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Introduction to Pasture Ecology

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Pasture-based livestock production is a near miraculous process. Starting with an egg cell from the dam and sperm cell from the sire a cow, ewe, or doe produces an offspring. Plants gather sunlight, fix solar energy, and take up soil minerals to make food for the grazing animals. The animals graze the pasture; microbes in the rumen digest the forage and are then digested by the animal to provide energy, protein and minerals for maintenance, milk production, or growth. Treaded plant tops, dead roots, manure and urine provide energy and protein to soil organisms that help maintain soil structure, water infiltration and water holding capacity of the soil. The majority of minerals are cycled back to the soil in dead plant material and manure or urine from the animals. These nutrients are then used to grow another flush of pasture. If all goes well, at the end of the season we have a new well grown calf or set of twin lambs or kids. Each produced from two cells, solar energy, and minerals harvested from a healthy soil by the grasses, legumes and forbs in the pasture.

This interplay of sunlight, plants, soil and animals are the parts of pasture ecology. The livestock producer who understands plant, soil, and animal ecology is prepared to be better pasture manager, to understand how to adapt to changes in weather, and interpret how research and farmer experience from other areas apply to their farm. For our introduction to pasture ecology we will discuss the four living components of the pasture ecosystem: plants, grazing animals, soil community, and human managers. But first let discuss some over-arching ecological principles.

Optimal environment vs. limiting factors

Each plant, animal, bacteria, protozoa, and fungus has its niche or place in its ecosystem. Each has an optimum physical and chemical environment and habitat. The habitat provides adequate food and cover, allowing the species to reproduce and maintain itself. The environment is determined by the climate, time of year, soil texture, position in the landscape, and human management.

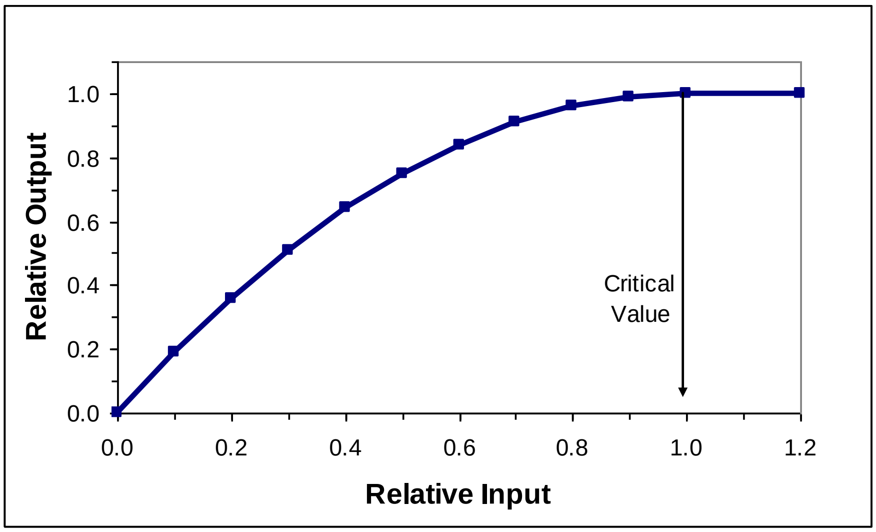
The flow of energy from the sun follows the food chain (tropic levels or food web) which is composed of primary producers who fix solar energy and other organisms that eat plants and each other to get their part of the fixed solar energy. These organisms are defined as primary consumers, higher level consumers or predators, omnivores, parasites, and detritus feeders or decomposers.

All organisms do best when they live in an environment that provides all their needed resources (temperature, nutrients, protection from predators and pest, ability to reproduce). If any one of those needed resources is below a lower threshold (low soil fertility) or above an upper threshold (excessive temperature) it will become a limiting factor to the health and productivity of the organism. If a second organisms is better adapted to this level of limiting resource it will be more healthy and productive and will out compete the first for space and use of other resources. When managing pasture plants or livestock it is imperative that we know what are the optimal resource conditions needed by the plants and animals and provide them if economically possible. When not economical we should then look at alternative plants and animals that do well within these limiting resource constraints.

In economics we talk about the law of diminishing returns (Figure 1). This principle applies to organisms within ecosystems for all of their resource needs. If the availability of a resource falls below a critical value the health and productivity of an organism decreases. For example clover plants need a soil pH above 6.0 and soil test phosphorus and potassium in the high range or their health and productivity decreases. If another plant, say tall fescue is more tolerant of low pH or medium soil test potassium it will have a competitive advantage and will increase in the stand at the expense of the clover.

When there is an excess of a resource there may be an upper critical value where health and productivity decreases. Looking at temperature as a resource, cool-season grasses have a lower critical temperature near 50^{o}F. When average daily temperature is below that their growth rate is limited by temperature. Likewise cool-season grasses have an upper critical temperature near 70^{o}F. As daily mean temperature increases from 70^{o} to 90^{o}F growth of cool-season grasses decreases from near maximum at 70^{o} to zero 90^{o}. If a warm-season grass is in the stand its growth rate goes from slow at 70^{o} to near maximum at 90^{o}F. That is one reason Bermuda or crabgrass can be dominant in a pasture in August but fescue dominant in October.

