Chapter 4
Working with Nature:
Towards Ecological Integration

> *Consider the land or buildings you manage. Each of us manages an ecosystem —whether it is ourselves and our household or a thousand acre farm. What plants and animals are in your system? Are there any mushrooms, fungi or lichens? Is there a forest? Do you have gardens? Are they mainly native species or not? Do you have both cultivated fields and animals grazing?*

Now with all this in your mind: How is all this managed? What role do you play in its management? How many inputs do you have to *buy* to make your system work? This chapter is about working with nature to manage our ecosystem. In forest, field and prairie, these natural ecosystems survive and thrive with only water and the sun as external inputs. Compare this to your own ecosystem.

> **Throughout this chapter we will review methods of resilient farmers using natural ecological processes to increase productivity and decrease external inputs. Our aim is to help you integrate relevant practices and provide references to practical literature which goes into more depth. As you read through this chapter, consider your own property and have a piece of paper handy for inspiration and new ideas.**

Ecosystems integrate and build subsystems that are crucial to resilience. The foremost subsystem of a resilient ecosystem is healthy, living soil. Man can mine the soil and other resources and create wealth and power. Such extraction is tempting, but transitory. In the US, we have recognized the importance of maintaining our soils and preventing their erosion since the 1930s.[144] This is not true in many other countries we have visited. Huge areas of deep soils in Ethiopia, for example, are being eroded away every year. Even in the US, we have yet to fully control erosion. Attempts to deal with erosion illustrate how farmers can work with nature.

Reduced tillage is an example of moving toward ecological integration. Since the dawn of agriculture, tillage of every field has been a standard practice before planting. Reduced tillage not only reduces erosion, it also leads to increased soil organic matter. Increased soil organic matter results in greater water holding capacity and drought resistance. The farmer who reduces tillage is letting natural processes help him achieve higher and more reliable yields. Eliminating tillage (no-till) maximizes soil health but can result in weed and insect problems. Strip-till, mulch-till, ridge-till and other reduced tillage methods are options which fit specific crops and systems and let natural processes maintain and improve soil fertility and reduce need for costly fertilizer.

Similarly, integrated pest management allows natural predators to control pests until they reach a threshold where pesticides use is required. This reduces pollution and costs of pesticides for the farmer.

These two examples illustrate how working with nature can benefit farmers by decreasing reliance on high cost pesticides and fertilizers. However, the problem is much deeper rooted. Nearly all human

[144] Helms, D. 2010. Hugh Hammond Bennett and the Creation of the Soil Conservation Service. Journal of Soil and Water Conservation, 65:37A-47A

cultures have shared this mindset: "**Be fruitful and multiply, fill the earth and** *subdue* **it; and** *have dominion over* **the fish of the sea and over the birds of the air and over every living thing that moves upon the earth**". The word "subdue," in the original Hebrew, is *kabash*. Its meaning is irrefutable; it does mean "subdue" or "enslave", and even connotes "molest" or "rape."[145]

This mindset is rooted in the brutal past experience of man learning to work with nature. In the search for food, our ancestor's plight was sometimes starvation and scrounging for anything edible. Our mastery of nature means that today's corn and melons are thousands of times more productive than those of prehistoric man. Today it is easier to farm and our yields are greater thanks to those who came before us and their desire to subdue nature.

From subduing to working with Nature. The attitude of dominating or subduing Nature has had the unintended side effect of creating pollution and destruction of entire ecosystems. This chapter is focused on methods and examples based on integration with ecological systems—working with Nature. All living systems can be understood as complex adaptive systems made up of successive scales of complex adaptive systems both above and below any particular scale. Within those infinitely complex systems are consistent and recurring opportunities for *symbiosis, or mutualism.* In order to manage a common threat, many systems of nature can and have become willing accomplices. They have and will always join with us in goals which also help them achieve their goals of reproducing, growing and maturing—e.g., fulfilling the adaptive cycle. We can unite with other species to create better, more powerful systems. When we enlist other systems, their resilience become ours, just as ours become theirs. In natural systems, as shown in the adjacent figure, the symbioses between species seem almost unlimited. Man can use those connections to let nature perform some of the tasks of producing food.

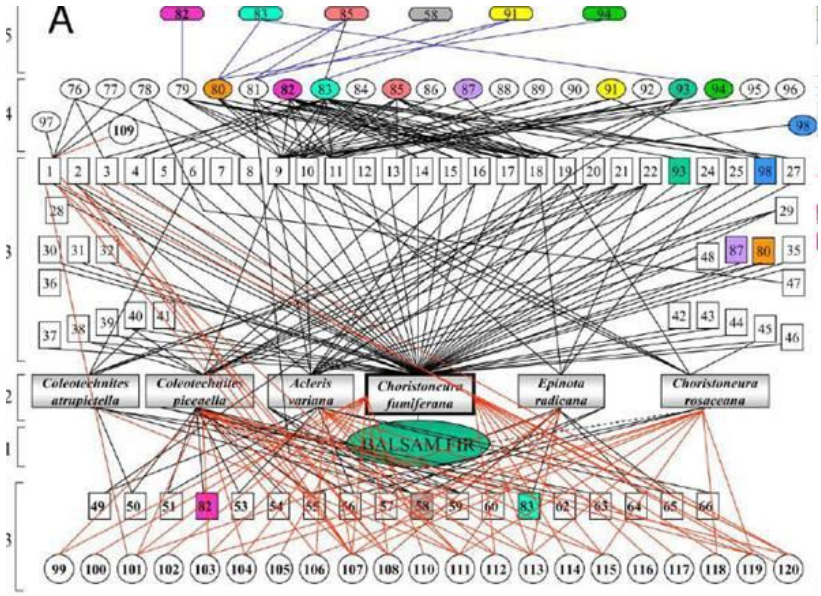


Figure 3 The web of a Balsam Fir's food sources[146]

[145] Stong's Concordance. http://biblehub.com/hebrew/3533.htm

[146] http://www.pnas.org/content/104/43/16976.full "Structure of the balsam fir source food web. (A) Total food web from all samples collected throughout entire study in all plot-years (1983–1993) and in all field experiments."

It is our opportunity as stewards of the land to use our collective creativity, ingenuity and problem solving to build systems that work together and adapt to change with less and less input from us.

Some would suggest that the best thing to do for soil in a natural ecosystem is to "leave it alone!" and that with time nature will do a better job. Nature does not want to be left alone any more than it wants to be subdued and conquered. As we come to understand natural processes, we see that nature is not an enemy to be fought, rather a partner to work with. Humanity is a part of Nature and we influence it with everything we do. We can fight Nature and lose. Or we can help Nature become more productive and resilient and supportive of our own productivity and resilience.

Mimicking natural processes. For thousands of years in Russia and Ukraine, natural predators herded large grazing animals (e.g., elk and deer) across barren lands of poor soils and created the richest soils in the world—several feet deep. American Indians created similar soils in the wetter Midwest by using fire to manage the forest and, like a predator, keep animals in herds to build up soils and create the second best soils in the world. Management-intensive grazing is, in 10 years or less, creating similar soils by understanding the processes which enable large grazing animals, grasses and soils to grow and thrive.[147]

"What occurs naturally on my property, and how can I work with it?" To figure out how we can work with Nature to achieve our goals, we must focus on our particular system. When we talk about nature, we're talking about *ecological systems*. These systems are made up of many relationships between organisms and environments. Some organisms are adapted to certain environments, like the cactus to the desert. When we force something, say a plant or animal, into an environment that is not suited for it, it fails--unless we are willing or able to exert excessive resources to upkeep by buying shade cloth, large greenhouses or potentially costly lighting systems.

Remember from chapter one how the ecological resilience concept arose: researchers noticed that natural forests withstood disturbance, cycled through stages of reorganization, rapid growth and matured into basically the same forest. Before man introduced artificial inputs and eliminated many of the natural players, natural systems were resilient. The systems cycled through stages, never reaching an equilibrium.

All natural systems, including our own, are always changing and coevolving to be better adapted. We see this with bacteria becoming resistant to drugs, weeds becoming resistant to herbicides. The technological fixes of man are overcome again and again as organisms adapt – often through a single gene change. A weed problem can definitely be taken care of through herbicides. But unless we understand why we have a weed problem and use systems such as cover crops to turn Nature into a cooperator, we will forever fight weeds. Herbicide resistance will inevitably result in the demise of every herbicides and the requirement for a new herbicide for those fighting Nature.

DDT did a great job destroying malarial insects and making vast areas of the United States free of the disease. Today's excessive dependence on insecticides has resulted in a technology treadmill where

[147] Hancock, D., 2015. The impacts of management intensive grazing on soil organic matter. http://www.caes.uga.edu/commodities/fieldcrops/forages/events/GS15/03SFNC/150512%20Hoard's%20H&F%20Grower%20article.pdf

insects develop resistance to a particular insecticide and a new one is required—unless we understand why they bother us and our crops. Then we can turn insects into cooperators.

There are insects and plants that have been bred and cultivated by humans for thousands of years to work with us. It's up to you to find out which of those will work on your property, in your system.

Symbiosis, mutualism, parasitism

Let's take a closer look at what it means to work with adaptive systems that fuel and manage natural environments. Some of the more common adaptive systems are bacteria and fungi that break down tree trunks in a forest, or, bats that manage insect populations as they flit about the night sky. These adaptive systems are radically diverse and express themselves in a myriad of forms through nature and it is our most noble pursuit to include them in our own agricultural systems.

So, if ecology is, "the relationship between an organism and its environment"[148], what is your relationship to your environment? Mankind's relationship with other species takes a variety of forms. Symbiosis is the general term for species which together (sym) live (biosis). Mutualism is symbiosis where both organisms benefit. In commensalism, one organism receives benefit while neither harming nor helping the other in any significant way. In parasitism one organism, called a parasite, benefits at the expense of the other.

Lichens, the firm green grey "moss" found on many stones, are fungi and algae (or cyanobacteria) working together in a *mutualistic* relationship. Plants and animals also require each other to survive. Many fruits require bats for pollination and bats require the resulting fruit for food. Parasites can even balance population levels through infections and viruses.

Mutualism is shown most powerfully in the relationship of bacteria and plants resulting in nitrogen fixation. This reaction is performed exclusively by prokaryotes (the bacteria and related organisms), using an enzyme complex termed nitrogenase. The plant gains nitrogen compounds, the bacterium gains carbohydrate and a preferred environment of reduced oxygen.

Man and nature: parasitism? Since industrial agriculture developed, man has considered the earth and its many ecosystems a resource to be mined and used. Be it soil for food and fiber, or the depths of the earth for fuel we have been working in a paradigm focused on the mining of resources. We have been parasites of the earth. This paradigm has led to numerous aftershocks, some of which we're only beginning to see. Other effects have been marked in history, such as the dust bowl of the 1930's brought on by a drastic mismanagement of the soil.

Figure 4 Image of Dust Bowl i 1930's

When the relationship of man to nature is parasitic, the host (nature) is destroyed. The United States

[148] The term was invented by Ernst Haeckel in 1866 in his General Morphology of Organisms.

recognized the mistakes which led to the dust bowl and began successful conservation programs such as the Soil Conservation Service, now the Natural Resources Conservation Service. Though these agencies make a dent, there is work to be done all around the world.

