this 90-acre field. This field, combined with other highly erodible land and the millions of acres of abandoned farmland in this country, represent a disproportionate advantage for restoration agriculture systems.

Research from the University of Missouri Center for Agroforestry has shown over and over again that when trees are planted in a pasture in what is called a silvopasture system, forage yields do not decline. In fact when designed well, forage yields can actually increase. The grass turns green earlier in the spring and stays green later in the fall representing additional feed and additional weight gain for those twelve steers. In addition to a longer growing season the partial shade cast by the evenly scattered trees helps the grass to grow more during the day.



In North America alone there are millions of acres of overgrazed, poor-quality pasture such as this and land that is too steep or rocky for annual crops to even be grown.

Photosynthesis occurs under a fairly narrow band of temperatures, and when grasses are growing in the shade, their leaf temperature is lower than if they were in the full sun. Partially shaded grasses continue to photosynthesize and grow when their full-sun compatriots have shut down to wait for cooler temperatures. Leaf temperatures aren't the only thing that shuts down photosynthesis in forages. The chlorophyll in a leaf can be thought of as a sponge. This green sponge soaks up sunlight as fast as it can while some of that sunlight is being used as the energy to manufacture basic carbohydrates. Once photosynthesis is happening as fast as it can and reaches its maximum, it can only convert sunlight into simple sugars at that fixed, maximum rate. If more sunlight is striking the leaf than the chloroplasts can use, then that leaf has become "light saturated." Additional light striking the leaf surface does not result in more photosynthesis. Some is reflected by the leaf and some is converted into heat which can further slow photosynthesis. Leaf temperatures can become so hot that moisture loss causes wilting and a further reduction in photosynthesis.

A restoration agriculture savanna would produce an even, dappled shade where forages stay in their optimal temperature and light level ranges for longer periods of time. As a restoration agriculture savanna, this 90-acre pasture would *still* be able to support twelve Holstein steers while simultaneously and symbiotically supporting 24 hogs, 24 sheep, 250 chickens 7,488 chestnut trees, 37,440 raspberry bushes, 22,464 hazelnut bushes, 7,488 grape vines, 29,952 currant bushes, and 3,744 apple trees. A more than impressive yield considering that somebody had the audacity to think that twelve steers were going to feed the world!

Perhaps we should ask ourselves, why do we have farms? Why is there agriculture? Isn't it so that people can eat and be healthy and nourished? If that is the case, then wouldn't it make sense for us to design an agricultural system that does exactly that instead of one where big farmers fight against little farmers and corporate hierarchies pass legislation making illegal any kind of production models other than the ones they economically control? Doesn't it make sense for us as civil (or even uncivil) human beings to all agree to figure out how to produce adequate quantities of the most nourishing food grown in ecological systems that are sustainable in the long-term? Shouldn't we focus the brilliance and innovation of our youngest adults to discover the optimal systems? After all, we all need to eat.

So at this point in time forgive me if I appear rude as I now turn the question back on the asker. Remember the big, mean, corn farmer about to blow a heart gasket when he said, "Yeah, but can you feed the world?" My reply now is, "Well sir, can *you?"* Can you feed the world *your* way? You obviously aren't doing it now. Besides that, the way you are growing crops now is degrading the resource base for future generations. Doing more of what doesn't work isn't going to make things better. Most of your corn and soybeans are being fed to livestock or burned as fuel in cars. The corn-based food being produced by your system is resulting in epidemic levels of extreme obesity, heart disease and diabetes.

Can you *nourish* the world?

Can you restore ecosystem function? Can you remove carbon from the atmosphere? Can you increase the populations of native pollinators, amphibians and other at-risk wildlife? Can you naturally aggrade soil over time without massive external inputs? Can you prevent runoff? Can you detoxify ground and surface water? Can you increase the numbers of wetlands? Can you restore springs, prevent erosion and floods? Can you do any of this while only planting your crop once every thousand years?

I know you, the reader, may have a hard time believing me, and I know that a lot of what has been said here in this book contradicts so much of what you've been told, but if you'll just relax and settle in for a few more chapters I'll show that what I am saying is entirely possible and show you just how easy the transition can be.

CHAPTER 13

Getting Started

THE previous chapter showed us quite clearly that an ecologically diverse, perennial polyculture, restoration agriculture system provides more total food per acre than row-cropped corn. It also showed us that the yields coming from such a system will change through time as the system matures, and that such a system can last literally thousands of years while being managed entirely without the use of fossil-fuel inputs (if we so choose). This all sounds great, but how do you make the transition from annual crops to perennial restoration agriculture, and where do you start? You've got to start right where you are standing and deal with the basics.

No matter where your farm or ranch is in North America, there's no undoing what your farm is right now. It has been cropped or grazed in certain ways for a longer or shorter number of years. It has its own particular soil type, soil structure, slope and degree of erosion. (All land that has been annually cropped is eroded. It is the degree to which this has occurred that differs from farm to farm.) Every individual farm has its own "family history," and even within a region that has very homogeneous soil types and cropping systems, the conditions on one farm will differ from others if only because of the fact that different people managed the land and had different scheduling of their operations.

Each farm or ranch differs in its perennialism. At one extreme is a row-crop or grain farm that grows 99.9 percent annual crops. On the other hand, a mob-stocked rotational grazing operation or grassfed dairy can have plantings that are 99 percent perennial. It is not within the scope of this book to go into the nitty-gritty details about how each type of farm can transition into ecosystem-based restoration agriculture. What is within this purview are the basic principles that apply to all farm-scale properties.

EARTH SHAPING AND WATER MANAGEMENT

As far as we know, water is the absolute, number-one plant nutrient without which we would get no plant life and no crops. No matter where you live and what crops you grow, they will not grow without water. Plants can survive and produce saleable crops with just about every soil nutrient deficiency known. In fact, *most* soils fit this bill and are deficient in one or more important mineral nutrients at any point in time. All farmers have soil that has deficiencies in something. The fertilizer industry and the soil balancing industry were all founded to address this fact. Overall our soils aren't as rich and fertile as they could be, but our crops still grow. Our livestock still graze and reproduce. Leave water out of this picture, however, and things are radically different. All plants will die without water. Even cacti eventually die without water.

Since water is of such critical importance for plant life and growth, the very first step for a restoration agriculture farmer, no matter where the farm is located, is to optimize the land's relationship with water.

The landforms all around us are a reflection of the land's relationship with water and gravity over the eons of time. Rain falls on the uplands and gravity draws it to the lowest localized point. One little rivulet of water joins with another; it increases in volume and velocity. It continues to travel along the lowest point, joining with other rivulets and picking up soil particles on its way downhill. Rivulets become brooks. Brooks become creeks or streams. Streams become rivers of increasing volume and eventually make their way to the sea. Whether your farm is in the desert or in regions that experience torrential rain, water has shaped the land.

> Although rainfall tends to distribute moisture evenly onto adjacent ridge and valley shapes, the water does not stay evenly distributed. Natural drainage removes the water from the ridges to the valleys very efficiently. As a consequence of this, ridges tend to be drier than valleys. Any compaction of the soil worsens the problem.
>
> *Ken Yeomans, Keyline Designs*

Water has shaped the land and sculpted it into an extremely effective drainage system. The water strikes the land, collects, and runs away. In nature's scheme of things perennial vegetation eventually covers the land. Plant roots, leaves and stem debris all decay and increase soil organic matter which acts as a biological sponge. Undisturbed soil, rich in organic matter, is the base of the soil food web. Organic matter (i.e. carbon compounds), like the diesel fuel in our tractors, coal in our power plants, or natural gas or heating oil in our homes, is the fuel that feeds all soil life. It is the life in the soil that acts directly upon the bare mineral rock through ingestion and digestion. The soil life also acts on the mineral rock indirectly through exudates and excreta, making the constituent bedrock minerals available for life further up the food chain.

Carbon is the energy source for soil fungal activity. Living and dead fungal bodies, hyphae and mycelium feed increasingly complex organisms as do the sugars (carbon again!) exuded by plant roots. Organic compounds, carbon in the soil — whether from plant or animal origin — act as sponges that soak up and hold water. Water in the soil is absorbed by organic matter.

Water is also held by surface tension on every single soil and mineral particle. Every little pebble and grain of soil can have a thin film of water clinging to its surface. Merely wetting all of the soil grains can take a tremendous amount of water.

Water is held in the pore spaces between soil grains. All life in the soil is 50–80 percent water and represents its own type of water storage. In short, the soil and the soil life represent a massive water storage system. In restoration agriculture systems we want to start with storing more water in the soil.

When beginning the transition to restoration agriculture one of the first acts is to develop a water management system for the entire farm property. For *most* sites, this means designing an accurately measured series of swales and berms to capture rainfall and spread the water out evenly instead of gathering it together in waterways and valleys where it gets exported from the farm.

Numerous references exist on water management strategies, but the one that I feel deserves the most attention and has not received enough, is the system described in *Water for Every Farm,* by Australian P.A. Yeomans. The Yeomans Keyline Plan is by far the most holistic approach to water management described to date. Keyline systems use all available strategies to capture every last raindrop that hits the farm, slow each raindrop down in the landscape, spread them out toward the ridges where they are needed so they can soak in, and store excess in the soil, ponds, tanks and ultimately the living tissues of increased plant and animal yields.

By slowing down fallen rainwater and spreading it out you then allow it to have an increased residence time in the landscape. This gives the rain time to soak in rather than run away. An exception to this would be, of course, sites that are pre-existing wetlands, although not if they were created by improper water management in the first place.

> An imbalance of water and air can cause aerobic soil organisms to die out and be replaced by anaerobic organisms. The soil will then become sour. Tussocks and water weeds in valleys are indicative of this problem. It is important that this result is not treated as a problem of excess moisture to be drained away but as a symptom of water probably being squandered from the upper slopes.
>
> *Ken Yeomans, Keyline Designs*

True wetlands are a biome of their own and represent other great restoration agriculture opportunities.

The key to the keyline system is exactly that — the concept of the keyline. Keyline planning is based on the natural topography of the land and its rainfall. Each farm has what I refer to as the "sweet spot" *somewhere* on it. The sweet spot is a line that every property has, that, with a single, water-collecting swale, will impact the water flow on a maximum number of acres of that particular property with the least amount of earth shaping. On most properties this sweet spot will be located somewhere near the keyline of a slope.

If you look at a watershed from a cross-section (end view), you would see a line that very closely resembles the human form from neck to hand in silhouette. The uplands, hill or mountain tops can be seen looking like your trapezius muscles above the shoulders. In many cases, the uplands are gently sloped *in a convex* form, in that it bulges out from the center of the Earth as one moves downhill. At a certain point (the outer edge of your shoulder), the slope changes from convex to con*cave* and bulges in toward the center of the earth. Using our arm analogy, a concave form occurs where your shoulder curves down toward your bicep. In mathematics the junction point of a convex slope turning into a concave slope is called the inflection point. This inflection point is one of the *key* lines on a slope. It is at this point that a minimum amount of soil needs to be moved in order to intercept a maximum quantity of water moving downslope. Installing or building just one water management structure at this "key line" will affect the hydrology of the entire hillside below it. This is also called the "key" line because it will establish the pattern for the cropping system downhill as well as uphill from this line. I will return to this after I finish discussing water moving downhill.

Below the uplands key line the hillsides continue in a manner that is analogous to the line formed by the side of your arm as you run your finger from your shoulder and approach the elbow. The inner crook of your elbow itself represents another inflection point. The hillsides at this point have changed their general direction, have crossed a keyline, and now are the valley floor. The inflection point between the hillsides and the valley floor is the next major keyline. Water collection structures or devices placed here will affect everything on the valley floor downslope from the keyline.

As the valley floor approaches the river or creek in the center of the watershed (or as your forearm approaches your wrist) the slope once again changes; from valley floor to the floodplain to the water. Although this is technically an inflection point and therefore a “key” line, it is the least useful of the three points mostly because there is so very little land downslope after this last keyline and the river or creek.

Locating the key line or keylines on your property is extremely important when starting a restoration agriculture conversion. The “sweet spot” is nearly always located on or near a keyline of the property.

Once the keylines are located, a laser level, transit or A-frame is used to accurately measure out where the water management swales will be located.

A swale, in our usage of the term, is a water harvesting ditch with a soft earthen mound located immediately downslope from it. The most common usage of the word swale implies that the swale is located perfectly on contour, and as a basic water management technology swales on contour are extremely useful. When the rainfall rate exceeds the soil infiltration rate, water sheets on the surface of the soil and begins to flow downhill. This happens even in an entirely perennial system. As the sheet of water moves downhill, it picks up tiny soil particles and fragments of organic matter. As this sheet of water encounters a swale, it collects in the swale and stops flowing. This gives the water more residence time in the landscape and allows the water to soak in.

In addition, the pore space between soil particles, rodent burrows, earthworm tunnels, and beetle bore holes in the permanently grassed-in swales act as bathtub drains bringing the water deep into the earth. Even rain falling on frozen ground, which happens commonly in the northern United States and Canada, can soak into the soil thanks to animal burrows that channel it deep underground. Ground squirrels, chipmunks, mice, voles and snakes don’t hibernate in the frozen ground if they can help it. Their hibernation burrows are deep enough to take them below the frost line and often their winter bedrooms are at a cozy 50° F temperatures. A late winter rain falling on frozen ground would find the burrow and pour down, deep into the warm, receptive soil. Over time, these swales collect and soak water into the soil where the roots of perennial plants and especially trees can access it.

Progressing beyond the elementary level of land shaping and water management, swales can be used as much more than merely on-contour water harvesting ditches. Swales can be used to move water *away* from wet spots of the farm and *toward* dry areas. Swales that take water away from wet spots are what are often referred to as spreader swales.

Technically, any excavated trench in the ground designed to move water from one location to another could be called a ditch. I prefer not to call these structures ditches though. In the most common use of the term, a ditch is used to drain water away from an area and to get it away fast. Conversely, spreader swales, in our usage of the term, travel downhill at a mere 1 percent slope (one foot drop over 100 feet). This is the degree of slope at which water will just barely begin to move. Unlike traditional ditches, spreader swales intentionally move the water *slowly* across the landscape allowing it more time to soak in. By accurately measuring the slope with the proper tools, we can take water *from* the valleys (higher up in the landscape) and move it *to* the ridges at a non-eroding 1 percent drop. This way we can spread the water from the valleys out to the ridges.

> Most people don’t have any difficulty appreciating the undesirable imbalance between the moisture of valleys and ridges. Keyline pattern cultivation is a simple way to solve the problem. It is a farm cultivating pattern that keeps the water on ridges longer and spreads water whenever it reached the valleys.
>
> *Ken Yeomans, Keyline Designs*

Like traditional ditches, swales can also be used to gather water and move it toward a desired low spot. These are called “collector swales” as they are used to gather water from a larger area in order to create a surface pond.

The terms spreader swale and collector swale may seem like a silly, self-important term for a ditch, but these terms help to make a significant distinction. A ditch is just a ditch … a trench in the ground design to drain water away from the site. A spreader swale or collector swale is a very precisely measured ditch that has almost exactly a 1percent slope. Once again, this degree of slope is extremely gentle, barely flowing and non-erosive.

Coupled closely with the keyline swales are what can be commonly lumped together under the term "pocket ponds." Pocket ponds are not necessarily intended to be fish ponds or farm ponds or for that matter aren't necessarily intended to hold water year-round. They are designed to hold water during large rain events and to make that water soak slowly into the soil profile. They are the "surge protection" for the swale system when a large rainfall event occurs. As ponds that drain and eventually disappear, they mimic what ecologists call vernal pools or ephemeral ponds. These are wetlands that only exist for a period of a few weeks or months during and slightly after that area's rainiest season. Whole hosts of plants and animals are adapted to life in vernal pools and will eventually take up residence in our pocket ponds. Arguably the most significant residents of our pocket pond systems are the insectivorous amphibians. Most of the amphibians that are native to the Corn Belt region in the Midwest are adapted to reproduce in vernal pools. By designing our farms with swales and pocket ponds we create rainwater harvesting structures that restore valuable amphibian habitat which has huge pest control benefits for the remainder of the system.

Water is life and on restoration agriculture farms every drop of rain that falls is slowed down, spread out from the valleys toward the ridges, and allowed to soak in recharging the groundwater table.

LARGE RAIN EVENTS

If water soaks into the soil at the rate of one inch per hour, and a three-inch rain falls in one hour, two inches of rain have nowhere to go and will form a sheet on the soil surface and begin to flow downhill. With keyline swales designed to accept the excess water during large rain events water is captured and moved to the pocket ponds and overall toward the ridges. Pocket ponds are designed to fill up with this "surge" water and then slowly drain it into the keyline swales. A properly designed keyline swale and pocket pond system should be designed to capture and hold a region's maximum rainfall event. It is entirely possible by design, to prevent all surface runoff from agricultural lands. Think of the implications of this. If every farm property captured and held *all* of its surface water, there would be no flash floods. Water that would have flooded downstream towns and villages will slowly filter down through the soil and bedrock and emerge downslope as springs. Stream and river levels would remain more stable throughout the season, and seasonal streams might become perennial.

Some pocket ponds actually *do* hold water throughout the season even when that was not the original intention. In addition, some ponds may indeed be intentionally designed to do so throughout the driest months of summer. When strategically located throughout the farm, water can be held in ponds located above where it may be needed. Pipes can be installed that will allow for livestock watering or irrigation when conditions warrant it.

Once the keyline swales and berms pattern is constructed on the farm an entirely new pattern of water "flow" has been established. No longer practical will be the rectilinear paddocks and fields that were arbitrarily created when land ownership was legally described using township, range, sections and so on, in a grid of squares. The pattern that now shows itself is the optimized earth-water relationship. Viewed from the air you now see somewhat of a reverse-herringbone pattern radiating outward from the former waterways in smooth, curved lines as the swale pattern extends around the "shoulders" of the ridges (see page 251). These newly established water management patterns provide an entirely new meaning to the word keyline. The swale-and-berm system is what sets the pattern of where woody plants will be planted. It sets the pattern of where roads and other vehicle or animal access lanes will be located, where fences will go, and the pattern that grazing will follow. It will reveal locations for infrastructure such as outbuildings for animals, storage or processing.

The pattern of swales with alleys between them also sets up the pattern for a management practice that is key to the keyline system. Since the alleys between swales are all parallel to the new water flow pattern, anything that we do with a tractor or vehicle now happens parallel to the swales.

Probably the most significant thing that we can do to complement the swale's water harvesting abilities is to couple them with annual subsoiling.

With keyline design, rainwater that would have otherwise flowed "away" increases total site productivity and in this case provides breeding habitat for insect-eating amphibians.

For those not familiar with a subsoiler, it is merely a glorified hook that is pulled behind a tractor. Every year, preferably before plant growth really gets started in the springtime, pull a subsoiler or a keyline plow (a subsoiler with a fighter-jet shaped shoe at the bottom) parallel to the swales throughout as much of the farm as possible. The subsoiler hook doesn't just cut a slot in the ground, it also slightly lifts the soil on either side of it and shatters compacted layers. Afterward, the slot and shattered hardpan freely admit water and air. With additional water and air in the soil, plant roots proliferate. Where plant roots go, there go myriads of soil life pooping and peeing, reproducing, living and dying. Plants and animals alike add their carbon to the soil and as that carbon oxidizes the soil begins to turn black. By combining properly located swales with annual subsoiling in the alleys, pale-colored subsoils can be converted into vital, living topsoil much faster than it would happen naturally. Topsoil is not added grain-by-grain by adding organic matter to the soil surface, but rather the subsoil gradually *becomes* the topsoil. Water and air and soil life convert the formerly compacted, lifeless subsoil into rich, fertile topsoil.

Changing the subsoil conditions to better suit aerobic soil organisms enables the conversion of the subsoil region into topsoil. These organisms need warmth, air and moisture, plus a plentiful supply of high-protein food.

> Keyline uses cultivation, irrigation and stock management techniques to greatly speed up the natural process of living soil formation. Conversion of subsoil into top soil may, under natural conditions, occur at 10 to 15 tonnes per hectare each year. On Keyline farms, during the conversion process, this figure may increase beyond 10 to 15 hundred tonnes per hectare each year. The numbers may be surprising but annually deepening the topsoil by 10 to 15 cm (i.e. 4 to 6 inches) achieves this result. It is a practical short term goal to deepen the living top soil to 30 and 45 cm (twelve to eighteen inches).
>
> *Ken Yeomans, Keyline Designs*

When I had first read Yeomans' text on keyline designs nearly 20 years ago, I pooh-poohed the idea that topsoil could be created that fast and from the top-down. After all, I had learned (by reading books and devotedly making compost) that topsoil was created from the top *up*. The logic was that plants and animals died on the soil surface and the cumulative effects of their piling higher and deeper, was a slowly deepening layer of topsoil. Also having watched mosses and lichens grow on rocks and slowly accumulate an incredibly thin and delicate soil layer, I could appreciate how important our soil is and the need to conserve it. Having made literally tons of compost by hand and yearly hauling it to garden beds in a wheelbarrow really drove home how important topsoil is and how much work in lifetimes it takes to make — especially when the effects of the compost seemed so fleeting and insignificant.

On this 5-acre site the keyline swale moves water from the wet valley to the drier ridge. It really does work!

The equipment used is dependent on the size of the site and the soil permeability. It can range from shovels and hoes to bulldozers and excavators.

The idea that soil could also be built from the top *down* was a somewhat radical thought that I believed was being promoted by crazy people trying to sell expensive equipment. In 1996 we laid out our entire farm in southwest Wisconsin using keyline principles, but because at the time I believed that soil was built from the top *up,* I knew that keyline subsoiling would not be necessary. It would merely be extra fuel wasted driving around pulling a silly hook for no apparent economic return.

It was a fluke that I later discovered an old single-shank subsoiler in the front yard of a friend's farm. A planter box full of purple flowering lobelia spilled out over it and geraniums and marigolds flocked around it in apparent utter adoration of this ancient rusty hulk. I asked my friend if it worked and he said that it had when he parked it there before his ma planted flowers around it. I asked him if I could borrow it and he said, "Yes." Here it is nearly 15 years later and I have yet to return the subsoiler back to him!

Keyline swales, berms and pocket ponds capture and spread out all rainwater while allowing access for vehicles, water lines, and livestock fencing while creating a beautiful, functional farming landscape.

The first time I used the device it would barely cut one foot deep into the hard clay soil. The tractor labored in low gear and I was frequently jolted to a stop as the hook dug deeper, beyond the capacity of my 35-horsepower tractor to pull it. I would have to shift into reverse, raise the hook and back it out of the slot then move forward and try again. Whenever I would lift the hook at the end of each pass (at row end), it would be weighed down, covered with yellow or red clay, depending on what was down there. Back in those days I carried with me a square-nosed shovel that I used to scrape the clay from the hook before I set it down again. If I didn't remove the stuck-on clay, the large soil lump would prevent the point of the subsoiler knife from diving down into the earth.

Through the years I've continued the practice of annual subsoiling, in my mind mostly as a water harvesting technique. I could see with my own eyes during every rain the vertical puddle that formed two inches wide by several feet deep extending down into the ground.

I knew that I was taking water that formerly would have run off and I was storing it in the soil. That was a good enough reason for me to keep doing it.

As time passed, though, I noticed that each year the subsoiler seemed to cut deeper into the soil than ever before. I also noticed that when I lifted the hook I no longer had wet, smeared, sticky potter's clay adhered to the tool, but an increasingly darkening loam that would crumble off on its own. This past spring, after nearly fifteen years of continuing this practice only *once* did I pull up the hook and see anything other than a rich, dark soil. By building berms and swales and by doing annual subsoiling parallel to those berms and swales, I captured the water that falls on our site. I can move the water from areas of surplus to areas of deficit. By doing annual keyline subsoiling we can increase the thickness of the topsoil layer on our farms from the top down. Increased topsoil means increased moisture and nutrient retention which leads to increased productivity — yet another virtuous cycle.

These simple techniques are part of the toolkit that restoration agriculture farmers use in order to restore degraded landscapes and to increase the fertility of farmed-out lands. For the restoration agriculture farmer, understanding keyline design should be a top priority.

For more information on keyline water management I highly recommend going directly to the source and obtaining a copy of P.A. Yeoman's book, *Water for Every Farm: Yeomans Keyline Plan,* but be warned you may have to learn how to speak Australian!

CHAPTER 14

The Transitional Strategy

IN previous chapters I have described many of the reasons why restoration agriculture is needed. I have shown that it can produce more human food per acre than annual agriculture and how and why this is so. The previous chapter gave a brief outline describing the need for a fundamental redesign of the relationship between the land and water. In this chapter I will briefly describe some basic cropping strategies for transitioning from annual agriculture to a perennial polyculture system.

AGROFORESTRY

Agroforestry is a term that is used to describe a set of agricultural practices in which woody plants, especially trees, are integrated with annual crops or livestock on the same piece of cropland. Although widely practiced around the world, agroforestry was not an official USDA-accepted agricultural practice until the mid-1980s. Even today, although some agroforestry practices are eligible for federal cost-sharing money, in the grand scheme of things relatively little agroforestry is being practiced in North America.

For the practitioner of restoration agriculture agroforestry represents the transitional forms that help a farmer or rancher transform his or her operation from an annual system to a more perennial system. Agroforestry practices allow a farmer to continue to do what they are doing today while they install the perennials that will be the mainstay of their future. Current cash flow is preserved while future cash flow is getting established and starts to grow. This is a critical element in restoration agriculture. Agroforestry represents the techniques that we use to bridge the gap between annual and perennial crops.

The transition from a cornfield to a deeply diverse, food-producing savanna system takes time. Succession must take place. Agroforestry will help us to leap across the scary chasm of the unknown during the years while our perennial crops mature and begin to bear fruit.

North American agroforestry is focused around five major practices — each with their own USDA technical manual describing it. The technical manual must be followed step-by-step if federal cost-sharing money is sought. Agriculture extension agents and USDA employees will refuse to offer assistance dealing with agroforestry practices unless they have a copy of the technical manual describing the practice (only then does this give them permission to help you) and are reminded of the USDA Agroforestry Strategic Framework adopted during the Obama administration.

A Letter from Tom Vilsack

MESSAGE FROM THE SECRETARY

The U.S. Department of Agriculture (USDA) developed this Agroforestry Strategic Framework to increase awareness and support of agroforestry. It brings together the ideas and resources of five USDA agencies, two key partners, and a diverse group of stakeholders. This strategic framework creates a roadmap for advancing the science, practice, and application of agroforestry as a means of enhancing America’s agricultural landscapes, watersheds, and rural communities.

While Governor of Iowa, I saw first-hand the benefits associated with the application of agroforestry to local farms, ranches, and woodlands. As the Secretary of Agriculture, I am pleased with USDA’s efforts to balance agricultural production with natural resource conservation. Established with assistance from USDA or other public agencies and private organizations, riparian forest buffers and other agroforestry practices have helped to reduce soil erosion and nutrient run-off and conserve natural resources, such as water and wildlife, on several million acres. These practices have been a key component of landscape conservation efforts, such as the Chesapeake Bay and Gulf of Mexico initiatives.

I have, however, also noticed that the application of agroforestry is not widespread. Agroforestry — the intentional combining of agriculture and forestry to create integrated and sustainable land-use systems — presents an opportunity to address agricultural and conservation concerns and enrich human lives not only at the local level, but at the State, national, and global levels as well. Agroforestry addresses several of the top priorities identified in the USDA Strategic Plan for fiscal years 2010—2015.

The USDA Agroforestry Strategic Framework is built around three simple goals: Adoption, Science, and Integration. These goals will enable USDA to provide additional knowledge, tools, and assistance to better combine agriculture and forestry for the benefit of landowners, communities, and the Nation. The principles of leadership, partnerships, engagement, and enrichment guide USDA efforts to enhance the production of food, feed, fiber, and renewable energy; to enhance the sustainability and prosperity of rural communities; and to protect, conserve, and restore natural resources.

I plan to release a policy statement on agroforestry and establish an Agroforestry Steering Committee that will guide the implementation of this strategic framework. Please join me in an "all lands/all hands" approach that expands the application of agroforestry and generates prosperity in new ways while helping to conserve the Nation's natural resources and ensuring sustainable production of food, feed, fiber and energy for the country and the world.