Figure 1. Law of diminishing returns. In some cases if the relative input is too high there is an upper critical value that causes production to decrease.



Plants

Plants are the primary producers in the pasture ecosystem. They intercept sunlight, fixing the solar energy in carbohydrates and proteins. Leguminous plants like clover and lespedeza fix nitrogen from the air that is used by plants for making proteins. Plants take up mineral nutrients from the soil to make enzymes, coenzymes, DNA, RNA, and cell structures within the plant. These minerals are used for similar purposes in the livestock that eat and digest the plants.

There are many different species of plants that live in a naturalized pasture. They differ in preferred thermal and radiant environment, growth habit, life history, forage quality and anti-quality components. Pasture ecology is complex but it is not difficult. There are a number of basic principles that apply to all plants. Some plants like it hot, some like it cool. Some need full sun, others tolerate shade. Some need long days to reproduce, others need shorter days. Some plants grow upright, some along the surface of the soil, and some in between. Plants differ in their cell wall thickness and cell contents due to species, growth age, and time of year. Some plants have toxins, others may have antitoxins to the toxins. There are grasses, legumes, forbs, shrubs, trees; tall plants, short plants, plants that have rhizomes and those that grow as a bunch of tillers. Some plants have roots that are fibrous, some have taproots. Some plants reproduce vegetatively, some sexually every year, others their first year then die, some live for two years produce seed then die. Knowing these characteristic for the plants in the pasture helps us understand how to manage them.

Photosynthesis

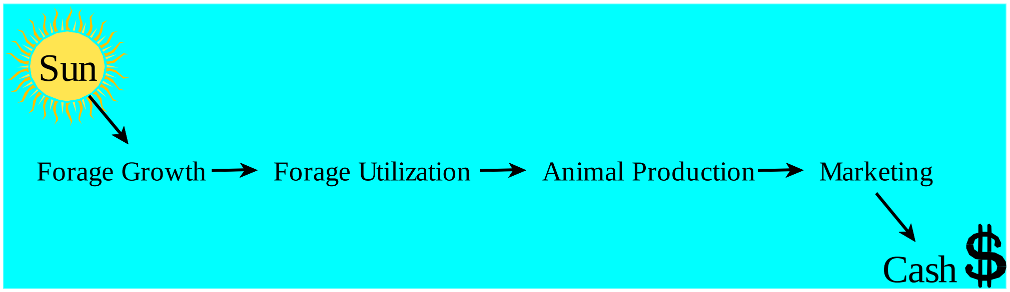
Plant growth requires energy. Plants capture energy from sunlight through photosynthesis. The green pigment (chlorophyll) in leaves absorbs energy from sunlight using it to combine carbon dioxide (CO_2) and water (H_2O) to produce simple sugars ($C_6H_{12}O_6$) and oxygen (O_2).

Plants use sugar, nitrogen, and minerals to make enzymes, DNA and RNA that control all metabolic activity in their cells. They combine sugars to make cellulose and hemicellulose for cell walls, and to make complex sugars and starches for storage as energy reserves. How plants partition their use of solar energy depends on the developmental stage of the plant and on environmental conditions.

Solar energy varies over the year due to how high the sun is in the sky and day length (June 21 highest and longest, December 21 lowest and shortest). This determines the daily potential photosynthesis; which is further affected by temperature and soil moisture, which controls the movement of CO_2 and O_2 in and out of the leaves.

The pasture manager's goal is to optimize plants capturing sunlight, converting it to high quality forage, utilizing that forage to produce livestock products which will be marketed to generate cash income (Figure 2).

Figure 2. The goal in pasture-based livestock production is to convert sunlight to net cash income in a sustainable manner.



Respiration

Plants also use respiration to maintain life and to grow. In a simplistic sense respiration is the conversion of carbohydrates to carbon dioxide and water to release energy needed to perform metabolic functions.

During the day, both photosynthesis and respiration occur with photosynthesis dominating so that there is a net increase in carbohydrates. At night respiration continues but photosynthesis ends when the sun sets. So during the night there is a net loss of carbohydrates. This can be seen in the cycle of sugar in plant leaves. The sugar content in a leaf is lowest at sunrise. During the day sugar content increases and sugars are used for leaf and root growth and are stored for reserve energy. After sunset, respiration uses up leaf sugar bringing it back to a low point in the morning. Both photosynthesis and respiration are affected by air temperature with different plant species having different responses to temperature.