The SCS sponsored Lowdermilk's classic work Conquest of the Land through Seven Thousand Years. Lowdermilk documented the collapse of civilization after civilization, including a hundred dead cities in Syria alone, due to the destruction of the ecosystems which made the civilization possible—soil, water and air.[149]

Today a thousand Lowdermilks are writing of the destruction of ecological systems throughout the world, but few read and comprehend. Those who take a parasitic, conquering approach to nature are increasingly destroying the ecosystems and species preserved by thousands of generations of ecologically resilient societies. Rapacious Chinese colluding with local elites in Africa and Asia are perhaps the most egregious examples.[150]

A resilient species doesn't go extinct. A resilient civilization doesn't allow its cities to disappear under the sands of erosion. We can collectively avoid such massive recoils by working with the environment and nature's processes instead of controlling or fighting nature. It begins with a mindset of collaboration with the subtle, and not so subtle, actors in nature like beneficial insects, nitrogen fixing plant varieties and regenerative, naturally occurring fertilizers. So let us again ask the question, "What is your relationship with your ecosystem?"

Coevolution

We are only beginning to discover the ways we are coevolving with other organisms. Some of the more recent coevolution has been with domestic animals. Some populations of people have developed the ability to digest milk as adults while cows have evolved to produce much more milk than their offspring need. Some populations have developed the ability to digest wheat gluten while wheat has evolved to produce copious amounts of seed which adhere to the stalk so we can harvest them. Similarly beef cattle have evolved with man to become gentle and produce tenderer meat as man has adapted to eat more meat.

One form of coevolution is a unique property called bio-mimicry. Researchers can see that over time certain insects and birds alter their appearance to mimic others of their species that are deadly to their predators. How this occurs is still a mystery to researchers, though there is today a butterfly that looks very similar to a monarch. The difference is that the monarch, eating milkweed all day, is poisonous to the bird that eats the monarch look alike.

Humans use bio-mimicry all the time, building habitats, water catchments and microclimates like hugelkulture[151] to mimic nature. It is important to remember that in designing for nature, there are always things we have to learn from nature. The planet's ecosystems are resilient enough to survive for

[149] http://www.soilandhealth.org/01aglibrary/010119lowdermilk.usda/cls.html--

[150] Just a few news articles from the end of 2014: http://www.washingtontimes.com/news/2014/dec/9/illegal-ivory-trade-out-of-control/; http://nationalinterest.org/blog/the-buzz/beware-chinese-hegemony-11896; http://www.bignewsnetwork.com/index.php/sid/228998671

[151] Link to Hugelkulture site explaining microclimates

millennia, largely if not totally because of coevolution. Species and organisms forming bonds and partnerships to share nutrients and shelter.

In ecologically integrated agricultural systems, we work with a multitude of species. All of us work together to achieve increased productivity, fertility and adaptability.

Flora, Fauna and Fungi

We will focus on the multicellular kingdoms of living things: plants, animals and fungi with references to the other kingdoms when they contribute through mutualisms. These three groups, though separate, are each an integral part of the whole. Each one contributing to the success of the other; bees pollinate the flowers, rabbits eat the flowers and fertilize the ground for trees that house bees, and so on. There are a tremendous, nearly innumerable, examples in nature of multiple species working towards the success of the whole. There are many instances where we can begin to combine these three agents together in symbiotic relationships to bolster the resilience of the whole system. Our quest through this chapter is to show how our management intensive agriculture can incorporate naturally occurring systems to, in effect, passively perform management functions.

Flora

Plants have shown a unique ability over time to adapt to drastic changes in climate, altitude and predators and it is by using those adaptations that we can produce higher yields with less, or no chemical input. Farmers with high levels of ecological integration often take part in **cover cropping, companion planting, forest farming, using manure based compost as fertilizer and sacrificial plots**. Let us take a closer look at some of these practices and their application to your farm. As farms become more ecologically integrated, they will use less pesticide and less fertilizer.

Cover Cropping

*The practice of planting certain crops for the primary benefits of **Accumulation of Organic Matter, Nitrogen Fixation, Moisture Retention, and Halting Soil Erosion** from runoff.*

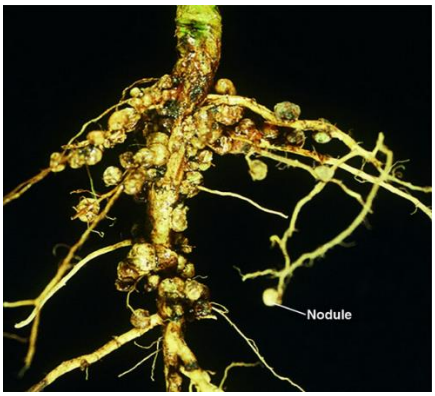
Accumulation of Organic Matter - Organic matter in the soil aids in drainage, accumulation of nutrients, moisture retention and can help you divert on-farm waste by decomposing that waste into the soil.

Four types of crops can help increase organic matter. Spring annuals are crops that remain in the field during the spring season until the soil is prepared for the summer main crop. Oat and triticale are grouped in this category in our region, which species are best for you depends on where you live. Summer annuals are planted after the winter main crop is harvested during the summer. Several summer annuals including buckwheat,

Table 1. C:N ratio of selected organic materials.

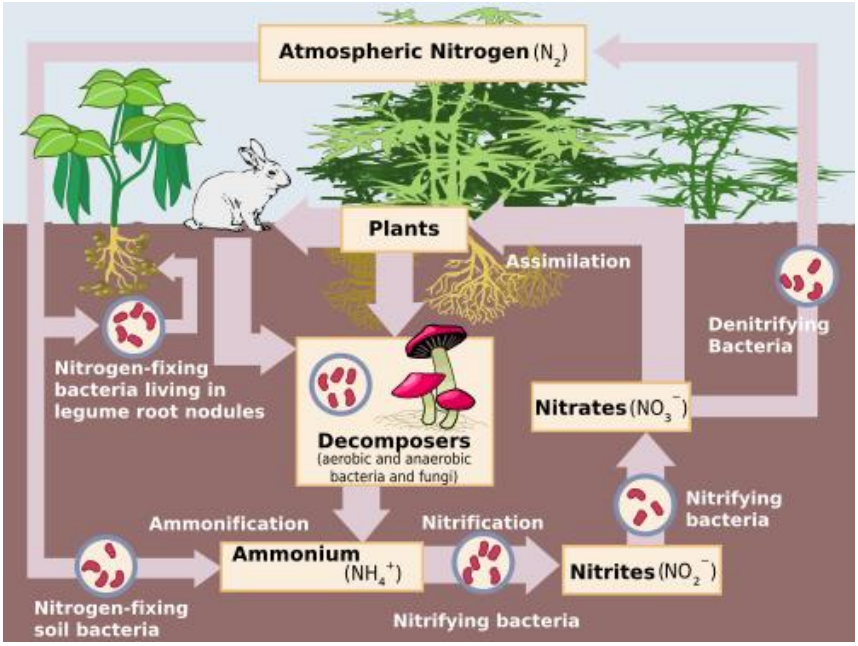
Organic Material	*C:N Ratio*
Hairy vetch /Alfalfa	10:1 to 15:1
Rye (seedlings)	12:1 to 15:1
Sweet clover	14:1 to 16:1
Food waste	14:1 to 16:1
Grass clippings	18:1 to 20:1
Rye (flowering)	20:1 to 21"1
Fruit waste	38:1 to 36:1
Dry leave	50:1 to 56:1
Corn stalks	58:1 to 60:1
Straw	60:1 to 72:1
Sawdust	250:1 to 500:1

cowpea, and sorghum are suitable for use in our area. Winter annuals are crops planted in the fall which remain on the field during the winter and resume growth in spring until the summer main crop is planted. These crops are essentially very good for adding organic matter as crops grow until maturity and produce significant biomass. Some legumes**,** such as hairy vetch, and grasses, such as winter rye, are very good options in our area. Biennials and perennials are grown for several years before being turned under (e.g., alfalfa) or remain in the field while other crops are growing. The latter require planting configurations which avoid competition between the species producing organic matter (e.g., leguminous trees) and the cash crop.



Nitrogen Fixation: Coevolution and symbiotic mutualism are epitomized in nitrogen fixation**.** The nitrogen cycle represents one of the most important nutrient cycles found in terrestrial ecosystems. Nitrogen is used by living organisms to produce a number of complex organic molecules such as amino acids, proteins, and nucleic acids. The store of nitrogen found in the atmosphere, where it exists as a gas (mainly N2), plays an important role for life. This store is about one million times larger than the total nitrogen contained in living organisms.

Nitrogen is an essential nutrient for all life on this planet. Although atmospheric nitrogen (N2) is abundant, the vast majority of organisms can use nitrogen only when it is combined with oxygen, hydrogen, or carbon. Resillient systems use the ecological relationships shown in the diagram below. Aside from energy-intensive industrial processes, only microorganisms are able to transform nitrogen from the abundant gaseous form to nitrogen compounds usable by plants.



Specific types of microorganisms are capable of carrying out different types of transformations, such as the oxidation of nitrogen compounds to nitrate or nitrite, the reduction of oxidized nitrogen compounds to ammonium, or the "fixation" of N2 from the atmosphere into ammonium. Bacteria that fix atmospheric N2 into biologically useable ammonium are referred to as "diazotrophic." These mainly plant-associated organisms convert nitrogen gases from the air into ammonium compounds that can be used by plants in the soil. Converted nitrogen is stored in root nodules, forming clusters on the surface of the roots.

Common nitrogen fixing crops: Clover *(Red and White clover are recommended for their capacity to re-seed themsevels most effectively)*, Legumes (*Peas, Alfalfa, Beans and Vetch)*, Soybeans, and Cowpea.

Moisture Retention – As we face unpredictable weather changes, often leading to record droughts interspersed with notoriously wet seasons, moisture retention is becoming a matter of vital importance for row croppers and cattle farmers alike. There are two main benefits to the moisture in your soil, **The Sponge Effect** providing long term moisture, and **Soil Decompression** allowing for deeper saturation of rain into the water table.

The Sponge Effect – As the plants root systems break up soil, they create micro and macro pores that hold and release moisture, much like a living organism, or a sponge. As rain falls on a cover cropped field, moisture is held within the roots as well that maintain moisture content through dry spells.

Soil Decompaction – When a field is left barren, it reacts differently to rainfall than a field with a cover crop. As rain falls on barren fields, the rain drops compact the soil particles along the top layer. This now compacted top layer of soil keeps rain from penetrating into the water table for future use. Moreover, the beneficial microorganisms integral to healthy soil are reliant on sustained moisture in the soils to survive through dry spells and droughts.

Halting Soil Erosion- Healthy soil is loose and fluffy making it easy for plants to take root and distribute nutrient. When these soils are left exposed to the elements, they are prone to run off during heavy rain fall. The root systems of cover crops help to amend that issue by **Weaving Fabrics**, and forming **Mycelium Networks.**

Weaving Fabrics - As cover crops extend roots into the soil the roots create a fabric that binds the soil together. There is a particular benefit to combining plants that reach different depths of the soil, further anchoring the soil while also pulling more nutrients from sub soils.