Thomas J. Vilsack

Secretary of Agriculture

The Agroforestry Strategic Framework (2011-16) outlines strategies that the USDA claims to promote in order to create productive, healthy farms, ranches, woodlands and communities. To do so, the USDA will provide knowledge, tools, and assistance to combine agriculture and forestry for the benefit of the landowner, the community and the nation.

Now that you are aware that the USDA itself wants to promote these important techniques, you have legitimacy in the eyes of "Big Ag" and the folks looking at what you are doing on your farm while scratching their heads.

The officially USDA-accepted agroforestry practices are as follows: windbreaks, riparian buffers, alley cropping, silvopasture and forest farming. A sixth practice was officially accepted on several occasions in the 1990s and 2000s, but suffered a slow, death by the bureaucratic process. The sixth practice had several different names, my favorite of which was "multi-story cropping systems," a term which actually begins to approach restoration agriculture in many respects. Unfortunately, the bureaucrats who were responsible for the development of the technical manual describing the practice had zero experience planting or managing such systems, and the practice that they eventually described was, for all practical purposes, totally unworkable. In some agroforestry circles the term "special applications" is used in order to include things like "multi-story cropping systems," the growing of woody biomass crops, as well as restoration agriculture and permaculture systems.

Putting the ineptness of those with no experience aside, the five officially accepted agroforestry practices actually *are* workable and provide an excellent transitional model for restoration agriculturists. Since agroforestry has actually been written about for decades and has been extensively researched, you are welcome to hide behind the vanguard of agroforestry when neighbors and family begin to wonder what you are doing. The restoration agriculture farmer is practicing agroforestry. We have not gone off the deep end; we are merely following good USDA agricultural practices that have the backing of universities and government agencies. Believe me, this can be important sometimes. The difference between USDA-approved agroforestry and restoration agriculture is that the latter is the practice of agroforestry on ecological steroids!

Agroforestry practices are relatively simple systems that are universally applicable in nearly all regions of the world. Probably the simplest of the practices and easiest to install and manage are windbreaks.

Windbreaks are linear plantings of trees or shrubs that are intended to mitigate the effects of the wind. Windbreaks help to prevent desiccation in field crops. They can prevent mechanical crop damage from wind-thrash and wind-throw. They can help prevent wind-generated soil erosion, preserving valuable topsoil, and preventing the sand-blasting of delicate field crops such as squash, melons, peppers and eggplants.

Much in the same way that windbreaks can protect field crops from the effects of wind, they can also be used to protect buildings from the same damage. Winter heating costs in buildings can be dramatically reduced with the proper planting of windbreaks, and the relentless winds of the Canadian prairie provinces can be mellowed to such a degree that the land immediately around the farmstead can become a pleasant microclimate suitable for badminton in the summer instead of just parasailing or studying wind-tunnel aerodynamics.

In the same manner that windbreaks can help to create sheltered spots for picnics, they can be used to dramatically reduce livestock stress. Windbreaks can provide shade against the summer heat and shelter from the shivering winter winds. Animals protected from winter winds require less feed to keep warm, reducing feed costs, animal mortality, and thereby helping the farmer's bottom line. Additionally, windbreaks are now being widely planted to block the view of increasingly unpopular animal confinement facilities while simultaneously reducing escaped odors.

Windbreaks can help to prevent chemical drift in either direction, either *from* the property in question (thereby reducing the risk of overspray liability) or they can help to prevent chemical drift coming onto a site from outside the property. The hybrid poplars surrounding New Forest Farm, planted purposefully as sacrificial trees, have taken a hit for the team during herbicide overspray events on a number of occasions. Instead of losing valuable chestnut or apple crops, all that was lost were a few thousand leaves and a month of growth on the inexpensive, fast-growing, expendable hybrid poplars.

Windbreaks provide a wide diversity of habitats for numerous beneficial organisms from the obvious nesting sites for birds to the not-so-obvious alternative pollen sources and homes for native wild bees. They provide shelter for tree frogs and toads, insectivorous spiders, and praying mantises and hiding sites for upland game birds such as pheasant, quail and grouse. This feature can add another enterprise to the farm — selling leases for bird hunting enthusiasts or offering tours for birdwatchers seeking the elusive bird "du jour."

When planted along roadsides or driveways windbreaks can act as living snow fences. You don't have to plow the snow from your driveway if you never let drifts accumulate there in the first place. With careful observation and planning you can design living snow fences so that drifts can be deposited where you would like to see increased soil moisture in the springtime and away from vehicle driving areas. Or windbreaks can be designed to spread out drifting snow for a more even accumulation of moisture. Yes, you can actually steer snowdrifts to reduce the need for plowing your driveway and to increase the soil moisture in a spot where you have planted some moisture-loving species.

Windbreaks can be made of varying densities, allowing for more or less wind penetration. They can be made of taller or shorter trees, in multiple or single rows, and using evergreens or deciduous trees (or a combination of all the above). Evergreens are more impenetrable to the wind and would be more suitable for livestock and homestead shelter, whereas more widely spaced deciduous trees would be more suited for breaking up a driving wind and for scattering snow more widely. Multiple rows of trees can be used to catch snow in between them. They will also capture autumn leaves or drifted topsoil from a neighbor's property. Although the idea of a windbreak may seem simple, their uses are only limited by the creativity of the observant landowner. In my opinion, the creative use of windbreaks has only begun to be explored.

Although it seems quite strange to me, the aspect of growing edible woody crops in windbreak configurations has only begun to be considered by USDA specialists. Instead of planting any old generic trees for windbreaks, why not plant edible woody crops such as apples and pears and cherries (on wind-fast rootstock, not delicate fully dwarfing rootstock)? Why not plant chestnuts or hazelnuts, plums or raspberries? For evergreens, why not plant pine nuts? This, in fact, was what we did around the central farmstead on New Forest Farm in southwest Wisconsin. Our original pine nut variety trials were planted to the north and west side of the newly built home which was exposed to the not-so-gentle breezes barreling down from the Yukon and Saskatchewan from November to March each winter. A small 400-watt wind turbine on a 20-foot pole that used to spin and howl with abandon now rarely turns, and we are serenaded by the sound of gentle breezes through the gracefully dancing young pines.

Windbreaks are simple to understand, simple to plant, and simple to care for. Their silent, patient benefits accrue through the years. Perhaps one day several of the pines in the windbreaks that I planted will be milled into the lumber that will make a box where I will be laid to rest one final time — now *that's* what I call long-term planning.

Another simple-to-understand agroforestry practice with innumerable creative applications is the planting of riparian buffers.

First of all, we need to understand a basic definition. Riparian zones are the area of land along the edges of bodies of water. The width of a riparian zone, immediately adjacent to any body of water, depends to a large extent on the size of the water body. The land area affected by the direct influence of the Mississippi River, for example, is much wider than the zone around your half-acre farm pond. Like windbreaks, riparian buffers tend to be linear in nature. In addition to their linearity, riparian buffers also resemble windbreaks in that they are used to interact with an energy flow. Windbreaks interact primarily with wind patterns whereas riparian buffers primarily interact with water patterns, not the streams themselves, but overland water flow from agricultural fields.

It seems simple and obvious, but nonetheless needs mentioning, that the removal of perennial vegetation from upland slopes for the production of annual farm crops results in erosion. The removal of trees and grasses reduce the rainfall infiltration rates, and with no grasses or trees and shrubs to slow its descent downhill, water not absorbed into the soil begins to flow. With the water are carried soil particles, organic matter and agricultural chemicals. As it travels farther downhill it accelerates enabling it to pick up more soil, larger soil particles, and eventually to carve gullies. There isn't an agricultural region in the country where the effects of erosion can't be readily seen.

Although riparian buffers don't prevent the original erosion in the first place, they perform an incredibly useful function as mechanical filters and biological sponges. When runoff encounters the perennial vegetation of a riparian buffer strip the velocity of the water is dramatically decreased as the rivulets attempt to weave their way through the stems of shrubs and the hairbrush bristles of perennial grasses. As the water slows down more of it has a chance to soak into the ground. Perennial root systems, rodent burrows and wormholes provide openings allowing the destructive flow to infiltrate. As the velocity of the overland water flow decreases it is not able to carry along the largest of the suspended particles and they begin to settle out, thereby capturing and accumulating soil in the riparian buffer. Agricultural chemicals, especially costly fertilizers, soak into the roots of the riparian buffer and no longer travel the streams that feed the Mississippi River down to the Gulf of Mexico (and help enlarge the dead zone). One of the main causes of the hypoxic dead zone in the Gulf of Mexico is overfertilization of the ocean caused by agricultural runoff. The fertilizer causes algal blooms which expand exponentially until the algae use up the fertilizer resource. When all the fertilizer is gone their populations crash. The subsequent decay cycle eliminating the dead and dying microorganisms uses up most of the available oxygen in the water column which becomes bad news for the higher-order sea creatures that depend upon oxygen to live.

At the local level, there are several regions in the country where streams smell like cat urine in the springtime. This is primarily caused by excess nitrogen fertilizers leaching from farm fields and traveling downstream, causing noses to wrinkle at the distasteful odor.

Riparian buffers as narrow as 60 feet that include trees, shrubs and grasses have been shown to remove nearly 80 percent of all agricultural chemicals from runoff water and even more of the suspended soil particles. In its Agroforestry Strategic Framework, the USDA admits that one of the reasons why woody riparian buffers are not implemented as often as they could is because farmers fail to see any income potential from land taken from annual agricultural production. This is as much a problem of short-sighted agroforesters as it is caused by USDA insistence that no harvests of riparian buffers take place because to a restoration agriculture farmer riparian zones present incredible opportunities. From ornamental woody crops such as red-, orange-, yellow-or green-twigged dogwoods to flowering plants such as American highbush cranberry and lilacs to the twenty some-odd different colors of pussy willows, several types of curly willows, and five or so species of birch — all bring higher prices at wholesale markets than do a bushel of corn or even cucumbers. Water-loving biomass crops such as sterile (and non-invasive) Miscanthus species or prairie cordgrass that can be burned directly for fuel are a perfect fit for riparian zones. Also the potential of cattail as an alcohol feedstock is a vast and currently underutilized resource. Imagine this, if you might … what if all of the flood plains of North America's largest rivers were planted to cattails instead of corn and soybeans? Remember, these are *flood plains.* When the river floods, these are the farm fields that you hear about that get covered with water for weeks at a time. It gets called a natural disaster, but it really isn't. Rivers overflow their banks on occasion. Flooding of our cornfields is a human thinking disaster. We shouldn't be growing corn there in the first place.

Corn and bean fields inundated by flooding is called a "natural disaster," but is merely the result of growing dryland crops where cattails would be more appropriate.

Corn and soybeans can't tolerate being underwater for weeks on end, but cattails can. They have actually evolved to live in flood plains. Remember, too, that 30 percent of corn in the United States is delivered to the ethanol plant where it is fermented into motor fuel. The distilleries already exist. We won't have to build them. All that we have to do is to change the feedstock from corn to cattails. It has been reported that cattails can yield up to four times the ethanol per acre as an acre of corn. Imagine now that the levees along the major rivers are now designed to keep the floodwaters in the *field* instead of in the *river*. Cattail swamps in the millions of acres could swallow up nearly any flood that nature attempted to throw at us. An added benefit for the flood plain cattail farmer is all of the free fertilizer imported from farms upstream.

In the fall, when the flood plains have dried sufficiently, the cattail reeds could be harvested like so much switchgrass, destined for the biomass burning powerplant. At this time, an adequately sized potato harvester could be driven across the fields to harvest the energy-rich roots to be delivered to the ethanol plant. Migratory waterfowl would see increased nesting habitat in the spring and summer, as would all wetland species. Water quality in the rivers would improve and agriculture's contribution to the Gulf of Mexico dead zone would dramatically decrease.

Part of a riparian zone strategy in the uplands would be to plant five or six rows of hazelnuts along the sides of smaller streams. The hazelnuts would benefit from adequate water and help to reduce the amount of free-flowing fertilizer going downstream to the cattail farmers.

With adequate water, nutrients and accumulating topsoil, riparian zones have the potential for higher yields than upland agricultural fields. For the restoration agriculture farmer riparian areas represent some of the richest places for creative income and energy potential.

Probably the simplest agroforestry technique to understand is the practice of alley cropping.

Alley cropping is the growing of a row of trees or shrubs (or both, and more!) in between annual crop fields. Alley cropping requires that a row crop farmer change only one thing in their farming operation, and that is to add rows of trees. Using your own current equipment to design a system works quite well and ensures that the new layout is compatible with all your tillage, planting and harvesting operations.

Since I have been using corn as an example so much in this book, I might as well stick with it and use it as an example of an alley-cropping system. It can't get much simpler than this. To lay out an alley-cropping field, all that you need to do is plant a field in the spring (just like normal) and have an extra person on hand with a bundle of survey flags to stick into the ground. As the corn planter approaches one end of the field, the flag person follows along and gets ready for the return trip. Approaching the headland, the person driving the corn planter turns (without lifting the planter and without stopping, backing up, or doing a three-point turn) and heads back down the field. Once the corn planter is turned around and heading back down the field, the person with the survey flags places them in the ground approximately 2 feet out from the edge of the last row of corn. These flags mark where the row of trees will go. (The corn is planted in the alley.) What you have just done is designed an extremely fuel- and time-efficient simple alley cropping system. Repeating the process in even numbers of passes, you will create a system where the farmer drives onto the field in the morning and drives off when finished (that afternoon or next Tuesday depending on how big the field is). No passes are wasted space. No stopping, no lifting the equipment, no shifting into reverse while turning around — one-pass farming.

Walnut is probably the most widely used tree in alley-cropping systems in North America providing shade, nuts, firewood and eventually timber.

Some other things to take into consideration when setting up an alley-cropping system are alley widths. For the most efficient number of passes across a field, alley widths should be in multiples of two times the width of the equipment being used. The tractor travels up the field then back, up then back, however many times it takes to reach a desired width. In southern regions pecans are an excellent tree for alley-cropping systems and eventually (100 years from now) branches will spread up to 50 feet on either side of the trunk. Alley widths of 100 feet are not entirely a bad idea. There will be fewer pecan yields in the early years since there are fewer trees, but a nervous first-time alley cropper will feel a lot more confident doing this while getting used to the system. For more northern growers black walnuts are a good choice, as are the oaks.

The trees that seem to do the best in alley-cropping systems are trees with taproots. They don’t have a shallow mat of roots to get compacted and damaged by equipment and they don’t steal as much water and nutrients from the crop. Another way to prevent nutrient theft is to drive a subsoiler along the row of trees every year from the very first summer after they are planted. This clips any young roots that attempt to go after the crop nutrients. It keeps roots within the tree row and encourages them to dive deep. If you wait until the tree is older before subsoiling, the tree roots are much bigger and the tree could suffer from all kinds of decay pathogens as well as it will not be as wind-fast. Root prune the alley cropped trees every year beginning in year one.

Some other considerations that I would like to share in alley-cropping systems are the shade density of the mature trees, the number of trees planted per row, and the orientation of the rows. Some studies from the University of Missouri-Columbia have shown that rows of trees oriented east-to-west show slightly greater tree crop yields (measurable, but not statistically significant). On a square, flat field, it might make sense to orient the tree rows that way, but in most of North America this doesn’t take into account the prevailing summertime winds or the usual direction of storm winds that might turn the alleys into a wind tunnel. North-south oriented rows of trees might also double as a windbreak.

On a restoration agriculture farm that has first installed a keyline water management system, the rows of trees would parallel the keyline. Instead of straight, rectilinear rows of trees, the trees would sweep gracefully along or near contour and would reveal the natural shape of the landscape as it relates to water. Keyline alley cropping systems are truly a beautiful sight to behold.

Weed management is a concern for most folks who have not yet attempted to establish major tree plantings. Weeds when unchecked and uncontrolled can and do take up valuable moisture and nutrients from young trees. So when transplanting young trees you will have a much higher tree survival rate when you manage the weeds within the tree row. For conventional farmers using herbicides, weed control is as simple as finding herbicides that are compatible and listed for use with *both* the woody crop in question and the crop being grown in the alley. The majority of alley cropping systems in the United States today are managed this way.

If no herbicides are used, light cultivation on either side of the tree row is a good way to control unwanted weeds. This is where designing the system to fit the equipment being used is an excellent idea. When done well the organic corn or bean grower can cultivate the tree row while simultaneously cultivating the annual crop. This was done on many acres at New Forest Farm. The trees benefited every time the cucumbers or winter squash were cultivated. Other methods of weed control are also adequate but represent more labor or input costs. Organic mulches, when applied thick enough, can smother out weeds around newly planted trees as well as retain soil moisture. Wood chips and sawdust all work well. Straw and hay also works fairly well, but won't smother the weeds as well and tends to provide habitat for dastardly little bark-nibbling rodents that might girdle and kill your trees. Plastic mulches are often used by produce growers and work quite well. Some plants such as hazelnuts appear to not appreciate the heat under black plastic mulches, so perhaps white or some other color would be more appropriate than black. Someone will have to test this. Geotextile and spun-polyethylene landscape fabric works well as a mulch, but definitely needs to be cut and removed in later years so as to not girdle the growing tree. "Weed mats," square sheets of plastic with a hole in the center, work well and conveniently stretch and rip as the tree outgrows the size of the hole.

The better the weed control (without damaging tree roots) the higher the tree survival rates will be and the faster your trees will grow.

The STUN Technique of Plant Care

It was at an Acres U.S.A. conference in 2004, where I was leading a workshop on agroforestry and permaculture that I invented the acronym STUN. STUN stands for: sheer, total, utter neglect. Of all the different ways to care for plants, STUN is the simplest. Since nothing is done to the plant, around the plant, or applied to the soil, it is also the least expensive method of plant care. When it comes to tree planting most people *think* that they're going to take excellent care of their trees and they *want* to take immaculate care of them, but somehow life gets in the way and the trees get ignored to a certain degree. Since this is what happens often anyway, we might as well dispose of all the guilt and *plan* to ignore our trees. Using the STUN technique, we can now ignore our trees on purpose.

What might that purpose be? Aside from the obvious cost and labor savings when you don't hand weed, hoe, cultivate or mow around trees, one of the most significant benefits of using STUN is the discovery of superior genetics. Think about it. If you plant 100 trees and ignore them, the only ones that will survive did so because they had some sort of competitive advantage. Maybe they developed deep roots more quickly than the others around them. Maybe they require less water or nutrients than the ones that died. Everybody has seen trees growing out of cliffs and observed that some trees can survive without any soil at all. STUN allows us to discover which trees are adapted to surviving in the unamended soil type that exists on a farm.

Another reason why I practice STUN is to approach the ease and simplicity that some corn and grain farmers enjoy. Here in southwestern Wisconsin that simplicity consists of: planting the corn, applying fertilizer, applying herbicides (or cultivating if it's grown organically), then ignoring the crop until harvest time.

We would not be able to grow the quantities of tree seeds that will allow them to be used as staple food crops if we spent the same amount of time and money caring for them that fruit and nut growers currently spend. All that you have to do is read articles in *American Fruit Grower* magazine, participate in the various tree fruit listserves online, or listen to tree fruit growers at conferences, and you will hear about the dire straits that fruit and nut growers are currently in. Their input costs are going up, diseases are becoming immune to chemical controls, and cheap fruit is being imported from other states or countries. If we want to produce staple food commodities from woody plants, we are going to have to approach the STUN technique. The less we do to a tree, the less the harvested product costs. In order to have trees that thrive with no inputs, we have to find them.

Using the sheer, total, utter neglect technique has its costs. If you invest several thousand dollars to plant a one-acre restoration agriculture plot and treat it with STUN, you are taking your chances. Plant mortality can approach 100 percent. Spending $40.00 on inputs and maintenance for a bushel of fruit that sells after harvest for $20.00 is the height of insanity and has been the road to financial ruin for every certified organic apple orchard in the state of Wisconsin for the past 17 years. Losing 100 percent of the trees in the first season is also not financially prudent. Somewhere between these two extremes a balance exists. It is simple enough to learn all of the things that we *can* do in order to take perfect care of our trees: Dig a $100.00 hole for a $10.00 tree, amend the soil to perfectly meet the trees nutritional needs, irrigate weekly, add fertilizer regularly, install tree shelters, foliar-feed, keep the surrounding soil perfectly weed-free, apply fungicides according to the perfect temperature-humidity algorithm, just read some of the literature on tree care. There is no end to all of the things you can *do* to care for your trees. Instead of wracking our brains figuring out what to *do* to our trees, restoration agriculture farmers ask what can I *not do* and get away with it. It is interesting that all of the literature you can read and all of the workshops you can attend (well, most of them anyway) are all telling you what to do, rather than *not do.* In addition, they only address two fundamental questions: "How do I keep this thing alive that wants to die?" and "How do I kill this thing that wants to live?" This is entirely backwards! If some trees of mine want to die, I say, "Good riddance!" I don't have the time and I'm not interested in spending the money on inputs to keep it on life support. I'm interested in discovering the genetics that are precocious, pest- and disease-resistant, and thrive in under a regime of STUN.

Please, *do* take care of your trees. You will have higher survival if you care for them. At *least* give them a little bit of weed control and water during their establishment years — 2–5 years depending on the site conditions. Just don't get hung up on trying to *do* everything that you can to help them. Try to figure out how little you can do and still get away with it. Give your new investment some care and support, but don't go overboard and follow the well-trodden path to input dependency and financial ruin.

Using the STUN technique is the lowest-cost approach. Tree seedling mortality will be higher if you do no weed control, and if you are growing poor quality nursery stock tree losses can be as high as 100 percent. Find something that works for you and give your trees the best care that you can for at least the first three years of their life.

The fourth USDA-sanctioned agroforestry practice is called silvopasture. This is the intentional combining of trees or shrubs with livestock and forage production. In its most simple form, silvopasture is planting trees in your pastures.

Allowing livestock to graze in a natural woodland without any tree or forage management is *not* silvopasture. Grazing livestock in the woods fails to provide the animals with adequate nutrition, eradicates forest regeneration, and — with no management of a forage layer — causes trampling of the groundcover layer potentially destroying important shade-tolerant forest plants. Likewise, having *one tree* in the pasture is also not silvopasture. Most rural folks have observed this scene over and over again all across the country — the one last remaining tree out in the middle of the pasture. Beneath that one tree can be seen an entire herd of animals crowding together to stay in the shade. The ground beneath the tree gets trampled to death, no grass is growing, and eventually the tree itself suffers from overfertilization, root damage from trampling and sometimes girdling from browsing animals. Just recently I was sickened by the scene of dozens of giant burr oak trees that had been completely girdled by too many underfed horses trying to survive on 5 acres of ground. Silvopasture is an intensively managed system where the overall system health is the goal. Trees *and* forage *and* livestock are managed together as a system and no one of the three is allowed to negatively impact the others.

Possibly the best way to describe silvopasture would be to think of the ultimate goal. An ultimate goal for a silvopasture system is to have trees evenly spaced across the landscape. Their crowns cast a dappled shade (between 40 and 60 percent is ideal) across the lush, dark green pastures. Livestock move through the system and are almost always in the partial shade. There is no need to bunch up under one tree when the shade is evenly spread. Livestock are kept in one paddock until they've eaten their preferred forage, then moved to the next paddock for their next "first bite."

There are two ways to get to that ideal. One, as previously mentioned, is to plant trees in your pasture. For an already existing rotational grazing paddock system, all that needs to be done is to plant a row of trees alongside the currently existing permanent fence. Temporary fence, moved whenever livestock are rotated, is strung alongside the trees and then across to the other hard fence. Where previously moveable fence was strung from hard fence to hard fence like the rungs of a ladder, temporary fencing now makes the shape of an "L." String it parallel to the permanent fence in front of the row of trees, *then* across to the other hard fence like the rungs of a ladder. This way the stock farmer has very little to change other than a bit more moveable fence.

The width of the fence-protected tree row does not need to be very wide at all. I have seen successful grazers who only have 18 inches of pasture taken up by each tree row. With cattle it is the height of the lowest strand of fence that determines how narrow the tree row can be. With a lower strand, the animals can't reach as far under the fence without getting a shock. Two-strand electric fence is easiest for this. When using a single-strand fence the tree row will need to be somewhat wider, 3-4 feet perhaps, mostly to keep the animals from reaching *over* the fence to browse your trees.

In a system established this way quite a few years will pass before it becomes an ultimately, semi-shaded savanna. In the early years it will merely be a regular grazing system with some extra fence to run. Another way to achieve the semi-shaded savanna system would be to establish pastures in trees.

Now I know that I have already mentioned that silvopasture is not grazing livestock in the woods, and that is still the case. However, there are millions of acres nationwide where there are woody plants, shrubs and trees growing in various stages of succession that don't really qualify as a forest. I can drive for days in an eastward direction from Wisconsin through Illinois, Indiana, Ohio, Pennsylvania and New York and rarely see what would qualify as *true* forest until I reach the Berkshires in western Massachusetts.

A very large percentage of the forested land in our agricultural states, is not really a functional forest. The original forest is long since gone, and the trees in existence now are undergrown by invasive species such as honeysuckle, multiflora rose, European buckthorn, garlic mustard and Japanese barberry. If any of these modern non-forests were former agricultural fields long since abandoned (like a majority of them in the low elevations along the Atlantic Ocean Seaboard), they may not have any true forest-dwelling plants in the understory and merely are a collection of opportunistic weeds of various degrees of shade tolerance. Eventually through the ages, hundreds of years perhaps, these places will settle in to being a true closed-canopy forest. But for now they are a tangle of briars producing very few ecological services aside from making oxygen and providing habitat for a few crows, blue jays and raccoons. They are certainly not producing any food for humanity except for the occasional mushroom found by a hiker or a hunter shooting corn-fed, suburban landscape-fattened white-tailed deer. These currently underutilized waste spaces represent a tremendous potential for silvopasture systems and for restoration agriculture in general.

In some states, especially in drier regions, there were vast areas of savannas that were grazed by bison for thousands of years, and then cattle by European settlers, that have been abandoned in recent years. Without regular grazing or periodic fires underbrush has grown up in these former grasslands, much of it regeneration of the oak and hickory overstorey. As the shade in these sites has increased the once abundant grasses have disappeared and an overabundance of trees has developed. The sites being naturally droughty are not able to support so many trees per acre and the trees grow poorly and slowly. They become increasingly stressed, and in extremely hot and dry summers like the summer of 2011 entire sections of forest have died all at once.

It is on sites like these that no corn is being grown and none is likely ever to be grown. The net contribution of the land to the human food supply is zero and its ecological services are negligible. Every calorie of food grown on such a site is a net-positive, and when such a site is managed so as to optimize its energy capture and therefore its productivity, everybody gains, wildlife included.

In these situations it is appropriate to clear out the underbrush, remove undesirable and invasive species, open up the canopy to let down some light, establish shade-tolerant grasses, and then graze in the shade.

On more productive sites, in regions with an active paper industry, it is possible to have the major clearing done at a profit. This is helpful since eliminating the underbrush and stump sprouts can be time consuming and costly. Chainsaws, weed eaters with a saw blade attachment, and skid-steer loaders with a mulching head attachment are all valuable tools for brush removal.

Once the undesired plants have been removed locally appropriate grasses and legumes can be sown and livestock moved in periodically to graze.

With silvopastures established this way controlling the re-sprouting of undesirable brush is essential. Herbicide is probably the most effective, but also expensive and of course toxic. Finish-mowing the pasture after animals have grazed is also effective, yet once again is an expense and can be difficult or impossible on really rough or rocky terrain. It is in situations like this that sheep and goats really excel. Sheep love to browse on woody plants, but nothing like goats do. In a silvopasture-rejuvenated non-forest, the desirable trees are too large and tall for goats and sheep to browse upon, but the stump sprouts and natural regeneration are fair game and are readily devoured. Goats and sheep are the perfect tool for keeping the brush from re-invading. Tree shelters can be placed on young trees of the desired species in order to protect them from browsing. New trees, protected the same way, can be planted beneath any excessively large holes in the tree canopy. Once again, 40-60 percent shade is ideal for forage growth.

