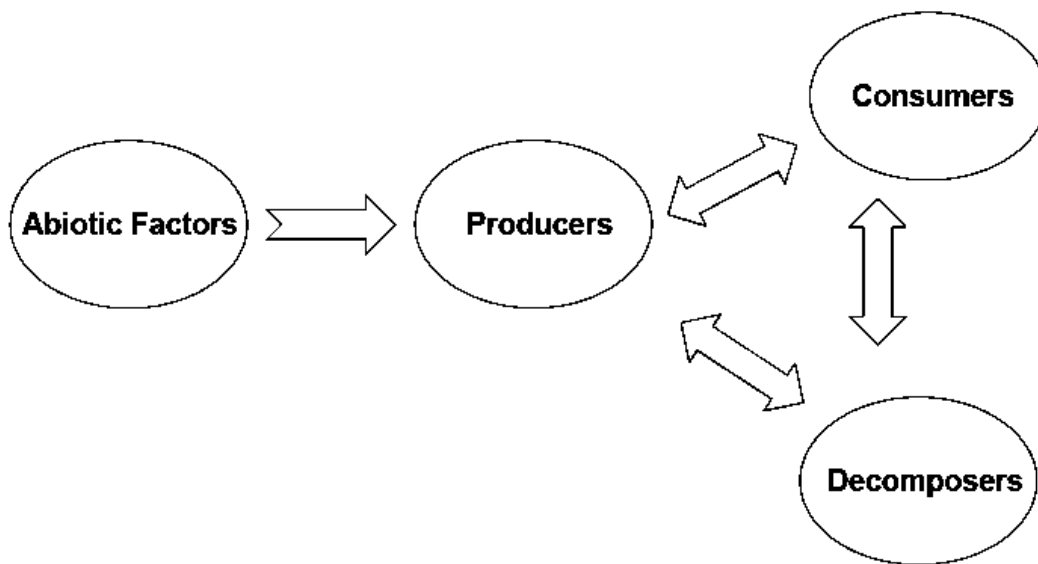


ECOLOGY 101

By Steve Gabriel

One way to consider the ecology is to draw an analogy to the narrative of a story. Like a good plotline, the forest contains characters (the species), which are constrained in the limits of a setting (the environmental factors). These parts are then taken through the plot, which is a series of conflicts and resolutions, which is analogous to the concept of forest succession over time, which is a progression the whole system follows while experiencing many disturbances small and large.

Within each of these parts, and the big picture pattern, there are many variables. This is why each forest is a truly unique combination of factors that are specific to one place and point in time. Recognizing that the forests we steward are unique does not mean that we cannot recognize generalized patterns and execute some general management strategies.



The Setting: Abiotic Factors

The word “abiotic” means non-living, and comprises the elements that a forest farmer should first recognize when assessing their forests. Since non-living elements are more fixed, or less easy to change, we consider these parts often to be limiting factors; which is defined as elements that control a process, which in this case are the characters who show up and how they interact over time.

The major elements are briefly discussed here, so that readers can be considering them as we discuss the particulars of a forest farming system. These abiotic factors are arranged from those that limit the system most to those that are do so less. This of course, all depends on where you are, as in specific context the list may appear different.

Temperature

The most influential element of the abiotic factors are the extremes of temperature; especially on the low end. This is known as “hardiness” and directly limits the species that will survive in an area. Of course, extreme high temperatures will also have effects on all the other living elements as well.

Precipitation

The common adage “water is life” couldn’t be more true. Whether we have sites that contain a relatively even distribution of rainfall or pulses of wet and dry, the amount and persistence of available water has drastic consequences for the forest ecosystem.

Latitude/Sunlight

The amount of sunlight available to our forests equals our latitude on earth, which equates most directly to the growth capacity of the trees and plants in the forest. The further north the latitude, the more dynamic the amount of available sunlight throughout the seasons. Since forest productivity is first determined by trees and plants photosynthesizing sunlight, this factor affects much of the character of a forest. The smallest microclimates from a southd facing slope, for instance, become more significant the further north a forest farm is.

Soil

The composition of the soil in a forest is fundamentally determined by it’s parent material (bedrock), land use change over time, and the species that are present. Soil is perhaps the most important element in supporting healthy ecosystems of all types, yet we can’t do a whole lot to change it’s composition, except add organic matter, occasionally take measures to decompact, and in some excrement cases, add amendments. The soil directly limits how well trees will grow in a given place.