A note on Nitrogen Fixation: Though all of these varieties are hosts for nitrogen fixing microorganisms, different plants require different microorganisms to achieve the end result. You can purchase these microorganisms at many seed stores or online, they are most commonly available in powder form to sprinkle on seeds or directly into the ground. **Ground application is often better for soils with particularly low levels of microorganisms as they promote more nodule development through the whole root systems.** Pre-inoculated seeds tend to promote nodules only around the seed.

Mycelium Networks - In healthy soil that has been amended with microorganisms and organic material, you will notice mycelium networks begin to emerge. These mycelium networks not only help bind soil together, it has been shown that **mycelium networks actually form thousands of symbiotic relationships with plants**. They distribute nutrients and moisture between plants and from deeper in the soil sub layers.

Companion Planting

*The combining of particular crops to **promote growth, optimize space, provide pest control, and***

soil aeration. *Note that on large acreages strip cropping and cover crops are used to capture some of the benefits of companion planting, but this section is most relevant to smaller plots.*

Promoting Growth – Certain plants actually grow *better* together for a number of reasons. The most common reasons are **Conditioning the Soil** and **Increasing Pollination.**

Conditioning the Soil – Radishes, Carrots, and Turnips often grow well with leafy plants like Lettuce, Spinach, Cabbage or plants that produce above ground fruit. Consider that your garden is like a puzzle; the root vegetables taking up considerable amounts of space below the ground and considerably less above. On the other hand leafy plants like lettuce or vining plants like peas and cucumbers have relatively smaller root systems with expansive growth above ground. Turnips and Radishes also do their part for surface dominating plants by breaking up deeper soil and drawing nutrients and moisture to higher levels.

Increasing Pollination – By increasing the amount of flowering plants in your garden you're increasing your pollinator habitat. As you increase the amount of pollinators in your garden (bees aren't the only ones!) you increase the amount of food you're producing. If there are not enough pollinators in your garden many of your plants simply won't fruit as they require pollen to be distributed. It is very important to ensure that you are providing pollen and nectar sources for pollinators throughout the year. Even though you may have a lot of flowers in the spring, if there are no more flowering plants through the year, pollinators are forced to move into different areas or will die off**.**

Optimizing Space – Companion planting is often more space efficient. Take the **Three Sisters Method**, used for generations by Native Americans and other cultures. By growing corn, pole beans and squash together the plants not only work together providing nutrients to one another, they also help to save space by combining three garden beds into one!

Providing Pest Control – By selecting certain flowers and plant varieties[152] you can repell the pests that are attracted to your garden or fields. Borage can deter hornworms and cabbage worms. Chrysanthemums kill root nematodes and repel Japanese beetles. Dahlias repel nematodes. Four O'Clocks attract and kill Japanese beetles. Lavender is repels both fleas and moths, and it can help protect other plants near it from whiteflies. Marigolds are probably the most well known plant for repelling insects. French marigolds repel whiteflies and kill bad nematodes. Nasturtiums planted

[152] Holdsworth, G. Pest-fighting flowers. Vegetable Gardnener http://www.vegetablegardener.com/item/10805/pest-fighting-flowers

near tomatoes and cucumbers can fight off aphids, whiteflies, squash bugs, and cucumber beetles. The flowers, especially the yellow blooming varieties, act as a trap for aphids. Petunias can repel asparagus beetles, leafhoppers, aphids, tomato hornworms, and others. Sunflowers draw aphids away from other plants. Most commonly it is the oils in the plants that are either irritating or toxic to bugs. Luckily for you, these oils often smell nice and often make great culinary herbs!

Aerating the Soil – By planting root crops and cover crops you can actually help to break up the soil below, creating more space for roots to grow. Commonly roots crops like beets, radishes and carrots are grown with lettuce and other leafy greens to provide for space underground. The benefits of soil aeration[153] are many and sometimes unusual.

Forests in Farming

In forest farming we're looking at how to optimize or build your forest spaces, whether they're large or small. Forests can serve as incredible habitats for fowl, cattle, pigs, beneficial insects and wildlife alike.

Agroforestry[154] is a land use management system incorporating perennial trees and annual crops or livestock species. These systems are built with an eye for maximizing productivity by growing a diversity of trees shrubs and grasses. Over time, management should decrease as the system becomes stronger with more vitality through accumulated organic matter. Fortunately nearly all natural ecosystems have enough rain to support trees and could become agroforestry systems. Resilient agroecosystems nearly always incorporate some form of agroforestry. We will look at **Silvopastures, Alley Cropping, Riparian Forest Buffers, Wind Breaks and Carbon Sequestration.**

Silvopasture[155] is a form of agroforestry that combines trees with forage and livestock production. The trees in a silvopasture system are typically managed for high-value sawlogs and, at the same time, provide shade and shelter for livestock and forage. The partial shade throughout a silvopasture can reduce stress on the animal, and in some cases, it can increase forage production and quality. During winter conditions livestock experience less cold stress and lose less energy keeping warm and are able to gain more weight. In plantations of conifers or hardwoods for timber or Christmas trees, managed grazing provides additional annual income from hay or livestock production. Silvopasture is a particularly popular agroforestry system in the Southeast, but it is becoming more popular in other areas across the country where coniferous trees exist.

[153] Benefits of Soil Aeration: http://ecochem.com/t_soil_aeration.html

[154] **Training Manual from the Center for Agroforestry, MO:** Includes chapters on marketing potentials, economic opportunities and hurdles, and considerations for wildlife: http://centerforagroforestry.org/pubs/training/index.php

[155] **Learn More About Silvopasture Practices:** http://www.centerforagroforestry.org/research/spmanagement.pdf, http://www.centerforagroforestry.org/pubs/training/chap4.pdf

Some nut (e.g. walnut and pecan) and fruit orchards may also be managed as a silvopasture.

Silvopasture is successful when the tree, forage, and livestock components are all compatible. Care must be taken to rotate pastures lest excessive grazing can destroy soils.

Alley cropping[156] is a type of agroforestry that involves growing an agricultural crop simultaneously with a long-term tree crop. It is broadly defined as widely-spaced rows of trees and/or shrubs (single or multiple), that create alleyways within which agricultural crops or horticultural crops are produced. Alley cropping is usually done with the specific purpose of providing annual income while the tree crop matures. Fine hardwoods, like walnut, oak, and pecan, are favored species in alley cropping systems and can potentially provide high-value lumber or veneer logs. Nut crops can be an intermediate product. In addition to cash crops such as corn, squash, and melon, fruit bearing shrubs such as blueberry and ornamentals can be grown in the alleyways.

Riparian forest buffers[157] are a form of agroforestry that involves the natural or re-established streamside forests made up of trees, shrubs, and grasses. They intercept and reduce the impact of non-point source pollution associated with agricultural operations on land adjacent to waterways. Riparian forest buffers also reduce bank erosion, protect aquatic environments from excess nutrients and sedimentation, enhance wildlife, and increase biodiversity.

Windbreaks[158] are linear plantings of trees and shrubs designed to enhance crop production and protect people, livestock, soil, and water. There are several types of windbreaks. Field windbreaks protect a variety of wind-sensitive crops, control wind erosion, and increase bee pollination and pesticide effectiveness. You can also spread snow evenly across a field, increasing spring soil moisture. Livestock windbreaks help reduce animal stress and mortality, reduce feed consumption, and help reduce visual impacts and odors. Living snowfences keep roads clear of drifting snow and increase driving safety. All properly designed windbreaks provide protection for wildlife from harsh winds. Over 50 bird species are known to use windbreaks during the breeding season.

[156] **Learn More About Alley Cropping Practices:** http://www.centerforagroforestry.org/pubs/training/chap3.pdf,
[157] **Learn More about Riparian Buffer Practices:** http://www.centerforagroforestry.org/pubs/training/chap5.pdf, http://www.centerforagroforestry.org/pubs/ripbuf.pdf
(succcess story: http://www.centerforagroforestry.org/practices/rb.php**)**
[158] **Learn More about Windbreak Practices:** http://www.centerforagroforestry.org/pubs/training/chap6.pdf

Carbon sequestration. Growing trees remove carbon from the earth's atmosphere. Several agroforestry applications can lead to substantial removal of carbon dioxide from the atmosphere and carbon storage. These include windbreaks, riparian forest buffers, and silvoculture. Properly planned field windbreaks can provide adequate crop and soil protection when only 2-3% of the farmed acres are planted to windbreaks. To illustrate this point, there are 185 million acres of tilled land in the Great/Central Plains. Planting only 2.5 percent of this field area to 30-foot-wide tree windbreaks would span 1.3 million miles and cover 4.6 million acres. As trees continue to grow, more carbon is stored. Carbon dioxide removal, based on 20-year-old plantings, would exceed: 80 million metric tons.

Waste Management. Excess nutrients and other chemicals from agricultural, municipal, and industrial operations impact surface and ground water quality. Trees can be a natural solution to compromised water quality. Fast growing tree crops, in particular hybrid poplar, hybrid willow, sweetgum, sycamore, yellow poplar, and loblolly pine, can use the water and excess nutrients found in agricultural, municipal, and industrial waste. At the same time, they can breakdown and filter harmful chemicals found in the waste. By applying tailwater, animal waste, and municipal and industrial waste, to trees, you are turning waste into a useful product. Consider too that by including certain mushrooms you can remove additional waste. The Oyster mushroom[159], one of the most common and easily propagated mushrooms grows well in a forest environment while also having the potential to metabolize petroleum products into degradable organic matter.

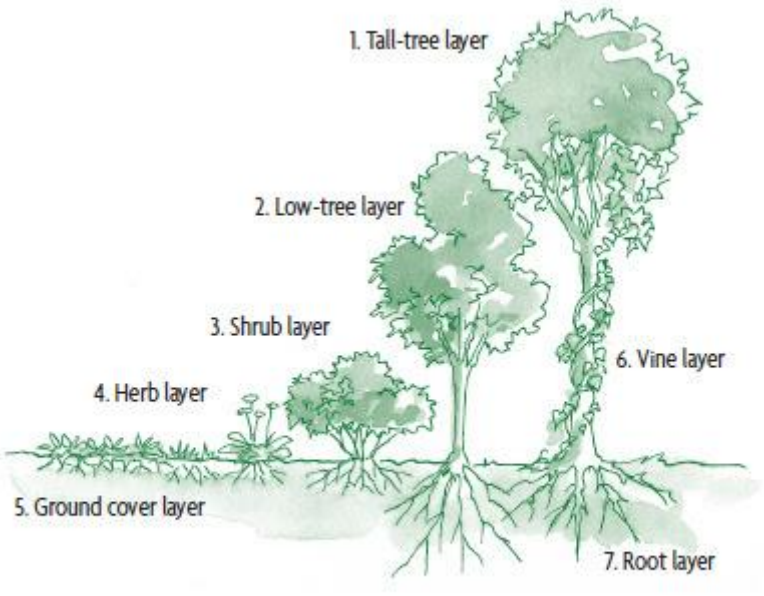
Forest Gardens[160]: In a forest garden we want to follow the patterns and functioning of established forests to create stable, resilient and diverse crop systems. Moreover forest gardens are famous for fixing or preventing acidification and salination, a growing problem for many land holders. By **Creating Layers** within the forest you, as the builder, stand to create a continual amount of leaf mulch as fertilizer and a bountiful crop of root vegetables, medicinal herbs, fruits, nuts and….whatever other perennial plants you're inspired to include!