Silvopasture established in this way is nearly ideal for a multispecies leader-follower system, especially when the largest trees include nut trees such as oaks and hickories. Cattle are almost the fussiest grazers desiring the highest quality forages. Sheep and goats can follow behind grazing on the remaining lush forage, but most importantly cleaning up the re-sprouts. Pigs can follow behind everyone grazing the "second bites" that the others ignored, and in the fall they are the perfect way for a farmer to take the normally unharvested wild fruit and nut crops and convert them into high-value bacon and pork chops.

Silvopasture systems, especially with sheep and goats, can also be established with woody plants that are intended especially for livestock feed. Cattle, sheep, goats and hogs all love to eat the leaves of various woody plants, but especially those of the white mulberry *(Morus alba)*. It's a given, of course, that goats and sheep will also eat mulberry twigs, but even cattle will browse them. The pigs stick primarily to the leaves. Mulberry leaves, in fact, are more nutritious than alfalfa and come with a delightful co-product — mulberry fruit. Mulberries are fairly high in protein for a berry, and of course are high in sugars meaning that they are a high-energy livestock feed. Poultry (as do all birds) love mulberries, but arguably the most satisfying mulberry relationship is between mulberries and hogs. Mulberries ripen their fruit over a long season, from mid-June in the southern states and lasting all the way into early September in the northern states. When there is fruit on the mulberries, that is where you'll find the pigs. Pigs will contentedly snuffle around beneath mulberry trees all day long not bothering to leave because one of their brothers or cousins will take their place and catch the next berries to fall. Mulberries have an interesting trait in that the pollen-bearing male flowers occur on one plant and the berry producing female flowers occur on another. This feature allows us to create a silvopasture system with both fodder production *and* berry production. Simply plant a row of mulberries with the plants spaced very close together, 3-5 feet, for example. Protect them from browsing for the first three or four years and by then the ones that produce male flowers and the ones that produce berries will become evident. In the late winter, the male plants at this age can be trimmed severely and the tops thrown to the cattle, sheep or goats. The female berry-producing plants can be left to grow tall and not allowed to be browsed. Cutting the male plants will not bother them but will instead stimulate them to send up numerous shoots, which will be delicious, tender and green for the livestock by mid-summer. With proper management a mulberry plant can be browsed twice each season without killing the plant. Over time the browsed mulberry row will develop a two-storey appearance with berry-producing trees up high (mulberries will grow to 25 feet or so) and forage-producing shrubs down low.

The American linden or basswood (Tilia Americana) resprouts readily from the stump when cut or browsed and both the leaves and flowers are excellent in salads.

There are many more woody plants besides mulberries that are good for animal browse. Most commonly, willows, alders and poplars are used, primarily for their rapid growth. Other plants are perfectly suited as browse and trees such as maple and apple are some of the favorites. The very shade-tolerant American basswood *(Tilia americana)* has such succulent leaves that they even make outstanding salad greens for humans. Including edible flowers in salads looks like it's a trend that is here to stay, so why not start the next trend in truly sustainable salads with basswood greens or birch leaves, especially the yellow birch *(Betula alleghaniensis)* and black birch *(Betula lenta),* both of which are wintergreen flavored.

In any silvopasture system it is probably ideal to plant deeply rooted trees. Trees with shallow roots can potentially suffer excessive and unnecessary root damage from animal trampling, and shallow roots tend to rob more moisture from the forage crops. Remember, a silvopasture system uses livestock as the cash flow. High-quality forage production is the primary concern. Since you will be planting trees, however, trees of a high-value timber should be given a priority.

Fruiting tree species, nut trees such as pecan and black walnut, and the various hickories and chestnuts are all outstanding candidates for use in silvopasture systems. In the southeastern United States there are many silvopasture systems utilizing slash pine and loblolly pine with the primary marketed products being pulp and timber, but with a secondary market potential for selling pine straw — pine needles used for landscape mulch.

Once again I find myself opening what appeared to be a tiny door by saying that in its most simple form silvopasture is planting trees in your pastures. What started out so simply can expand into a nearly infinite degree of complexity with tremendous and multi-faceted yields: ornamental plants, wildlife habitat, livestock, fruit, nuts, timber, browse and more. The restoration agriculture farmer will see, of course, that once we begin to aggrade the ecosystems around us, to quote permaculture's founder Bill Mollison, "We are surrounded by nearly insurmountable opportunity."

The fifth agroforestry practice is one that finds many applications both on a large or small scale and is called forest farming. Forest farming worldwide is somewhat different than what some people are now referring to as "forest gardening." Worldwide and in agroforestry circles forest farming is the intentional manipulation of the forest canopy and ground layer in order to simultaneously improve *both* the forest stand and to create ideal conditions for an intensively grown, shade-tolerant crop. This is slightly different from forest gardening, as is popularly defined in the recently published book *Edible Forest Gardens, Volumes I & 2,* by Dave Jacke, and other books such as those by Martin Crawford, Patrick Whitefield, and the grandfather of forest gardening, the late Robert A. De J. Hart. Forest gardening is actually more akin to the agroforestry practice that was never adopted by the USDA of multi-storey cropping systems where a diverse, multi-layered system of useful woody plants are vertically integrated one on top of the other.

Most forest garden systems in existence are on a suburban lot or a homestead scale and don't quite reach the total production levels that I am referring to as forest farming or restoration agriculture. Forest gardens are an important part of future food security and environmental health, but in most applications aren't planted to the scale where they are a major producer of staple food crops for the human food supply. What I am referring to here differs in scale and intent. Forest farming, agroforestry and restoration agriculture as a whole are intended to produce staple food crops that feed the world. These systems produce on a broad-scale the foods, fuels, medicines and fibers that then feed the human population (the majority of which is now urban based) in an ecologically sound, economically profitable manner — sustainably, perennially and forever.

In the agroforestry practice of forest farming let's use as an example a similar non-forest as described in the silvopasture section (the one with some underperforming trees and an abundance of invasives and brush). In a forest-farming system the economically unproductive and possibly invasive under-story can be removed and an economically valuable crop planted in its place. The understory is an ecological niche available for exploitation by plants and animals. When we remove the buckthorn and honeysuckle we can plant something of food, medicinal or ornamental value in its place.

Forest farming, by its nature, takes place in a closed-canopy, or near closed-canopy forest. Grasses and livestock forage require at least 40 percent light in order to thrive, so typically forest farming takes place in forest stands where the shade is more than 60 percent. Grasses, aside from a few rugged sedges, do not thrive in such a densely shaded environment. Many other valuable plants do, however. Medicinal herbs such as ginseng, goldenseal, black co-hosh and blue cohosh all thrive beneath a forest canopy. The market for these medicinal herbs is quite large, and if you don't believe this all that you have to do is go to Walmart, look at the supplement section near the pharmacy, and check out the ingredient labels on some of the herbal remedies. Walmart does not deal with niche products and won't carry items that don't have a good selling potential. Every one of the products in their stores sells at high volumes and at a high turnover rate. All of the shade-tolerant herbs mentioned above can be found in the herbal remedy section of Walmart. They are mass-market crops. That means that you can grow and sell sufficient quantities of them and get enough in return to pay your bills.

Other crops that can be grown in a forest farming situation are edible crops such as ramps (a wild leek), gooseberries and currants. Persimmons are partially shade-tolerant as are pawpaws, nannyberries and mayhaws — all of which are sorely underutilized, useful food plants.

One of the simplest crops to grow in the shade of a forest are the mushrooms. They have forms that are both edible as well as medicinal. Mushrooms also bring us into another phase within the cycle of life and that is the decomposition cycle. Ecological systems that have been aggrading for some time and gone through succession from bare soil to grassland and shrubland, to open canopy savanna, then into closed-canopy forest, have accumulated an abundance of carbon. Carbon dioxide from the atmosphere, a gas, is breathed in by the plant realm and turned into the leaves and tissue of woody plants. Over time leaves and wood accumulate and begin to decay. The organisms that actually are doing the work of decomposition are yet another income and productivity opportunity for the restoration agriculture farmer. In the natural world the workhorses of decomposition are the fungi. Mushrooms, toadstools, conchs — whatever you call them — are all fungi. Books and entire industries have been built around the lowly mushroom, and growing them intentionally in a forest farming setting is not only simple, it can be profitable and is a great way to obtain some cash flow from the decomposition part of the cycle of life.

It is just as easy to ignore a persimmon you have planted as it is to ignore a wild one and it might even taste better.

There are edible, marketable mushrooms that can be grown on the logs of nearly every species of tree, and there are a host of mushrooms that can be grown on wood chips, sawdust or leaf litter.

Medicinal mushrooms often bring in higher prices than edible mushrooms, and no matter what type of mushrooms a forest farmer grows there will always be individual mushrooms that are less than perfect in appearance and therefore unmarketable. The forest farmer then has to learn how to be creative and make dried mushrooms, mushroom powder, mushroom seasoning mixes, teas, soups and, of course, eat more than his or her fair share of what is considered by many to be a delicacy. One of the benefits of being a restoration agriculture farmer is that you get to eat extremely delicious and nutritious food on an almost daily basis and be subjected to … "But Dad," as my then five-year-old whined in front of a number of guests, "Do we have to eat asparagus and shiitake omelets with homemade cheese *again?*

Forest farming is not merely wildcrafting, that is finding wild edibles or medicinals. Wildcrafting actually does form the basis of much of the medicinal herb industry in North America, but forest farming is different. If you live in an area where ginseng grows wild and can be wildcrafted, forest farming ginseng would be a sure winner. Instead of hunting for ginseng where nature might (or might not have) put it, forest farming intentionally creates the conditions for the crop to thrive and then plants it there. Dedicated planting beds, irrigation, soil amendments, and weed control are all a part of high-yielding forest farming system. Nature might only plant a handful of goldenseal plants in a particular area, but a forest farmer might plant intensive beds with thousands of plants per acre. Likewise with mushrooms. Nature might scatter a few puffballs here and there or a patch of morels in profusion, but only for one year out of a dozen years. A forest farmer creates the conditions to produce large quantities in a small space. Log yards for shiitake, maitake, oyster or enoki mushrooms would be constructed with access to water (for maintaining adequate humidity when nature refuses to cooperate). Nature might only have one or two mushroom flushes per season, but with well-timed watering or misting, a forest farmer has the ability to stimulate mushroom logs or woodchip beds to fruit and this way can maintain consistent harvest throughout the season. Shiitake and oyster mushrooms can yield so consistently that the forest farmer might actually get tired of the abundance. Abundance is a problem that we all could use more of!

All of the agroforestry practices from windbreaks to riparian buffers to alley-cropping and silvopasture systems will eventually grow and mature to the point when they can be allowed to go into the final stage of being a closed-canopy forest and be used for forest farming. Densely planted agroforestry systems can actually create forest-shade conditions when quite young. At New Forest Farm, forest floor-type conditions have been created beneath tightly spaced rows of high-density chestnuts within five years. The double rows of seedling chestnuts began to crowd one another out at this age and some trees needed to be removed to make room for the more productive trees. The trunks that were removed were small, but were perfectly suited for inoculation with shiitake spore spawn and can then be placed on the ground between the rows where they came from. Some two-inch-diameter logs have actually produced flushes of mushrooms for nearly ten years.

The wood eventually decays and returns to the soil, which it would do anyways, but using this technique a forest farmer can rot their brush and serve mushroom omelets on the side.

Dynamics and Change

In addition to having little research data available on North American restoration agriculture farms, any yield data that you will find is unfortunately a snapshot in time. When restoration agriculture is first established into abandoned farmland or on a barren site with inadequate soil for annual agriculture, the cropping system will look radically different than it will in 5, 10 or 30 years. Crop rotation in a perennial polyculture also takes on an entirely new meaning here. Crop rotation in an annual cornfield might look something like this:

Corn	Year 1
Soybeans	Year 2
Alfalfa	Year 3-5
Corn	Year 6

And the pattern keeps repeating. It is quite common for farmers in the United States to grow continuous crops — that is corn (or wheat or…), year after year after year. For this to work, chemical fertilizers, insecticides, fungicides and herbicides (applied with precision GPS satellite control) take care of fertility, pest and disease control.

Crop rotation for a perennial polyculture would follow the natural successional pathway for the region where it is being practiced and could take several thousand years. A simple crop rotation for a restoration agriculture farmer might begin with corn and would travel through the successional pattern by morphing into chestnuts, apples (or plums or cherries), and hazelnuts. By the 30th year chestnuts would dominate the site, and apples and hazelnuts would become the understory. Livestock would be present through all the years. By year 100 or so, the system would be dominated by chestnuts and the understory fruits and hazelnuts would be beginning to decline in vigor, then quite possibly (after a 1,000 years or so) the whole system could be clear-cut to harvest the high-value timber and then bulldozed to make way for corn, and the beginning of the next crop rotation.

CHAPTER 15

Managing a Healthy Farm Ecosystem

BY now it should be obvious that a restoration agriculture system is not merely how to grow one particular crop or another. Restoration agriculture is *not* about adopting conservation practices to put on your farm, nor is it about creating habitat islands for beneficial insects and wildlife. Restoration agriculture is the intentional design of productive agricultural ecosystems that are patterned after natural ecosystems. These productive agricultural ecosystems are deeply diverse and are full of beneficial synergies between the elements within the system. A restoration agriculture system's starting point is at the place in successional time where the farm currently exists and it develops its complexity and richness through the years, lifetimes, and potentially even centuries and millennia. Although you may be starting with row crops such as corn or wheat and evolving through the establishment phases of alley cropping (where an agricultural crop is grown simultaneously with a long-term tree crop), and silvopasture (combining trees with forage and livestock production), what I am discussing here is not a single agricultural technique, but a system of techniques. Instead of learning how to grow a new crop (hazelnuts, for example), farmers will be learning how to manage a *system* of crops with its own successional trajectory into the distant future. Since this is an interconnected group of crops, the old rules of monocultures don't necessarily apply. A restoration agriculture farmer growing a system that includes apples won't necessarily be doing the same things at the same time as an apple orchardist (or even an organic apple grower). A deeply diverse system actually operates quite differently than an orchard of anything.

There are some things, however, that are universal to good agriculture whether you're raising 100 acres of a single crop or are mimicking an ecosystem. These things should still be practiced in restoration agriculture and not be entirely ignored. Where possible, start with healthy soil. The first order of business in creating a healthy soil is water management, which I've already discussed. Life as we know it is dependent upon water, and soil life is no exception. Capture and use the water that enters your farm property whether it is rainwater or water from streams (imported water) or from springs and ponds. Where there is water, there is life. Even in desert areas there is enough rainfall to support life. If we capture that water, store it in the soil, store it in the plant life and soil life, then recirculate it as many times as possible, deserts could support even *more* life as has been proven with permaculture projects around the world.

GREENING THE DESERT

Plants can survive in some incredibly poor soils. Most of us have seen plants sprouting from cracks in roadside cliffs, joints in between the pieces of sidewalk, and even on the asphalt shingles of a roof. Plants will grow in some incredibly poor soils. However plants will be much happier, will grow more rapidly, and bear more abundant and more pest- and disease-free crops if they are actually growing in good soil and in soil with the proper balance of minerals.

Although 99 percent of a plant's physical structure is carbon, hydrogen and oxygen (all of which the plant takes from the air), the plant needs certain mineral elements that it can only effectively obtain from the soil. These mineral elements come either from the original bedrock of the region, or if your soils were deposited by wind, sedimentation or volcanism, from the components found in the debris that has now become your soil. All soils have various mineral components in different percentages. Crushed granite bedrock in central Maine (and they do call it soil there) is quite low in calcium. However, the same granite-derived soil is typically quite sufficient in potassium, iron, magnesium, silica and other trace minerals. Plants living in granite-derived soils show in their bodies the results of having adequate potassium. In plants, potassium is essential for stalk strength, winter hardiness and disease resistance. It is also essential for good protein and carbohydrate synthesis as well as sugar translocation.

Soils derived from crushed limestone bedrock, as is found in much of the Midwest, has a different mineral composition than that of crushed granite in Maine. Many limestone-derived soils are deficient in potassium and silica and most are deficient in magnesium (except for soils derived from dolomite limestone). If you are a farmer or rancher, you are most likely already familiar with soil mineral balancing from reading frequent magazine articles in *Acres U.S.A.* on this topic. The same rules for building healthy, productive soils also apply to restoration agriculture with some slight modifications. For those who are not all that familiar with soil mineral balancing, I highly recommend the book, *The Biological Farmer* by Gary Zimmer, available at Acres U.S.A. When you manage your water resource and adequately hydrate your soil, plants can grow. When you balance your soil minerals, your plants can go beyond merely growing into a state of really thriving.

The slight modifications when building healthy soils that apply to a restoration agriculture system are these … remember, of course, that if your land were abandoned today, plants would continue to colonize the site ad infinitum — even if you had done no soil mineral balancing whatsoever. At first the only plants that would thrive on your site would be the ones that are adapted to do well there. If your soil is calcium-deficient, it will simply not be colonized by calcium-demanding plants. If your soil is high in calcium and deficient in potassium, it will only be colonized by plants that can survive and reproduce under those soil conditions. No matter what your soil type is and no matter what mineral balance/imbalance it has, there are economically valuable and food plants that will grow there. You just might not currently recognize them as food, however, since many of them do not appear on grocery store shelves.

Arguably the most cost-effective way to maintain plants on your site is to grow plants that are adapted to your particular soil chemistry. It is the patchy and irregular assortment of soil types with their own unique deficiencies and abundances that has, in part, been a selection pressure on plants and has contributed to the development of the wide variety of plant life across the planet. There are variants of each keystone species (a plant that plays a disproportionately large role in the community compared to its abundance) that are adapted to different conditions. Knowing the actual mineral composition of your soil will help you to guide your plant variety decisions, and a quality soil test is recommended.

With a good soil test you will know with measured certainty what the mineral balance of your soil actually is — at least in the top foot or so. (I recommend Midwestern Bio-Ag in Wisconsin, International Ag Labs in Minnesota, or Kinsey's Agriculture Services in Missouri.) With a soil test a restoration agriculture farmer now has the tools to dramatically reduce mineral amendment inputs. How would this work? Let's take an asparagus and chestnut alley-cropping system on New Forest Farm in southwestern Wisconsin as an example.

The soils in the Driftless Region of southwesten Wisconsin are unglaciated and derived primarily from dolomite limestone. For calcium-loving plants, dolomite limestone is a blessing because it has adequate levels of magnesium in it. However a hundred years of farmers using local, crushed dolomite limestone on their fields every spring this has caused an imbalance between the amounts of calcium and magnesium. The calcium in the readily available agricultural lime has been taken up by the plants and oftentimes is exported from the farm along with the harvested crop. *The* magnesium stays behind and accumulates over time. Excessive magnesium in the soil causes the existing calcium to become less and less available to the plants. Magnesium also tends to cause soils to lose their loft (fluffiness) and become stickier and compacted. Adding lime year after year like this can, over time, actually chemically create clay soils. Asparagus would only be moderately happy in such a heavy soil where calcium is abundant but not available because of excess magnesium. One way to correct this situation would be to amend the soil with a suitable calcium source — a source that did *not* have magnesium.

The same soil, though, would actually be adequate for chestnuts. Although chestnuts don't prefer high-calcium soils, the excess magnesium makes these soils appear to be somewhat calcium deficient. Here is where restoration agriculture systems have better returns per acre, not only because of increased total yield, but because of decreased expenses.

If we had wanted to plant asparagus on these same soils, the soil tests showed that we would have had to add calcium and phosphorus (the soils were deficient in phosphorus as well) in the tons-per-acre range in order to get good yields. If we had done this we would have created conditions that the chestnuts wouldn't like. Instead of broadcasting calcium and phosphorus and eliminating the chestnut option, a band of calcium phosphate was poured into the bottom of the trench when the asparagus was first planted. Putting the minerals where they were needed and where the asparagus would readily take them up allowed for us to use nearly nine times less calcium phosphate per acre. Also since the high-calcium soil region that we created is in a narrow band immediately beneath the asparagus, the chestnut growth is not inhibited by the excess calcium. Root pruning the chestnut trees (between the trees and the asparagus) every year after they were planted acts to help separate the fields into narrow bands of differentiated soil types. Inputs for the chestnuts (elemental sulfur being the only one used so far) can be drastically reduced as well.

I did not intend for this book to be a treatise on how to amend soils for individual crops, and hopefully this small section on soil minerals has not frightened anybody into thinking that instead of amending soils by the field we're now going to be doing it in foot-wide strips. This section is merely intended to reinforce some of what is important — and that is to know the mineral balance of your soil. With restoration agriculture we are no longer talking about managing single crops (monocrops) in isolation. We are managing systems of crops grown in association with one another.

The knowledge gained from a soil test will help you make your decisions about what species and varieties of plants to use and the soil test will help you to decide which and how many amendments to use on your alley crops (which are essential for cash flow in the early years). When in doubt, imitate nature. Look around you and identify the plants that are thriving near you. Identify the perennial plants, observe how they grow in relation with one another, then imitate what you observe using selected, productive variants of the wild plants.

Recently I was working with a farmer who has been establishing a silvopasture system for the past five years using cattle and sheep as the livestock. I was hired as a consultant to help with some problems that he was having with the system. He was having a terrible time keeping oaks and chestnuts alive on this site. It was an incredibly rocky, excessively well-drained site that could barely keep grass alive, and the crushed rocks beneath our feet could hardly qualify as soil. Many of the oak trees that had originally existed on the site were also struggling. Disease was devouring them and borers were tunneling beneath the bark and girdling them before they could reach a mature and economically useful size.

The farmer was unable to get chestnuts established on the site presumably because the trees lacked adequate water during their establishment year. The farmer was not able to irrigate them due to the fact that he had planted them on a remote site that was inaccessible, even to a trailer-mounted water tank. His other problem was his inability to control an invasion of shagbark hickory. The sheep wouldn't eat them and they were taking over the places that he had reserved in his mind for oaks and chestnuts. He wanted to know what soil amendments he could use to encourage the survival of his chestnuts and get better health in his oaks. He was also looking for advice on how to poison or effectively remove the hickories. My reply was to point out the following, "Why is it, that so much of what we are taught in agriculture is how to kill stuff that wants to live and how do we keep this stuff alive that wants to die?" When in doubt, follow nature's lead. On that particular site hickory, an incredibly delicious edible nut, wanted to live. Rather than fight against hickory at great expense while struggling to get oak and chestnut to live, a far more efficient use of our time, energy and inputs would probably be *helping* the hickory and learning how to work with it in the system.

Once the land has been shaped to optimize its relationship with water, moisture will be available to grow plants. Soil testing and correcting any major mineral imbalances will allow those plants to thrive, and the system starts to hum. Thriving plants put down more root mass and exude more sugars into the soil. Minerals are brought up from deep in the soils to be deposited on the surface as leaves and stems are shed and decomposed. Leaves, stems, roots and sugars are all carbon compounds. The carbon in plants came from the atmosphere. Photosynthesis is an incredibly miraculous process. Radiant energy from the sun is transformed into molecular bonds between carbon molecules and stored as carbon compounds. This energy is the very basis of the soil food web and is the energy that drives all of the fertility of the site.

What I have described in this chapter so far are two of the three primary control mechanisms that a farmer has in order to steer a restoration agriculture farm. The first is the physical or mechanical properties of the soil. These are manipulated during the land-shaping process, during root pruning and keyline subsoiling, and to a lesser extent (in a perennial system) by tillage. Tight soil can be loosened by the mechanical action of a subsoiler. Air can be introduced by various techniques including using a subsoiler, disc harrow, cultivators and plows, and suitable seedbeds can be created with disc harrows, tillers and spading machines. As the physical/mechanical properties of the soil change through the years, different strategies can be employed to manipulate it to make conditions more favorable for the crops. My favorite soil manipulation technique is to do absolutely nothing at all, although I regularly root prune between rows of perennials and the alley crop between them, which serves to lift and loosen the soil in addition to admitting air and water deep into the root zone. I also will till lightly with a disc harrow or rotovator when rejuvenating pasture or establishing legume cover crops.

The second control at a farmer's disposal is the chemical/mineral one. Soil tests will show what minerals are actually present and in which proportions to one another. Some research will reveal what the preferred soil chemistry is for each crop in question. Using the research data and the levels revealed by a soil test, a restoration agriculture farmer can decide to add various minerals to the soil. At New Forest Farm calcium phosphate has been applied to address a phosphorus deficiency and balance the calcium-magnesium ratio, which was previously mentioned. Elemental sulfur has been added to create a slightly more acidic soil and to assist with protein synthesis in the chestnut rows. Various trace minerals such as selenium, zinc and boron have been regularly added to make up for their deficiencies. One way these minerals can be applied to a restoration agriculture farm is through the agency of livestock. Cattle, hogs and chickens can all be given free-choice access to the minerals that are shown by a soil test to be deficient. The livestock will consume the minerals, their systems will use what they need, and the remainder will be excreted in their manure in a package of nitrogen fertilizer that just so happens to be loaded with acids, enzymes and digestive bacteria and fungus.

This leads us, of course, to the third major control — biological activity. The life *in* the soil is as important, and sometimes even more important, than the life above the soil. Soil organisms, from the microscopic to the macroscopic, are what cycle and recycle the mineral elements available to plants.

As previously mentioned, soil organism bodies serve as a reservoir of water, and in the same way they act as a reserve of soil minerals. This is especially important with minerals that leach readily from the soil such as boron and sulfur. If you are purchasing and applying mineral amendments to the soil, you don't want to merely toss this money downstream into your creek. Leaching of soil nutrients is potentially even more possible on properties that have set up keyline water management systems since more water will be soaking into the soil rather than running away. One of the possible reasons why this has not yet been observed in keyline systems is that with a more even distribution of water and additional air in the soil, the soil life thrives and incorporates the additional water and nutrients into the bodies of additional billions of fungi, bacteria, nematodes, springtails, earthworms and more.

If we merely address the physical/mechanical qualities of the soil this will change the types and quantities of life in the soil. If we merely address the chemical/mineral composition of the soil this will affect the life in the soil as well. Changing the soil biology itself through the additions of composts, teas and microorganisms will likewise affect the chemical/mineral composition of the soil as well as the physical/mechanical nature of it. These three means of taking control all affect one another synergistically.

The simplest way to affect the life in the soil of a restoration agriculture farm is to do nothing. As a farmer changes practices from annual cropping to perennial cropping to an eventual three-dimensional agricultural savanna, the soil life itself will change through the years. The soils in annual crop fields and the soils in pastures and grasslands are dominated primarily by bacteria. Forest soils, on the other hand, are dominated by fungi. The successional shift from bacteria-dominated soils to fungi-dominated soils in nature may take hundreds, and in some cases thousands, of years to occur. This change would have happened naturally with the populations of soil organisms shifting as their food sources changed. So, in the same way that the above-ground systems undergo successional change, so does the soil life.

In nature exposed soil gets colonized by fast-growing annual plants which gradually make way for the biennials and perennial grasses. These in turn are replaced by coarse, woody perennials, which are eventually replaced by pioneer trees and shrubs that are sun-loving and able to compete for water and nutrients in a heavy-sod or grass environment. After a time (which is different for each species in different regions) the sun-loving pioneer trees and shrubs are replaced by mid-successional sun-loving trees and shrubs, which are eventually undergrown and replaced by shade-tolerant trees and shrubs. Late-successional trees such as sugar maple are simply *not* happy when planted in a bacterially dominated cornfield. Some shade-tolerant conifers, such as the eastern hemlock will almost refuse to grow unless their roots are living in decaying wood with a network of the proper soil fungi.

You can follow the time-tested path of the natural successional change, but you would be prudent to begin the transition by using early successional plants such as raspberry and hazelnut. Spores of fungi are free-floating in the air and will eventually show up on their own and will begin to reproduce and thrive on a site as the conditions change and allow them to do so. This process can be accelerated, though, and many restoration agriculture farmers choose this route.

When planting perennial woody crops, commercially available mycorrhizal (a symbiotic association between a fungus and plant roots) fungi spores can be used as a pre-planting root-dip or can be applied annually as a liquid soil spray. If you want to follow a more natural and cost-effective path, you can simply go to a nearby patch of the trees in question, and gather up some of the soil beneath them, and make a compost tea with this soil in order to spread suitable soil life onto the perennial polyculture crops.