Landform

The various elements of landform, including elevation (in relation to sea level), slope (how steep a hill is) and aspect (the direction the slope faces) are all extremely critical in understanding forest ecology, especially in temperate systems. For instance, Sugar Maple (*Acer Saccaricum*) is often found on steeper northd facing slopes, while Oaks (*Quercus* spp.) prefer the warmer South and Southd west facing hillsides, versus Black Walnut (*Juglans nigra*) likes warmer, wetter, bottomlands as a general rule.

Taking the time to research and learn the unique combination of non-living factors for a forest allows a greater understanding of the more dynamic cast of characters that make up a story of the forest; the living plants, animals, fungi, and bacteria who evolved to adapt to the particulars of place.

The Characters: Living Organisms

Many familiar with basic ecology understand the differences between the three main groups of living organisms one finds in the forest;

Producers are plants, those organisms that photosynthesize sunlight as a form of energy.

Consumers eat plants or other consumers.

Decomposers break down the waste debris and make it available again as matter, nutrients, minerals, etc.

More important than simply identifying these elements is to understand the unique role that each group, and even members within each group, performs. By offering a “job title” for each category, we can better appreciate the complex and critical roles that come with each group.

Producers: Catch & Store Energy

The amazing and unique quality of plants lies in the distinction that they are able to create energy from sunlight, and then capture, store, and distribute that energy to others. It's amazing to consider the incredible diversity of shoots, leaves, root structures, flowers, seeds, shapes and sizes that plants come in.

Producers are also incredible at capturing, storing, and cycling water. Though the capillary action in plants water defies gravity and, in the case of trees, is brought sometimes hundreds of feet upward and released into the air.

Consumers: Cycle Materials & Nutrients

This group, otherwise known as animals, are as vast and varied as the plant producers – the millions of species of birds, insects, mammals, and amphibians one can come across in the temperate forest is amazing – yet as we grow and cultivate our forest farms we might regard these as an afterthought – after all, what role do forest creatures offer other than as pests? This is the general perspective of much of the agricultural community; that animals are either a nuisance if wild, or fit for a singled product role if domesticated.

One of the truly sad realities of humanity is how much we have missed the potential benefits, and perhaps even necessities of engaging with animals in our systems.

What unique roles do animals play? One word; movement. Animals are the great distributors of seeds, fertilizer, and biodiversity in our forests. And in the case of domesticated species, they can complete tasks that we consider “work” with far more ease and skill than we can.

The patterns of animals as they feed, reproduce, migrate, run from predators, and defecate are sometimes straightforward but often rather eloquent. One underappreciated example is salmon, a breed of fish that is well known for its annual “spawn run,” where hundreds or thousands of fish can travel upstream in a single creek. What is often ignored are the implications of a large number of fish moving UP a watershed, reproducing, and then dying. In fact, Pacific Salmon are considered critical carriers of a significant amount of nutrients from the Pacific Ocean back to the land. (Cederholm et al, 1999)

Decomposers: The Recomposers

This group of animals, bacteria, and fungi have one simple job; take complex compounds and break them down to essential nutrients, which are then made available to both the producers and consumers. Without these organisms, we’d literally be up over our heads in waste. Perhaps the most enchanting processes and relationships exist in this group, as these creatures have evolved rather creatively in their pursuit of decomposition.

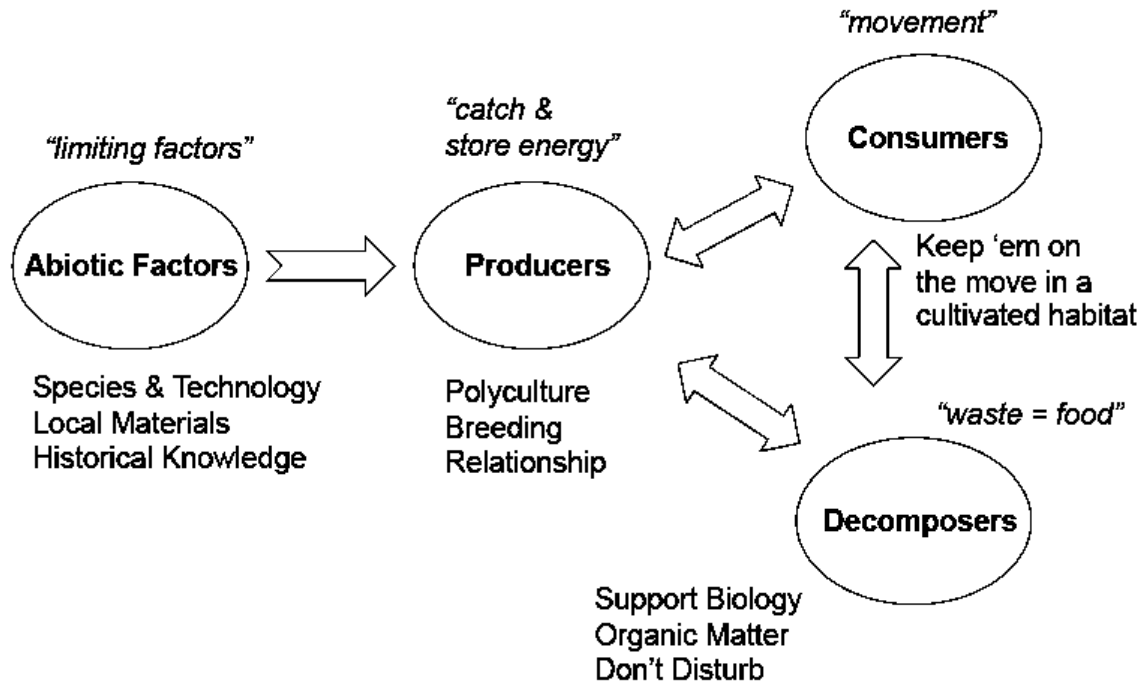
Fungi, including yeasts, molds, and mushrooms, often take an initial crack at the debris. Fungi are unique in that they are the ONLY organisms able to break the tight bonds of lignin in wood, making the food then available to all the other organisms in the soil. Fungi also have the unique ability to spread feet and even miles through the soil, and unlike bacteria don’t need a lens of water in the soil in order to survive.