Creating Layers: Forest gardens are supported by the intentional layers built into the system. Most literature suggests a ***7 layer*** approach to gain the greatest yield, efficiency and effect from your plants. Over the long term the layers allow sufficient light for particular plants, aeration of the soil, nitrogen fixing and fertilizer. ***Following are the 7 layers with some of the more common plants used in our area, though bear in mind to cater to your bioregion!***

[159] http://matteroftrust.org/2261/photo-gallery-oily-hairmat-eating-mushrooms-treatability-study

[160] **Learn More about Forest Gardening/Food Forests:**
http://www.centerforagroforestry.org/pubs/training/chap7.pdf
http://www.permaculture.org/demonstration-site/food-forest/

- **1) Canopy/Tall Tree layer –** (Walnut**,** Chestnut, Oak, Hickory) Consisting of primarily tall trees, the canopy over time will develop to shade the clearings while maintaining enough distance to barely, or never, touch each other's branches.
- **2) Low or Shade Tolerant Trees–** (Mulberry, Paw Paw, persimmon Apple, Pear) This mid story should be planted between your larger, canopy, trees. Their roots are often much shallower and they don't demand the same amount of light as canopy trees. Many fruit trees need more light than others, take this into account while designing your garden.



The seven layers of the forest garden.

- **3) Shrubs and Bushes –** (Blueberry, Elderberry, Oregon Grape, Currant, Gooseberry, Sassafras, Hazelnut…) These can be grown closer to the canopy trees and are important resources for birds and small creatures alike.
- **4) Herbaceous Layer –** (Perennial Herbs and Vegetables such as Bloodroot, Mayapple, Ginseng, Goldenseal, Rosemary, Black Cohosh, Wood Betony). For many, this is where the fun begins. Choosing herbs, flowers and vegetables that work together to support you and the surrounding wildlife. Be aware of what is native, supplying a long season of flowering plants for pollinators and what vegetables and herbs need the sparse full sun areas of your food forest.
- **5) Ground Cover –** (Grasses, Purslane, Sorrel, Strawberry, Nasturtium, Thyme, Clover) Choose something that is non-invasive and beneficial to the soil. Something for you to walk on along paths and through your forest garden beds. To gover any expose areas.
- **6) Vertical Layer –** (Grapes, Hops, Loganberry, vining legumes or flowers…) How can you maximize the potential that tall trees provide? Consider what vining plants you enjoy, and plant them!
- **7) Root/Underground Layer –** (Mushrooms**,** Radishes, Potatoes, Carrots, Garlic, Jerusalem Artichoke, Earthnut Pea, Pignut, Horseradish…) All these things help to break up compacted soil, provide food and often form beneficial relationship with other plants.

-Using Compost as a Fertilizer-

Compost, or biodegraded materials, are rich in nutrient, microorganisms and mycelia that benefit plants. These brief introductions to **Developing Humus, Microorganisms: Growing your Own, Compost Tea**, **Recycling Waste, BioChar** *and* **On Farm Inputs** *are meant to guide you in learning more about the importance and potential of making and using compost as fertilizer.*

Developing Humus: To develop humus you must first understand **composting**. Compost is composed of layers of decaying organic matter, and organic matter can be described dead plants and animals of *any* kind in *all* stages.

> **Ideal ingredients to make compost are** - 1/3 dry vegetation, 1/3 green vegetation and 1/3 soil. ***In heavy clay soils, less soil is required.*** The soil is critically important for providing the compost pile with microorganisms and fungi that are instrumental in breaking down all organic matter.

In John Jeavon's renowned Bio-intensive gardening method[161] he describes microorganisms as the "pulse of the soil" made up of bacteria, fungi, insects and multitudes of other organisms. Collectively these organisms spread through compost, absorbing nutrient and breaking down organic matter into a state that plant roots can absorb: **Humus**.

Microorganisms: Growing your Own – Microorganisms are the heart of living soil and you can grow your own with some very simple practices! Without these beneficial bacteria and organisms your plants are largely unable to access the nutrient available to them. The following are stepping stones to ensuring that your fields and garden beds have the living organisms that they need. **Korean Natural Farming** (or simply, Natural Farming) is a method that provides much more than just microorganisms, it enables farmers to generate his inputs on the farm.

> **Korean Natural Farming** – A do it yourself approach to microorganisms, this style of farming concentrates incredible amounts of energy into building rich colonies of microorganisms into the soil. Through relatively easy processes, farmers are creating concentrates that fertilize whole fields with only 5 gallons of material. This practice harnesses IMO's, or, Indigenous Microorganisms from your own land and propagates them throughout the property. For the cost of a large bag of rice, some time, and wheat hulls you can grow your own IMO's in no time.
>
> There are also methods for pest control, increasing plant vitality and building soils. You're strongly encouraged to research this practice for yourself and yield the incredible results available to you.[162]

Compost Tea – If you irrigate your fields or garden beds, compost tea is an easily accessible and effective method of fertilizing your plants. There is no salt as with many other fertilizers, and with only 4-6 applications annually it's a relatively low input. Remove compost from the bottom most layer of your compost pile which has the most IMO (*Indigenous Microorganisms*) to gain the greatest benefits***. If***

A Note on Humus: like most soil, humus carries a negative charge and many nutrients (Potassium, Calcium, Sodium, Magnesium and others) carry a positive charge. Humus actually bonds with these nutrients, carrying them into your fields and garden beds. The negatively charged nutrients are uniquely contained within microorganisms living in the humus.

As roots grow into humus rich soil, something amazing happens! Plant roots are surrounded by a kind of "halo" of hydrogen ions, also positively charged. These hydrogen ions actually trade their positive charge for nutrients stored within the humus. This all occurs at the rate which that the plant demands nutrient.

[161] http://growbiointensive.org/

[162] Though this website is based in Hawaii, the practices and material provided by this website are a fantastic resource of Dr. Cho's Korean Natural Farming Method.
http://naturalfarminghawaii.net/learn-natural-farming/
http://naturalfarminghawaii.net/learn-natural-farming/cgnf-materials/

you don't have any compost on hand, consider contacting a local gardening club or starting your own. It is advised to both irrigate the roots and spray the leaves of your plants with compost tea. By feeding the plants through the root and the leaf many farmers are yielding greater fruits than with standard soil-only irrigation.

> **To make compost tea-** simply fill a bucket with approximately ¼ compost and ¾ water. Let compost remain in the bucket for 5-7 days then strain compost out of the water. After you've finished straining the compost, seal the tea in air tight container to preserve nutrient. ***If only city water is available allow the water to aerate for 5 days before adding compost.***

Recycling Waste – This concept is contingent on two things, your imagination and what biodegradable waste is available to you. The more rich compost you can generate on your farm, the more produce you can create with minimal investment. So often in our urban areas we generate incredible amount of food waste in our restaurants alone. A large majority of restaurants welcome the idea of having someone pick up their compost. It saves them money every month by reducing the weight and amount of their garbage. ***You MUST be willing to regularly pick these items up though. One missed pick up note only looks bad, it can end your agreement.*** By transforming waste into value, you create more value in your operation and minimize spending on fertilizer.

Owners of large tracts of land might consider starting a compost business to support their own farm and those around them. Particularly if you are located near a variety of enterprises that you could channel waste from, for instance: a wood mill for pulp, chips and sawdust; A large city center to get food waste like vegetables and coffee grounds; A rice or oat processor that could send you (often truckloads) of rice or oat hulls. It can become exciting when you realize the opportunities that abound when you begin working with industrial scale waste to develop industrial scale fertilizer!

BioChar – Made from wood fire coals by removing the coals before they are allowed to burn completely and sealing them from oxygen. By either burying them in the ground, or sealing them in a fire proof container you remove the coals from oxygen. After the coals are allowed to cool they create sterile, very porous bits of carbon. It has been shown in studies of fields fertilized with biochar that organic matter was built from 1% organic matter to 5% in a matter of two years. Moreover the biochar acts like a kind of sponge, holding moisture in the ground longer than top soil alone. [163]

Figure 5 Biochar in different forms and consistencies

Much research has been done since the early 20th century on the benefits of biochar, citing the benefits of its use in the soil[164] as well as use with livestock. Today throughout Europe biochar is a common food additive for cows, chickens and goats. If you have a diversified operation with both vegetation and livestock,

[163] http://www.terra-char.com/micropores.html

[164] http://www.dyarrow.org/CarbonSmartFarming/docs/BiocharUseInSoil.pdf

consider pre-treating your biochar by feeding it your cattle[165], chickens and other fowl[166], in appropriate doses and including it directly in the manure[167]. Otherwise, see about working with a neighboring farm who specializes in livestock and share the benefits of biochar with them.

Replacing external inputs with those generated on-farm. Look around your farm, what do you have available? Can you generate your own BioChar? Fish emulsion? Microorganism rich pond sludge? Sand? Clay? Stone? What do your neighbors have? Networking opportunities abound when you're looking for naturally occurring fertilizer that often disguises itself as waste.

Fauna

The environment is filled with creatures of all sizes that work within our agricultural systems. In this section we will look at some of the most common animals and creatures that interact with most farms and fields, looking at strategies that manage and incorporate them when possible. We'll look at the management and benefits of **Domestic Animals** *including:* ***Poultry, Swine, Goats and Sheep and Cattle*****.**

Again, let's begin with a few questions about ecological integration on your farm:

Do you have refuges for beneficial insects or practice integrated pest management?

By providing space for beneficial insects and practicing integrated pest management we can begin to control pest populations before they enter our fields. Some build insect hotels[168] to create lasting refuges and some purchase swarms for seasonal applications. It is recommended to build habitats for insects into your farm to avoid that continued cost of purchasing insects that would otherwise rejuvenate themselves every year. Consider that a habitat could be as small as a modest "insect hotel" or as large as a riparian buffer that hosts snags and other large scale insect refuges. So, where can you build a habitat?

Do you have more than one species of animal present on your farm?

Many farmers today are specializing and narrowing their operations to keep costs low and management at a minimum. Often times having a combination of animals can actually help to *lower* costs and management when species work well together like poultry following cattle in raising pastured meat.

Domestic Animals

Through selective breeding and handling, what were once wild animals have become docile, producing more plentifully than ever. We can continue to develop those beneficial traits while also harnessing other benefits including fertilizing and land management.