Instead of merely making liquid life brews, you can also choose to make full-blown custom composts to incorporate into the original soil around your new crops. If you are establishing an agricultural oak savanna mimic, you can gather leaves (with permission) from beneath the oak trees in a park or from the curb in a nearby town and then inoculate them with some soil taken from beneath oak trees in an oak forest. The same could be done for overstory trees of different species. Walnut compost can be made to help establish walnuts, maple compost for new maples, and pine compost for new pines, etc.

Another way to affect the soil life in a new planting is to use organic mulches. Wood chips, sawdust, old hay and corn stover are all readily available mulch materials in farm country and all will effectively change the soil life while simultaneously conserving moisture and smothering competing weeds. Some care should be taken if using organic mulches, since a soft, fluffy mulch will provide a nice nesting habitat for mice and voles that like to girdle the bark of young trees and shrubs. Spiral plastic tree guards can be placed on each young tree for several years until the trees are firmly established and their bark becomes tough enough to resist the chewing action of mice.

Care should be taken if you are obtaining free mulch that is often available from tree service companies who clear brush, do timber stand improvement, and invasive species control. These companies are very often more than happy to supply landowners with tons of chipped brush, but this could prove to be a curse in disguise. It may have been that the tree service company was clearing out an area that was colonized by multiflora roses, tatarian honeysuckles, European buckthorn, or tree of heaven (Ailanthus) and the seeds of these aggressively growing, opportunistic plants may cause you management challenges for a lifetime.

As these organic mulches decompose, a soil life more suitable for woody plants will be created sooner than they would naturally have developed.

Mulches *do* represent quite an up-front investment in materials and labor. Rarely is mulch an option on larger plantings of several acres or more. Plastic and rolled paper mulches can be mechanically installed while planting a new system, but some plants, such as hazelnuts, don't appear to like the hot environment created by plastic or geotextile mulches, and the mulches themselves are persistent and represent a disposal challenge in later years. Some spun-polyethylene landscape fabric mulches, although they allow plants to root down through them over the years, can actually girdle trees as they grow and attempt to stretch open the original hole cut for them in the mulch. Shredded plastic ten years from now may be something that you choose to deal with in exchange for weed control and a slower soil life change in the early years, but it is not necessary.

It is probably becoming fairly obvious that I am talking about dynamic and complex systems instead of individual crops. Rather than planting a single species of an annual plant, such as a field of corn, I am talking about planting a fairly wide range of perennial plants in a diversified system. I no longer treat the soil as a uniform medium to which I apply water-soluble forms of nitrogen, phosphorus and potassium, so-called fertilizers.

Your soil properties will be physically and mechanically different in the establishment years than it will be ten or twenty years down the road from establishment. The chemical/mineral composition of the soil will also be different as will the soil life. Although these systems can be complex, they are not complicated.

Through the eons nature has figured out how to solve the problem of survival on planet Earth. Plant and animal systems survive everywhere on this planet. All that we have to do is to learn *what* survives where we live, how it does that, and then imitate those patterns.

In addition to complex cropping systems and complex soil management, growing our staple food crops and livestock in perennial agricultural ecosystems presents different complexities when it comes to pests and diseases. In order to understand the principles behind pest and disease control in complex systems it may be helpful to simplify it at first and gain a little foundational understanding of how population ecology works.

Imagine an orange sitting out on your kitchen table. It represents a food source for something. It can be your food, if you eat it in time, or the food for what we commonly refer to as spoilage organisms should you not get around to eating that orange in a timely manner. The orange sitting on the table is analogous to a monocrop of something out in a large field. When you place an orange on the table all by itself organisms that consume an orange will eventually find it. Decay may set in first as a slightly discolored, sunken soft spot, or it might appear as blue mold. The organisms that are attracted to the orange are the ones that consume oranges. You usually won't find a dog or a cat eating your orange. You'll only find organisms that like eating oranges. Likewise in a cornfield. If you plant only corn expect to find pests and diseases that thrive on corn. A large acreage of corn provides ideal conditions for corn pests and diseases to thrive. Isn't this obvious? There is plenty of corn to support large populations of corn pests and corn diseases and their populations can run wild and they do. Monocrops of anything attract the pests and diseases that infect those crops from annuals like soybeans to perennials such as apples. Whether grown using agricultural chemicals or under certified-organic management, a monocrop of anything provides the ultimate habitat for the pests and diseases of that particular crop.

Back to our orange example that is beginning to mold. You could choose to spray that orange with a mold inhibitor and you might just see rather rapid results with the mold appearing to be gone. However, it will be back. You will have to spray the moldy orange over and over again in futile efforts to keep it mold-free. There is no way to truly prevent the mold from colonizing the orange.

In the same way there is no way to prevent the spread of pests and diseases in monocropped agricultural systems. These pests and diseases exist on this planet and they will not go away. As we rely more and more on monocropped fields of staple food crops we will only increase the populations of the pests and diseases that affect them. As sprays of either chemical or organic controls for those pests and diseases are used we will only kill the subjects that are susceptible to our sprays. The only pests and diseases that survive are the ones that are resistant to our sprays. By growing monocrops we favor the proliferation of the pests and diseases of those crops, and by spraying to eradicate those pests and diseases we only create more resistant pests and diseases. This is an unwinnable fight. We will never be able to eradicate the pests and diseases of our agricultural crops. Now, back to our orange …

Looking at this orange on the table, the first thing that will colonize it are the organisms that eat oranges — the blue molds *(Penicillium italicum)*. If we do *nothing* to eradicate that first blue mold, the first thing that we will notice is that the blue mold proliferates. The mold populations are growing at an explosive rate. It appears to be attempting to colonize the entire orange. Eventually, another organism will move in. Pretty soon the populations of one type of mold bump into the other and a boundary condition is created where neither of the two have the upper hand. As the populations of the two or three or however many happen to eventually colonize the orange skin expand, pretty soon there is no more easily captured territory. As the landscape gets crowded, the growth of the individual populations begin to slow down. At this point, there is also now a wider diversity of foods available. In addition to some orange skin still remaining there now exist large populations of orange flesh-eating mold which itself is food for some other type of organism.

Beneficial insects is a term that is commonly used to describe the organisms that are beneficial and eat or infect crop pests. Large industries exist with stainless-steel rooms, sterile growing systems, and laser-guided robots where they produce large numbers of beneficial insects and diseases. Everything from Bt *(Bacillus thuringiensis)* to green lacewings and trichogramma wasps are available for purchase to release into your crops in order to control the destructive pest or disease.

Secondary infections, organisms that eat the mold that eats the orange skin, will only show up when there is enough mold to supply that organism with enough food to grow and reproduce. Likewise, beneficial insects and secondary pest diseases will only show up in our crop fields when there are enough pests to feed them. In annual monocrops an initial infestation of a pest or disease can be catastrophic for a farmer. The blue mold on the orange can rapidly colonize the entire fruit and eventually the orange can be lost. There are no organisms that can do battle with the blue mold and populations of the organisms that consume blue mold cannot grow fast enough to control the blue mold before the entire orange is lost. The same can hold true for a monocrop of corn or apples in a predominantly apple orchard.

However, in a long-term, perennial system, rarely is the entire crop lost. In a long-term perennial system, since we are imitating natural systems and attempting to work in harmony *with* ecological laws, there are several ecological realities that kick in to help us to deal with pests and diseases. The first, of course, is diversity. Restoration agriculture systems by design have a wide range of crop plants and numerous different types of livestock. If this year happens to be a year that is climatologically conducive to fire blight, the bacterial disease that attacks apples, perhaps it will also be a year that is extremely favorable for a strong asparagus crop. Conditions that suit destructive pests and diseases affecting one crop might be conditions that are beneficial for other crops. Even if fire blight finds a toe-hold in one apple tree, the conditions might not exist for that bacteria to spread. In an orchard made up exclusively of apples, fire blight can spread like the fire that it is named after because it finds nothing but apples around it. Corn borer populations can also grow explosively because the female moths find a buffet table of nothing but corn plant after corn plant in very close proximity to one another.

The deep diversity in a restoration agriculture planting ensures that no one pest or no one disease will wipe out the entire crop. One season cucumber beetles may cause a 50 percent crop loss in the squash, but apples and chestnuts and cattle might yield average crops, and perhaps the poultry will do better than usual due to higher insect populations. This is one way that restoration agriculture systems limit pest "problems."

Another way that these systems are more resilient in the face of pests and diseases is through the process of population ecology itself. As previously mentioned pests or diseases are most often sprayed with chemicals or organic products in order to directly eliminate the pest or disease. Beneficial organisms can also be applied in various different ways. Even in certified-organic systems releases of beneficial organisms rarely establish permanent populations of those organisms and the grower is stuck on the same treadmill as a chemical farmer. Instead of having to buy chemical inputs over and over, they have to continually purchase the beneficials from the manufacturer. The organic grower gets stuck purchasing predatory or parasitic insects and the chemical farmer gets stuck purchasing insecticides. Without enough pests to eat, however, the predatory insects don't have enough food in order to sustain their populations, and without adequate nesting sites and alternative food sources, their populations dwindle. This knowledge has led to the establishment of habitat islands within and around organic production areas to provide the beneficials with a refuge where they can hopefully take hold. A restoration agriculture system, on the other hand, doesn't really need habitat islands, simply because it *is* a habitat island. A restoration agriculture system has a wide diversity of perennial plants providing multitudes of microclimates and habitats for beneficial insects, amphibians, insect-eating birds, and more. A deeply diverse system is actually a hostile environment to individual destructive pest organisms.

Before moving on, however, I have to restate this concept in another way so that its full impact can be seen: In order to have populations of predatory insects (and amphibians and birds) you must have a high enough population of the pest in order to feed them. In order to have enough blue mold-eating fungus on an orange you have to have enough blue mold to feed that fungus. In order to build populations of cucumber beetle-eating creatures and in order to build up high enough levels of cucumber beetle diseases you have to have high enough populations of cucumber beetles in order to feed them. In order to have pest and disease control you have to have enough pests and diseases to feed the control organisms. This means no killing sprays. If you spray for corn borer you will never be able to feed a population of hungry corn borer-eating creatures and you will never have enough corn borers to build up corn borer disease populations. In order to create a sustainable natural pest control environment you've got to let the pests and diseases run wild. If you spray organic sprays to control pests in your system, you will never have enough pests to feed the beneficials.

With no more killing sprays, eventually a balance will be discovered. At first the pest populations will begin to boom, which actually may indeed be economically distressing at first, but then through the years the control mechanisms will come into play and eventually a balance is reached. There must be enough of the pest or disease present in order to feed the organisms that eat that pest or disease.

Many people don't believe that this can happen, but it is true. Even among organic growers, who are used to using less toxic and biodegradable insecticides, some don't realize that the very pest control that they are using is defeating the purpose of long-term, balanced pest control. This can be shown the most clearly using amphibians as an example. Tree frogs, toads, and many other amphibians thrive in restoration agriculture systems. They are provided with hiding spaces, egg-laying sites and, when un-sprayed, plenty of insects to eat. If a grower sprays a pest control product, not only does that pest control product deprive amphibians of food it also poisons them directly. Amphibians derive over 50 percent of their oxygen directly through their skin. In all cases their skin is thin and moist. Any toxin applied in liquid form goes directly through their skin. One very common organically approved pest control spray is the botanical insecticide, Ryania (Ryanicide). Ryania, as well as rotenone and pyrethrum, is an all-natural, plant-derived poison. The most prevalent active ingredient in it doesn't always kill insects, but is debilitating enough to the pests that they stop feeding and starve to death.

By spraying a biological insect control spray, farmers are also controlling the amphibian population. Toads that have been sprayed with Ryania, even at tiny doses, absorb the poisonous alkaloid directly through their skin, which can cause every affected cell to rapidly flush out calcium which leads to massive fatal muscular contractions. By spraying to control insects you effectively eliminate your natural pest control posse by starving the beneficials (like tree frogs) or killing them outright.

When you spray to control pests and diseases you are actually actively breeding pests and diseases that will be immune to your sprays so you have to use more frequent, stronger products, or invent and discover new ones to use. Instead of breeding more resistant pests and diseases, shouldn't we be breeding more pest- and disease-resistant crops? Also, how can we tell if our plants (and animals) are naturally pest- and disease-resistant if we keep attempting to eliminate pests and diseases?

In the natural world outside of our realm of tightly controlled agriculture, if a plant is lethally susceptible to a disease, it does not reproduce. Its disease susceptibility genes are not transmitted to the next generation, and that particular variant disappears. If a plant is strongly resistant to a disease, the genes that confer that resistance are readily passed along into future generations, and a future of disease-resistant plants is assured. Let's take a look at two quick examples to show

how this works.

The McIntosh apple (the food, not the computer product) is the fruit of what was a wild apple seedling discovered by John McIntosh in 1796 on land that he was clearing in order to establish a farm near Morrisburg, Ontario, Canada. The seedling was transplanted, and then when big enough, twigs were grafted onto other apple roots. Now after millions of trees have been propagated, every Mac that you eat today is grown on branches that were originally from that one tree.

Before John McIntosh began to clear his land, apples had been established in the wild and each generation of wild apple trees grew up within a context of pest and disease pressure and within a complex, wild system. The traits that caught McIntosh's attention may have been large fruit size and zesty flavor, and probably a certain degree of natural pest and disease resistance. The latter can only be guessed at, but it is probably quite likely that the tree and its fruit showed natural pest and disease resistance simply because back in those days there were no pest- or disease-controlling sprays in use. An apple had to show inherent resistance or it was not commonly used.

It's time to bring the apple back into the natural stream of evolution of life on this planet and to discover the genetic variants that are resistant to pests and diseases.

Since its discovery, the McIntosh apple has been planted on literally millions of acres across the globe and in those two hundred years apple growing has changed considerably — and so has life on this planet. By the early 20th century apple growers were beginning to use lead arsenate to eliminate most pests in the orchard, and since then an entire industry of poisonous chemistry has arisen around the cultivation of apples. Every generation of pest or disease control poison does indeed eliminate a great deal of pest pressure in the orchard and helps to create that picture-perfect fruit that you find in the grocery store. However, what has happened out in the orchard is quite sinister. Aside from the obvious toxicity of the chemicals in use, the biological changes in life itself are extreme. Only the apple pests and diseases that showed genetic resistance to lead and arsenic were able to survive and pass their resistance genes on to their offspring. The same is true for the pesticides Imidan, Malathion, Methoxychlor, Sevin, Captan, Benlate and one hundred years of chemical warfare waged against insects, fungus and bacteria. Let's face it, we've lost the war and will always continue to lose the war. Every time we invent a new poison to kill pests and diseases, the ones that survive are resistant to our attack and resume their peaceful lives of consuming our crops.

Once again, our cultural practices have created super bugs, while the McIntosh apple has not genetically changed in 200 years — it has no more "tricks" up its woody sleeve.

It's time to discover new varieties. It's time to bring the apple back into the natural stream of the evolution of life on this planet and to discover the genetic variants that are resistant to pests and diseases. In order to find out if a particular wild apple seedling is resistant to pests and diseases, there have to be enough pests and diseases present in your planting in order to properly infect your trees. If your particular apple tree gets infested and dies, then it is not the variant that you're looking for. It's really quite simple to generate new varieties. Simply produce more plants from seed and let the losers die out.

Another example of the connection between our cultural practices and the fate of a plant is the connection between the American chestnut and chestnut blight. The American chestnut was perhaps the most dominant tree in the eastern half of the United States until the early 1900s when a blight, introduced from China, began to ravage them. Many states tried different strategies to control the spread of the blight, but none of them succeeded. Probably the most ridiculous strategy employed was the outright removal of all trees, promoted in part by an eager timber industry always on the lookout for inexpensive raw material. Beginning in Pennsylvania and spreading as fast as the blight travelled from there, a wholesale eradication of the American chestnut was begun. The reasoning was to cut down all existing chestnut trees to prevent the spread of the blight. No thought was given to population ecology and little to no institutional effort was applied toward finding genetically resistant variants. Perhaps several dozen different genetic mechanisms existed among the billions of chestnuts growing in the wild that would confer resistance to the blight, but we will never know of them now. The American chestnut was wiped out as much by people as it was by a disease.

To many people this entire chapter may seem like a doctrine of heresy. Yes, I do indeed propose that we grow woody crops in deeply diverse polycultures rather than in fossil fuel-controlled orchards. I also do claim that trees actually can and do grow in less-than-perfect soil. I do claim that soil is comprised of a multitude of (little understood) life forms in addition to being a medium to hold the plants upright. I do also propose that as a species human beings once again reconnect with the reality of planet Earth and adapt our agricultural production practices to nature, rather than forcing nature to bend to our intellectual concepts. Humans must continue to be aware in our own lives of the difference between an observation and our intellectual concepts, and when to discard concepts that are no longer helpful and might be downright destructive. Nowhere is this more important than when it comes to the breeding of our food plants and animals.

CHAPTER 16

Plant & Animal Breeding

IN no way shape or form would any self-respecting Ph.D. geneticist claim that I'm a plant breeder. I have a smattering of college-level biology and genetics under my academic belt and twenty years of continuing education and field experience. No self-respecting plant geneticist would call the Native American tribes plant breeders either, according to the modern definition of the word. But it is these same Native American tribes and villages that selected the plants that have become mainstays in the human diet: tomatoes, peppers, eggplant, squash, pumpkins, potatoes, and the modern-day king of industrial-scale agriculture — corn. Somehow these uneducated hunter-gatherers bred the plants that supply much of the world's food today. No self-respecting geneticist would call Luther Burbank a plant breeder either, yet he is the individual who is credited for creating more individual plant varieties than any other person in history. Once again we have to be aware of what is an observation and what is a concept. A plant breeder is a concept. It is an intellectual construct that is currently defined and defended by a small elite cadre of people who like to cloak themselves in the garb of professionalism. As a highly educated clique they hold fast to their concept in order to continue to garner high salaries and so that they don't lose control, which in today's world means loss of sales for the companies that employ them or royalties to the university that they serve.

We are led to believe by these experts that plant breeding is mysterious, arcane and quite difficult and can only take place in ivory towers, sterile greenhouses and laboratories. These are all concepts *about* reality and are not actually reality itself. These are all ideas that keep them and their companies in charge of our food supplies and keep us subservient to the system that keeps them in power.

Once upon a time everybody who grew anything saved their own seed. If you didn't you would trade some of your seed with somebody else who had what you were looking for. Plants were grown in "actual reality," in that there were no toxic pesticides, herbicides and fungicides. This meant that plants had to have a certain degree of natural resistance to pests, diseases, drought and fungus or they wouldn't survive to set seed. It was really quite a simple thing to save seed. The plants that looked like they were supposed to, performed the way you wanted them to, and were pest- and disease-resistant were allowed to set seed and that seed was replanted for the next generation. Simple enough.

This wasn't entirely *quite* enough, though, and for more reasons than we have space to explore in this book. One problem with small-scale seed-saving is the loss of hidden genetic traits over time. The amount of DNA (deoxyribonucleic acid, the genetic "code") within a seed is actually quite large. Segments of DNA are the instructional code for a cell to manufacture proteins and enzymes. If you plant a seed, it is quite possible that in its lifetime that plant will not make all of the proteins or enzymes for which it has instructions. Some sections of DNA only manufacture their particular proteins and enzymes when certain environmental conditions occur. These silent sections of DNA may actually be very important sections of code that confer resistance to a disease, perhaps, or help a plant to survive drought stress. When planting small lots of seed (and small is relative as each plant species is different) it is entirely possible that extremely important traits are lost because seed was saved from plants that did not express that particular gene and the seed saver never knew it was (or wasn't) there. It is the losing of traits and gaining of traits that make plant breeding the thrilling work that it is. Consequently, in part because it was possible to lose important traits, plant breeding done by growers was eventually relinquished to well-funded professionals. Over time many traditional varieties degenerated as newer varieties performed better.

A more significant reason why plant breeding migrated toward bureaucracy was the uniformity of the crop. In a world that was becoming more and more urban and where more and more people bought their food from grocery stores instead of growing their own, standardization of farm products became the rule rather than the exception. A customer looking to buy an acorn squash would have certain expectations of what an acorn squash looked like and tasted like and would not necessarily want something that didn't meet their expectations. Variability is more of the rule in nature than uniformity, and uniformity needs to be constantly enforced or else the plant varieties eventually will revert back to their original forms (as commonly described). Plant breeding is an essential skill and every farmer and gardener should at least have a little plant breeding knowledge.

It is at this point in the discussion when most other farming and gardening books would begin to go into a treatise about the history of the field of genetics, Gregor Mendel, pink and white petunias, wrinkled and smooth peas, zygotes and alleles … but not here. The details of how characteristics are inherited are a subject worthy of study, but aren't really necessary for a restoration agriculture farmer. The aforementioned Native Americans and Luther Burbank all did their plant breeding wizardry before chromosomes and DNA had even been discovered. There was no way for Hopi elders to learn college-level genetics back in 2000 BCE, yet they bred a wide range of food crops. Luther Burbank had no more than an elementary school education, yet he bred nearly 800 different plant varieties, the most famous of which is probably the Russet Burbank potato, which is the primary variety used in McDonald's French fries today. Even in his day, Burbank (1849-1926) was ridiculed by "real" scientists and plant breeders because he kept very few notes, engaged in very little research, and was not very "scientific" in his process. Like a farmer, Burbank was results-oriented. And like the restoration agriculture farmer he was interested in observable reality instead of conceptual ideas or scientific theory. Where Luther Burbank, visual observations, tangible concepts and restoration agriculture intersect is a place that is very familiar to most people.

Beginning around the sixth grade in school we were taught a rudimentary knowledge about plants and genetics in science class. We were told that it is the separation of the sexes in plants that is the basis of all variation in life forms and that if you save the seeds from a plant, the resulting offspring will look quite different than the parent plants. This is actually an observable phenomenon that is more noticeable in some plants than in others. It is not very noticeable in many heirloom plants that have been open-pollinated and selected through the generations.

One of the things that we were told is to not bother saving seed from an apple. The resulting tree will vary greatly from the parent tree and will not bear fruit like the parent. In fact, the variability in apple seedlings is so great that you might have to plant up to 1,000 seeds before you get one decent apple variety. Here is where we need to be aware of the difference between an observation and a concept. It may just well be that it would take 1,000 apple seeds in order to come up with one good variety worth planting. This is possibly an observation. (The very first apple that I ever grew from seed actually produced fantastically delicious apples.) We could test this observation by planting 1,000 seeds and seeing how many good apple varieties come out of that planting. If 1,000 is the number, then *that* is observable by anyone who bothers to do the test. It is as real as reality gets in this world.

However, the idea that since the seedlings don't all produce the desired outcome "therefore you shouldn't save and plant your apple seeds" is merely a concept. This is an idea that is linked to the observation, but it is only weakly linked and it is a terribly disempowering idea. Having been told since we were young that "it would take 1,000 seeds to get one good apple variety, so therefore don't bother to plant your apple seeds," the result is that most of us have *not* planted apple seeds. What if we took the same observation, however, and just changed the concept — just changed the idea? What kind of a different world would we have today? What if we stick with the original observation that you have to sort through the offspring of 1,000 apple seeds in order to find one good variety, and then ask the question, "How many apple seeds do you need to plant in order to create five (or fifteen or a hundred) new varieties?" If we were taught beginning in the sixth grade that it takes 1,000 apple seeds to discover one good variety, and then this was followed up with masses of school children planting their lunchtime apple seeds in re-purposed empty milk cartons, perhaps by the time those sixth grader's graduated from high school we would have one new apple variety per school system. Multiply that by the power of the tens of thousands of schools in the temperate zones and you would have literally hundreds of thousands of new apple varieties within ten years and a continuous supply of new varieties arriving annually forever. Our concept has crippled our reality, and we live in an impoverished world because of it.

But, you may be asking yourself, how will we know if those apple varieties are any good? The school children aren't plant breeders. The trees aren't produced through controlled crosses of genetically known parents and they're not being grown in side-by-side variety trials at some gleaming university. How will we know if these plants are any good?

Simple. We can evaluate the plants using the same tools that Luther Burbank, the Native Americans, and all of our ancestors used going back into the faded past — we use our senses. We observe and we select the varieties that have the characteristics that we find preferable. If some day in the future our descendants decide for their own reasons that the food plants that we bred aren't any good (much in the same way that I don't like the McIntosh apple and don't grow it), then so be it. Conditions will be different in the future and the people of that time will be growing plants in different conditions than we are right now.

When Luther Burbank created the Russet potato, it was more like he discovered it, than bred it. Burbank was looking for a potato that was highly productive and one that was resistant to late blight, the fungal disease that caused the great potato famine in Ireland. Like most apples, potatoes are vegetatively propagated when quantities and the same qualities are needed. Pieces of the parent plant tuber are planted in the ground and a clone of the original plant springs up from that severed part. In edible woody crops like our McIntosh apple, pieces of the parent plant are grafted onto another root. With both the apple and the potato the edible portion is grown on a plant that is genetically identical to the first plant — John McIntosh's Ontario tree and Luther Burbank's plant. But that is *not* where McIntosh or Burbank got their original plants. In both cases, they got their original plant from seed. Pollen from one variety fertilized the ovum of another and a genetically unique individual plant was created. This is the source of all natural variation and where we must return in order to create new food plants for the future. If John McIntosh ever wrote down *why* he selected our present-day McIntosh apple from all the seedlings on his farm, the reasons are lost to time.

Luther Burbank, however, *did* write down why he saved seed from a potato to discover the Russet Burbank. Luther Burbank was intending to roll the genetic dice and come up with a combination of traits that would resist blight. This didn't happen in a sterile laboratory where he hand-pollinated one parent potato flower with another. It happened in the wild outdoors, most likely by insect, and according to some people, happening completely by chance. Since his potatoes were grown outdoors, they were subjected to the pest and disease pressures of their day. If his plants were susceptible to late blight, they likely would have died and would not have been propagated further. The plants that would eventually become the Russet Burbank (it took several generations of failures to get there) produced two to three times more tubers per plant than any others in his garden plot. Did every potato that he grew from seed become a new French fry variety? Of course not. One out of an unknown number of dozens of plants showed the desired traits of productivity and disease resistance, and he used that plant to breed more.

The Burbank Russet potato is the result of thousands of potato seeds grown by Luther Burbank and it happens to be the one miraculous genetic variant that tolerates late blight and is extremely productive.

If we begin to generate new plant varieties within our school systems, in our backyards, and on our farms, we will have to use a plant breeding technique that was once called "Burbanking" and now called mass selection.

Mass selection is the plant breeding workhorse technique used outside of the laboratory. Mass selection is the physical outworking of the fact that it might take 1,000 apple seeds to get one good variety. If it takes that many seeds to get one good variety, then we plant that many seeds. In most cases we will actually plant more. One thousand apple seeds or chestnut seeds or hickory seeds or whatever seeds you choose do not take up very much space. A nursery bed that holds 1,000 tree seedlings can be as small as 4 feet by 8 feet. The seeds are planted closely together and allowed to grow with my trademarked STUN growing technique. STUN, once again, is the acronym for the growing technique of sheer, total, utter neglect. Why use utter neglect? We do this because we are rolling the genetic dice and looking to roll a Yahtzee. In this dice game, five dice are rolled and the best roll — five of any kind of the same number — constitutes a Yahtzee.

In a typical commercial orchard with grafted clones of the same plant far fewer stems per acre are used. With chestnuts, for example, it is recommended that you plant Chinese chestnut trees 30 feet apart which gives a plant density of only 48 trees per acre. The reasoning given is that in twenty years, when the trees are large, they'll need all of that room so that each individual plant can produce its maximum number of nuts. In a restoration agriculture system where total system yield is the goal and not total individual crop yield, planting 48 chestnut trees per acre is like playing Yahtzee with only three dice. You can never roll five of a kind in one roll if you're only using three dice.

Another concept that I would like to mention that can trip us up is the belief that "trees take too long to begin to bear fruit" (or nuts, or cones, or…). Some indeed *do* take a long time to begin to yield. As humans, we might get lucky enough to be physically fit for seventy to ninety years, but I don't have enough time to wait around for a tree to begin bearing in fifty years. As a farmer growing food, I need to have plants that will bear fruit quickly. In the plant world that trait is called precociousness.