Bacteria, the earliest form of life on earth, are important recomposers of soil second only to fungi. They can grow and reproduce in massive quantities and are key players in converting nutrients into useful forms for plants. Bacteria mostly feed on root exudates as plants grow and die and thus most live around the root zones of plants. Their presence is key to nutrient retention in the soil and in the case of nitrogen fixing bacteria, bringing this critical element into the system through fixation.

Other members of the soil community include archea, protozoa, nematodes, earthworms, and larger reptiles, mammals, and birds. This community of creatures orchestrates a back and forth that takes dead plant and animal material and turns a waste into a resource, recycling nutrients and matter over and over again.

In the process of digesting organic matter of all shapes and sizes, what the decomposers do is create soil; rich, healthy, living medium that the plants, and ultimately all creatures, depend on for survival. In the end, any natural system is only as productive as the health it contains in the soil. With this in mind it may seem less surprising to learn that the vast amount of biomass (over two thirds that is produced in a forest ecosystem) goes directly to decomposers. (Perry)

The implication of this is that, in order to produce good soil, a lot of biomass must be produced *solely* for decomposition.



Putting it all together: An example from the Pacific Northwest

As compelling as each group is to ponder, a full appreciation for the complexity and evolution of the relationships between these organisms is really the key to understanding ecology. As much as science has offered in our understanding of this, there are relatively few well-documented instances of the incredible symbiosis that brings together the abiotic factors, producers, consumers, and decomposers in an incredible theater of activity that is unique in each time and place. One example, well documented in the temperate Pacific Northwest region of the US by scientist Chris Maser, offers a glimpse at this impressive combination of events.

This story begins in the Pacific Northwest, in coastal forest dominated by the Douglas Fir. The climate is temperate, with considerable precipitation.

Living high in the tops of these trees, which can sometimes tower hundreds of feet in height, is a most curious creature, the Northern Flyer squirrel. The favorite food of the flying squirrel, and of many of the smaller forest dwelling rodents, are mushrooms, and sometimes even the mycelia of the fungus. In this case, the white truffle is the delicacy of choice for the squirrels.

Saying “truffle” is much like saying “apple.” It describes a larger group of mushrooms that form their fruiting bodies underground. Thus the squirrel must sniff out and dig to get at it. The fascinating part is that as the squirrel consumes the mushrooms, it also inevitably picks up bacteria and minerals through contact with the soil. The result, Maser points out, is a “pill of symbiosis” – in other words, the feces is a package of nitrogen fixing bacteria, the spores of the truffle, and the complete mix of nutrients to support their establishment of a new place in the forest. These organisms, fungal and bacterial, have evolved to persist through the digestive tract of the squirrel.

Even more amazing is that the primary predator of the northern flying squirrel, the famous spotted owl that is an icon for activism around deforestation in the northwestern states, appears to also support living fungal spores and nitrogen fixing bacteria as it is digested through *their* system. This further expands the range and potential of moving these species dozens if not hundreds of miles.

If we take a step back and view the big picture, we can see the entirety of the ecosystem in the setting, characters, and plot. We can see the sequence of events which perpetuates, regenerates, and develops a forest through a succession; a series of transitions facilitated by the interaction between each of its organisms.