Poultry – Poultry, including ducks and turkeys can provide a number of benefits to farms of all sizes. Most notably they produce a nitrogen rich fertilizer from their litter, this litter can be

[165] http://www.ithaka-journal.net/pflanzenkohle-in-der-rinderhaltung?lang=en,
[166] http://www.dyarrow.org/CarbonSmartFarming/docs/PoultryFarmingBiochar.pdf,
http://www.dyarrow.org/CarbonSmartFarming/docs/PoultryImprovesFertilizer.pdf,
http://www.dyarrow.org/CarbonSmartFarming/docs/PoultryNLossReduce.pdf
[167] http://www.dyarrow.org/CarbonSmartFarming/docs/PoultryLitterAmmonia.pdf
[168] http://www.learninglandscapesdesign.com/insect-hotels/

optimized by including biochar in the litter on the floor of poultry houses. Some farmers use **Chicken Tractors**[169] in their fields to allow their poultry to eat bugs out of their fields while fertilizing the field directly. While growing the healthier free range chickens consumers are increasingly demanding. The knowledge that the chicken (turkey, duck, or other poultry) has been in fresh air eating bugs off the ground is an attractive fact for buyers. The use of chicken tractors can both increase your bottom line by adding value to your poultry, it also drastically improves soil quality when rotations are done correctly. Though this tactic requires more direct interactions with your chickens as the tractors needs to be moved daily, this practice has proven to be profitable by a number of small and large scale producers.

When used in rotation with cattle in large fields, chickens and other poultry have been shown to scatter cattle mature and also remove parasites. The combination of poultry litter with cattle manure amplifies the fertilization of your fields.

Cattle- Across the globe Cattle and other "cloven hooved" animals have been directly responsible for the growth of human population and the fertilization of the fields around those populations. On the other hand, when poorly managed, cattle can compress soil, over-graze, and in the long run destroy the health of a field. Through practices like **Management Intensive Grazing**[170] we can mimic natural processes that build soil instead of destroying it.

Management Intensive Grazing is the practice of rotating livestock (cattle, hogs, goats, etc.) through small sections of field promotes rapid regrowth of grasses. Moreover, by rotating livestock to freshly grown grass you increase the amount of nutrient consumed per animal.

By rotating animals into small portions of the pasture, much of the field is allowed to "rest". These rests allow plants to renew energy reserves, rebuild vigor, deepen their root systems and give long-term maximum protection from drought.

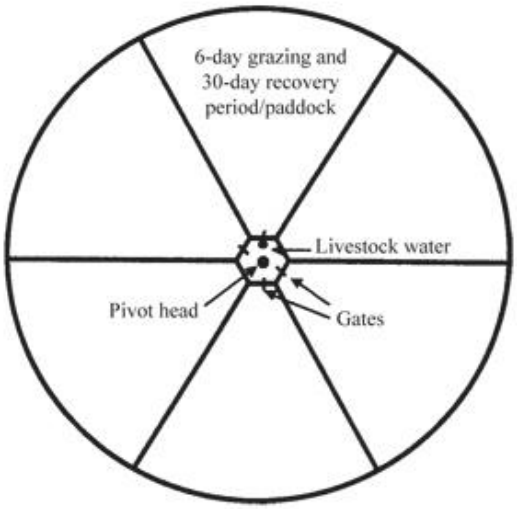


Figure 6 Management Intensive Grazing Example Plan

Swine – Though a challenge to manage, swine can be a great addition to many farms if markets can be found. As with poultry, most markets are controlled by large vertically integrated firms. Therefore you will be developing a **direct-market**[171] approach. This means you will be selling quality and especially taste. That means

[169] **One example of a larger scale kit to order or build:** http://www.featherman.net/broilerschoonerkit.html
[170] **More about Management Intensive Grazing:** https://www.extension.purdue.edu/extmedia/AY/ay-328.pdf,
[171] **Information of development of Direct Marketing**:
http://www.agmrc.org/business_development/operating_a_business/direct_marketing/direct-marketing/

your customers should determine what your hogs eat since what they eat determines their flavor.

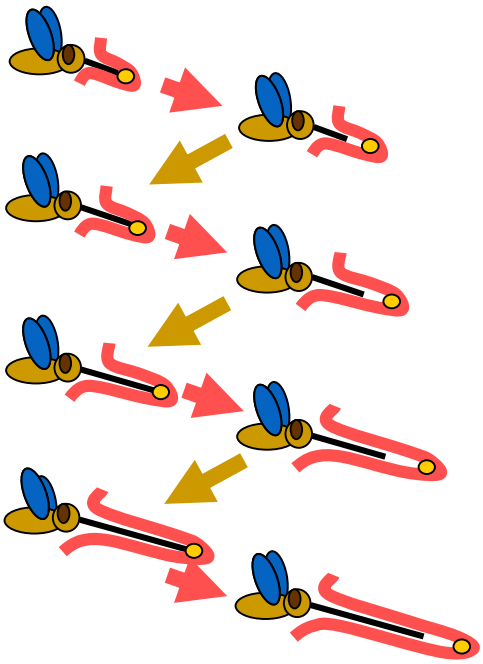
Hogs can be fed a variety of foods including pumpkins, squash, onions, eggs, nuts and dairy products. Some producers look out for end of season sales on items like pumpkins. This can also be a great opportunity to network with other farmers that have excess production. **Clearing overgrown forests with hogs** requires diligent monitoring as hogs can easily and quickly destroy the forest floor after over-turning the layers of leaf mulch. There are great benefits to be had though by mimicking the principles of **Management Intensive Grazing** through the forest. Prepare to say goodbye to thickets and overzealous vines! Moreover, as hogs rummage through the forest floor they uncover nuts, insects and dirt that improve overall meat quality by adding oils from the nuts, protein from insects and trace minerals from the dirt while converting their forage to fertilizer.

Goats and Sheep: Though goats can be difficult to keep inside fences and sheep are more vulnerable to wild animals, they both serve many important functions in land management. Goats and sheep will browse on woody plants and weeds that cows and hogs won't touch. They can clear long overgrown fields and forests to make room for developing a lush understory. Moreover, they have a unique tendency to remove invasive species.

It's important to realize though that there are many different types of sheep and goats and to be mindful to purchase the right varieties for your goals. Whether it's meat goats, milking goats, or and number of sheep varieties there are distinct differences, advantages and limitations to each breed.

Pollinators

Often when we consider the word "Pollinators" our imaginations jump to the large, yellow and black honey bee flying from flower to flower and back to its hive. This is one of a few common misconceptions about pollinators. They come in many shapes and sizes, not all of which are bees. Some wasps and even birds can be pollinators, helping with the monumental task of pollinating all the worlds many species of plants.



Except perhaps for nitrogen fixation, pollination is the most powerful example of coevolution and ecological integration. Darwin received a specimen of the orchid Angraecum sesquipedale and predicted from it that there must exist a pollinator with a proboscis measuring 10-12" This prediction was not confirmed until 1903 with discovery of the Xanthopan morgani moth.

More than 250 species of bats eat some fruit, nectar, or pollen. In doing so, bats often provide dispersal and pollination services to at least 130 plant genera (Howell and Hodgkin, 1976). These interactions have profoundly influenced the evolution of some bats and plants. For example, the leaf-nosed bat, Leptonycteris sanborni, has morphological and physiological traits that allow it to subsist entirely on flowers and fruits, whereas the same traits make it impossible to eat insects (Howell and Hodgkin, 1976). On the other hand, plants such as the calabash tree and dragonfruit are unable to reproduce without bat assistance. The structure of its flowers and night flowering make pollination impossible by other animals.

As land holders, large or small, we have a duty to preserve and bolster the populations of both wild and domestic pollinators to ensure the ability of future generations to generate their own food, fibers and fuels. By strategizing and optimizing your property you can gain the immediate benefits of better crops as well as the peace of mind that you're helping secure the future of the magnificent and diverse plant species all around us.

Native Bees

Native pollinators play a monumental role in the pollination of our forests, fields and farms. For instance, 250 orchard mason bees can pollinate an area that would require anywhere from 60,000 to 120,000 honey bees, similarly A single hornfaced bee can visit 15 flowers a minute, setting 2,450 apples in a day, compared to the 50 flowers set in a honeybee's day[172].

Native pollinators tend to be smaller, have longer foraging seasons, are solitary, don't have stingers and will continue to pollinate even in cold or wet weather. European honey bees, the most commonly used honey bees in the United States, tend to be picky about flowers, relatively clumsy compared to native pollinators and overall are drastically more effective at pollinating.

[172] http://www.ebeehoney.com/Pollination.html

It is important to understand their **Habitat(s)**, **Dietary Needs**, and **Seasonal Needs** to ensure that you maintain populations while also generating more pollinators for your area. Not only will you have higher yields per plant, produce from well pollinated fields tend to taste better.

Dietary and Seasonal Needs: Each bee prefers different flowers and seasons. If your plan is to bolster your native bee population it is imperative to plant successions of flowers that occur throughout the season. Some bees are **Generalists**, consuming nectar and harvesting pollen from a variety of flowers. Others are **Specialists**, catering to specific plants like squash or blueberry. Specialists will only harvest *pollen* from specific flowers but will often harvest nectar from a different variety. So whether you plan to make habitats for specialists or generalists, it is best to have a wide variety of native flowering plants to fulfill their needs. *The material here is partial with only the most common characteristics and bees charted. For more information pursue books and online material for specific bees*[173] *in your region.*

Alkali Bee: The Alkali bee is a solitary bee that makes its home in dry, sunny patches of sandy soil. When spotting habitats for Alkali, be sure that the soil is on an incline to ensure that during the rainy season that there is no *standing* water. You do want moist soils though, enough that when the dirt is clumped together in your fist, upon tapping the clump it breaks apart into chunks. The alkali bee is one of the best documented native bees and much information can be found online and in book stores on building artificial and natural environments.

Alkali bees require a few years to establish a highly reproductive colony, 3-5 under favorable conditions. This is because the nests are long tunnels with chambers branching off from the main shaft. Over the years alkali bees build onto the old tunnels with more and more chambers branching off.

2-3 days after emerging in the late spring, female alkali bees will begin to harvest nectar and pollen to build "pollen balls" with one flat side. She then lays the larvae on the pollen ball and moves onto constructing new chambers and new pollen balls. Female alkali bees can produce anywhere from 9-20 offspring over her life of 4-6 weeks.

It is important to ensure that sufficient flowers are available just before the emergence of the female bee. Male bees occupy these flowers overnight so that in the early morning when the females emerge, they are ready to mate.

Bumble Bee: A unique bee, the Bumble Bee needs patches of tall native grasses to make their home. As tall grasses fall over in clumps during the fall, bumble bees make their home underneath the fallen grass. They are also known to inhabit old underground rat's nests. A tactic used by many landholders is to include tall grasses in their **hedgerows** along field lines that remain undisturbed over throughout the year.

[173] http://www.bugguide.net/node/view/475348

Emerging in early spring their hives will last until late summer or early fall. They are also **Generalists**, meaning that they are not accustomed to a certain plant and will forage on a variety of flowers. Bumble bees are particularly sought after for their ability to pollinate tomato plants and many year round greenhouse producers favor these bees above others.

Carpenter, Mason, Blue Orchard, and Leafcutter Bee: In nature these bees will occupy old snags in the woods, occupying old termite or beetle dwellings. Bees will clean out these holes and lay their larvae stacked on top of one another for the depth of the tunnel. They each use different materials to achieve this stacking. Leafcutter's use leaf bits, mason bees use clay, and others use small pebbles or other materials held together with nectar.