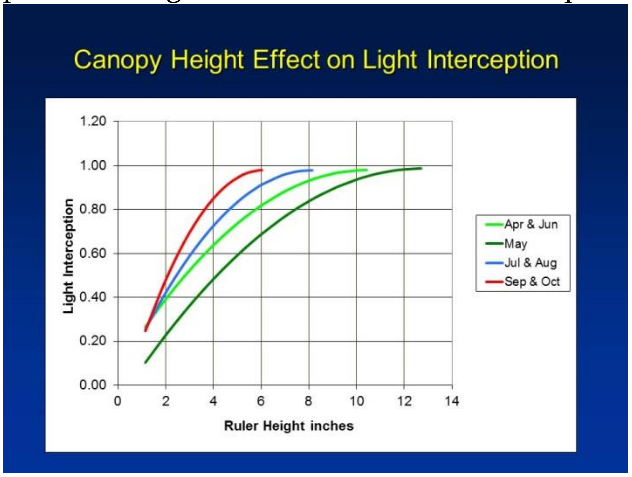
In cool-season plants there is a second type of respiration called photorespiration. These plants are called C3 plants because their metabolic pathway uses 3-carbon sugar. Warm-season plants are called C4 plants because their metabolic pathway uses 4-carbon sugar which does not allow photorespiration. Photorespiration increases with air temperature more quickly than conventional respiration. The C3 plants grow well when average daily temperatures are cool (50^o to 70^oF) but poorly when temperatures are hot (over 80^oF); thus their name cool-season plants. The C4 plants do well at high air temperatures (80^o to 90^oF); thus being called warm-season plants. The C4 plants have a semitropical origin and are usually sensitive to cool weather and light frosts while many C3 plants tolerate light frosts and some hard freezes.

Light Interception: Canopy Height and Time of Year

Light interception is determined by how tall and thick the pasture canopy is and how high the sun is in the sky (Figure 3). A tall, thick pasture intercepts more light than a short, thin pasture. The light that is not intercepted by the leaves is lost to the plant for making sugar. The sunlight hitting the ground will heat the soil and air which may increase respiration in the plants. On cold spring days this could be good. On hot summer days this could be bad. In the fall C3 plants benefit having some sunlight at the base of the canopy since this is needed to stimulate the formation of tiller buds that will produce tillers the following year.

When the June sun is high in the sky, rays of sunlight shine deeper into the canopy then do rays from the October sun which is low in the sky. In June a pasture height of 8-inches is needed to capture 90% of the sunlight (midday in WV) while in October a height of about 4.5-inches captures 90% of the sunlight (Figure 3). More light penetrates the canopy in May than June. When pastures start going to head in May grass tillers elongate raising some of the leaves above others allowing more light to penetrate into the canopy. Once the reproductive tillers are removed and the pasture is again dominated by vegetative growth light interception increases.

Figure 3. Light interception by a pasture is determined by the sun's height in the sky and the pasture's height which is an estimate of the pasture's forage mass and leaf area.



Energy Reserves Cycle With Growth

In many plants there is an energy reserve cycle during periods of growth after harvest. Let use tall fescue and white clover as examples (Figure 4). When leafs of these plants are grazed off new leafs start to grow. When most of the leaves are removed, energy for new growth comes from stored energy reserves. The site of stored energy reserves is species specific. Tall fescue stores energy reserves in the lower leaf sheath and underground stems called rhizomes. White clover stores energy reserves in the above ground stem called a stolon.

Over a period of days the energy reserves decrease as new leafs grow. As leaf area increases, more sunlight is intercepted and photosynthesis increases, providing more energy for growth. At some point photosynthesis is great enough to produce more sugar than is needed for growth, resulting in sugar moving into storage with an increase in energy reserves in the plant. As leaf area increases further energy reserves return to the high level needed to sustain the next growth cycle. As leafs grow beyond maximum light interception they shade one another, older leaves become less efficient and die. Beyond this point net growth is reduced and forage quality declines.

Growth Under Rotational Grazing

When all photosynthetic active leafs are removed from a plant new growth is dependent entirely on stored energy reserves. When some leaf area is left plant regrowth may be faster since it is powered by photosynthesis and stored energy reserves. This is one reason we do not want to overgraze pastures. For example a grass-clover pasture was allowed to grow to a dry matter (DM) forage mass of 3000 lbs. DM/acre. Cattle then grazed the pasture to 1500 lbs. DM/acre. After the cattle were removed growth was linear during all growth intervals (Figure 5). In September growth plateaued at just over 2000 lbs. DM/acre due to dry weather. Residual forage mass was maintained above 1200 lbs. DM/acre since animal forage intake is limited and animal performance decreases at lower residual forage mass.

Figure 4. When a plant's leafs are grazed off new growth is powered by carbohydrate reserves and photosynthesis in remaining leafs. As new leafs grow they use reserve carbohydrate and the reserves decline. Latter when new leafs produce carbohydrates in excess to plant growth needs, carbohydrate reserves increase.