With restoration agriculture systems we have the opportunity to discover new plant varieties — precocious plant varieties — that bear fruit or seed within a few short years. In addition to this, we are discovering plant varieties that are naturally pest- and disease-resistant and varieties that are adapted to our local soil types, rainfall patterns, summertime heat, wintertime cold, variability of climate, and all sorts of other variables. Restoration agriculture farmers are especially looking for plants that have heavy yields of food crops that are delicious and nutritious.

Once, while giving a farm tour at New Forest Farm, I was explaining the basics of mass selection plant breeding to a small crowd that was duly impressed with the abundance of wild profusion that surrounded them. One participant, feeling somewhat overwhelmed at the volume of new information she was receiving and that it was from a radically different perspective, sighed in frustration and exclaimed, "But I can't select new plant varieties. How do I know which ones are any good?" I smiled at the comment, relishing the teaching moment and walked the group into an apparent thicket. Several of the trees were pear trees. All the pears were surrounded by cherries and mulberries, were underplanted with currants, and were being climbed upon by grapes. The pear trees were originally planted from seed. That meant that each tree was a genetically unique individual. It also meant that each one just might be the 999th tree with lousy fruit on it.

In order to get a better roll of the "genetic dice," these seedlings had been grafted with the stems of other pear varieties so that each individual root had up to a half-dozen different variety branches growing on it. We stopped at one pear tree and the lesson began, "Each branch is a genetically unique pear variety." I continued to explain, "On these few trees there are over fifteen different varieties in addition to the original seedling variety." Grafting many varieties to one rootstock is another simple way to practice mass selection on a small piece of land.

I pointed to a branch that had no fruit on it and asked the question, "Would you like to eat the fruit from this branch?"

"There isn't any," was the reply back.

"My point exactly," I said as I pointed to the next branch. The next branch actually did have some fruit on it, but the surface of the fruit was covered with deep cracks that had become encrusted and brown with a disease called scab. "Would you like to eat the fruit from this branch?" I asked.

"No way!" was the quick response.

No way was the response to many of the other branches as well. If there was fruit on the branch, much of it was riddled with disease, and other branches had fruit inhabited by caterpillars. Lastly I pointed to a branch that was bent nearly to the ground and was covered with large, nearly unblemished fruit. "Would you like to eat the fruit from *this* branch?" I asked.

"Of course!" was the answer. It really is that simple. Plant enough genetic variation, don't spray to control pests and diseases, and only the ones that are naturally suited to the site conditions will thrive.

"But what variety is it?" the original questioner about selecting new varieties asked.

"Who cares?" was my reply — which was not intended to be a glib response at all. The name that gets attached to that particular branch doesn't interest me at all. What interests me is that it is extremely productive, it is pest- and disease-resistant, and it requires no inputs from me in order for it to produce this way, and it tastes delicious! Like Luther Burbank, I don't really need to have an extensive notebook full of scientific records when I have a highly productive, pest- and disease-resistant tree growing right on my farm. Burbank didn't need notes. He had the potato.

I know this variety works here because the plant itself stands as testimony for all to see. Besides, if we were to take branches from this tree, give it a fancy name, and graft it onto a pear root at your farm, it might not behave the same way. My soil and rainfall patterns are different than yours. The pest and disease populations are different — in fact the pest and disease populations are probably *higher* here than other places. If a plant can't thrive and bear crops with little or no care, it gets cut down and turned into edible or medicinal mushrooms or it gets made into lumber or wooden toys or firewood. What it is called is somewhat irrelevant.

If the fruit were a Bartlett pear or McIntosh apple (a selection from over two hundred years ago), the orchardist would be spraying to keep pests and diseases from the tree. The pests and diseases would be evolving through time, immersed in actual reality, but the trees wouldn't have evolved. They would always be the variety that they were when they were first selected. The McIntosh apple was discovered in 1796, a time when the planet was radically different from how it is today — hardly any of the conditions are the same now.

Someday the conditions may change and today's outstanding variety may no longer have the ability to resist the newly evolved pests and diseases. At that time I, or whoever else is managing this farm at the time, will look around to see which anonymous varieties are doing well in the new conditions. Those varieties will then be grafted on to the roots where the old variety was cut out.

Restoration agriculture farmers are "Burbankers" extraordinaire. We imitate nature in the species that we plant and we imitate nature's pattern of planting by growing *way* too many seedlings in the early years knowing that there are those that just won't survive.

After a workshop once, an older fellow scolded me for what he said was leading the participants astray by recommending that they plant Korean pines for the pine nuts that they bear. "I planted two Korean pines nearly thirty years ago and those gol-dang things haven't had a single cone yet!" he barked.

"You evidently planted the wrong two." Was my reply.

Plant way too many food-producing trees and shrubs in the early years. Remove the ones that don't bear at a young age. Continue to remove the ones that are susceptible to diseases and that are attacked by pests and continue to plant new seedlings and varieties year after year after year. Let the dynamics of population ecology kick in and let pest and disease populations stabilize. A deeply diverse system will provide habitat for predatory insects, birds, reptiles and amphibians. If a plant wants to die, *let it!* We're not interested in the ones that get diseases. We are not interested in the ones that are unproductive. We are not interested in the ones that require tons of specialty fertilizers manufactured in gleaming factories thousands of mile away. We're interested in the ones that live. We're interested in the ones that live and thrive and reproduce at an early age. We want the ones that are pest- and disease-resistant and need very little care. If a plant wants to live and thrive and reproduce, we will harvest its seeds, its fruit, its leaves or other edible, medicinal or otherwise marketable products. This is the essence of the permaculture principle of working with nature instead of fighting against it. Figure out what is working effortlessly well in perennial polycultural systems and run with it.

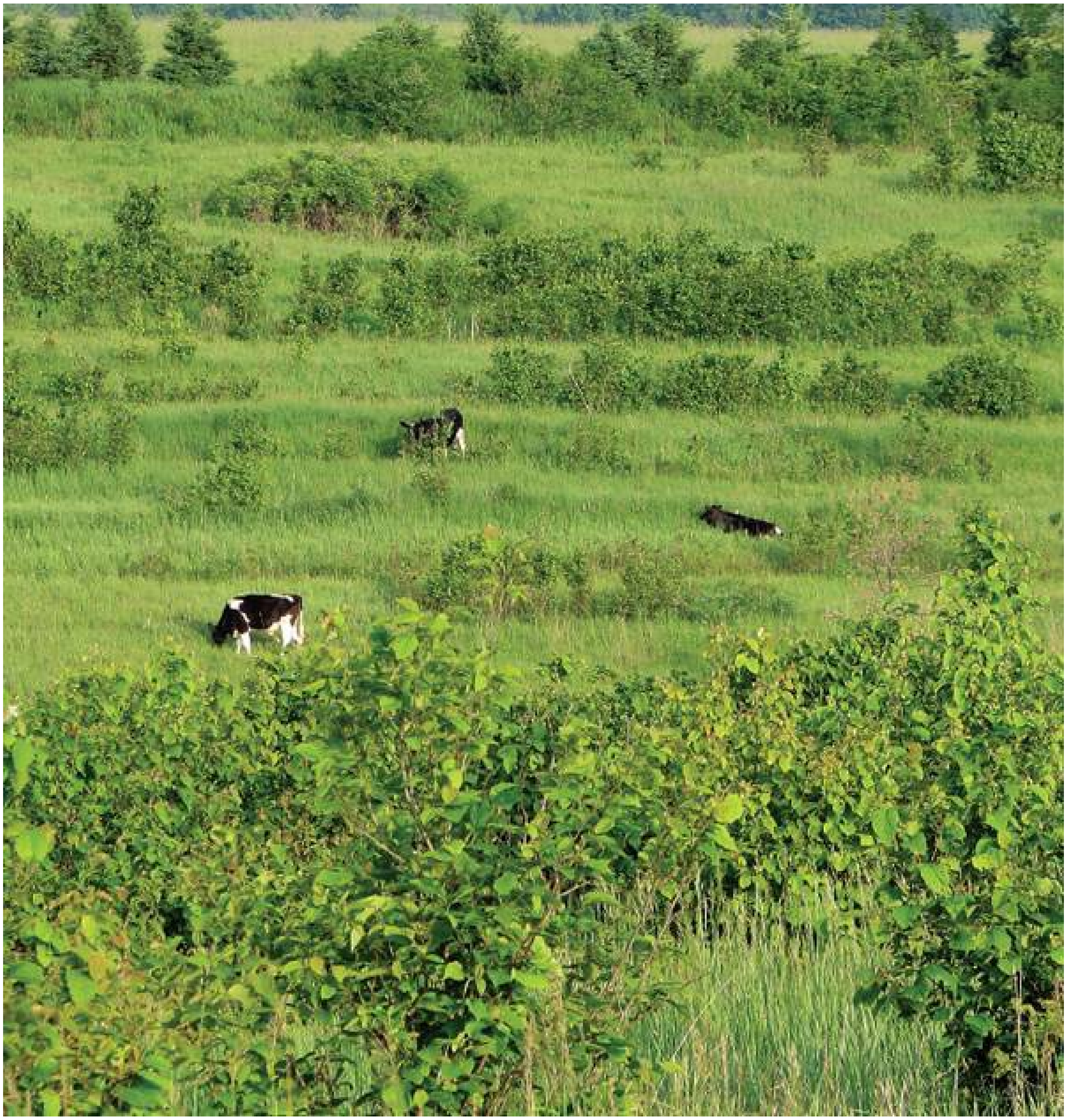
PHOTO TOUR OF

New Forest Farm

Pictured here is an example of how nature creates multiple levels of productivity. Stacked together in a ten-foot-diameter circle are (from tallest to shortest) pine, serviceberry, hazelnut, raspberry, wild rose, lowbush blueberry, wild strawberries and lingonberries. In the middle of the thicket and not visible here are shade-tolerant gooseberries and wood-decomposing fungi. This site is on a bare rock face in northern Minnesota. Natural succession from lichens and mosses to grasses and "brush" have created the soil out of thin air by exuding sugars, sloughing roots, and dropping leaves, needles and stems where they decompose into a thin, young soil.

The author next to the "key" pocket pond in one sub-watershed of the farm. In a part of the country where no brooks, streams or ponds exist for miles, New Forest Farm has breeding populations of seven different kinds of insectivorous amphibians. Note the presence of the uncommon Leptothrix discophora (red color in water), a bacteria that metabolizes iron and releases oxygen. At more advanced stages it produces kaleidoscopic colors.

The same location as above. The purpose of the "key" pocket pond is to provide surge capacity for the system during heavy rain events and to act as the distribution point from where the water is redirected toward the ridges. On all soils rainfall at rates that are faster than the soil's ability to absorb it begins to sheet and flow. The pocket ponds, swales and berms of a Keyline system intercept this flow, slow it down, and spread the water toward the ridges. In this photo excess rainfall would travel straight down the grassy waterway, pick up speed, drop 100 feet in elevation, and leave the farm within 600 linear feet. Because of the keyline system, that same water flow is spread out toward the ridges (to the left and right of the pocket pond) where it travels 1,200 linear feet and only drops 12 feet in elevation. The water stays on the farm and soaks into the soil.



A silvopasture system is an intentional combination of forage and trees with livestock. Repeated university research shows that with proper management, forage yields increase, forage digestibility improves, and animals gain faster at lower costs. Here, Holstein steers graze in the hazelnut savanna: two crops from the same acre! Recently populations of savanna sparrows have begun to expand. Ecological restoration can occur simultaneously with agriculture, not separate from it.

Eeyore (we name our livestock!) grazes in among the hazelnuts. Animals are rotated frequently to avoid hoof damage to tree roots. A portable two-strand polywire fence with a solar charger is all that is needed. For pigs, both strands are lowered to nose and ear height.

Not your typical apple “orchard.” Daffodils at the base of the trees eliminate sod while repelling rodents and providing early spring nectar and pollen for bees and cutflowers. Iris between the trees also provide sod control while yielding cutflowers and tubers used by a skin-care products company. Comfrey (large green leaves) is used by a medicinal herb company and accumulates potassium and calcium while providing overwintering habitat for predatory insects and substrate for morels. This “guild” of compatible plants is only a small part of the larger system which includes (on the left) chestnut, grape, hazelnut, rugosa rose, Siberian pea and currants and pears, with seedless grapes (on the right). The pattern then repeats itself across the hillside. Hogs are used for pest control when they graze through the system to harvest the pest infected “June drop” and after harvest when they eat the pest riddled fruit that pickers toss on the ground.

Pictured here is the “brush” on the side of the now abandoned “Old Highway 56” that runs through the middle of New Forest Farm. It is an example of a truly sustainable agriculture. In this “mess” are: hickories, black cherry, mulberry, elderberry, grapes, staghorn sumac, wild plum, raspberries, stinging nettles, goldenrod, Queen Anne’s lace, common milkweed, dandelions, violets, gooseberries, morel mushrooms in the spring, chanterelles, chicken of the woods and turkeytails in the summer, and puffballs later in the fall. Nobody plowed this land. Nobody planted this system. Nobody did any weed control or spraying for pests and diseases. In fact, since this was the ditch on the side of the road it was no doubt originally cleared by Norwegian bachelor farmers, plowed with horses, mowed with a sickle bar, slashed with chainsaws, pushed into a pile and burned — and later in its life ground up with the highway department’s brush chipper and the stumps sprayed with herbicides. 150 years of abuse and yet the system keeps coming back. That’s sustainable agriculture! All of the above plants are edible, many are medicinal and all are perennial, never having to be planted again. We can skillfully and easily design ecosystem mimicked, perennial woody polycultures that can provide sustenance to body and soul indefinitely into the future.

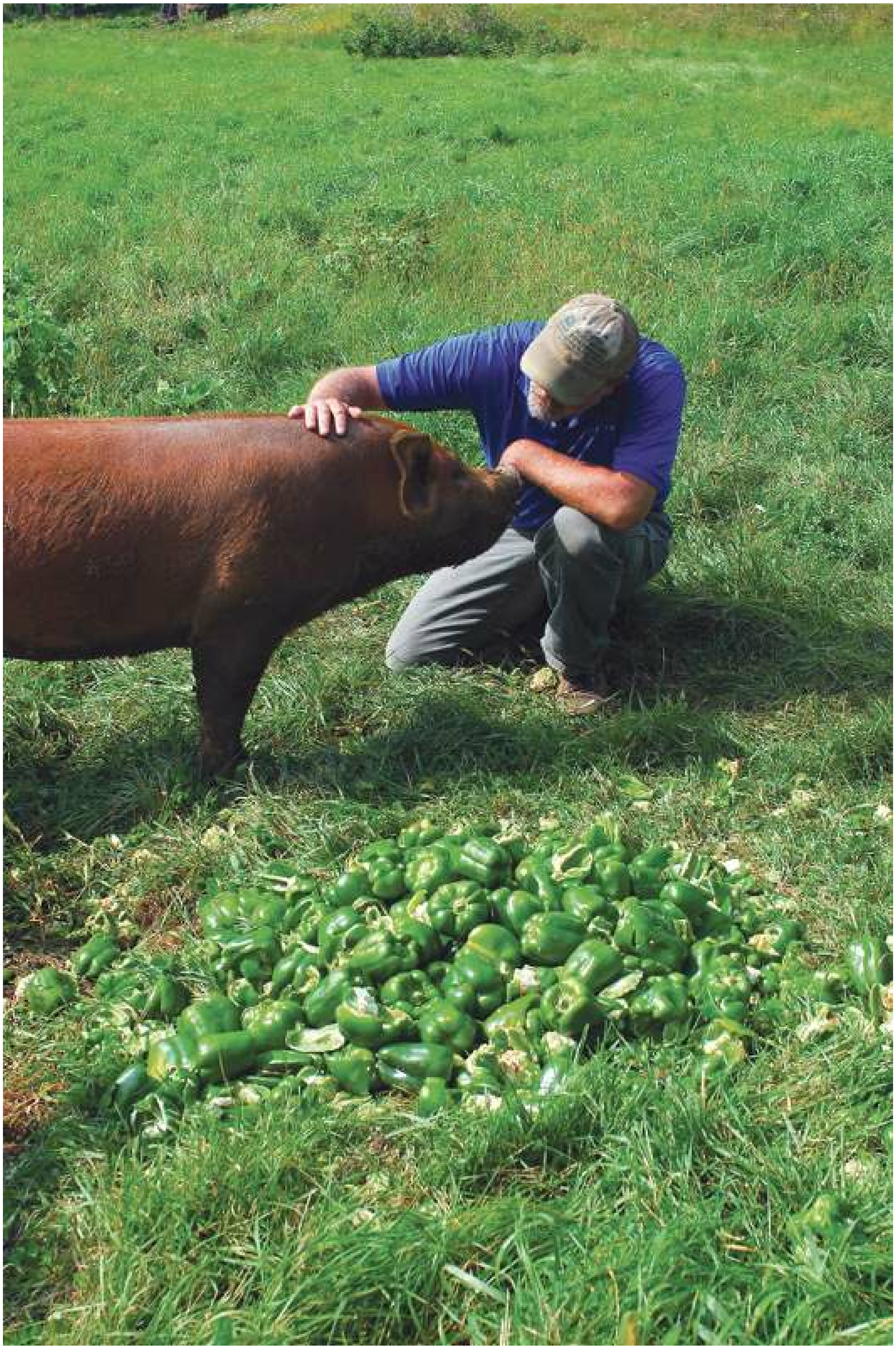
Once a system is designed and planted, unexpected surprises show up. When no fungicides are used on apple trees and when they were underplanted with daffodils, iris and comfrey and grazed by pigs in the fall, morel mushrooms moved in to inhabit the duff layer beneath the system. In favorable years there may be more income from morels in the apple orchard than from fruit!

A view across the "savanna" at New Forest Farm. Comprising about 40 acres, this section of the farm is planted to white oak (on 60-foot spacings to provide a park-like savanna in 120 years) chestnuts, apples and a main crop of hazelnuts. Cattle and poultry are rotated through this system throughout the summer.

A view from the "polyculture" block to the "north ridge chestnuts." The foreground is a polyculture that consists of four rows of hazels, then one row of chestnut, apple, serviceberry, mulberry, black alder and raspberry. The pattern is repeated several times *over ten acres. This was done an attempt to maximize tree canopy area exposed to the sun which should result in greater total photosynthetic yield. At the top of the ridge are young chestnut trees, planted with the intention of establishing a closed-canopy forest over time. Woody crops are planted at very high densities (oftentimes 1,000-4,000 trees per acre) in order to discover the genetic variants that are young to bear, heavy producers, and thrive under a regime of sheer, total, utter neglect. Losers in this human-guided process of natural selection are used as firewood, mushroom substrate or material for local craftsmen and wooden toy manufacturers.*

There were less than three acres of clearcut woodlands when New Forest Farm was purchased in 1995. The young regrowth provided the only shade on the farm for the previous owner's stocker cattle operation. Oftentimes over a hundred cattle would seek shelter from the blazing summer sun in this small area. Within a short period of time the forest floor had been obliterated leaving nothing to prevent the massive erosion that defined the previous history of the farm. With minimal care (careful selection harvest of firewood, cultivation of forest-grown medicinal herbs and edible fungi) and time, true forest function is restored. Forest-dwelling plants such as jack-in-the-pulpit, mayapple, several species of ferns, and trilliums have begun return. Although this is a young forest, mature forest species have returned including scarlet tanagers and flying squirrels.

Opposite: Tammy, the Tamworth matriarch, enjoys her pats while telling the author about the state of the herd. Of all the breeds we've tried, Tamworths seem to thrive the best on a no-grains, pasture and tree crops diet. The pigs rations are comprised of mulberries, cherries, apples, hazelnuts, hickories and chestnuts and, of course, visually imperfect produce of all kinds from asparagus to green peppers.



In an alley-cropping system, less of the alley crop is grown as the tree crops mature. Annual alley crops can be replaced with shade-tolerant perennials. In this block of chestnuts elderberries are grown in the alleys between rows of chestnuts, and shade-tolerant currants are grown beneath the chestnuts. When mulberries, raspberries and grapes volunteer, they are allowed to stay as long as they don't interfere with the rest of the system. As a system matures it begins to propagate itself and expand. Some of the most common "weeds" in a system like this are seeds from other crops on other parts of the farm (hazelnuts, mulberries and grapes). Seed is is spread by wildlife which requires no supervision, no workman's comp insurance, and works for less than minimum wage. After the last crop of chestnuts are harvested in the fall, cattle and hogs are grazed in the system to trim the grass, clean up any stray nuts, and put the system to bed for winter with a nice application of fertilizer. From right, the pattern is visible: alleycrop, swale, berm, tree, alley (a vehicle way) swale, berm, tree, fence… repeat!

The agricultural hazelnut savanna flanks this valley on three sides. Crops harvested are hazelnuts, chestnuts, apples, cattle, chickens and eventually acorns. The bottom valley is the home of the future "farm pond" intended to hold water year-round.

Here an alley between rows of chestnut is prepared for acorn squash, our most reliable annual produce crop. Asparagus (in the left alley) is by far our most successful produce crop. Alley width is determined by the eventual size of 30-year-old chestnut trees when they will shade out the asparagus that is reaching its longevity limits.

An example of an "overyielding polyculture": rows of chestnuts and raspberries with green peppers, sunflowers and acorn squash. Asparagus is visible off to the far right. Although each individual crop might yield less than it would if it were planted all by itself, the total site yield is greater than any single crop would be. All crops are still planted in rows to allow for mechanical tillage and cultivation and yet are three-dimensional and interesting. Weeds are not an enemy to be defeated, but a system condition to understand and work with. Annual "weeds" (such as foxtail, smartweed, bindweed and velvet leaf) reveal the status of the soil and are the first stage of natural succession. Ten thousand years of agriculture have not been able to stop them, so we don't try too hard. We'll merely plant the species that belong in this biome (oak savanna) and farm them… chestnut, apple, hazelnut, cherries and plums, raspberries, grapes, gooseberries, fungi and animals.

CHAPTER 17

Making a Profit

On the whole, unless someone has special circumstances, nobody is really making any money in agriculture. The Leopold Center for Sustainable Agriculture at Iowa State University has reported on numerous occasions that, of those farmers in the United States who file an IRS Schedule F (farm income and expenses), 80 percent receive the majority of their income from something other than farming. The fact that the USDA has huge agricultural subsidies (both direct and indirect) is evidence that there's something wrong with the economics of agriculture. Farmer direct payments, Loan Deficiency Payments, Counter-Cyclical Payments, Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Environmental Quality Incentives Program (EQUIP), disaster assistance programs, extremely low-interest loans, and an enormous food-buying program (in place to keep farmers in business and to feed the poorest Americans) are all evidence that the economics used to describe agriculture in this country doesn't look that pretty. These are all federal programs that benefit farmers above and beyond the ordinary revenues that they would receive from selling their crops or livestock.

Economic analyses have been done in many parts of the country using USDA agricultural census data showing that on average the expenses related to agricultural production exceed the revenues in most of the cases studied. This is disturbing enough in and of itself, but when the "ripple effect" of how money ripples out through agricultural communities is analyzed it shows that farmer's money is not even being spent in their communities, but in small cities some distance away. Farmers' money is then taken away by the owners of the large corporate stores where they shop. These large corporate stores divert their profits to states or even countries even farther away. In most cases studied it was revealed that farmers are selling their bulk, commodity products at wholesale prices, then going to the supermarket and buying their food at retail prices; a situation of selling low and buying high. In many cases, farmers go to the supermarket and pay retail prices for food that they could have grown themselves. It may sound bizarre, but it actually happens across the country where there are farmers that sell a bushel of corn for $8.00 and then use the dollars earned to buy a six-pack of high-fructose corn syrup-sweetened soft drinks, a bag of corn chips, and some corn tortillas, but then run out of money before being able to buy a head of lettuce, tomato, green pepper, or a pound of ground beef. From this small illustration it can be seen that a farmer growing 300 acres of corn doesn't even earn enough money to feed himself throughout the course of the year, and can only afford to drink a six-pack of soda and eat a bag of chips per day. This is insanity! Increasing awareness is being directed to the fact that huge numbers of North American farm families live in virtual food deserts, having corn, beans or wheat as far as the eye can see, but no real food to be found, and no grocery stores within an hour's drive.

For many of you reading this book none of this information is new. Among the farmers in the audience we know that we are not "striking it rich" by any stretch of the imagination. The USDA data mentioned earlier simply confirms what we all know, and that is that most of us have at least one member of the farm household that is working at an off-farm job in order for us to pay the bills. Part of what I am here to say is … don't beat yourself up because of this.

It's not our fault that the economic system is designed to underpay the producers of the basic, raw materials of our economy. It's not our fault that market pressures seeking to obtain something for less push farmers into earning less and less for the same amount of work (or more). Things were economically bad in my grandfather's day. The times were so bad that it was called the Great Depression. This label was not without justification. However, with only 60 acres and a two-horse team my grandfather was able to raise six children and send half of them to college. (Before he went broke and lost the farm.) Their shopping list when they went to town once a week was simply sugar, coffee and flour. They could have done without buying sugar because they made maple syrup and maple sugar, but the maple products were far more valuable to them converted into dollars than they were consumed as a sweetener on their kitchen table. They grew almost 100 percent of what they ate — back in 1929.

Now in the present (using 2007 agriculture census data), the USDA reports that the average farm size has increased to 418 acres and nearly 15 percent of all farmers live below the federal poverty level with annual earnings of less than $22,314.00. Adjusted for inflation, those are about the same total wages earned by my grandpa back in 1929, and he paid to send his kids to college. The farmer of today earns the same wage as my grandfather did back in 1929 and is in the poorest segment of the total population. Only if his children are smart enough, get enough scholarships, or if they're willing to indebt themselves for life, can they go to college. Rural America is overworked, underpaid, and in an unhealthy environment — breathing air laden with herbicides, pesticides and fungicides, and dust from the toxic, denatured topsoil that leaves the farm with the wind. So how is it that farms and farmers are surviving and what does this have to do with restoration agriculture?

The main point that I want to make in this chapter is to suggest that we accept all this data at face value and to not lay any value judgments on ourselves or others when it comes to handling farm finances. Most farms are not economically prosperous. Most farm families earn the majority of their economic livelihood off the farm. These are the facts, and let's all just face them. Once we've done this, let's then put a halt to one trend that isn't as helpful as it might seem.

All across the country (and around the world) there are conferences and workshops that farmers and ranchers can attend to meet and network with one another to continue to educate themselves about new or different farming or marketing ideas, and in most of these workshops presenters lay out their material enshrouded in a web of an all-pervasive myth. This myth is the myth of profitable agriculture. Farmers attend workshops where they're told that raising raspberries in plastic high-tunnels will increase their farm's profitability, or that growing fish in farm tanks and basil in the fish waste stream is profitable, or how profitable their farm will be if they only buy XYZ seed from the PDQ company because their seed yields *big* harvests and big yields pay. Most of the workshops that farmers attend and most of the educational material that farmers and ranchers can buy, all propagate the myth of profitable farming.

Folks, if farming was all that profitable, people all over the hemisphere would be flocking to this high-paying, prestigious occupation and the pathways to get there would be well known and clear. But that is not the case at all. All of these workshops are preaching from within the shell of a hollow myth of profitability. Buy this and get higher yields and be more profitable. With one of these expensive pieces of equipment your work will be cut in half and you'll get twice as much done in half the time and be more profitable. Spray this for bigger profits. Add that for bigger profits.

Get over it … farming doesn't pay. More accurately, though, it is our economic system that fails to describe accurately what agriculture is, what it does, and the true value that agriculture has for humanity. Agriculture is what it is and it doesn't fit into the nice, tidy box of economic theory. Living on a farm or ranch and paying the bills with wildly erratic and oftentimes tiny cash flows is a challenge for everybody who is doing it.

In my seventeen years of restoration agriculture farming I have seen countless farmers (both young and old) get into farming, and within a few short years go broke and lose the farm. A recurring reason why many of them lost their farm is that they were operating under the myth that their farm was going to be profitable. They were smarter or they were younger. They direct-marketed, specialized, diversified, or some such thing that was their brilliant leg-up on everybody else. Every one of these people got into farming and then lost their dreams and their life savings because they believed in the myth that agriculture could be profitable.