Many landowners will take *untreated* 4x4 blocks of wood and drill holes of a range of diameters. The most common diameter in commercial bee nests is 5/16 of an inch, the preferred diameter of blue orchard bees. It is unnecessary to use only untreated 4x4 blocks though as many people use 4x6 blocks, or simply old logs.

A Note on Hedgerows: Hedgerows are only beneficial as habitats for native pollinators if you are using either *No* pesticides or a *Very Limited* amount as hedgerows also act as buffers for pesticide drift. Moreover, hedgerows are a fantastic place to plant a succession of flowering plants for bees to visit through the year. Most bees travel 3/4 mile or less to find nectar and pollen, so constructing their habitat along hedgerows ensures their ability to pollinate your fields.

In one side of the chosen piece of wood drill a series of holes between 3/32 and 3/8 of an inch. Holes ¼ inch or less in diameter should be between 3 and 5 inches in depth. Holes larger than ¼ inch should be 4-6 inches in depth. The hole should be about ¾ of an inch from center to center and no closer than that to the edges.

Another option is to take bamboo or other large hollow stems like teasel or common reeds. Cut each of these so that there is one open end, the node of the plant closing off the other. Bundle these together and place horizontally in a sheltered location. ***Be sure to over winter these bundles in a place that will remain at least 34 degrees.*** Some farmers will sell the individual stems at farmers markets or online as native bee starters.

Carpenter Bee: Males emerge early in spring to hover around flowers that soon females will visit. During this time males can be aggressive in defending their territory, even to humans, but they have no stingers. Both males and females are **generalists**, feeding on a variety of plant flowers. The females who carve out their homes with their strong mandibles have been known to steal honey from long throated flowers by cutting the base to take nectar without pollinating the flower.

Leafcutter Bee: Their life cycle is between early spring and late summer coming out about the same time as the mason bee. The difference is that the mason bee completes its life cycle by mid-June, long before leafcutter bees are finished. They are **Generalists** though prefer rose leaves to construct their nest sites.

Mason Bee: Emerging in March and dying off in mid-June, they align with most orchard blooming schedules. Females construct rows of larvae in long tubular dwellings of pine or fir. Most often the tubes contain females occupying the back end and males towards the front so they can emerge first. They are **Generalists** visiting fruit blossoms, dandelions, Oregon grape and particularly likes bullhead waterleaf; consider planting the bullhead waterleaf close to nesting boxes. If using for commercial orchards, nest boxes should allow for 500-1000 nesting sites per acre.

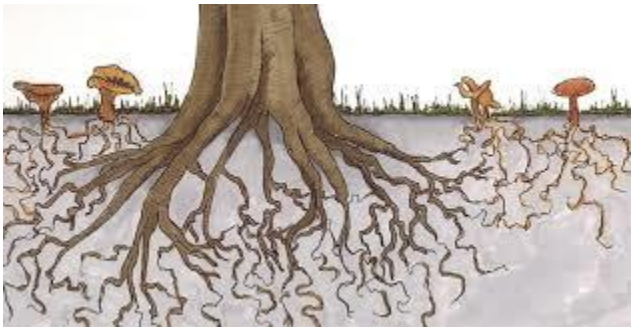
Blue Orchard Bee: A new breed to be used by producers, these bees are a bright blue throughout their bodies. They are specifically used to pollinate orchards of cherries or almonds, though their application is growing as more people begin using them.

Squash Bee: Just as their name indicates the squash bee is specifically interested in cucurbit species. Cucumber, squash, pumpkin and zucchini are among their preferred plants. Their season begins when temperatures are right for cucurbits. Often making their homes underneath the plants themselves, be aware that there may be squash bees developing beneath your feet throughout the rest of the year.

Blueberry Bees: Native to the Southeastern portion of the United States these bees live for the duration of blueberry flowering. Like bumble bees they shake their flowers of the blueberry to vibrate pollen out.

Fungi

Sometimes when we think of fungi, we think of infection and disease: rusts, powdery mildew, blackspot in plants, nail fungus and various lung diseases in animals. Please escape this attitude! Decomposing fungi are primary agents in composting which is the magic of turning garbage into gold. Not only do our plants love the rich humus and organic matter produced by fungi, but pesticides and herbicides are also broken down. Much of the body of soil itself is made up of fungi, especially loamy, well-aerated soil. Mushrooms mostly live underground. What we see are just the fruiting bodies which come to the surface to release spores.



Mycorrhizae. Perhaps most important are the symbiotic fungi which form mutually beneficial relationships with plants. These associations of absorbing roots with fungal mycelium are known as mycorrhizae, from “mycor”- fungus and “rhiza”-root. Even though these beneficial relationships were

discovered in 1885, it is not widely known today that 95 % of all plants on earth intermingle their roots with mycorrhizal fungi.

Fungi lack the chlorophyll which allows green plants to make their own food out of sunlight, carbon dioxide and water in the process of photosynthesis. Instead they are more like animals in that they must get their nutrition from already-made carbohydrates and amino acids. And so for millions of years, fungi have made relationships with plants: some parasitic which can harm or kill the host plants; some saprophytic, living off the tissues of dead plants; and some symbiotic, like the mycorrhizal fungi which benefit plants.

To think of these mycorrhizal fungi as “infecting” the roots of plants is to underestimate the mutual evolution that derived these specialized relationships. The natural world is a highly competitive environment where few seeds that germinate reach maturity and fewer live long and vigorous lives. One of the primary structures of survival for a plant is an extensive root system, and here is where the mycorrhizal fungi expand the concept of “survival of the fittest.” Usually we think of this Darwinian concept as symbolizing the struggle of the mightiest to the top of the gene pool. However all sorts of alternative strategies have proved successful: the skunk, the turtle, the tapeworm and the human, to name a few. In this case, the successful strategy was non-aggressive mutual aid.

Mycorrhizal fungi mycelium is more branching, fine and extensive and far more efficient than roots in contacting the soil--expanding the surface of a root sometimes by 700%. An investment of 10-20% of a plant’s carbohydrates, vitamins and amino acids in the development of symbiotic fungi will give a return of over 100 times the value of that investment in root-like development. Plus these mycorrhizal fungi are able to mobilize complex nutrients otherwise unavailable to plants. Plants and fungi have a marriage made in earth.

This marriage continues today to benefit plants. Dr. Donald H. Marx, a leading scientist who founded the Institute for Mycorrhizal Research and Development for the US Forest Service contends that the fungi bring water, sometimes from as far as 30’ away, to the roots making the plants more drought-tolerant. The fungi bring minerals essential to plant health to the roots: phosphorus, nitrogen, zinc, manganese and copper. The fungi present physical and sometimes antibiotic barriers to root pathogens, thereby preventing diseases. They increase the tolerance of plants to extremes in soil temperatures and pH. They increase the longevity of absorbing roots. Finally, they help plants tolerate stresses like transplant shock, soil compaction, soil toxins and heavy metals.

The addition of mycorrhizae in a multiple-species cocktail has been the most beneficial reclaiming mine sites, deserts and arid locations, nutrient-poor and depleted soils and subsoils. These are the same mushrooms as are found around many new homes. Dr. Marx says that sticking a tree into a barren soil is like trying to raise a polar bear in Florida.

Mycelia from one mushroom can form a continuous network connecting many acres of a forest, creating an “intelligence” where the mycelium guards the forest’s overall health, budgeting and multi-directionally allocating nutrients. Because the fungus is connected to the whole area, it has an interest

in the prosperity of the whole forest, upon which it is dependent. The largest living organism on earth is a fungus more than 2 miles across found in the Blue Mountains of Oregon.[174]

If the mycorrhizae already present in the soil are given more supportive conditions, they will populate in larger numbers. Conditions which support mycorrhizae also support other beneficials like soil bacteria and earthworms. These conditions include: mulching, incorporating composted organic matter, keeping the soil moist but not soggy, fertilization with slow-release organic fertilizers or low doses more frequently, and avoiding habitual use of fungicides and pesticides.

Recently, many companies have sprung up selling mycorrhizal fungi products to nurseries and gardeners. However there are many differences of opinion as to their effectiveness. Lakshri Sridharan, who has a PhD in microbiology says, "Initial investment on mycorrhizae may appear to be a little expensive, but inoculations with mycorrhizae will save money on water bills, chemical fertilizers, pesticides or fungicides." But Christina Wells at Clemson University said of her research, "In general we found little benefit from mycorrhizal products, as all products purchased through typical consumer channels contained no living inoculum." One of the problems is that mycorrhizae are living beings that may dry out on the shelf of a garden center or overheat in direct sunlight.

Mycorrhizae can be increased most rapidly in association with photosynthetic bacteria that can not only fix atmospheric nitrogen, but also change raw materials into sugars that feed the fungi. These bacteria can rapidly adapt to new environment and can dramatically improve conditions for fungi and plants. Its not just elements like N-P-K that support plant life; it is biological life.

Mushrooms and Ecological Resilience

When gourmet and medicinal mushrooms are involved as key organisms in the recycling agricultural and forest by-products, the bio dynamics of permaculture soar to extraordinary levels of productivity. Not only are mushrooms a protein-rich food source for humans, but the by-products of mushrooms cultivation unlock nutrients for other members of the ecological community. The rapid return of nutrients back into the ecosystem boosts the life cycles of plants, animals, insects (bees), and soil microflora.

What follows is a short list of the ways mushrooms can contribute to ecological resilience. [175]

[174] Unfortunately, we know about this fungus because it kills the trees it infects (http://www.bbc.com/earth/story/20141114-the-biggest-organism-in-the-world; http://www.scientificamerican.com/article/strange-but-true-largest-organism-is-fungus/). We don't know the size of beneficial fungi because their effects are more subtle: increased plant health.

[175] This section is deeply indebted to Paul Stamets work. Please visit his website fungi.com to learn more.

Oyster Mushrooms can be grown indoors on pasteurized corn stalks, wheat, rice, & rye straw and a wide range of other materials including paper and pulp by-products. Soaking bulk substrates in cold water creates a residual "tea" that is a nutritious fertilizer and potent insecticide. Submerging the bulk substrate in hot water produces a different brew of "tea"": a naturally potent herbicide. Oyster mushrooms can also be grown on hardwood stumps and logs. (Some varieties of Oyster mushrooms in P. pulmonarius species complex naturally grow on conifer wood.) Pleurotus thrive in complex compost piles, and are easy to grow outside with minimum care. The waste substrate from Oyster production is useful as fodder for cows, chickens, & pigs. Since half of the mass of dry straw is liberated as gaseous carbon dioxide, pumping this CO2 from mushroom growing rooms into greenhouses to enhance plant production makes good sense. (Cultivators filter the airstream from the mushroom growing rooms so spores are eliminated.) Furthermore, the waste straw can be mulched into garden soils, not only to provide structure and nutrition, but also to reduce the populations of nematodes which are costly to gardeners and farmers.

King Stropharia is an ideal player in the recycling of complex wood debris and garden wastes, and thrives in complex environments. Vigorously attacking wood (sawdust, chips, twigs, branches), the King Stropharia also grows in wood-free substrates, particularly soils supplemented with chopped straw. I have seen this mushroom flourish in gardens devoid of wood debris, benefiting the growth of neighboring plants. Acclimated to northern latitudes, this mushroom fruits when air temperatures range between 60-90° F (15-32° C) which usually translates to ground temperatures of 55-65° F (13-18° C).