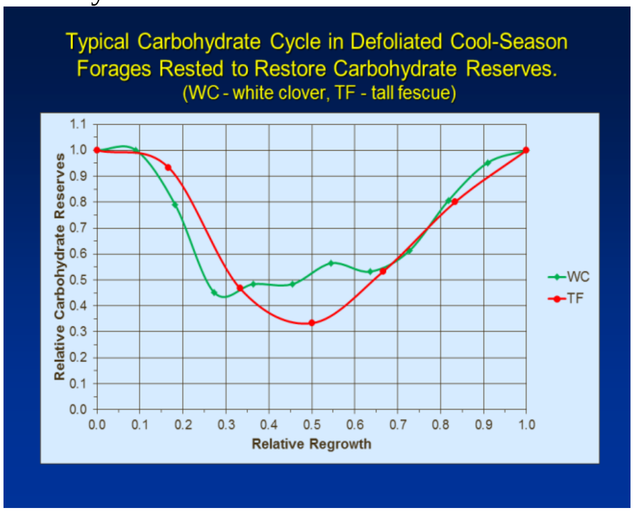
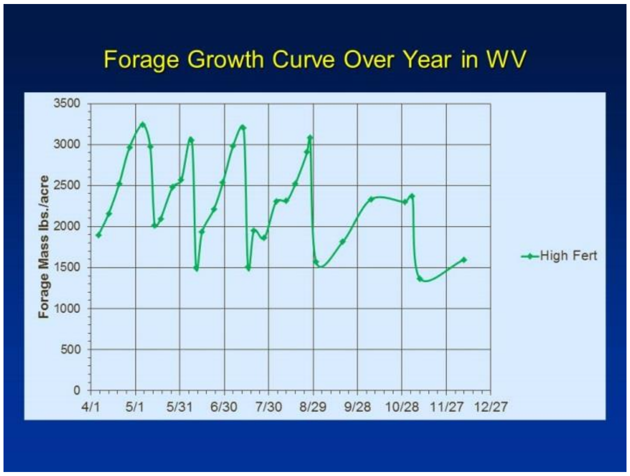


Figure 5. Weekly measurements of pasture forage mass in a rotationally grazed grass-clover pasture showing the maintenance of linear growth powered by carbohydrate reserves and residual leaf area.



Root Growth

Root growth determines the ability of a plant to take up water and nutrients. Root growth is controlled by actively photosynthesizing leafs. When energy is in short supply, it is used by plant tissue nearest to the site of photosynthesis. Therefore, roots receive energy when more energy is produced by photosynthesis than is being used by top growth. (Grass roots are not used for reserve carbohydrate storage while the tap root of legumes and forbs are used for storage.)

Some cool-season grasses tolerate close grazing (2-inch height) if adequately long rest intervals (4-weeks) are provided between grazing events (Figure 6). However, upright growing native warm-season grasses do not tolerate close grazing since little leaf area remains and leaf sheaths that may contain reserve carbohydrates are removes (Figure 7).

Figure 6. Cool-season grass response to rest interval when grazed to a 2-inch residual height (photo courtesy Dr. Ozzie Abaye Va. Tech.).

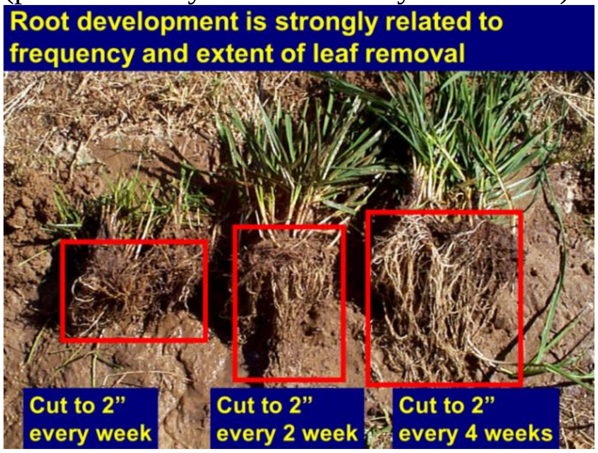
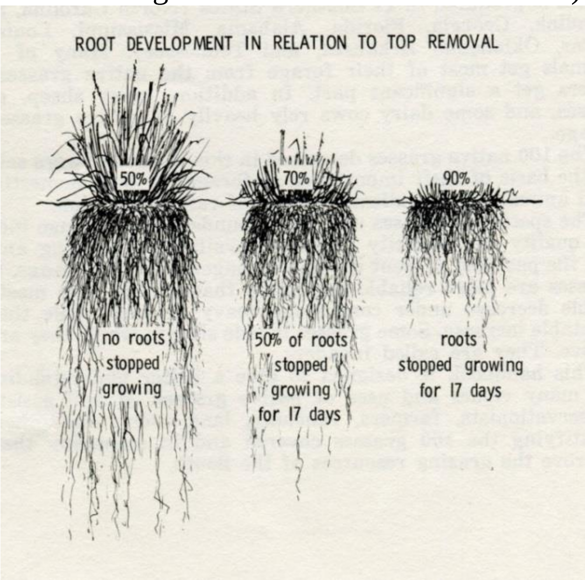


Figure 7. In native warm-season grasses that grow upright, root growth after defoliation is proportional to the intensity of removal of top growth (USDA/SCS, Ag. Handbook No. 389, 100 Native Forage Grasses in 11 Southern States).