My advice is to get over it. Your agricultural enterprise probably will not pay all of your bills. Don't beat yourself up over this. Don't hold yourself up to a standard that the entire agricultural economy is not attaining.

This doesn't mean don't get into farming or ranching. What it does mean is understand that you are playing blackjack against "the house" and the house is using a rigged deck. Rural life is incredibly rewarding and despite the fact that farming doesn't really pay, we can figure out how to stay in the countryside, stay on the farm and live a good life. Going out of business is one of the many forms of unsustainability.

I hope that I have already made a reasonable enough argument to impress upon you that annual agriculture is ecologically unsustainable. Whole, intact, three-dimensional, species-diverse, perennial ecosystems have to be destroyed by the plow, tiller or herbicides in order to plant annual crops. Soil devoid of perennial cover blows away in the wind and washes away in the rain. Annual agriculture destroys topsoil. Period. This is not something that I'm asking you to believe. This is a fact that has over 6,000 years of history behind it and nearly 100 years of detailed agronomic records to prove it. If annual agriculture *didn't* degrade the topsoil, nobody would have to buy fertilizer and nobody would have to add mineral amendments or make compost, rotate crops, or let their fields go fallow. With annual agriculture the resource base degrades and the need for inputs increases. Yields decrease over time and eventually the annual agricultural economy collapses. In every instance so far (and I'm crossing my fingers on this current one) *every* culture that has based its staple food crops on annual plants has collapsed. How do we do things differently? We use restoration agriculture.

I propose that we need to start where we are today and re-enter into a relationship with the process of natural succession and actively "farm" using the process of restoration itself and the species involved — through the dance of time. It is time for us to invade cornfields with perennial grasses and to farm that grass. It is time to replant the shrubs and cane fruits of an early successional brushland savanna while grazing the forage between the rows and harvesting the crops from our shrubland. It is time to replant the sun-loving trees that reach skyward above the shrubs and cane fruits and are themselves covered with vines, while underneath these the shade-grown plants and fungi complete the whole system. Replant the ecosystem and harvest the yields. What is amazing about this process is that as soon as it is embarked upon, farm expenses begin going *down*. This is key to a successful restoration agriculture farm.

Once a perennial, ecological farming system is set in place, it is there practically forever. It may seem simple and somewhat obvious that perennials last a long time, but what people oftentimes overlook are the *huge* financial ramifications of this. When your planting cost is incurred only once you can essentially divide that planting cost over the lifetime of the crop in question (and yes, some marathon-running perennial crops like chestnuts or hazelnuts will outlive the sprinter crops like raspberries). You will have to replant raspberries and asparagus eventually. Your actual annual expenditure for planting costs approaches zero when amortized over the life of the plants.

When the crops chosen for a restoration agriculture enterprise are locally adapted, specifically bred for harvesting when extremely young, genetically pest- and disease-resistant, site-adapted to the current soil conditions, and able to produce high yields with no inputs, then you can see that the costs of production go down yet again. No more spraying to kill pests, diseases or fungus. Lowering the cost of production is absolutely key to financial solvency on the farm. This is so important that even the USDA cites this point over and over again in their cost of production bulletins:

> Farmers who are more successful tend to maintain lower ratios of costs to output, while less successful farmers have higher costs per unit of output.
>
> *USDA Statistical Bulletin #974*

This mantra is repeated in bulletin after bulletin and is one of the reasons why "Big Ag" keeps on getting bigger and bigger. The larger the field, the more corn gets planted (or harvested) at the same time. The fewer passes that are made through a field, the lower the cost of production. The lower the cost of production, the more potential income per acre there is for the farmer. Yes, one way to lower the per bushel or per pound cost of production is to increase the size of our operation, but what will ultimately be the most effective will be for the farmer to imitate nature. As far as we know nature has yet to spend one red cent on producing staple food crops. For millennia nature has grown chestnuts, hazelnuts, cherries, apples, grapes, raspberries, gooseberries, currants, pecans, hickories, oaks, mulberries, persimmons, pawpaws, pomegranates, and thousands upon thousands of highly nutritious staple food crops without ever spending a thing. By designing our staple food production systems this way we can benefit from the lowest-cost production methods known to humankind. Again, by designing our staple food production systems this way, we can benefit from the lowest-cost production methods known to mankind.

Let's pause here briefly and go over what was addressed at the beginning of this chapter. The majority of all IRS Schedule F-filing farmers are receiving the majority of their income from off-farm activities. These are the "system conditions." Just like gravity, this is an undeniable observation. This is the way things work. These are the conditions under which we must create the abundant, ecological agriculture of the future.

One of the permaculture design principles that applies in this case is to observe and *understand* what the system conditions are, then design a farming system that works *with* the existing economic system in order to create appropriate earth care, people care and an equitable distribution of products. Once we have dispensed with the myth of profitable agriculture we can look clearly at our farming enterprise and design a system that costs us nothing.

If we annually spend $250.00/acre on inputs, tillage, herbicide and seed for planting corn and then have the crop destroyed by hail, we have still spent $250.00 for every acre farmed. If we've decided to gain economies of scale by purchasing huge equipment and more acres of land, that $250.00 production cost gets multiplied by however many acres we're farming and we have to throw in the additional cost of bigger equipment. USDA production cost statistics from 1999 show that for 100 acres of corn a farmer would have to spend nearly $250.00 per acre per year (every year) in order to produce a crop. That is an annual cost of $25,000.00 for 100 acres of corn — just to have the crop destroyed by hail. It's time to get another part-time job at the hardware store.

To continue with this illustration, this time using the 100-acre New Forest Farm in Viola, Wisconsin as a restoration agriculture farm example, in 2010 the annual production costs came to a grand total of $8,672.00, or $86.72 per acre. This is a mere third of the production costs of an annual crops farm. What is quite significant about New Forest Farm costs is that most of the expenses were incurred from the planting of 6 acres of annual crops, sunflowers (an oil crop), and winter squash, both chosen as a high-return cash crop. If we merely look at the $16,000.00 annual savings per year, it becomes apparent that the up-front investment in perennial plant material is paid for quite quickly simply by *not* planting annuals. *Not* burning diesel fuel to *not* plow fields is less work and less expensive than plowing and planting.

Remember once again that I am proposing the growing of edible perennial ecologies *not* for the production of high-value specialty or niche crops but for the production of staple food crops. Restoration agriculture is the growing of perennial polyculture ecosystems for the production of the carbohydrates, proteins and oils required as the staple food crops for humanity. This will not happen if all that we do is imitate what is currently done with so many of the edible woody crops that are at our disposal. In restoration agriculture we do not manage our crops the same way as monocrop growers. I've used apples before as an example, so let me use hazelnuts as my example this time.

The hazelnut industry in North America has been primarily located in Oregon, Washington and British Columbia. The plants in use are European hazelnut *(Corylus avellana)*. In the wild, the European hazelnut is a large, multi-stemmed shrub. Beginning back in Roman times, hazelnuts were brought under intentional cultivation and the wild shrubs were planted in neat rows just like the legions of soldiers that forced the pastoralist-nomadic peasantry to settle down and farm — like good Roman subjects. After a few hundred years of using unselected wild hazelnut plants, superior-yielding individual plants were selected, vegetatively propagated and planted out in mass monocultures.

Not being satisfied with an unruly bush for a production platform, European hazelnuts are regularly renewal pruned, which reduces the number of stems from dozens to a manageable amount. Today in parts of Europe hazelnuts are grown as clumps with three or four stems. In the extreme most United States growers prune the shrub down to a single stem and expect the hazelnut bush to act like a small orchard tree. Annually the plant has a natural tendency to send up more sprouts from the root crown and it usually does. These sprouts are either removed by pruning or kept to a minimum by the spraying of sprout disrupting chemicals or hormones. By doing this meticulous application of unnecessary work and not allowing the hazelnut shrub to be its natural form — a shrub — the modern hazelnut grower creates even more problems that need to be solved. The hazelnut, finding itself unable to convert its excess stored root energy into the formation of basal sprouts (which cause the plant to be a multi-stemmed shrub), the tree puts this extra energy into making a tangle of branches in its top. The canopy of this once-upon-a-time shrub, now forced to become a tree, becomes a tangle of branches that shade one another and reduce nut yields. This problem is solved by pruning/thinning the tops of the hazelnuts. But once again the problems that need to be solved in the modern hazelnut orchard are problems that were caused by human beings attempting to force nature to behave according to our concepts, in this case the concept that the hazelnut "should" act like and be managed as a small tree. Thinning a shrub thicket down to a single stem causes rampant basal sprouting. The pruning of basal sprouts causes a tangle of top growth which requires even more pruning.

By allowing the hazelnut shrub to be a shrub and adapting to it, instead of laboring to force it to act like a tree (which it is not), and by supplying its needs with other parts of the system, we can eliminate all production costs except for the harvest.

By *doing* something in the first place we have automatically tripled the work involved in growing this formerly easy-to-grow wild crop. Somehow through the ages we have come to believe that hazelnut shrubs that naturally grow in polycultural plant associations are supposed to act like trees and should be grown in monocultural phalanxes like the original Roman legions who first sent them to boot camp.

It takes work, an expenditure of time, energy and labor, to force nature to act according to our concepts. By working to force nature to comply with our concepts, it creates more work. Plants taken out of context and grown in enforced isolation from the natural world, develop diseases, are attacked by pests, and create still more opportunities for more work and more expensive inputs. What all of this does in the traditional woody crops industry, is to produce nuts (or berries or fruit) that are too expensive to be used widely as staple food crops. Because of this they become more expensive "specialty" items used for nibbles at holidays and parties instead of the *food* that we eat at every meal.

The only way to affordably produce staple food crops from edible woody plants is to stop doing so much to them. Stop growing monocrops of plants. Put them back into a more natural context in symbiosis with other trees, shrubs, plants and animals. Stop coddling the weak, sickly varieties that need continual inputs of chemical medicines to keep them alive and pest-free, and stop trying to force shrubs to be trees. Let them grow free and unfettered — as much as practical. Strive to discover what we can *not* do and still obtain crops.

With the proper selection of plants that thrive and produce high yields in semi-natural perennial polyculture systems we can produce highly nutritious, staple food crops at the lowest possible cost. There isn't an input-based agricultural system that can produce staple foods at as low of a cost as a no-input system. As our production systems more closely approximates natural systems, our production costs approach those of nature. Nobody has beaten nature yet for low-cost production.

A successful farming operation can't rely on lowered production costs alone, however. You have to actually *yield* something and then get that yield to market.

Typical to the complexity of the systems that we are planting in restoration agriculture, the question of yield is complex as well.

At the time of this writing only two university-sponsored restoration agriculture field trials are in existence. Both of these happen to be in the heart of the Corn Belt in Illinois. They were first established in 2012 by the Restoration Agriculture Institute so all the data is recent and they don't have years' worth of yields to report. These research plots, run by the University of Illinois at Urbana-Champaign, are by far the most complex perennial polyculture systems being studied to date and despite this fact they are still ecologically rather thin. They are each comprised of a mere six perennial woody crops and one alley crop. One of the alley crops is a perennial grassy hay and the second was research plot was begun with corn. The researchers working on the projects are currently debating among themselves whether or not to convert the corn alley crop to hay immediately or to harvest corn for one year before changing alley crops. Their decision-making process is beyond my pay grade and is most likely being done in order to have data that is the most statistically relevant when comparing it to other research. Some of the things being measured at these sites will be carbon flux (how much flows through the system, how much accumulates or outgases, etc.), total site yield, total human food calories produced, total human nutrition produced, total biomass energy produced, total monetary costs of production, and so on. These research projects are the ones that we should be watching.

Other yield research is being done at the MacDaniels Nut Grove and Dilmun Hill Student Farm at Cornell University in Ithaca, New York and most significantly at the Center for Agroforestry at the University of Missouri-Columbia.

For nearly twenty years the Center for Agroforestry has been collecting yield data on various agroforestry practices across the Midwest and has shown that over time the yields of the individual crops within an agroforestry system do not go down, but in many cases actually go *up*.

Ecological research, as practiced by ecologists and not agroecologists (who I feel appear to not even study much ecology), shows that when it comes to total site yield, the more the merrier. Consistently through decades of ecological research it has been shown that the greater the species diversity of a site, the greater the total site yield. As farmers, isn't this really what we're looking for — how to get the greatest total yield from my acres of land? When you couple this question with the process of minimizing expenses for each acre of land, you will end up with two of the three factors for successful farming working in your favor. Through perennialism and an active on-farm breeding program, crops will be produced at costs approaching zero, and through species diversity, total site yield will be increased.

Yes, total site yield is increased, but what about the individual crops? If a diverse system is planted, will there be enough of any one crop to be harvested, processed and marketed efficiently. The answer to this question, at this time, is yes. But it is not known yet at what scale these efficiencies do happen.

Since nobody knows yet at what scale maintenance, harvest and processing efficiencies happen, let's divert this discussion to marketing. The economies-of-scale question is parallel for maintenance, harvest and processing as well as marketing.

In southwest Wisconsin in 1988 a small group of organic produce growers gathered together to see if they could help solve a common problem that they were all having. All of them were small-scale produce growers. The largest among them at the time grew only around 20 acres of vegetables. All of them grew more product than they could sell through their own individual markets. The question that they met to address was, "How can we work together in order to pool our produce in order to accumulate enough of a volume to get it on a truck and gain access to large wholesale markets?" That question led to the formation of what was first called the "Coulee Region Organic Produce Pool," or CROPP for short. Their produce was in demand in the larger marketplace, but being from a region that only has around 100 frost-free days in the growing season, their time *in* the market selling produce was less than a third of the entire year. Additional items to sell were contemplated in order to keep the business in front of the buyers year-round. Some of the farmers began selling their organic milk to a small-scale local cheesemaker in order to make cheese that could be stored and sold year-round. What started with only a handful of committed collaborators twenty-five years ago and has been subject to constantly changing challenges is one of the most incredible success stories in American agriculture in recent times. From these humble beginnings the now more than 1,600-member farmer-owned cooperative known as Organic Valley was born. The details of how Organic Valley grew through the years are less important to us here than having an understanding of the general model of how Organic Valley operates.

Organic Valley (and now Organic Prairie for meats) is an aggregator. Most of the farmer/owners of Organic Valley are smaller-scale farmers. All of the farms are family-owned. They range in size from one- to two-acre produce growers to dairies with several hundred cows.

The business end of the co-op acts as the organizing principle for the membership and is managed by the growers themselves. Each production pool (dairy, eggs, produce, soy, feed, citrus, meat) within the co-op has its own governing body that helps with the planning. Products are grown or raised by members, then delivered to centralized facilities for basic processing. Eggs get picked up at the farm and delivered to a common facility for cleaning and packaging; produce goes to a centralized warehouse for re-packing and distribution. Milk is picked up on-farm and delivered to various dairies to be bottled as fluid milk, and made into butter, cheese, yogurt, cream cheese and a wide array of value-added dairy products.

It is this type of aggregation model that will make restoration agriculture farmers more and more successful over time. Instead of achieving the massive economies of scale at the crop level by planting ten thousand acres of corn, for instance, the economies of scale are moved to the processing level. A diversity of crops are harvested and delivered to their appropriate processing centers. Since many of the Organic Valley farmers are smaller than average in scale, their on-farm production costs are in many cases higher than those of their peers. In the "Big Ag" world this would result in the smaller-scale or less efficient farmer earning less and less money and eventually going out of business and selling out to a larger, more efficient neighbor. Part of what makes the Organic Valley model work is that the farmers themselves are the owners of the processing and marketing company. As the company grows and sales increase, the farmer-owners receive a return on their original membership investment.

Another part of the successful formula, which began in the dairy pool, was the decision to institutionalize a fair and consistent pay price to its members. Instead of having milk prices fluctuate up and down with the whims of the market (which is frequently driven on pure speculation by men in business suits in cities far from where the products are grown), the Dairy Executive Committee consults with the membership and a fair farmer pay price is decided upon: no wild fluctuations, a decent economic livelihood and a steady predictable income stream around which family financial plans can be made. The pay price to Organic Valley farmers is typically higher than elsewhere, and this higher pay price trickles down through the organization. (This has caused its own challenges for growth and expansion which is good because it has forced creativity within the management of the organization.)

Since restoration agriculture systems are almost infinitely more diverse than a monocrop of corn, or even an Organic Valley combined dairy, egg and produce operation, a restoration agriculture farmer would be prudent to begin his or her enterprise with the understanding that ultimately they will be collaborating with others.

Ecological studies provide us with the evidence that we need in order to know that restoration agriculture systems produce more total yields per acre than annual monocrops. This will be proven every time. The individual crops in question, however, are likely to be smaller in volume per farm than that same commodity grown as a monocrop. What will be needed in time are farmer-owned aggregation, processing, value-added and marketing ventures. These aggregation centers will accumulate the basic products (hazelnuts, for instance), husk them, crack them, separate the shells from the nutmeats, then to process the kernels into whatever value-added products the company sees fit. Several aggregation centers can be owned by the same corporate entity as is the case with Organic Valley (dairy, eggs, produce, meat, soy, juice, etc.) or can be separate interdependent business entities. Either way, the infrastructure for the basic processing of *everything* produced in an ecosystem will eventually need to be in place in every region. Everything from raspberries to pecans and hickories, medicinal herbs to edible oils and fuel for equipment, will be needed over time. The human population is not small. The creation of these aggregation, processing and marketing centers will have to be done on a massive and widespread basis, not merely as “niche” enterprises, although they may start that way.

Most of the crops grown in restoration agriculture systems are already mass-market crops. This helps. The equipment needed to handle and process them already exists. However, it only exists for those who grow these crops as monocrops. We will need to invent harvesting, maintenance and processing machinery for use in polyculture systems. Although this might sound daunting to those who would still like to cling to inaction, it really isn’t. Human beings have figured out the tool-making business pretty well. There are machines to do everything from harvesting berries to sorting and separating them by size, weight, relative density, firmness, color and so on. There are machines that can drill into your brain and not damage any gray matter, and there are machines that can fly to Mars and roam around for several years with no driver on board while sending pictures home to earth. Just because the equipment doesn’t currently exist to harvest elderberries grown in polycultures doesn’t mean that it won’t exist soon. When there are enough growers with restoration agriculture systems on the ground, there will be enough of a demand by those growers for the necessary equipment. In fact, polyculture equipment manufacturing represents yet another investment or career opportunity in restoration agriculture. This brings up another interesting point.

One of the fascinating things about the process of restoration agriculture is that in addition to the plant and animal systems moving in the same direction as ecological succession, the same results apply to the farm and a farming region as would apply to a natural ecosystem. In a natural ecosystem there are many niches available to be inhabited by a diversity of life forms. The more diverse the system, the higher the total yield and the more diverse life forms can exist there. Remove the diverse ecosystem and replace it with a monocrop of corn, and the only niches available are for corn earworm, smut and one corn farmer on two thousand acres.

As annual agriculture increased in scale in the 20th century dozens of small-scale, diversified family farmers gave way to one or two big operators. Thousands of once-prosperous towns withered up and blew away until, as in the example of Ash Ridge, Wisconsin, many are only inhabited by two truck drivers, three retirees, and a handful of stray cats.

As we begin to aggrade the health of the actual ecosystem it becomes more perennial, the soil improves, and the species diversity increases. Then more yields are harvested. The system ultimately creates more niches. More niches mean more livelihoods for more plants and animals — and more niches for people as well. In a healthier system new businesses are formed because more opportunity has been created. Destroy the ecology and you will destroy the economy. Restore the ecology and you will restore the economy.

Restoration agriculture creates the resource base of the future. Our forebears inherited a richly diverse, clean and healthy planet. They were able to extract from the savings account of nature and create the most materially prosperous civilization in the history of humankind. We, on the other hand, have inherited a radioactive, toxic and denuded wasteland with no more massive herds of bison, no more salmon runs choking the streams, or passenger pigeons blotting out the sun for days. All but a few museum pieces of our old-growth forest heritage have been eradicated to line a few pockets with money and to be made into toilet paper for the rest of us. The vast prairies now exist as fragmented remnants struggling to survive. The great American chestnut no longer cloaks the eastern half of North America burying it beneath millions of tons of highly nutritious food produced at no dollar or input cost.

Restoration agriculture is about planting the natural abundance of the future. Nobody is making any more nature for us to inherit. It is up to us to create the nature that our children and grandchildren may inherit. It is *our* responsibility to create the rich, lush, living green planet that our children will inhabit. With restoration agriculture, there will be more and more ecological niches created and we can fill them with people. Nature will fill in with her own, if we will only give her the place and the time. Ecosystem restoration is a virtuous cycle that never has to stop. Restored ecosystems produce more resources, more food, more medicines, more biofuels, and more industrial ingredients than bare, exposed dirt. Restoration agriculture is the ecological and agricultural backbone of the dawning restoration economy.

We might not get as far as we want in our lifetimes. The process of building successful businesses based around restoration agriculture farms may take quite some time to achieve. It is underway in fits and starts in several places across the country and is growing stronger with each day. Like the ecological systems that these restoration agriculture farms are modeled after, they typically start thin and slowly build depth and complexity. My experience with the Organic Valley (CROPP) cooperative has lasted for seventeen years, and in that time I have seen it change from a produce and cheese company where all of the employees could fit around two picnic tables in LaFarge, Wisconsin to a widespread organization with growers from the Atlantic to the Pacific oceans (including Canada), where annual business meetings are held in multiple public sports arenas and simulcast via satellite. This restoration agriculture process takes time and must begin today with each and every one of us participating.

We cannot sit around and wait until the aggregating and processing infrastructure is in place, though. Trees take time to grow. Ecological systems take time to mature. It takes years and in some cases may take several generations in order for certain pest and disease cycles to fall into a reasonable equilibrium. The time to plant these systems is now so that we will actually *have* the crops needed to feed a rapidly expanding population.

If we do this while still earning the majority of our income from off-farm sources, we are no worse off than our corn-farming neighbors. (Once again my apologies to corn and bean farmers, I'm just surrounded by this crop for almost as far as the eye can see. If I were in wheat or rice country I'm sure I'd be saying the same about them.) Not only are we not worse off, we are *way* better off.

By planting a diversity of crops we have hedged our bets and aren't putting all of our eggs in one basket. If the season is good for one crop, it might not be for another. If a late freeze destroys the apple crop, at least we'll have hazelnuts or chestnuts, or chokeberries or shiitake mushrooms or any number of other crops. For the short term we are better off because our cash flow will be spread out over a longer season which will give us some price and income stability. In the fall, when everybody in North America has an abundance of harvested grains, the price is as low as it gets all year. Oversupply helps to stimulate a low price. This can be overcome in part through the building of storage facilities and commodity futures trading, but at what cost? It seems that the only answer that conventional annual agriculture has to its own self-created problems is to spend more and do more in the hopes that this time the solution won't create worse problems, more work and even lower returns to the farmer — which it always has. Albert Einstein is reported to have defined insanity as "doing the same thing over and over again and expecting different results." Industrial monocrop agriculture, "Big Ag," fits this description. With a diverse system crops are harvested over a longer season and price volatility is less in crops that have shorter periods of oversupply.

Long-term the restoration agriculture farmer will be better off for many reasons, but if for nothing else, we will at least be better off because we've created a spectacularly beautiful park-like setting that will sell for top-dollar when we finally retire.

A number of years ago I consulted with a farmer who operated a grass-based dairy in an area being invaded by housing developments. All summer he rotated his herd through the system and harvested hay for winter use. His farm was one of the most beautiful silvopasture systems that I've ever seen with an overstory of black cherry and oaks of various kinds. His herd of 75 Jerseys grazed on lush, green grass beneath the dappled shade. The cows had accustomed themselves to coming up to the fence by the road whenever a car would stop by, which was frequently. This was because the people who lived in the subdivision next door would stop on their way home from picking their children up from day care and they would feed the cows carrots or apples or handfuls of grass. The youngsters would "moo" at the cows and the cows would "moo" back at them. By creating a beautiful, silvopasture farm this farmer influenced untold hundreds of suburban kids and has provided them with a lifetime of beautiful memories. His system has acted as an ambassador on behalf of beautiful, ecologically sound, and humane farming for years and it will exist for centuries in the memories and family stories of those who were touched by its pastoral beauty.

In contrast was the 280-cow confinement dairy immediately next door to the silvopasture dairy. The confinement operation had a double-walled iron-clad building that was armored like a military tank. It sat within a leak-proof concrete basin which was surrounded by chain-link fence, the gate of which was always locked. This building held the farm chemicals. Another building held the bulk fertilizers, stored in huge piles like road salt at the highway department. The farming structure that led to the greatest controversy and eventually to the farmer's downfall was a gigantic blue steel manure storage tank.

Whenever that tank would get full the farm crew would spend an entire day filling tank trucks and spraying the slurry on the fields, not a bad practice at all. However, because the manure in the tank had been stored anaerobically for long periods of time it really didn't smell all that pretty, even to a farmer. The suburban neighbors proceeded to take the confinement farmer to court to get him to stop, in their words, putrefying the neighborhood. The farmer argued, and rightly so, that he was there first and had always been farming this way and that the people should have known that he was a dairy farmer and was going to be spreading manure periodically. Besides, he argued, he was breaking no laws, was following all of the current best management practices, and that indeed his manure storage tank was far superior to the leaky, groundwater contaminating lagoons so common to the area. The farmer prevailed in court, but the neighbors persisted. Soon they started to claim that the stinky manure was spreading disease. Another time he was blamed for a Pharaoh's plague of flies and all sorts of skin and respiratory ailments.

One time in court the embattled farmer blurted out in frustration, "I'm a dairy farmer just like that other guy next door, so why are you suing me and not him?" The general consensus was, "No, you are *not* just like the other farmer. His farm doesn't stink!"

Once again the confinement farmer prevailed in court, but he had lost his personal drive to fight and no doubt a small fortune in attorney's fees. He sold the herd and put the farm up for sale.

About the same time that the confinement dairy went up for sale, the silvopasture farm next door experienced a death in the family and their farm was offered up for sale as well.

Here's a question that I will let you answer for yourself. In situations when these two types of farms go up for sale, which one will sell for a higher price?

Farm A: 300 acres of corn or soybean stubble, 1970s-era ranch-style house with a well and septic system, 300-cow freestall barn, milking parlor, a fertilizer shed, manure storage tank, and a chemical storage locker (the latter three probably qualifying as contaminated hazardous waste sites).

Farm B: 300 acres of grassy meadows growing beneath towering oak and cherry trees, a classic 1880s barn, restored 1880s hand-hewn log home, a well and septic system.

In restoration agriculture we are creating tremendous future value. In addition to growing the future's food and wood supply, we are creating beautiful, value-added real estate. The USDA and the extension service both report that owning farmland is the farmer's best financial move.

It is the continuing increase in land prices that is allowing farmers to continue to capitalize their operations. If a farmer happened to buy farmland at the beginning of the 1970s Big Agriculture boom and sold it in 2009, that farmer's real estate investment would have gained 882 percent in value. Farming *is* financially rewarding long-term, *if* you can keep paying the short-term bills.

Even if a farmer bought land at high prices and sold them at low prices — buying at the beginning of the ethanol boom when farmland began to skyrocket and sold it in the post 2008 recession — that farmer's real estate investment would have gained a 75 percent in value. For those of you with stocks or mutual funds held during that same time period, did anyone have a portfolio that yielded a mere 75 percent return on investment?