Bees love King Stropharia. They expose the mycelium to the air and suck the sugar-rich cytoplasm from the wounds. A continuous convoy of bees could be traced, from morning to evening, from beehives to the mushroom patch, until the bed of King Stropharia literally collapsed. When a report was published in Harrowsmith Magazine (Ingle, 1988), bee keepers wrote to explain that they had been long mystified by bees' attraction to sawdust piles. Now it is clear the bees were seeking the underlying sweet mushroom mycelium.

King Stropharia is an excellent edible mushroom when young. However, its edibility quickly declines as the mushrooms mature. Mature King Stropharia is a good base medium for generating fish food though. Fly larvae proliferate inside the developing mushrooms. In raising silver salmon, it was found that when mature mushrooms were thrown into the fish-holding tank, they would float. Fly larvae emerge from the mushrooms, struggling for air. Soon the fish strike the large mushrooms to dislodge the swollen larvae into the water where they were

eagerly consumed. After several days of feeding mushrooms to fish, they strike at the King Stropharia in anticipation of the succulent, squirming larvae as the mushrooms hit the water.

Growing King Stropharia can have other beneficial applications in permaculture. King Stropharia depends upon bacteria for growth. A farm which included a small herd of Black Angus cows, established two King Stropharia beds at the heads of ravines which drained onto a saltwater beach where a neighbor commercially cultivated oysters and clams. Prior to installing these mushroom beds, fecal coliform bacteria seriously threatened the water quality. Once the mycelium fully permeated the sawdust/chip beds, downstream fecal bacteria was largely eliminated. The mycelium in effect became a micro-filtration membrane. By properly locating mushroom beds, "gray water" run-off could be cleaned of bacteria and nitrogen rich effluent. Overall water quality improved. Massive mushrooms formed. After three to four years, chunks of wood are totally reduced into a rich, peat-like soil, ideal for the garden.

Shiitake/Nameko/Lion's Manes. Outdoors, inoculated logs can be partially buried or lined up in fence-like rows. Once the logs have stopped producing, the softened wood can be broken up, sterilized, and re-inoculated. Indoors, these mushrooms can be grown on sterilized substrates or on logs. Once the indoor substrates cease production, they can be recycled and re-inoculated with another mushroom, a process called species sequencing. Later, the expired production blocks can be buried in sawdust or soil to elicit bonus crops outdoors.

Shiitake Mushroom

Nameko Mushroom

Lion's Mane Mushroom

Maittake/Reishi/Clustered Woodlovers can be incorporated into the management of a sustainable multi-stage, complex Medicinal Mushroom Forest. Logs can be inoculated and buried or stumps can be impregnated. The greatest opportunities for stump culture are regions of the world where hardwoods predominate. Presently, only a few gourmet and medicinal mushrooms grow on coniferous woods. Nevertheless, Enokitake (Flammulina velutipes), Reishi (Ganoderma lucidum), Clustered Woodlovers (Hypholoma capnoides), Chicken-of-the-Woods (Laetiporus sulphureus), and Oyster (Pleurotus spp.)are good candidates for both conifer and hardwood stump decomposition.

Shaggy Manes (Coprinus comatus) grow in manure rich soils, disturbed habitats, in and around compost piles, and in grassy and gravel areas. Shaggy Manes are extremely adaptive and tend to

wander. Shaggy Mane patches behave much like King Stropharia and Morels, travelling great distances from their original site of inoculation in their search for fruiting niches.

Morels grow in a variety of habitats, from abandoned apple orchards and diseased elms to gravelly roads and stream beds. However, the habitat that can be reproduced easily is the burn-site. Burn-sites, although increasingly restricted because of air pollution ordinances, are common among country homesteads. If a burn-site is not possible, there are alternatives. The complex habitat of a garden compost pile also supports Morel growth. When planting cottonwood trees, you can introduce spawn around the root zones in hopes of creating a perennial Morel patch. Cultivators should note that Morels are fickle and elusive by nature compared to more predictable species like King Stropharia, Oyster and Shiitake mushrooms.

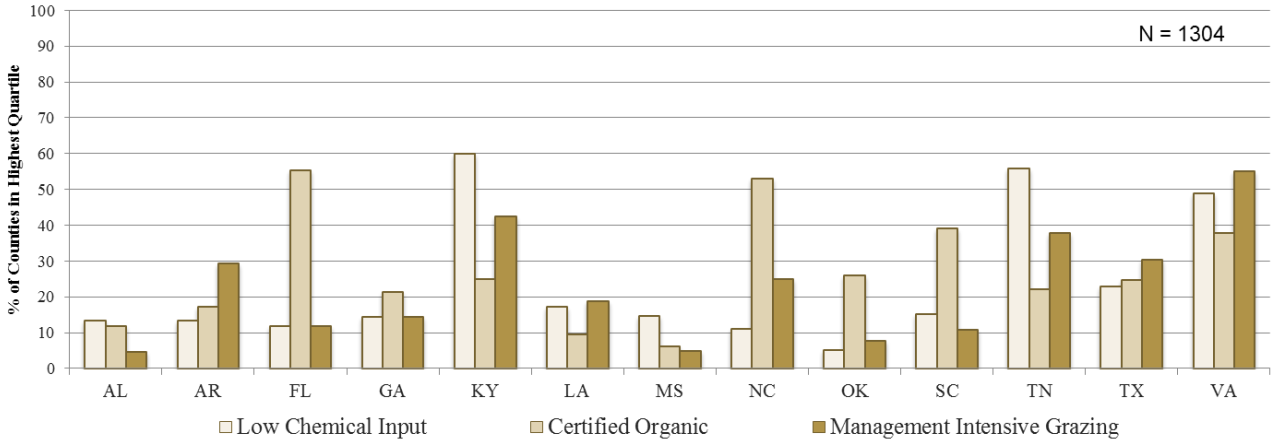
Mycorrhizal species can be introduced via several techniques. The age-old, proven method of satellite planting is probably the simplest. By planting young seedlings around the bases of trees naturally producing Chanterelles, King Boletes, Matsutake, Truffles or other desirable species, you may establish satellite colonies by replanting the young trees after several years of association. For those landowners who inherit a monoculture woodlot of similarly aged trees, the permaculture inclined steward could plant a succession of young trees so that, over time, a multi-canopy forest could be re-established.

These are but a few mushroom species that can be incorporated to help make your system more resilient by increasing ecological integration. Part of a larger, community-based strategy should also include Mushroom Response Teams (MRT's) which could react quickly to catastrophic natural disasters such as hurricanes, tornados, floods in the profitable recycling of the enormous debris fields they generate.

Clearly, the use of mushrooms energizes ecological integration to a level otherwise not attainable. I hope readers will develop these concepts further. When fungi are incorporated into your system, the ecological health of the whole planet will benefit enormously.

Secondary databases to measure ecological integration in the 13 Southern States. At this point in our study of resilience in the 13 Southern states, we have identified several variables which appear consistent with the factor of ecological resilience and have available county-level data bases. Results for each Southern state are presented in the following chart. See Appendix for methods.

Integration of Natural Ecological Systems in Agrifood System by State
% of Counties in State Ranked in Highest Category



Sources: 2012 Census of Agriculture; extra calculations by the University of Mississippi Center for Population Studies. Scores based on standardized score rankings on: Low Chemical Input = % of acres not treated with herbicide, % of acres not treated with insecticide; Certified Organic = % of operations certified organic; Management Intensive Grazing = % of operations practicing management intensive/rotational grazing. Because of low organic certification rates, this variable was only ranked in two categories. Analysis based on 1304 counties.

Table 4 shows state by state comparisons of measures of the ecological integration (EI) quality of resilience. Four county-level indicators were available for this quality: percent crop acres not treated with herbicide, percent crop acres not treated with herbicide, counties with USDA certified organic acres and percent of counties with rotational or management-intensive grazing (MIG). The first two measures were combined into a pesticide use index. See Methods for details.

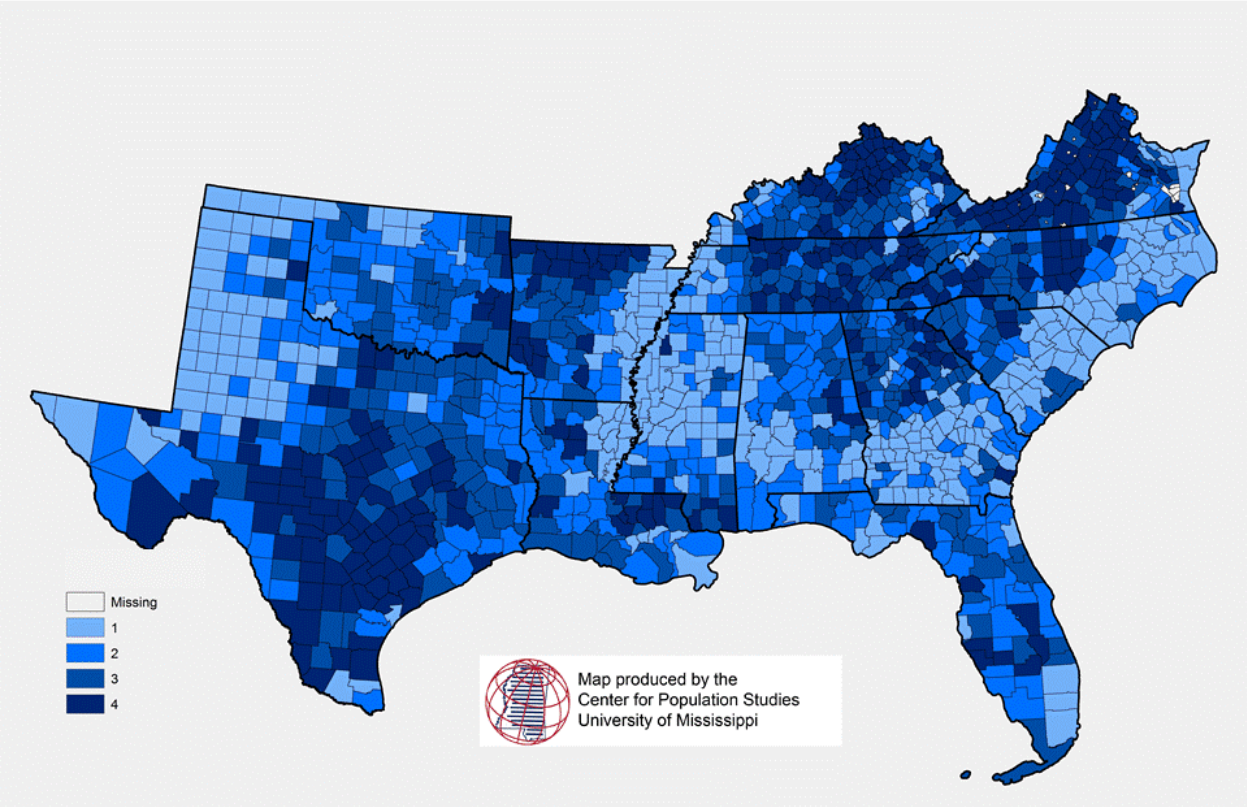
States ranked by % of counties in highest quartile on the production diversity index				
Certified organic	MIG	SRI	State	%
1	9	5	Florida	55.2
2	6	2	North Carolina	53.0
3	10	4	South Carolina	39.1
4	1	1	Virginia	36.7
5	2	3	Kentucky	25.0
6	8	9	Georgia	21.4
7	11	10	Oklahoma	20.8
8	4	11	Texas	20.5
9	3	7	Tennessee	20.0
10	5	8	Arkansas	16.0
11	13	12	Alabama	11.9
12	7	6	Louisiana	9.4
13	12	13	Mississippi	6.1

MIG rankings were highly consistent with overall SRI with some exceptions. High SRI scoring states of Virginia and Kentucky were top ranked. Low SRI states of Oklahoma, Mississippi and Alabama raned at the bottom of counties with high percent of MIG.