Optimal yield depends on harvesting leafs without adversely affecting top or root growth. This is based on the proper timing and intensity of grazing relative to energy reserves and residual leaf area.

Growth has two phases

Pasture growth is observed as the plants increase in height (Figure 5). However, within the plant, growth is composed of two phases; cell division then cell enlargement. Both phases require adequate energy, protein, mineral nutrients and water.

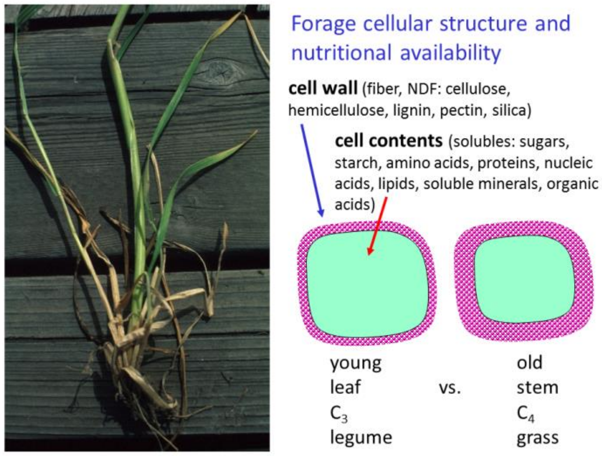
Plant cells differ from animal cells in that they have a cell wall. A young cell has a thin cell wall and a high proportion of cell contents. As the cell matures the cell wall thickens and the proportion of cell contents decreases (Figure 8). Young cells need to have thin walls so they can stretch during expansion. Mature cells in stems need thick cell walls to support the stem and seed head.

The growth pattern from young to mature cell affects forage quality as well as production. Cell contents are about 98% digestible while the cell wall material can be 70% digestible in young forage but only 30% digestible in mature forage. The cell wall becomes less digestible as more lignin is deposited around the structural fiber. In cool-season forages this is most pronounced in hot weather.

Growing Points

Cell division occurs in specialized cells located at growing points of the plant. There are four main types of growing points in forage plants: terminal, axillary, intercalary, and root tip. Terminal growing points are on the end of a shoot. Axillary growing points are in the axis of the leaf, the angle between the leaf and stem it is attached to. Intercalary growing points are found in grass leaves and provide growth on each side of the region of cell division. Root tip growing points are at the tip end of the root, as would be expected. Growing point locations are characteristic of each plant species and determine what the plant looks like or its morphology.

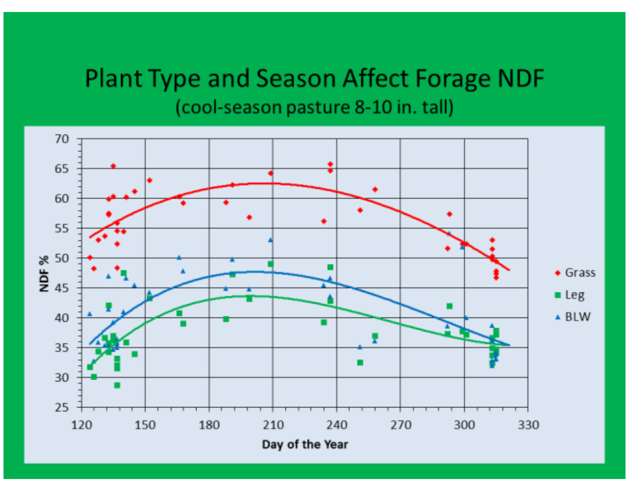
Figure 8. A young plant cell is relatively thin and can stretch as the cell expands to grow. As the cell matures the cell wall thickens. The cell wall is a relatively larger part of the cell in old vs. young forage, in C3 grasses vs. C3 legumes, in C4 grasses vs. C3 grasses, and in stems vs. leaves (courtesy Dr. Tom Griggs, WVU).



Cell Wall Content Changes with Season and Plant Type

Forage cell wall content is estimated using neutral detergent fiber (NDF) analysis. The NDF content of pasture changes over the growing season due to growth stage and temperature affecting the balance between photosynthesis and respiration. Pasture NDF is also affected by species composition since gasses have higher NDF than forbs (a.k.a. broad leaf weeds) and legumes have the lowest NDF content (Figure 9).

Figure 9. Neutral detergent fiber (NDF) is an estimate of plant cell walls and varies by forage type with grasses being highest, legumes (Leg) being lowest, and forbs/broadleaf weeds (BLW) being intermediate. In the cool weather of spring and fall cool-season plants are in vegetative growth (no stems) and photosynthesis is relatively greater than respiration resulting in higher levels of nonstructural carbohydrates within the cell and lower levels of NDF.