This example is used because it is one of the more that documented ones. Care studies of these complex inter-species connections and evaluation are rare, partly because it's challenging on the part of the scientist to document the relationship thoroughly. Take away any one element of the picture; the trees, the squirrel, the fungus, the owl – and the entire community suffers.

As forest farmers we can strive to better understand these types of relationships in our own woodlands; and we can draw a number of lessons from the observations of this interaction. We might value the role of rodents in a new light. Mike Demunn, a local forester in the Finger Lakes Region who is Seneca Native American has said, “the squirrels are the tree planters.” He leaves trees standing that other foresters would often cut; the large hardwoods that lose a branch and develop a large cavity, known to foresters as a “den tree.” Squirrels in all temperate forests bury caches of nuts at a much larger rate than they consume them; partially because most nut trees fruit in a cycle of “mast years” where one year the tree puts out hundreds of nuts, and then might only produce a limited few for the next several before again producing a mast. This evolutionary development both limits the energy expenditure for the tree and to limits overpopulating a forest with nut-loving mammals.

Bacterial and fungal kingdoms are the web that connect all things; they are critical to the restoration and sustaining of forest ecosystems. The adage “build it and they will come” is key to supporting soil health.

While as forest farmers we might not be able to develop our systems to such a high degree of symbiosis, this example provides inspiration for the types of ecological relationships we want.

Applying Ecosystem thinking to Permaculture System

We can apply this type of ecosystem framing to our own systems, though they are not likely to have the same level of symbiosis and interdependence; at least not at the outset of system development. We have to remain humble in claiming to design ecosystems and relationships, and recognize that all evolutions in nature are the result of many decades or even thousands of years of work on the part of the organisms. The best we can do is set up the opportunity for organisms to interact, observe, and tweak the system as we learn from it.

At Wellspring Forest Farm there has been a concerted effort to look at the relationship between the forest where mushrooms are raised, ducks, and slugs. This can be considered a four-way relationship that has been intentionally cultivated to work together. (Or in the case of the slugs, to reduce or eliminate the population).

The woods is a one-acre forest almost entirely composed of *sugar maple* trees. About 100 of these trees are tapped each winter for maple syrup production, which averages around 20 gals of finished syrup when all is said and done.

Necessary to the continued health of the sugar maples is periodic thinning of diseased, crowded, and structurally unsound trees. This produces a decent yield of logs in the range of 4 – 10" in diameter, which can be inoculated with shiitake mushrooms as another yield. There is an inherent symbiosis in this relationship from a management perspective, since the fact that mushrooms are a high-value cash crop means the farmer has an incentive to thin the woods, which ultimately makes the forest a healthier system.

Any mushroom grower has had plenty of interface with the slug world; it's sort of a given if you are going to grow mushrooms in the woods. Taking a nod from Permaculture cod-founder Bill Mollison's quote, "You don't have a slug problem, but a duck deficiency", which encourages a paradigm shift from seeing "problems" as indicators of a missing piece to the ecosystem design, we brought ducks into the mushroom yard starting in 2010, first at a very small scale.

Ducks like it cool and moist, and so the forest becomes a perfect refuge for them, especially in the summer months. Putting the animals on a rotation is key to reducing negative impact on the forest floor. The ducks don't "hunt and peck" slugs off the logs, but instead reduce the population BEFORE the slugs can get to the logs.

While after two seasons the ducks have, at least on an anecdotal basis, proven to be useful as a slug deterrent, they are not a perfect solution. As with any farming system, the weather, the timing of when ducks are moving into the mushroom yard (and moved out), and the ability of the farmers to observe and make decisions to change this or that as the system moves through the seasons are all part of the evolution.

In this example, there are abiotic factors that influence the living organisms in the system. The maple trees are the major producers that synthesize sunlight and

feed the system from the ground up. Mushrooms act as primary decomposers for the wood, which ultimately also feeds all the other elements of the soil biology and then ultimately the root systems of the trees. The consumers interact to balance populations (ducks eating slugs and humans eating ducks, or duck eggs). It isn't a full, intact ecosystem, but it's a start.

Designing our farming systems to be more like ecosystems means we are headed in the right direction, toward increased interaction and symbiosis. In the process we reduce time, labor, and resource inputs into the system. At Wellspring Forest Farm, the ducks don't spend all their time in the woods, but have become critical weed and pest control agents on the entire farm, for the bettering of all the systems.

The "Plot": Forest Succession & Disturbance

As if the abiotic factors and biological organisms were not enough of a dynamic to work with, it's critical to remember that each of these elements is changing in relationship to the others and in the context of events taking place over time. Forest ecosystems, in particular, are especially long in their cycles of growth, death, and decay.