These are all numbers generated from the sale of bare-dirt fields. What would the gain be in value if you bought a bare-dirt farm and transformed it into the garden of Eden? In addition to speculative real estate value, the restoration agriculture farmer is creating *real* value. A piece of barren farmland has been transformed into a fully functional, food-producing ecosystem that is home to a wide array of wildlife and will be there practically forever even if it is not actively farmed. The restoration agriculture farmer is planting staple food crops for human consumption, and trees that can be coppiced for biomass fuel, logged to be made into toilet paper, or sawn into high-quality lumber or veneer. In a pinch, a farmer who has established a restoration agriculture system can buy a tree spade and begin selling full-sized trees as edible landscaping specimens to their suburban neighbors. Restoration agriculture used solely as a real estate investment strategy is a powerful model. Unlike a cardboard condominium shoddily made in two weeks by a speculator intending to sell to real estate flippers, restoration agriculture produces *real* value: food, fuel, medicines, fiber, building materials, clean air, purified water, wildlife habitat, beauty, spiritual renewal, and more. These are the "real" things in life. Without a spiffy investment property in a vacation community in the Sunbelt, people can still live healthy and fulfilled lives. Without clean, nutritious food, clean air, clean water, and a place to stroll beneath the shade of trees holding hands with a lover, life is not worth living at all.

Some readers may argue that I have still avoided answering the fundamental question, "Can a farmer make any money in restoration agriculture?" I will grant those people their right to ask that question despite the fact that most "regular" farmers aren't making any money today either while spending three times per acre what a restoration agriculture farmer does. And regular farmers are doing this all the while steadily destroying the resource base and washing it out to sea, polluting the groundwater and surface water, and slowly bleeding rural economies to death. They are doing this at taxpayer expense as well.

For those who still insists on asking, "But can I make any money doing this?" More than likely you are still firmly within the mind control of the "myth of profitable agriculture" and are not likely to believe me anyway when I actually dare to say "Yes!" However, nobody has to believe me. Instead I will defer entirely to the international agroforestry community.

Around the world agroforestry systems (ecologically "thin" restoration agriculture systems) have been studied for decades and shown to be more profitable and more sustainable than monocrop systems. From agroforestry systems utilizing cashews in Indonesia to rubber production in India, coffee and cacao in Africa and South America, to black walnut, pecan and chestnuts in North America, research has shown that agroforestry systems are more profitable than monocrop systems nearly everywhere they have been studied. I am not going to belabor the issue, but will merely make some simple comparisons here.

Let's use corn as an example one last time:

Take corn at the $8.00/bushel selling price x 150 bushels per acre = **$1,200.00 per acre in gross revenue**.

The $1,200.00 per acre gross revenue minus a $250.00/acre cost of production = **$950.00 net per acre**.

Now for chestnuts:

Chestnuts at the $5.00/pound selling price x 1,000 pounds (at the low end of their production range) per acre = **$5,000.00 per acre in gross revenue**.

The $5,000.00 per acre gross revenue minus a $83.00/acre cost of production = **$4,917.00 net per acre.**

Do we really need to discuss this further or should I meet you down at the bank where you might be borrowing more money to plant corn? Now what if the chestnut farmer is also harvesting 7,000 pounds of red currants on that same acre? And 2,000 pounds of asparagus? And two cattle, four hogs, 10 turkeys, a family of bluebirds, a colony of least weasels, and three species of endangered prairie flowers?

The Center for Agroforestry at the University of Missouri-Columbia can provide the economic models if there are any still unconvinced readers. I would recommend contacting them and considering their economic models. Visit their website at www.centerforagroforestry.org for more information. We should all applaud these researchers and the entire agroforestry community for the dedication and professional work that they have done through the years with far too little recognition and nowhere near enough funding.

A discussion of restoration agriculture farming economics would not be complete unless I returned again to food. Most studies that I have read show that the majority of American farmers do not even grow much of their own food. Many will have a small tomato, green bean and zucchini patch, but most American farmers do not grow their own food. The economics of growing one's own food can actually prove to be quite complicated, and in many cases it can actually be proven that it does not make any economic sense for a farmer to grow his or her own food. If a grain or dairy farmer is already overworked just trying to keep up with their primary farming enterprise, he or she probably doesn't have any free time to till, plant, weed and harvest a family food garden. Doing so would represent an economic net loss for the farmer because they could be doing something more productive with their time instead of pulling weeds in the cabbage patch. Although this doesn't make nutritional sense, in many cases it might actually make economic sense.

However, on a restoration agriculture farm growing your own food becomes a by-product of the primary farm enterprise. No matter what the season, from spring to fall, a restoration agriculture farm has an abundance of food being harvested. The primary farming activity in the springtime, for example, might be harvesting asparagus for market. Not all harvested asparagus will be of a high enough quality to be bundled and sold at market. There will be plenty of curled, undersized, oversized, too open, or insect-damaged asparagus spears that are perfectly nutritious and delicious to eat. The restoration agriculture farmer gets buried in surplus farm crops each and every season of the year as a result of their main farming activity. What customers and family don't eat then goes to the pigs — which the farmer will eat later. Staying with asparagus as an example we can see that the restoration agriculture farmers can reduce not only farm costs, but family household costs as well. For example, my breakfast on many mornings is from by-products of my primary farming activity — an asparagus and shiitake omelet with pork sausage on the side — was built entirely on the discards of the rest of the farm. The asparagus and mushrooms were cosmetically inferior, the eggs were either over- or undersized and not suitable for shipping, and the pork sausage was made from the pig scraps that our customers didn't want. (By the way, I eat a *lot* of liver sausage because of this.) Every season of the year, aside from deep winter, has its abundance of rejects that fill the plate, the freezer, dehydrator, smokehouse and pickle jar. How do you put an economic value on this?

To do so I went to our local food co-op. When I did this, of course, I brought product that I was selling to them. I then wandered the store and priced out some of the food that my family eats instead of having to purchase it. Organically raised seasoned pork sausage was $6.00/lb. But the co-op didn't carry grassfed, hazelnut- and chestnut-finished pork. The closest that I could find was acorn-fed pork chops at $17.50/lb. Other items I noted were grassfed ground beef at $7.25/lb and sirloin was $14.95/lb. The same exercise can be carried out for every single food item that a restoration agriculture farmer supplies for their family kitchen table. Our family consumes about 400 pounds of grassfed, hazelnut- and chestnut-finished pork during the year. Even if we bought low-cost organic sausage, for example, instead of the higher priced nut-fed chops that I found at the co-op, our family would have to pay $2,400.00 for our pork. Our pigs probably yield around 60 lbs. of pork chops, so it would be fair to price them similar to the most comparable product at the co-op market which was $17.50/lb. That would come to another $1,050.00 to purchase additional pork for the table.

In addition, having 800 lbs. of restoration agriculture beef in the freezer would easily represent $5,800.00 worth of ground beef, or an astronomical $11,960.00 worth of certified-organic, grassfed steaks. In our diet, meat is *part* of the meal. Our plates are piled high with certified-organic asparagus, kale, beets, green peppers, chard, wild greens, green beans, pickles and mushrooms. Our freezer is stocked full of mulberries, cherries, raspberries, blackberries, blueberries, and a dozen varieties of apples and pears. The pantry is stocked with 100 quarts each of spaghetti sauce and salsa (at $4.25/quart at the co-op this is nearly $1,000.00 worth of food), pickled and dried hot peppers, dilly beans, carboys of vinegar fermenting in the corner, jellies and jams, and grape, cherry, elderberry and currant juice. The sweeteners we use are several gallons of maple syrup and honey (we often have gallons of honey left from last year when it is time to harvest more). Our yearly three-gallon consumption of maple syrup would have a 2012 dollar value of somewhere around $150.00, and the honey used during a year, at $50.00/gallon wholesale, would have cost us $750.00 to purchase. We'll also have to throw in hundreds of pounds of hazelnuts, hazelnut oil, homemade vinegar, and chestnuts to be eaten whole, steamed, mashed, pureed, sweet hazelnut desserts, or savory hazelnut main courses. Wash this all down with some of the finest hard apple cider in the world and you've got a recipe for wholesome, healthy eating — and all for free. There is no *way* that my family could eat this well on our annual income if we had to buy comparable products in the store.

Harvested food that does not meet the visual standards of demanding consumers could be considered a waste. In restoration agriculture this becomes yet another yield, another resource. It becomes a food, sweetening or seasoning cost that is not paid. Food not eaten or stored by the farm family feeds the pigs which represents yet another avoided cost and in the long-term generates additional sales when that pig is sold to a customer. The goal of a well-designed restoration agriculture system is to imitate nature and produce no waste. Nutrients and energy are cycled and recycled as many times within the system as possible and the consumers of those products (pigs, chickens, cattle and people) all accomplish useful work (building soil, increasing biodiversity, aggregating soil nutrients, etc.) during their daily activities.

Restoration agriculture systems can produce more human food per acre than is currently produced by corn. Restoration agriculture creates soil, increases biodiversity, purifies groundwater and surface water, prevents runoff and erosion, can re-create springs, provide habitat for wild pollinators, reduce the need for external farm inputs, remove carbon from the atmosphere, pays more per acre than corn, and never needs to be planted again. That sounds like permanent agriculture to me.

As we create more permanent agriculture we take responsibility for increasing the health and abundance of the entire planetary habitat. As we increase the health and productivity of the ecosystems that support us, with everything from food to inspiration we help to create a new social order that is based on the creation of abundance and ecological increase, rather than the “dog-eat-dog” culture patterns that scarcity, fear and resource extraction engender.

The morning after Ashley’s graduation party, mentioned back in chapter 6, I was strolling through the rich green and gold of trees and sun at New Forest Farm. The gale-force winds blowing dust from her father’s bare dirt fields are moderated by the trees and become a mellow breeze cooling my skin. The dappled sunlight filters through the chestnut canopy overhead and dances kaleidoscope patterns on the lush pastures and prairie flowers below. The roses are blooming. Plums and cherries swell lush and green in the trees. I sample some of the first ripe currants of the season (still a bit too tart) and assess the raspberry crop soon to come. The pigs munch contentedly on dandelion and red clover while looking curiously to see if I have any special treats. Bird songs of species too numerous for me to count float on the breeze and lift my spirits.

Recently two researchers from the University of Wisconsin-Madison walked the long grassy driveway from the road to our farmhouse and counted twenty-seven species of birds in a mere 1,300 feet. They continued their census throughout the day and added many more to their total.

The asparagus harvest is a bit higher than usual this season, no doubt due to an early spring, and will likely measure over 2,000 pounds this year. Young hazelnut clusters are beginning to become visible on the tips of branches, and after looking around I feel it in my bones and know it in my soul that life can be good.

CHAPTER 18

Creating Permanent Agriculture: A Call for New Pioneers

> I see a million hills green with crop-yielding trees and a million neat farm homes snuggled in the hills. These beautiful tree farms hold the hills from Boston to Austin, from Atlanta to Des Moines. The hills of my vision have farming that fits them and replaces the poor pasture, the gullies, and the abandoned lands that characterize today so large a part of these hills.
>
> The unplowed lands are partly shaded by cropping trees — mulberries, persimmons, honey locust, grafted black walnut, grafted heart nut, grafted hickory, grafted oak, and other harvest-yielding trees. There is better grass beneath these trees than covers the hills today.
>
> *J. Russell Smith,* Tree Crops: A Permanent Agriculture

> I believe that a revolution can begin from this one strand of straw. Seen at a glance, this rice straw may appear light and insignificant. Hardly anyone would believe that it could start a revolution. But I have come to realize the weight and power of this straw. For me, this revolution is very real.
>
> *Masanobu Fukuoka,* One Straw Revolution

> In a world where we are losing forests, species and whole ecosystems, there are three concurrent and parallel responses to the environment:
>
> Care for surviving natural assemblies, to leave wilderness to heal itself.
>
> Rehabilitate degraded or eroded land using complex pioneer species and long-term plant assemblies (trees, shrubs, ground covers).
>
> Create our own complex living environment with as many species as we can save, or have need for, from wherever on earth they come.
>
> What is novel, and often overlooked, is that *any* system of total common-sense design for human communities is revolutionary!
>
> *Bill Mollison,* Permaculture: A Designers' Manual

The human race — indeed the entire planet — is now at a crossroad in the early 21st century. Across the globe we have data to show that we are living during the sixth great mass species extinction. Still there are those living in deep denial of this who claim that much of the global change happening around us is "purely within the long-term statistical average" and that it cannot be proven that human activity is the cause of these mass species extinctions and the radical transformation of the atmosphere into something that has never before existed in the history of the planet. For argument's sake, I will grant them their point. Perhaps humans aren't the cause of the largest species extinction since the age of the dinosaurs and perhaps the CO_2 emissions from fossil fuel use aren't the cause of climate perturbations, but what we can say is this … since the dawn of modern human civilization, human beings have obliterated hundreds of millions of square miles of ecosystems on this planet in order to expose the soil so it would accept the seeds of our annual plants. Some people cite the wisdom of ancient manuscripts and claim that it is the right and purpose of humanity to "subdue and have dominion over the birds of the air and beasts of the field." But, humankind has destroyed instead of simply rendering harmless and has conveniently forgotten the responsibility that comes with beneficent dominion.

We have a responsibility for all of the life on this planet. Our privileged status as consciously thinking beings capable of creating complex social forms, able to create vehicles that can fly us to the moon, or weapons that can destroy five million souls in an instant, brings with it the ultimate responsibility. We are responsible for the health and well-being of all life on earth, not just human life. This takes us all the way back to one version of the prime directive of permaculture: The only ethical decision is to take responsibility for our own existence and that of our children.

Yes, we are at a crossroads. We have come to a time in history where technological change has never occurred so fast. We live in a time where the human population has never been so large and where the majority of the human race now lives in cities instead of embedded within the natural landscape. In fact, we live in a time where hardly any landscape can truly be considered natural anymore. Discarded plastic bags blow in the wind and can be found on the remotest mountaintops in the world. Radioactivity from nuclear weapons and power plant meltdowns can be found in Antarctic seal blubber. The task before us is enormous, and yet it is not impossible.

It is not impossible because there are those of us who have come to this point in our lives, with book in hand, and we are going to act. We will take responsibility for restoring our planet to good health and vitality and productivity. Those of us who are restoration agriculture farmers will do so while creating sustainable, profitable businesses as well.

Although we may be of different socio-economic backgrounds, have different colors of skin, differing religious or political views, we all have something in common — we act. When it comes to creating the abundant ecosystems of the future, there is no time left for head scratching — please plant plenty of pecans!

We all eat. We all eat and we all can take responsibility for restoring perennial, food-producing polycultures no matter where we live. We can take personal responsibility for the transformation of the natural world around us and we can plant trees, shrubs, vines, canes, fungi, forage and animal systems that create clean water, pure air and build the soil. We can plant the systems that provide abundant, low-cost yields of highly nutritious foods for humanity for all times.

Who is it again that will do this work? You and I.

We can no longer afford to wait for the universities or governments or any other "them" to get started. We can no longer afford to wait for more research to be conducted or for the ultimate varieties to be developed. We can't wait for incentives and cost-share programs that may never happen and would bind us with bureaucratic red tape. We can't relinquish the revolutionary power of one and wait for a hoped for perfect organization to form.

We are the ones who must do this, and we must do it starting now.

As farmers, homesteaders or rural landowners we are now embarked on a journey that will last for the rest of our lifetime. We need to convert our annual crop farms into perennial polyculture ecosystems. One tree at a time. One vine at a time. Over and over again for as long as we live. (I will give up my tree planting spade only when they pry my cold, dead fingers from the handle!) The journey of a thousand miles begins with a single step. Put one foot in front of the other and keep on walking.

As food producers we manage more land than our urban and suburban brethren (in our culture), so we have the ability to produce tons of surplus food to keep the cities nourished. We have the management authority over hundreds of millions of acres and hence have the ability to create broad-scale ecological change. Yes, as more farmers begin the restoration agriculture process, the rivers, lakes and streams of North America will in measurable fact be cleaner, and the dead zones in the Gulf of Mexico, Chesapeake Bay and others will become dramatically smaller. Seafood and freshwater fish will become more abundant and healthier. Nationwide the costs of agricultural production will go down. Fossil fuel dependency will decrease. Wild pollinators will have more places to thrive, and migratory insect-eating birds will find more food and safe travel corridors.

As an example, a square 160-acre farm has a perimeter of 2 miles. If it were divided into four 40-acre squares, it would have an additional linear mile of interior fence lines that could be planted to perennial polycultures. If all that we did was plant a single row of perennial polyculture on every 40-acre parcel of the 95 million acres of soybeans grown in the United States it would make nearly 2 million miles of perennial, food-producing systems. Two million miles! Linear systems of this amount would make a single row of perennial polyculture that would crisscross the United States nearly 650 times. The multiplicative power of restoration agriculture in rural America is potentially astounding.

But since most Americans don't live in the countryside — most live in the suburbs and cities — what can urbanites do?

We are what we eat. It appears that until now most Americans are chicken! (And most chicken is made of genetically modified corn and soybeans.) We however must be bold and unafraid. We will plant perennial food ecologies in every nook and cranny of our suburban and urban lots, and many will go forth from here and plant in vacant lots, spaces between railroad tracks and back alleys, and anywhere a hazelnut, walnut or raspberry will fit. Even if it won't fit, we will turn it loose and give it a chance to make its own way. When we surround ourselves with perennial, food-producing systems everywhere we will have come a long way toward having more food security as a nation. Why do perfectly well-meaning people sit around discussing how to solve the problem of urban food deserts when they could be out planting food in those very same food deserts? Everyone! Everywhere!

When not planting food-producing systems everywhere, transform your diet to a diet of perennials, especially products from restoration agriculture farmers. What you eat is the market demand that "pulls" production methods. Go to your local grocery store and ask the manager to carry perennial foods, and especially foods produced by permaculture and restoration agriculture farmers. Better yet find a local restoration agriculture farmer and buy directly from them, or at least make the connection and introduce the grocer to the farmer so they can begin the dance that will transform how we eat as well as the ecology of the planet.

Increased sales at the grocery store will create the incentive for farmers to plant more perennial, woody-crop systems. Your food dollars are essential for the creation of the new trend toward perennial agriculture. Instead of beans and rice, begin to buy more tree fruit, nuts, berries, juice beverages, nut “milk” and grass-fed animal products.

Starting a non-profit organization to bring attention to our food production problems is only useful if that cause has a reality on the ground. The world is overburdened these days with non-profit shells that exist to only “talk” about an issue or “raise awareness.” They have no tangible example on the ground, of what things would look like if the world were to operate the way they think it should. If you know any of these non-profits or if you operate one yourself, now is the time to make it real. Turn your vision for a healthy, abundant, verdant future into something actual on the ground. One step at a time, over and over, is all that it takes.

A brilliant example of a “real” non-profit is Growing Power, founded by Will Allen in Milwaukee, Wisconsin. Instead of merely talking about the topics of food deserts and urban hunger, Growing Power builds greenhouses and gardens where they raise goats, poultry, earthworms, garden vegetables and fish in very tightly integrated systems right in the city. Growing Power has now expanded nationwide, and in my opinion, mostly because it is doing something real. They really are growing food and they really are training people how to do it in urban environments. They are helping to solve the urban “food desert” in addition to discussing it.

Empty bloggers don’t quite understand what restoration agriculture is all about, either, even though their words might read as if they do. Even many permaculture and sustainable agriculture bloggers don’t get it. There are dozens of permaculture and sustainable agriculture bloggers who have extremely popular websites and blogs, but don’t have an actual earthsite. I know of several people who have even written books and educational material that are the result of years and years of painstaking research, they lecture widely on the topic, and yet they sit down to their certified-organic, annual-grain falafel sandwich and don’t have so much as a perennial broccoli plant or a hazelnut bush in the front yard of their apartment.

On this planet actual reality must take priority over virtual reality. The urgency of our times calls us to be *doers* in addition to *beers* and way more than just mere talkers. Once you have your system in the ground, then you’ve got something to talk about. At any point in time there will be people of all skill levels and in all phases of the restoration agriculture succession, so nobody will be left out of the conversation, provided they’ve planted their first tree.

The urgency of our times calls for us to plant polyculture systems everywhere and to dispense with naysaying, procrastinating, talking the subject to death, or making excuses as to why we’re not doing this. We must practice what we preach. Do it first, then talk about it, not the other way around.

We must start right now, right where we are, and with the resources that we have available. One tree at a time, over and over again, forever.

If after reading this book you decide not to implement at least some of the strategies in it, you might as well dig a hole, toss the book in it, then plant a hickory tree. The book will at least have done some good. Better yet, give this book to someone who will actually do something.

Once we’ve begun, we will organize and collaboratively create this new agriculture on the broad scale. Rural producers need to organize in order to effectively process their edible woody crops and to make the value-added products to be consumed by our urban and suburban partners. Food growers and food eaters are in a symbiotic relationship in the re-creation of healthy, perennial edible ecologies. Yes, you can have a green, healthy planet and eat nacho cheese-flavored hazelnut chips, too!

There was a time before recorded history, when the world was dominated by giant reptiles — the dinosaurs. In their glory before their final demise dinosaurs were truly amazing. Some were as tall as a three-story building and others as long as a railroad car. A dinosaur, simply because of its huge size, had to consume literally tons of food every day just to stay alive. It is a good example of a linear, top-down organizational system that has reached titanic proportions. The “global economy” and its governmental “organs” act very much today like a dinosaur did back then. A very small brain, with perhaps a few other small brains down along the spinal cord, runs the whole show. A tremendous amount of energy is required to just keep the system running and genuine change is glacially slow to happen. Most dinosaurs became quite specialized in what they ate and where they lived. In the same way, the governments of today seem to see things from their own perspective and not from the perspective of ordinary people. A dinosaur's knowledge was limited to its specific ecological niche and fossil evidence shows that the dinosaurs were not very adaptable to change.

Toward the end of the dinosaur's reign, mammals began to appear. These small, mouse-like creatures who moved quickly, adapted to changing conditions. Instead of having 3 tons of biomass within one skin as one creature with only one walnut-sized brain, 3 tons of mice might have equaled 20,000 or 30,000 individuals each with their own brains making decisions that interacted collectively. We all know the story. The mice eventually took over and the dinosaurs are now gone, except for a few relic species or perhaps an undiscovered sea monster. All that it took was one space rock smashing into Mexico in order to change the system conditions fast enough that the dinosaurs could not adapt. The decentralized, distributed-net intelligence of the swarm of mice, however, could adapt. The individuals within the population may not have been able to adapt, but the population as a whole could and did — they survived.

The world of the hierarchical, top-down, command-and-control organization is coming to a close. The days of a king ruling the entire kingdom have given way to democracies in many places, plutocracies and kleptocracies in others. The age of the giant corporation with the top-down hierarchy of CEO, management team, middle management, administrative staff, manufacturing and distribution is nearing its last days. Even when the dinosaurs were at their greatest, largest and most ferocious, their doom was assured. Their reign was over.

The mice have won. Over and over again, nature has shown that gigantism only has limited effectiveness. Once an organism becomes too large and too specialized, it has become fatally vulnerable to slight changes in the ecological system and extinction is assured. Anthropologists have shown over and over again that as a hierarchical organization becomes larger and more complex it eventually reaches a point where the energy needed to merely maintain itself is greater than the benefits derived from the gigantism in the first place.

The one "global economy" is at that point. There are many reasons why it is at this point, but the main theme discussed in this book is the fact that no system can persist for long when at its core it is a system of destruction, of extraction. The current world economy is fed by a system of annual agriculture. By necessity annual agriculture must destroy ecosystems in order to plant rice, wheat, corn, beans … and the list goes on. This narrow-minded and short-sighted, highly specialized process has always ended in collapse for the society that has embraced it. The loss of soil with its subsequent loss of fertility results in poorer and poorer quality nutrition for a populace living in an increasingly complex society which takes more energy to maintain it than it gains through that maintenance process. School test scores going down? Childhood obesity and diabetes increasing? These are not conservative-caused problems or liberal-caused problems. These problems are caused by overspecialization, gigantism, excessive societal complexity, and are fed by the empty calories of annual grass seeds grown in increasingly toxic and infertile soils.

This too shall pass … it is over. The dinosaurian, industrial, big- ag, monocrop agriculture is screaming in agony and gasping its last breath. Let's hope that its dying convulsions aren't too traumatic. The simplistic, reductionistic, annual crops system is being replaced by the next successional phase. Like gravity, the process of natural succession is unstoppable, and life on earth is beginning the turnaround. Annual weeds (they call them crops) will give way to perennial grasses being grazed by multitudes of life forms. Sun-loving shrubs and nut- and fruit-bearing trees will invade by the millions. Vines and canes laden with fruit will begin to crawl over the young trees and rubble of the next "past age." You can't stop succession. You know this in your garden because you've never been able to stop the "weeds" from taking over.

I know that the corner has been turned, the old world is over, and the new, lush, living planet is being born. I know this, because this one little mouse, me … I plant trees. Won't you join me?

It all starts with you.

Appendix

IN the "Nutrition & Perennial Agriculture" chapter I presented a Meat Nutrient Summary table. The most convenient way to present the nutrition available in animal products, was to produce a single table rather than a list of the individual edible parts of an animal. The summary table is a composite of every animal part for which we could possibly find USDA nutritional data, from tongue to spleen, to ears, tails and tripe.

For those of you who raise and butcher your own livestock, you know how much more there is to an animal than steaks and chops. Animal muscle meat, although high in protein, vitamins and minerals, pales in comparison to the organ meats. Of all the organ meats, liver is king! In fact, if you look at lists of the top ten foods for any particular vitamin or mineral, liver is usually somewhere on that list. I hate liver! I can't stand the consistency of it. I can't stand the flavor of it, and I can't stand the smell of raw liver or it even cooking on the stove. Add onions and butter and I totally gross out and consider becoming a vegetarian.

It was my intellectual understanding of the outstanding nutritional values of organ meats and my disgust for liver, however, that led me into the world of cured and processed meats. *Real* cured meats (salted, smoked, seasoned, brined, lacto-fermented, etc.) can actually be some of the most nutrient-dense foods one can eat. Bologna, Braunschweiger (liverwurst), hot dogs, sopresotto, salami, and other cured meats are one way that the highly nutritious, but less common animal parts can be made into delicious and highly nutritious foods.

Industrially produced, cured meat-food products are *not* the same as home-made or craftsman-produced charcuterie. The hot dog that you get from the convenience store is a highly effective industrial waste disposal system. It is laced with chemicals to kill the toxic bacteria that is likely in it. Dozens of industrial chemicals are used to tenderize and even dissolve meat proteins in order to form them into a fused, artificially flavored and colored, reconstituted meat-food product. They are probably not good for you — at least my mom says so.

Not so with a hot dog made with no artificial ingredients, no chemical additives, natural herbs and spices and made from the nutrient-dense liver, spleen, pancreas and kidneys of multiple species of animal. In the same way that livestock can be used to either degrade a pasture or improve it, a hot dog can be proven to cause birth defects in children, or can actually be a health food of the highest degree! (You see, kids! I'm lookin' out for ya!)

The following tables provide the baseline data that was summarized on the Meat Nutrient tables in the "Nutrition & Perennial Agriculture" chapter.