Plant Morphology and tolerance to grazing
Most plants can be graze successfully when the timing and intensity of grazing is controlled within the bounds tolerated by the plant. Some plants tolerate long regrowth periods while others do best when defoliated at shorter intervals. A main factor is lack of tolerance to shading or self-shading which reduces tiller production or growth. Lack of tolerance to self-shading often occurs in species considered pasture species (Table 1). Hay species tend to be more tolerant and do well under longer growth periods. When species differing in tolerance or requirement for rest interval are present in a pasture the rest interval imposed will determine the dominant species in the pasture (Table 2).

Forage quality, anti-quality, and palatability
Plants differ in forage quality and palatability. The primary determinant of forage quality is age of the plant material. Young growth will be higher quality than older growth. Another determinant is that legumes have lower neutral detergent fiber and higher cell soluble content than grasses (Figure 8). Some plants have major anti-quality components such as wild endophyte KY-31 tall fescue.

When grown in mixtures within a paddock species differing in palatability can cause non uniform grazing of the paddock. This can result in the less palatable species coming to dominate the paddock. However, when the same species are grown in their own paddock, animal performance may indicate similar forage quality (Table 3).

Table 1. Plant species differ in tolerance to long growth periods and shading.

Tolerant (hay type)	Intolerant (pasture type)
smooth bromegrass	tall fescue
timothy	orchardgrass
reed canarygrass	perennial ryegrass
quackgrass	kentucky bluegrass
red clover (+/-)	white clover
alfalfa	
birdsfoot trefoil	
native WS grasses	

Table 2. Plant growth habit is related to the plant's tolerance to harvest frequency. At frequent harvest intervals Ladino clover was most productive and yield of the 3-way mix reflected Ladino clover yield. At a lax harvest interval alfalfa was the most productive and yield of the 3-way mix reflected alfalfa yield (adapted from Peterson and Hagan).

Weeks rest	2	3	4	5
Avg. no. cuts/yr.	16	11	8.5	7
Species	Avg. lbs. forage/harvest			
Ladino clover	699	1209	1725	2286
Broadleaf trefoil	455	831	1231	1977
Alfalfa	465	884	1715	2943
3-way mix	661	1138	1772	2809

Table 3. Forage palatability in small plots does not always predict animal performance when grazing uniform pastures to an appropriate height. Kentucky bluegrass-white clover had low palatability but provided high daily gain per head and per acre. (Blaser et al. Res. Bul. 45)

Forage mixture/management	Percentage of growth consumed	Relative palatability	Steer days per acre	Daily Gain per head	Gain per acre
Orchardgrass-ladino clover	60	100	257	1.28	329
Orchardgrass-200 lbs. N/a	45	75	311	1.07	333
Ky-31 tall fescue-ladino clover	45	75	303	1.02	309
Ky-31 tall fescue-200 lbs. N/a	25	42	403	0.91	367
Kentucky bluegrass-white clover	40	67	258	1.21	312

Competition between plants

Plants compete with each other for space, sunlight, water and nutrients. When allowed, tall growing plants will overtop short plants allowing them access to more sunlight. Deep rooting plants will be more competitive for water than shallow rooted plants. However, in a dry year with light showers that only wet the upper soil plants with dense fibrous shallow roots will capture the water before it penetrates deep enough for the deep rooted plants.

Grasses are more competitive than legumes when nitrogen is available and when potassium is low. When legumes fix nitrogen for a few years, the nitrogen status of the soil will increase which stimulates the growth of grasses. This vigorous growth can crowd out the legumes for a while until the excess nitrogen is used up allowing the legumes to come back into the stand. Due to the nature of their roots grass roots take up potassium more readily than legume roots. Therefor when managing for legumes as the nitrogen source in pastures, maintaining the soil test potassium in the high range is essential to keep potassium from limiting legume health and vigor.

The grazing animals

Grazing animals are primary consumers. Their nutritional requirement is determined by age, production state and production rate. A dry cow has the lowest beef cattle nutrient requirement (Table 5). Her requirement increases toward calving; maxing out at peak milk production prior to breeding. It is important to meet the cow’s nutrient requirement in order to have a live calf every year. Once a calf is on the ground, how fast it grows depends on the quality of the diet consumed (Table 5). For a 500 lbs. steer increasing the TDN in the diet from 54% to 68% (26% increase) increases ADG from 0.5 to 2.0 lbs. per day (300% increase).

Forage Mass and Dry Matter Intake

Timing and intensity of grazing determines animal as well as plant performance. Forage age impacts forage quality and forage mass which affects selective grazing and intake. Cattle and sheep are able to eat the most forage when pasture young, thick and tall. When forage mass drops below about 1200 lbs. DM/acre there is not adequate forage for the animal to eat as much as the rumen can hold every day (Figure 10). In a mixed grass-clover pasture 1200 lbs. DM/acre is a 3- to 4-inch ruler height.

Selective grazing

Livestock have the ability to selectively graze. Selective grazing is where animals select and consume forage of a higher quality than the average forage quality in the pasture. The degree of selectivity is determined by how tight the pasture is grazed (Table 6). The quality of the diet consumed is determined by the average pre-grazing forage quality and the degree of utilization.