The change of species composition over time defines the character of the ecosystem, and when we look at the big picture we are examining the concept of succession; that ecosystems naturally evolve from scattered, competitive, and disorganized groupings of plants and animals that initially scramble during a large flux in nutrient availability. The stages of succession are generally characterized by:

Pioneer or Early Succession

This stage is characterized by fast growing, often annual, and opportunistic species that quickly move into to capture the free flow of water, nutrients, and sunlight made available by a recent disturbance. Species that thrive in this stage are sun-loving, often tolerant of a wide range of limiting factors such as drought or excessive water, and one can find many nitrogen fixing species in this group.

Mid Succession

The best phrase to describe this phase of succession is diversity. Here a wide mix of groundcovers herbaceous plants, shrubs, and small trees prevail. Light density is often around 40 – 50%, sometimes called open woodland. Picture an orchard as a template, with many species packed into every available space. Cool season grasses thrive in this environment.

Late Succession/Climax

In this phase, the forest canopy is close to if not entirely filled out, nearing 100% cover of the forest floor. The potential species that can live in this environment are diminished. Nutrients, water, and sunlight are "locked up", and each plant carves out a rather specific and limited niche for itself.

Models of Succession

While the different stages classified have been more or less agreed upon by ecologists, the understanding of the patterns, or *how* these stages play out over time has changed rather dramatically in the last few decades.

A. Linear model of succession

The first notion of succession was simple; ecosystems moved through one stage to the next, from pioneer to midsuccession to eventual climax, which in early thinking was a straight curve where the climax was seen as the end point, or apex of ecosystem succession. Once an ecosystem reached the climax, there was some variation, but mostly the system remained in a “steady” state indefinitely.

B. The “pulse” model of succession

The problem with the above characterization was that scientists simply couldn't find a many examples of ecosystems that had existing in the climax steady state, at least not for very long. Each time an ecosystem was getting close, or there, a disturbance would come along and change the dynamic, sometimes dramatically. Thus, as it appeared, the model of linear succession, which suggested reaching a destination, the climax, was flawed. Indeed, in nature each ending is a new beginning, and scientists began to consider that disturbances to this upward trend – fires, floods, large weather events, and so forth, were essential and important elements in the equation. And, rather than seeing them as setbacks to the development of the system, they began to be seen more as key components in characterizing a given ecosystem. Rather than interruptions to a desired end, they were merely milestones on a pathway.

Disturbance as a positive force

As we examine the different concepts of succession, the key point to remember is that disturbances happen; and while often are damaging or even catastrophic in the short term, they tend to propel an ecosystem in some positive way. For example, floods deposit nutrients into floodplain ecosystems, and fire often assists in the germination of many dormant seeds in the forest, while also reducing pest populations and breaking down forest litter, making it more available to the soil.

Whether we like it or not, disturbance happens. The more we can accept and take it into account as we design our forest farms, the better off we will be in both the short and long term. While the specific timing, magnitude, and breadth of a

disturbance cannot be predicted with much foresight, we can do some “worst-case scenario” thinking and plan ahead, to the best of our ability.

With the onset of more rapid climate change, resilience to disturbances, both environmental and social, will be critical. As forest farmers we are fortunate in that forests are already more buffered against disturbances, yet they are not immune. Careful

C. Shifting Mosaic model of Succession

At some point, it was recognized that the linear form of succession, even with the addition of disturbance as an inevitable force, became recognized as an unhelpful way to consider the process of succession. This model represents the forces at work as a cycle while still recognizing the stages of succession and the disturbances which transition the ecosystem from one phase to another. This third model of succession, named the “Shifting Mosaic” pattern, acknowledges the idea that, rather than ecosystems climbing the ladder to the top of the mountain (climax), the important pattern to recognize was that ecosystems of all types simply go through shifts from one type to the next. Thus, no stage is necessarily better than the other. What is more important is to identify the stage a specific ecosystem is in, while also tracking the past and future transitions from one type to the next.

This concept is complicated by the factors of time and scale. A forest may remain in late or climax succession for centuries, while a field may turn into forest in only a few decades. The scale can range from a catastrophic event like an ice storm or hurricane, to a gap created in the forest when just one tree falls from the canopy, opening the forest floor to an influx of light. It's important, then, to take the overall pattern in concept, but recognize that each unique site will be its own unique iteration of the process. Like the thousands of books that sit on library shelves, each a bit different than the others, yet in the end all using the same language, the same standards for spelling and grammar, and the same method of delivering information from author to reader.