Beef Nutrient Summary 1 OF 3

NUTRIENT	UNIT	BEEF TRIMMED V/100g*	BRAIN V/100g*	TALLOW V/100g*	HEART V/100g*	KIDNEYS V/100g*
PROXIMATES						
Water	g	52.87	76.29	0	77.11	77.89
Energy	kcal	299	143	902	112	99
Energy	kJ	1,251.00	600.00	3,774.00	467	413
Protein	g	26.22	10.86	0	17.72	17.4
Total lipid (fat)	g	20.75	10.3	100	3.94	3.09
Ash	g	1.1	1.51	0	1.1	1.33
Carbohydrate, by difference	g	0	1.05	0	0.14	0.29
MINERALS						

Calcium, Ca	mg	9	43	0	7	13
Iron, Fe	mg	2.5	2.55	0	4.31	4.6
Magnesium, Mg	mg	24	13	0	21	17
Phosphorus, P	mg	203	362	0	212	257
Potassium, K	mg	356	274	0	287	262
Sodium, Na	mg	63	126	0	98	182
Zinc, Zn	mg	5.62	1.02	0	1.7	1.92
Copper, Cu	mg	0.104	0.287	0	0.396	0.426
Manganese, Mn	mg	0.015	0.026	0	0.035	0.142
Selenium, Se	g	19.8	21.3	0.2	21.8	141
Fluoride, F	g	22.4	0	0	0	0
VITAMINS						
Vitamin C, total ascorbic acid	mg	0	10.7	0	2	9.4
Thiamin	mg	0.09	0.092	0	0.238	0.357
Riboflavin	mg	0.21	0.199	0	0.906	2.84
Niacin	mg	4.39	3.55	0	7.53	8.03
Pantothenic acid	mg	0.38	2.01	0	1.79	3.97
Vitamin B6	mg	0.37	0.226	0	0.279	0.665
Folate, total	g	8	3	0	3	98
Folate, food	g	8	3	0	3	98
Folate, DFE	mcg_DFE	8	3	0	3	98
Choline, total	mg	99.9	0	79.8	0	0
Betaine	mg	13.1	0	0	0	0
Vitamin B12	g	2.49	9.51	0	8.55	27.5
Vitamin A, RAE	mcg_RAE	0	7	0	0	419
Retinol	g	0	0	0	0	419
Carotene, beta	g	0	88	0	0	0
Carotene, alpha	g	0	0	0	0	0
Cryptoxanthin, beta	g	0	0	0	0	0
Vitamin A, IU	IU	0	147	0	0	1397
Lycopene	g	0	0	0	17	20

Vitamin E (alpha-tocopherol)	mg	0	0.99	2.7	0.22	0.22
Tocopherol, gamma	mg	0	0.05	0	0.02	0.02
Vitamin D (D2 + D3)	g	0	0	0.7	0	1.1
Vitamin D	IU	0	0	28	0	45
Vitamin (phylloquinone)	g	0	0	0	0	0

******V/100g = Value per 100 grams*

Beef Nutrient Summary 2 OF 3

NUTRIENT	UNIT	LIVER V/100g*	LUNGS V/100g*	PANCREAS V/100g*	SPLEEN V/100g*
PROXIMATES					
Water	g	70.81	79.38	65.2	77.2
Energy	kcal	135	92	235	105
Energy	kJ	564	385	983	439
Protein	g	20.36	16.2	15.7	18.3
Total lipid (fat)	g	3.63	2.5	18.6	3
Ash	g	1.31	0.98	1.3	1.38
Carbohydrate, by difference	g	3.89	0	0	0
MINERALS					
Calcium, Ca	mg	5	10	9	9
Iron, Fe	mg	4.9	7.95	2.22	44.55
Magnesium, Mg	mg	18	14	18	22
Phosphorus, P	mg	387	224	327	296
Potassium, K	mg	313	340	276	429
Sodium, Na	mg	69	198	67	85
Zinc, Zn	mg	4	1.61	2.58	2.11
Copper, Cu	mg	9.755	0.26	0.06	0.168
Manganese, Mn	mg	0.31	0.019	0.15	0.073
Selenium, Se	g	39.7	44.3	24.7	62.2
Fluoride, F	g	0	0	0	0
VITAMINS					
Vitamin C, total ascorbic acid	mg	1.3	38.5	13.7	45.5
Thiamin	mg	0.189	0.047	0.14	0.05

Riboflavin	mg	2.755	0.23	0.445	0.37
Niacin	mg	13.175	4	4.45	8.4
Pantothenic acid	mg	7.173	1	3.9	1.081
Vitamin B6	mg	1.083	0.04	0.2	0.07
Folate, total	g	290	11	3	4
Folate, food	g	290	11	3	4
Folate, DFE	mcg_DFE	290	11	3	4
Choline, total	mg	333.3	0	0	0
Betaine	mg	4.4	0	0	0
Vitamin B12	g	59.3	3.81	14	5.68
Vitamin A, RAE	mcg_RAE	4,968.00	14	0	0
Retinol	g	4,948.00	14	0	0
Carotene, beta	g	232.00	0	0	0
Carotene, alpha	g	11.00	0	0	0
Cryptoxanthin, beta	g	13.00	0	0	0
Vitamin A, IU	IU	16,898.00	46	0	0
Lycopene	g	0	0	0	0
Vitamin E (alpha-tocopherol)	mg	0.38	0	0	0
Tocopherol, gamma	mg	0.07	0	0	0
Vitamin D (D2 + D3)	g	1.2	0	0	0
Vitamin D	IU	49	0	0	0
Vitamin K (phylloquinone)	g	3.1	0	0	0

**V/100g = Value per 100 grams*

Beef Nutrient Summary 3 OF 3

NUTRIENT	UNIT	THYMUS V/100g*	TONGUE V/100g*	TRIPE V/100g*	BEEF TOTAL V/100g*
PROXIMATES					
Water	g	67.8	64.53	84.16	793.24
Energy	kcal	236	224	85	2,667.00
Energy	kJ	987	937	355	11,155.00

Protein	g	12.18	14.9	12.07	181.91
Total lipid (fat)	g	20.35	16.09	3.69	205.94
Ash	g	1.38	0.8	0.55	12.74
Carbohydrate, by difference	g	0	3.68	0	9.05
MINERALS					
Calcium, Ca	mg	7	6	69	187.00
Iron, Fe	mg	2.1	2.95	0.59	79.22
Magnesium, Mg	mg	14	16	13	190.00
Phosphorus, P	mg	393	133	64	2,858.00
Potassium, K	mg	360	315	67	3,279.00
Sodium, Na	mg	96	69	97	1,150.00
Zinc, Zn	mg	2.06	2.87	1.42	26.91
Copper, Cu	mg	0.048	0.17	0.07	11.74
Manganese, Mn	mg	0.12	0.026	0.085	1.00
Selenium, Se	g	18.1	9.4	12.5	415.00
Fluoride, F	g	0	0	0	22.40
VITAMINS					
Vitamin C, total ascorbic acid	mg	34	3.1	0	158.20
Thiamin	mg	0.109	0.125	0	1.44
Riboflavin	mg	0.345	0.34	0.064	8.70
Niacin	mg	3.452	4.24	0.881	62.10
Pantothenic acid	mg	3.026	0.653	0.227	25.21
Vitamin B6	mg	0.16	0.31	0.014	3.42
Folate, total	g	2	7	5	434.00
Folate, food	g	2	7	5	434.00
Folate, DFE	mcg_DFE	2	7	5	434.00
Choline, total	mg	0	0	194.8	707.80
Betaine	mg	0	0	0	17.50
Vitamin B12	g	2.13	3.79	1.39	138.15
Vitamin A, RAE	mcg_RAE	0	0	0	5,408.00

Retinol	g	0	0	0	5,381.00
Carotene, beta	g	0	0	0	320.00
Carotene, alpha	g	0	0	0	11.00
Cryptoxanthin, beta	g	0	0	0	13.00
Vitamin A, IU	IU	0	0	0	18,488.00
Lycopene	g	0	0	0	37.00
Vitamin E (alpha-tocopherol)	mg	0	0	0.09	4.60
Tocopherol, gamma	mg	0	0	0.02	0.18
Vitamin D (D2 + D3)	g	0	0	0	3.00
Vitamin D	IU	0	0	0	122.00
Vitamin K (phylloquinone)	g	0	0	0	3.10

**V/100g = Value per 100 grams*

Lamb Nutrient Summary 1 OF 2

NUTRIENT	UNIT	LAMB V/100g*	BRAIN V/100g*	HEART V/100g*	KIDNEYS V/100g*	LIVER V/100g*
PROXIMATES						
Water	g	59.47	79.2	76.71	79.23	71.37
Energy	kcal	282	122	122	97	139
Energy	kJ	1180	510	510	406	582
Protein	g	16.56	10.4	16.47	15.74	20.38
Total lipid (fat)	g	23.41	8.58	5.68	2.95	5.02
Ashg	0.87	1.33	0.93	1.26	1.44	1.1
Carbohydrate, by difference	g	0	0	0.21	0.82	1.78
MINERALS						
Calcium, Ca	mg	16	9	6	13	7
Iron, Fe	mg	1.55	1.75	4.6	6.38	7.37
Magnesium, Mg	mg	21	12	17	17	19
Phosphorus, P	mg	157	270	175	246	364
Potassium, K	mg	222	296	316	277	313
Sodium, Na	mg	59	112	89	156	70
Zinc, Zn	mg	3.41	1.17	1.87	2.24	4.66

Copper, Cu	mg	0.101	0.24	0.397	0.446	6.979
Manganese, Mn	mg	0.019	0.044	0.046	0.118	0.184
Selenium, Se	g	18.8	9	32	126.9	82.4
VITAMINS						
Vitamin C, total ascorbic acid	mg	0	16	5	11	4
Thiamin	mg	0.11	0.13	0.37	0.62	0.34
Riboflavin	mg	0.21	0.3	0.99	2.24	3.63
Niacin	mg	5.96	3.9	6.14	7.51	16.11
Pantothenic acid	mg	0.65	0.92	2.63	4.22	6.13
Vitamin B6	mg	0.13	0.29	0.39	0.22	0.9
Folate, total	g	18	3	2	28	230
Folate, food	g	18	3	2	28	230
Folate, DFE	mcg_DFE	18	3	2	28	230
Choline, total	mg	69.3	0	0	0	0
Betaine	mg	10.2	0	0	0	0
Vitamin B12	g	2.31	11.3	10.25	52.41	90.05
Vitamin A, RAE	mcg_RAE	0	0	0	95	7,391.00
Retinol	g	0	0	0	95	7,391.00
Vitamin A, IU	IU	0	0	0	316	24,612.00
Vitamin E (alpha-tocopherol)	mg	0.2	0	0	0	0
Vitamin D (D2 + D3)	g	0.1	0	0	0	0
Vitamin D	IU	2	0	0	0	0
Vitamin K (phylloquinone)	g	3.6	0	0	0	0

**V/100g = Value per 100 grams*

Lamb Nutrient Summary 2 OF 2

NUTRIENT	UNIT	LUNGS V/100g*	PANCREAS V/100g*	SPLEEN V/100g*	TONGUE V/100g*	LAMB TOTAL V/100g*
PROXIMATES						
Water	g	79.7	73.77	78.15	66.6	664.20

Energy	kcal	95	152	101	222	1,332.00
Energy	kJ	397	636	423	929	5,573.00
Protein	g	16.7	14.84	17.2	15.7	143.99
Total lipid (fat)	g	2.6	9.82	3.1	17.17	78.33
Ashg	0.87	1.4	1.3	0.92		10.55
Carbohydrate, by difference	g	0	0	0	0	2.81
MINERALS						
Calcium, Ca	mg	10	8	9	9	87.00
Iron, Fe	mg	6.4	2.3	41.89	2.65	74.89
Magnesium, Mg	mg	14	21	21	21	163.00
Phosphorus, P	mg	219	400	280	184	2,295.00
Potassium, K	mg	238	420	358	257	2,697.00
Sodium, Na	mg	157	75	84	78	880.00
Zinc, Zn	mg	1.8	1.93	2.84	2.32	22.24
Copper, Cu	mg	0.254	0.061	0.121	0.212	8.81
Manganese, Mn	mg	0.019	0.04	0.051	0.049	0.57
Selenium, Se	g	17.7	34.3	32.4	15	368.50
VITAMINS						
Vitamin C, total ascorbic acid	mg	31	18	23	6	114.00
Thiamin	mg	0.048	0.03	0.047	0.15	1.85
Riboflavin	mg	0.237	0.25	0.348	0.38	8.59
Niacin	mg	4.124	3.7	7.895	4.65	59.99
Pantothenic acid	mg		1		0.97	16.52
Vitamin B6	mg	0.11	0.07	0.11	0.18	2.40
Folate, total	g	12	13	4	4	314.00
Folate, food	g	12	13	4	4	314.00
Folate, DFE	mcg_DFE	12	13	4	4	314.00
Choline, total	mg	0	0	0	0	69.30
Betaine	mg	0	0	0	0	10.20
Vitamin B12	g	3.93	6	5.34	7.2	188.79

Vitamin A, RAE	mcg_RAE	27	0	0	0	7,513.00
Retinol	g	27	0	0	0	7,513.00
Vitamin A, IU	IU	89	0	0	0	25,017.00
Vitamin E (alpha-tocopherol)	mg	0	0	0	0	0.20
Vitamin D (D2 + D3)	g	0	0	0	0	0.10
Vitamin D	IU	0	0	0	0	2.00
Vitamin K (phylloquinone)	g	0	0	0	0	3.60

***** *V/100g = Value per 100 grams*

Pork Nutrient Summary 1 OF 4

NUTRIENT	UNIT	PORK V/100g*	LARD V/100g*	FEET V/100g*	HEART V/100g*
PROXIMATES					
Water	g	61.06	0	64.99	76.21
Energy	kcal	263	902	212	118
Energy	kJ	1,100	3,774	889	494
Protein	g	16.88	0	23.16	17.27
Total lipid (fat)	g	21.19	100	12.59	4.36
Ashg	0.87	0	0.68	0.84	0.32
Carbohydrate, by difference	g	0	0	0	1.33
MINERALS					
Calcium, Ca	mg	14	0	70	5
Iron, Fe	mg	0.88	0	0.58	4.68
Magnesium, Mg	mg	19	0	6	19
Phosphorus, P	mg	175	0	75	169
Potassium, K	mg	287	0	63	294
Sodium, Na	mg	56	0	132	56
Zinc, Zn	mg	2.2	0.11	0.76	2.8
Copper, Cu	mg	0.045	0	0.07	0.408
Manganese, Mn	mg	0.01	0	0	0.063
Selenium, Se	g	24.6	0.2	23.3	10.4

VITAMINS					
Vitamin C, total ascorbic acid	mg	0.7	0	0	5.3
Thiamin	mg	0.732	0	0.026	0.613
Riboflavin	mg	0.235	0	0.106	1.185
Niacin	mg	4.338	0	1.13	6.765
Pantothenic acid	mg	0.668	0	0.303	2.515
Vitamin B6	mg	0.383	0	0.053	0.39
Folate, total	g	5	0	10	4
Folate, food	g	5	0	10	4
Folate, DFE	mcg_DFE	5	0	10	4
Choline, total	mg	0	49.7	0	0
Vitamin B12	g	0.7	0	0.52	3.79
Vitamin A, RAE	mcg_RAE	2	0	0	8
Retinol	g	2	0	0	8
Vitamin A, IU	IU	0	0	0	25
Vitamin E (alpha-tocopherol)	mg	0	0.6	0.02	0.63
Vitamin D (D2 + D3)	g	0	2.5	0	0
Vitamin D	IU	0	102	0	0

**V/100g = Value per 100 grams*

Pork Nutrient Summary 2 OF 4

NUTRIENT	UNIT	JOWL V/100g*	KIDNEYS V/100g*	LUNGS V/100g*	PANCREAS V/100g*
PROXIMATES					
Water	g	22.19	80.06	79.52	67.18
Energy	kcal	655	100	85	199
Energy	kJ	2741	418	356	833
Protein	g	6.38	16.46	14.08	18.56
Total lipid (fat)	g	69.61	3.25	2.72	13.24
Ash	g	1.17	0.8	1.12	1.53
Carbohydrate, by difference	g	0	0	0	0
MINERAL					

Calcium, Ca	mg	4	9	7	11
Iron, Fe	mg	0.42	4.89	18.9	2.13
Magnesium, Mg	mg	3	17	14	17
Phosphorus, P	mg	86	204	196	234
Potassium, K	mg	148	229	303	197
Sodium, Na	mg	25	121	153	44
Zinc, Zn	mg	0.84	2.75	2.03	2.62
Copper, Cu	mg	0.04	0.622	0.083	0.09
Manganese, Mn	mg	0.005	0.123	0.017	0.157
Selenium, Se	g	1.5	190	17.8	40.8
VITAMINS					
Vitamin C, total ascorbic acid	mg	0	13.3	12.3	15.3
Thiamin	mg	0.386	0.34	0.085	0.105
Riboflavin	mg	0.236	1.697	0.43	0.46
Niacin	mg	4.535	8.207	3.345	3.45
Pantothenic acid	mg	0.25	3.13	0.9	4.555
Vitamin B6	mg	0.09	0.44	0.1	0.46
Folate, total	g	1	42	3	3
Folate, food	g	1	42	3	3
Folate, DFE	mcg_DFE	1	42	3	3
Choline, total	mg	0	0	0	0
Vitamin B12	g	0.82	8.49	2.75	16.4
Vitamin A, RAE	mcg_RAE	3	59	0	0
Retinol	g	3	59	0	0
Vitamin A, IU	IU	9	198	0	0
Vitamin E (alpha-tocopherol)	mg	0.29	0	0	0
Vitamin D (D2 + D3)	g	0	0	0	0
Vitamin D	IU	0	0	0	0

**V/100g = Value per 100 grams*

Pork Nutrient Summary 3 OF 4

NUTRIENT	UNIT	SPLEEN V/100g*	STOMACH V/100g*	TONGUE V/100g*	EARS V/100g*
PROXIMATES					
Water	g	78.43	73.5	65.9	61.25
Energy	kcal	100	159	225	234
Energy	kJ	418	665	941	979
Protein	g	17.86	16.85	16.3	22.45
Total lipid (fat)	g	2.59	10.14	17.2	15.1
Ashg	0.87	0.63	0.9	0.6	0.5
Carbohydrate, by difference	g	0	0	0	0.6
MINERALS					
Calcium, Ca	mg	10	11	16	21
Iron, Fe	mg	22.32	1.01	3.35	2.4
Magnesium, Mg	mg	13	11	18	7
Phosphorus, P	mg	260	130	193	41
Potassium, K	mg	396	140	243	55
Sodium, Na	mg	98	75	110	191
Zinc, Zn	mg	2.54	1.85	3.01	0.19
Copper, Cu	mg	0.131	0.169	0.07	0.006
Manganese, Mn	mg	0.072	0.038	0.011	0.012
Selenium, Se	g	32.8	31.1	10.4	4.3
VITAMINS					
Vitamin C, total ascorbic acid	mg	28.5	0	4.4	0
Thiamin	mg	0.13	0.051	0.49	0.08
Riboflavin	mg	0.3	0.201	0.485	0.11
Niacin	mg	5.867	2.48	5.3	0.78
Pantothenic acid	mg	1.055	1.22	0.641	0.068
Vitamin B6	mg	0.06	0.034	0.24	0.02
Folate, total	g	4	3	4	0
Folate, food	g	4	3	4	0
Folate, DFE	mcg_DFE	4	3	4	0
Choline, total	mg	0	194.8	0	0
Vitamin B12	g	3.26	0.3	2.84	0.07

Vitamin A, RAE	mcg_RAE	0	0	0	0
Retinol	g	0	0	0	0
Vitamin A, IU	IU	0	0	0	0
Vitamin E (alpha-tocopherol)	mg	0	0.04	0.29	0
Vitamin D (D2 + D3)	g	0	0	0	0
Vitamin D	IU	0	0	0	0

*V/100g = Value per 100 grams

Pork Nutrient Summary 4 OF 4

NUTRIENT	UNIT	TAIL V/100g*	BRAIN V/100g*	LIVER V/100g*	PORK TOTAL V/100g*
PROXIMATES					
Water	g	46.05	78.36	71.06	925.76
Energy	kcal	378	127	134	3,891.00
Energy	kJ	1582	531	561	16,282.00
Protein	g	17.75	10.28	21.39	235.67
Total lipid (fat)	g	33.5	9.21	3.65	318.35
Ash	g	0.87	1.13	1.44	12.53
Carbohydrate, by difference	g	0	0	2.47	4.40
MINERALS					
Calcium, Ca	mg	18	10	9	215.00
Iron, Fe	mg	0.99	1.6	23.3	87.45
Magnesium, Mg	mg	8	14	18	184.00
Phosphorus, P	mg	50	282	288	2,383.00
Potassium, K	mg	349	258	273	3,235.00
Sodium, Na	mg	63	120	87	1,331.00
Zinc, Zn	mg	2.31	1.27	5.76	31.04
Copper, Cu	mg	0.084	0.24	0.677	2.74
Manganese, Mn	mg	0.011	0.094	0.344	0.96
Selenium, Se	g	2.7	15.9	52.7	458.50
VITAMINS					
Vitamin C, total ascorbic acid	mg	0	13.5	25.3	118.60

Thiamin	mg	0.21	0.155	0.283	3.69
Riboflavin	mg	0.11	0.275	3.005	8.84
Niacin	mg	2.06	4.275	15.301	67.83
Pantothenic acid	mg	0.673	2.8	6.65	25.43
Vitamin B6	mg	0.37	0.19	0.69	3.52
Folate, total	g	5	6	212	302.00
Folate, food	g	5	6	212	302.00
Folate, DFE	mcg_DFE	5	6	212	302.00
Choline, total	mg	0	0	0	244.50
Vitamin B12	g	0.88	2.19	26	69.01
Vitamin A, RAE	mcg_RAE	0	0	6,502.00	6,574.00
Retinol	g	0	0	6,502.00	6,574.00
Vitamin A, IU	IU	0	0	21,650.00	21,882.00
Vitamin E (alpha-tocopherol)	mg	0	0	0	1.87
Vitamin D (D2 + D3)	g	0	0	0	2.50
Vitamin D	IU	0	0	0	102.00

**V/100g = Value per 100 grams*

Chicken Nutrient Summary 1 OF 1

NUTRIENT	UNIT	CHICKEN V/100g*	GIBLETS V/100g*	HEART V/100g*	LIVER V/100g*	CHICKEN TOTAL V/100g*
PROXIMATES						
Water	g	73.24	69.8	64.85	76.46	284.35
Energy	kcal	143	168	185	119	615.00
Energy	kJ	598	703	774	496	2,571.00
Protein	g	17.44	17.89	26.41	16.92	78.66
Total lipid (fat)	g	8.1	9.21	7.92	4.83	30.06
Ash	g	1.17	0.97	0.72	1.06	3.92
Carbohydrate, by difference	g	0.04	2.13	0.1	0.73	3.00
MINERALS						
Calcium, Ca	mg	6	10	19	8	43.00
Iron, Fe	mg	0.82	5.93	9.03	8.99	24.77

Magnesium, Mg	mg	21	18	20	19	78.00
Phosphorus, P	mg	178	198	199	297	872.00
Potassium, K	mg	522	226	132	230	1,110.00
Sodium, Na	mg	60	77	48	71	256.00
Zinc, Zn	mg	1.47	3.01	7.3	2.67	14.45
Copper, Cu	mg	0.065	0.275	0.502	0.492	1.33
Manganese, Mn	mg	0.016	0.151	0.107	0.255	0.53
Selenium, Se	g	10.2	56.1	8	54.6	128.90
VITAMINS						
Vitamin C, total ascorbic acid	mg	0	11.4	1.8	17.9	31.10
Thiamin	mg	0.109	0.097	0.07	0.305	0.58
Riboflavin	mg	0.241	1.106	0.741	1.778	3.87
Niacin	mg	5.575	8.53	2.803	9.728	26.64
Pantothenic acid	mg	1.092	3.275	2.654	6.233	13.25
Vitamin B6	mg	0.512	0.52	0.32	0.853	2.21
Folate, total	g	1	350	80	588	1,019.00
Folate, food	g	1	350	80	588	1,019.00
Folate, DFE	mcg_DFE	1	350	80	588	1,019.00
Choline, total	mg	58.8	0	0	194.4	253.20
Betaine	mg	7.7	0	0	16.9	24.60
Vitamin B12	g	0.56	10.83	7.29	16.58	35.26
Vitamin A, RAE	mcg_RAE	0	3,152.00	8.00	3,296.00	6,456.00
Retinol	g	0	3,152.00	8.00	3,290.00	6,450.00
Carotene, beta	g	0	0	0	56.00	56.00
Carotene, alpha	g	0	0	0	11.00	11.00
Cryptoxanthin, beta	g	0	0	0	11.00	11.00
Vitamin A, IU	IU	0	10,497.00	28.00	11,078.00	21,603.00
Lycopene	g	0	0	0	40	40.00
Vitamin E (alpha-tocopherol)	mg	0.27	0	0	0.7	0.97
Tocopherol, gamma	mg	0.17	0	0	0.31	0.48
Tocopherol, delta	mg	0.03	0	0	0	0.03

Vitamin K (phylloquinone)	g	0.8	0	0	0	0.80

**V/100g = Value per 100 grams*

Resources

BOOKS

Edible Forest Gardens, Volumes 1 & 2, by Dave Jacke and Eric Toensmeier (Chelsea Green Publishing, White River Junction, Vermont, 2005). Jacke and Toensmeier spell out and explore the key concepts of forest ecology and apply them to the needs of natural gardeners in temperate climates. Volume I lays out the vision of the forest garden and explains the basic ecological principles that make it work. In Volume II, Dave Jacke and Eric Toensmeier move on to practical considerations:concrete ways to design, establish, and maintain your own forest garden. Along the way they present case studies and examples, as well as tables, illustrations, and a uniquely valuable "plant matrix" that lists hundreds of the best edible and useful species.

Twilight of the Mammoths: Ice Age Extinctions and the Rewilding of America, by Paul S. Martin (University of California Press, Berkeley, 2005). Paul Martin traces his career as a paleontologist seeking the whodunit truth about the extinction of North America's megafauna 13,000 years ago, and makes a thoughtful yet passionate call to restore the ecological richness and evolutionary potential of North America by returning the ecological equivalents of North America's lost camels, elephants, cheetahs, lions, horses, and other large species.

The Ghosts of Evolution: Nonsensical Fruit, Missing Partners, and Other Ecological Anachronisms, by Connie Barlow (Basic Books, New York, 2000). By looking at odd, rare plants, whose fruits are no longer being dispersed, Barlow shows how the extinction of the North American megafauna discombobulated ecosystems and ecological and evolutionary processes throughout the continent.

Quaternary Extinctions: A Prehistoric Revolution, edited by Paul S. Martin and Richard G. Klein (University of Arizona Press, 1984). A magnificent anthology discussing the role of Stone Age humans in causing the Pleistocene megafauna extinctions. Paul Martin's chapter "Prehistoric Overkill: The Global Model" is one of the most important scientific papers of the last 50 years.

The Call of Distant Mammoths: Why the Ice Age Mammals Disappeared, by Peter D. Ward (Copernicus, New York, 1997). Ward, a distinguished paleontologist at the University of Washington, gives a clear, highly readable study of mass extinctions and their causes. His main focus is the Pleistocene extinction, however, and by drawing on a sweep of research he makes a solid, convincing case that humans caused the extinction of megafauna around the world.

The Winds Of Change: Climate, Weather, and the Destruction of Civilizations, by Eugene Linden (Simon & Schuster, 2006) (Collapse)

Rewilding North America: A Vision for Conservation in the 21st Century, by Dave Foreman (Island Press, 2004) (Conservation Biology)

Profitable Farms and Woodlands: A Practical Guide in Agroforestry for Landowners, Farmers and Ranchers, coordinated by Joshua O. Idassi (USDA National Agroforestry Center, Lincoln, Nebraska, 2012). A practical step-by-step guide for small farmers and woodland owners to adopt best management technologies in agroforestry for the purpose of enhancing the economic and environmental benefits of their farms and woodlands.

ARTICLES

Print articles:

Paul S. Martin and David Burney, "Bring Back the Elephants!" *Wild Earth,* Spring 1999, pages 57-64.

Connie Barlow, "Rewilding for Evolution," *Wild Earth,* Spring 1999, pages 53-56.

"Serengeti in the Dakotas," editorial, *Scientific American,* June 2007, page 8.

Josh Donlan, "Restoring America's Big, Wild Animals," *Scientific American,* June 2007, pages 70-77.

Available online as a downloadable PDF:

Josh Donlan, Harry W. Greene, Joel Berger, Carl E. Bock, Jane H. Bock, David A. Burney, James A. Estes, Dave Foreman, Paul S. Martin, Gary W. Roemer, Felisa A. Smith, and Michael E. Soulè, "Re-wilding North America," *Nature,* Vol. 436, No. 18, August 2005, pages 913-914.

Josh Donlan, Joel Berger, Carl E. Bock, Jane H. Bock, David A. Burney, James A. Estes, Dave Foreman, Paul S. Martin, Gary W. Roemer, Felisa A. Smith, Michael E. Soulé, and Harry W. Greene, "Pleistocene Rewilding: An Optimistic Agenda for Twenty-First Century Conservation," *The American Naturalist,* Vol. 168, No. 5, November 2006, pages 660-681. This article is the basic document for Pleistocene rewilding, with several illustrations and a boatload of references.

Josh Donlan, "Claws and Effects," *Grist,* November 8, 2005.

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