Foraging preferences by animals is partly a species behavior and partly learned behavior. Grazing animals differ in their ability to be selective graze based on mussel width (deer vs. cow). Animals also differ in their ability to consume course high fiber forage based on rumen size and flow rate. For example, deer have a relatively small rumen with high flow rate and need to be selective foragers of rapidly digestible plant parts. A beef cow has a relatively large rumen and does well with high fiber forage that reside in the rumen for some time to be digested.

Table 5. Nutrient requirements of beef cattle, NRC 1984.

Body Weight lbs.	Avg. Daily Gain lbs.	Dry Matter Intake lbs.	Crude Protein %	TDN %
Dry pregnant mature cows, middle third of pregnancy.				
1200	0.0	20.8	0.07	49
Dry pregnant mature cows, last third of pregnancy.				
1200	0.9	22.3	0.08	53
Cows nursing calves, 10 lbs. milk/day, first 3-4 months postpartum.				
1200	0.0	23.0	0.09	56
Cows nursing calves, 20 lbs. milk/day, first 3-4 months postpartum.				
1200	0.0	23.8	0.11	64
Growing Steers				
500	0.5	11.5	0.09	0.54
	1.0	12.3	0.09	0.59
	1.5	12.8	0.10	0.63
	2.0	13.1	0.11	0.68
	2.5	13.0	0.13	0.74

Figure 10. Forage mass or dry matter (DM) yield of a pasture affects the relative DM intake of livestock on the pasture (relative intake of 1 is 100% of potential intake). When forage mass drops below about 1200 lbs. DM/acre intake decreases due to lack of forage availability.

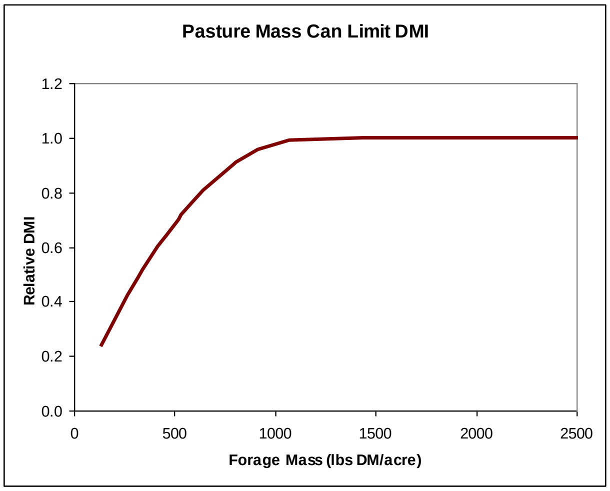


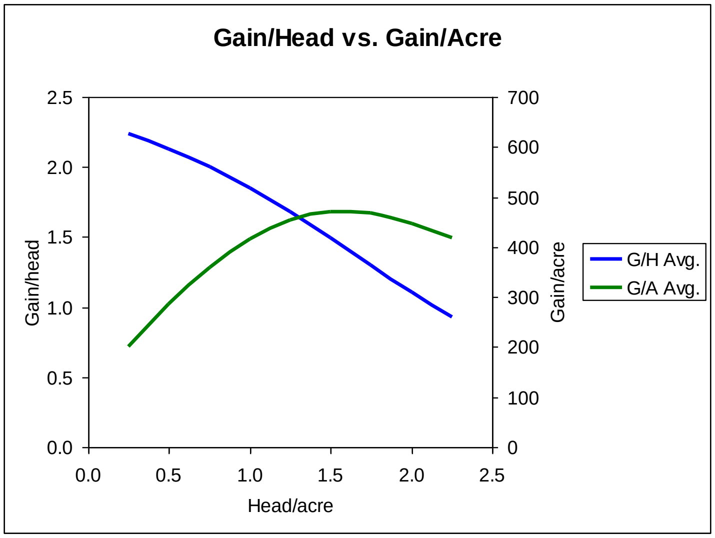
Table 6. Selective grazing allows cattle to eat a higher quality diet than the average forage quality in the pasture if they are not required to graze the pasture too close. As pasture utilization increases selective grazing decreases.

Whole Pasture TDN Percent	Pasture Utilization Percent			
	20	40	60	80
	Apparent Diet Quality TDN Percent			
60	68	65	63	60
65	73	71	68	66
70	79	77	74	72

Competition for forage or Gain/head vs. Gain/acre

Another pasture management principle is competition for forage within a herd of grazing animals. When choosing a stocking rate (SR, lbs. of livestock for a period of time) for a pasture there is a tradeoff between gain per head (GPH) and gain per acre (GPA). As stocking rate is increased, GPH will decrease but GPA will increase up to a point where GPA plateaus then decreases (Figure 11). As stocking rate increases the available forage has to be shared between more animals so each one has less to eat and gains less weight. However, at a low SR the gain on the next animal added to the pasture is greater than the reduced GPH from the other animals already in the pasture so that the total GPA increases. At a high SR the gain on the next animal is too low to make up for the loss of gain of the other animals on the pasture so the GPA decreases.