Two anomalies were the drop in relative ranking of North Carolina and, especially South Carolina and the rise in relative ranking of Texas.

The map below shows graphically county level rankings for MIG.

Integration of Natural Ecological Systems: Management Intensive Grazing (Quartile Ranks)



A higher quartile ranking indicates a higher level of resiliency on this measure. State of the South data sources: 2012 Census of Agriculture, 2013 Food Atlas, and 2014 review of state policies and regulations; extra calculations by the University of Mississippi Center for Population Studies. Analysis based on 1304 counties.

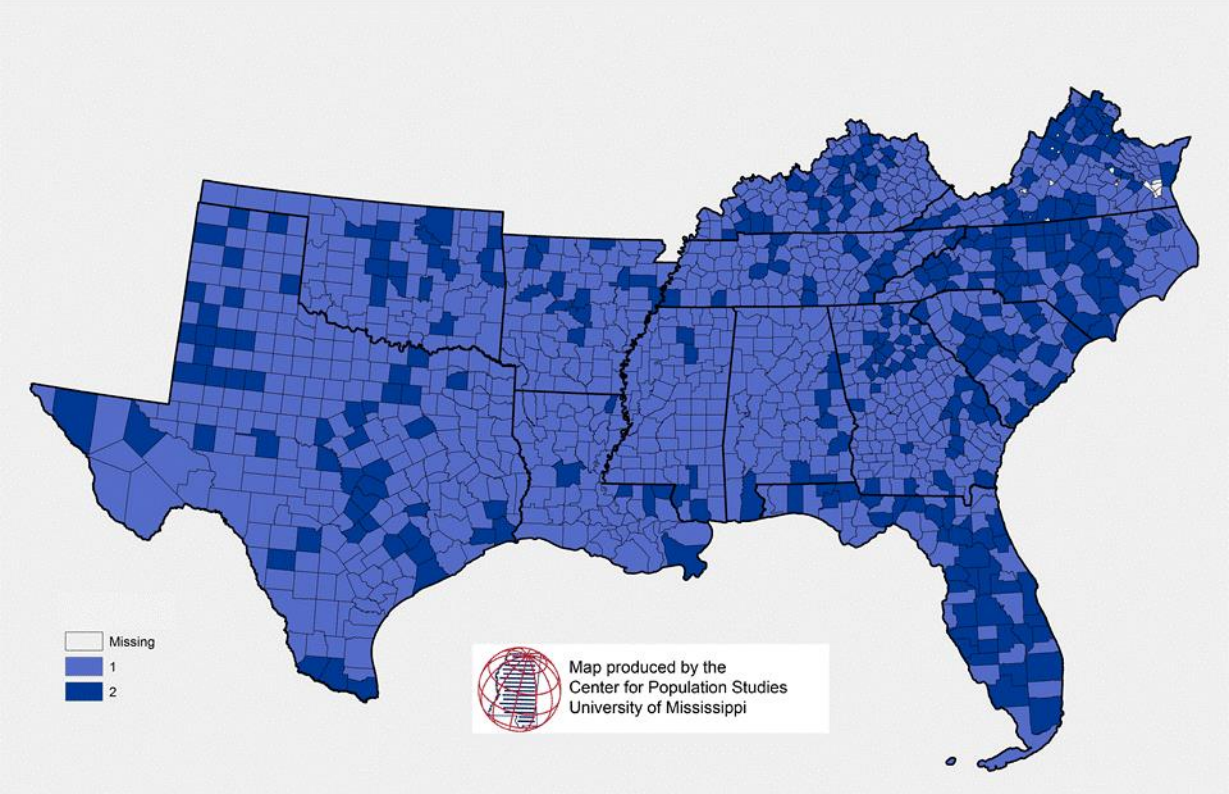
Ranking of states for certified organic acres is shown compared to rotational grazing (MIG) and overall SRI in the adjacent box. Presence of certified organic acreage in a county is very consistent with overall SRI scores. The top five states on SRI were also the top five or organic acres. The two lowest counties on SRI are among the three lowest or organic acres.

Louisiana is an outlier in that its high ranks on MIG and SRI are not reflected in its ranking on organic acres. Other SRI rankings are roughly parallel to certified organic rankings.

States ranked by % of counties in highest quartile on the counties with certified organic acreage				
Certified organic	MIG	SRI	State	%
1	9	5	Florida	55.2
2	6	2	North Carolina	53.0
3	10	4	South Carolina	39.1
4	1	1	Virginia	36.7
5	2	3	Kentucky	25.0
6	8	9	Georgia	21.4
7	11	10	Oklahoma	20.8
8	4	11	Texas	20.5
9	3	7	Tennessee	20.0
10	5	8	Arkansas	16.0
11	13	12	Alabama	11.9
12	7	6	Louisiana	9.4
13	12	13	Mississippi	6.1

The map below shows graphically county level scores on certified organic acreage.

Integration of Natural Ecological Systems: Organic Production (Ranked)



A higher ranking indicates a higher level of resiliency on this measure. Two options are listed because the percentage of organic farms is low across the region. State of the South data sources: 2012 Census of Agriculture, 2013 Food Atlas, and 2014 review of state policies and regulations; extra calculations by the University of Mississippi Center for Population Studies. Analysis based on 1304 counties.

The adjacent box shows the ranking of states on use of pesticide, certified organic acres and SRI. The top three states on SRI (Virginia, North Carolina and Kentucky) are all among the top four in not using pesticide.

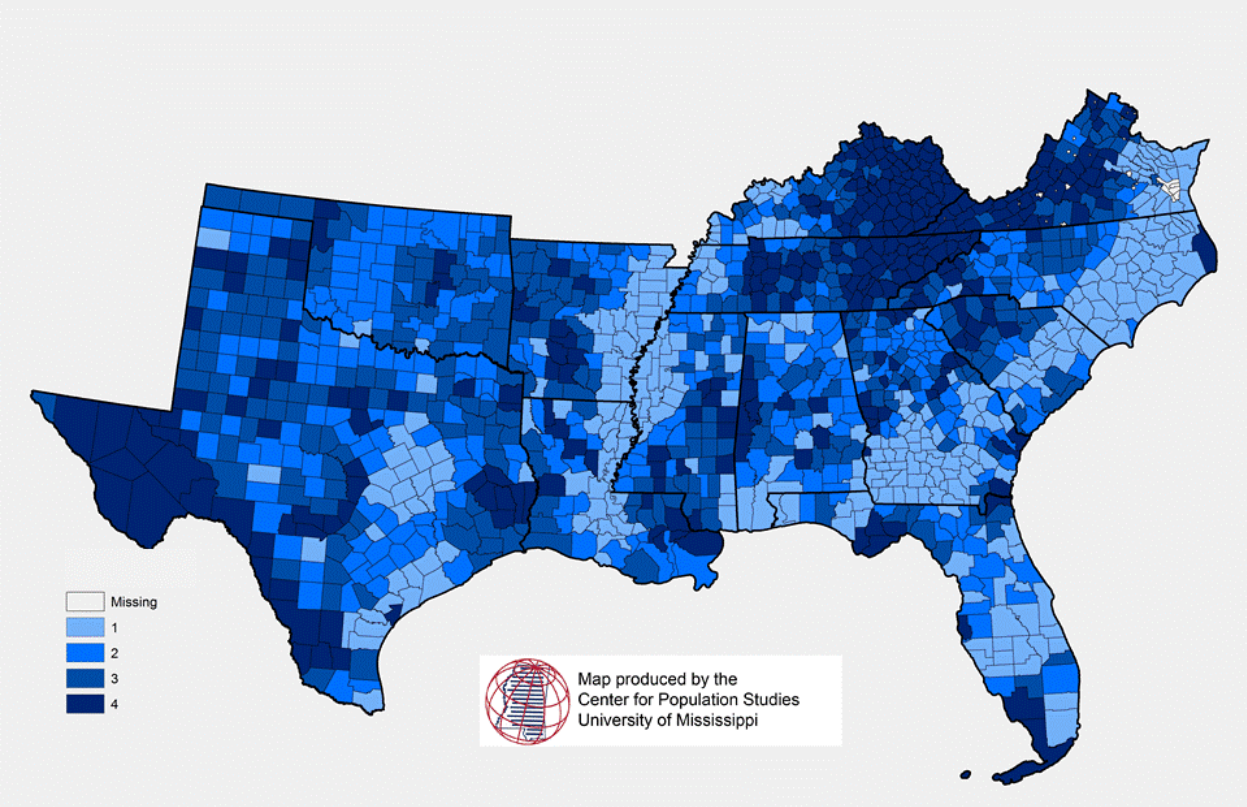
Lowest ranking states on the overall SRI are largely in the lower tier of the pesticide use measure of ecological integration with the exception of Texas.

Also noteworthy are the high scores on the low pesticide use indicator of three states (Tennessee, Virginia and Kentucky) compared to all other states and the low score of Florida even though Florida ranked highest on the organic indicator and in the top five on overall SRI.

States ranked by % of counties in highest quartile on the lack of use of pesticides.				
No use Pesticide	Certified organic	SRI	State	%
1	9	7	Tennessee	55.8
2	4	1	Virginia	48.4
3	5	3	Kentucky	42.5
4	2	2	North Carolina	25.0
5	8	11	Texas	22.8
6	12	6	Louisiana	18.8
7	3	4	South Carolina	15.2
8	6	9	Georgia	14.5
9	11	12	Alabama	13.4
10	10	8	Arkansas	13.3
11	1	5	Florida	11.9
12	7	10	Oklahoma	6.5
13	13	13	Mississippi	6.1

The following map shows graphically the rankings of counties across the South in production diversity.

Integration of Natural Ecological Systems: Low Chemical Input Index (Quartile Ranks)



A higher quartile ranking indicates a higher level of resiliency on this measure. State of the South data sources: 2012 Census of Agriculture, 2013 Food Atlas, and 2014 review of state policies and regulations; extra calculations by the University of Mississippi Center for Population Studies. Analysis based on 1304 counties.

In Summary. In agriculture we are working with formidable allies that have been working with humanity since the dawn of time. Through mindful practices, flexibility in approach and humble patience we can receive the rewards of working with nature to accomplish a common goal: engendering the integrated systems of life which create resilience. Our next chapter looks at a topic very closely related topic: diversity.