Figure 11. As stocking rate increases gain per head decreases while gain per acre initially increases, then plateaus, and ultimately decreases. The optimal stocking rate is generally to the left hand side of the plateau depending on economics and risk aversion.



The soil ecosystem

The soil is often the most over looked part of the pasture. The soil is the most important determinant of which plant species will grow best (Table 7). This can be overridden by poor grazing management that prevents the preferred species from growing at their natural potential.

Soils differ due to parent material, landscape position, and mineral content. They differ in potential rooting depth, texture, water holding capacity, surface and internal drainage. Due to previous management soils can differ in pH, fertility, and organic matter. Soil organic matter is the source of food for the large assortment of organisms that maintain soil structure, water infiltration, and water holding capacity.

Table 7. Expected yield for grass-clover and grass-alfalfa hay (tons/acre/year) and grass-clover pasture (animal unit days, AUD/acre/year) under good management, for three soils found on the Alleghany Plateau. The major soil determinants of forage yield potential are available water holding capacity in the potential rooting depth, slope, and drainage.

Soil	Slope %		Grass legume hay		Pasture
			clover	alfalfa	
			tons/a		AUD/a
Berks shaly silt loam	3	8	3.0	3.5	200
Berks shaly silt loam	15	25	2.0	3.0	170
Dekalb channery loam	5	12	2.8	3.2	120
Dekalb channery loam	12	25	2.6	3.0	105
Frankstown silt loam	3	10	3.5	4.5	165
Frankstown silt loam	10	20	3.2	4.3	160

Most of our day-to-day efforts are spent with the livestock, managing the above ground portion of the pasture ecosystem to ensure that the livestock are properly fed. However, there is more biomass and biological activity below ground than above (Table 8). It is this subterranean community that maintains soil structure and water infiltration when it rains, cycles nutrients from organic and mineral sources for use by the plants and ultimately the animals and us. These organisms enable us to achieve our production goals. Our above ground management enable the soil community to be healthy and vigorous.

Citizens of the soil community

Here is a short introduction to the citizens of the pasture soil community (Figure 12).

Plant roots are an essential portion of the above ground producers. Roots gather water and nutrients for the plant and provide a major source of live and dead organic matter for food to soil organisms. Legumes within this group, with their symbiotic rhizobia bacteria, fix nitrogen from the air and provide it to the rest of the pasture community. Algae and moss are other primary producers that provide organic matter to the community. Some algae fix nitrogen from the atmosphere for making protein similar to the bacteria in legumes.

Earthworms eat dead plant material (detritus). They are opportunistic predators when they consumer soil containing bacteria, protozoa, nematodes, and fungus. They provide the ecological service of shredding large pieces of organic matter making it more accessible to bacteria and fungus. They aerate and invert the soil, improving soil drainage, water infiltration and aggregation of soil particles. They are food for birds, moles, skunks, and carnivorous slugs and nematodes.

Slugs and snails are consumers of live plant material with some carnivorous species being predators of earthworms and other slugs. They provide the service of shredding large pieces of organic matter into smaller pieces. They are food for birds, mice, daddy longlegs, beetles, and firefly larvae (glowworms).

Nematodes are consumers of plant roots and algae; predators of bacteria, protozoa, fungus, and other nematodes, and parasites of insect larva, slugs, and earthworms. They provide an important function in the nitrogen cycle by eating bacteria and releasing nitrogen back into the soil for plants and other organisms. They are food for other nematodes, fungus, and mites.

Woodlice feed on dead plant material. They are shredders of coarse organic matter. They are food for birds and spiders.

Spiders are predators. **Mites** are consumers of algae and predators of nematodes, springtails, fungi, insect larva and eggs, and nematodes. Some species are detritus feeders while others are insect parasites.

Centipedes are predators of insects, slugs, and worms. **Millipedes** predominately eat detritus and fungus but sometimes are consumers of live plants and their seeds.

Table 8. The biomass of organisms above ground on the pasture is much less than that which is below ground within the pasture soil.

Organisms	Standing crop biomass lbs./acre
Above ground	
1200 beef cow[1]	450
Pasture dry matter[2]	2500
Below ground	
Pasture plant roots[3]	2500
Bacteria	2052
Actinomycetes	2052
Fungi	6244
Algae	219
Protozoa	80
Nemetodes	62
Mites	65
Collembola	65
Earthworms	624
Other fauna	40
Adapted in part from Brady and Weil 2002	
1. Cow weaning 600 lbs. calf needing 3 acres/year for pasture, hay and aftermath grazing	
2. Cool-season grass-clover pasture, 10 inches tall at grazing.	
3. Roots equal to top growth at grazing	

Spring tails consume dead organic matter and fungus. Some consume plant seedlings, small nematodes, and dung of other soil animals. They are food for ants.

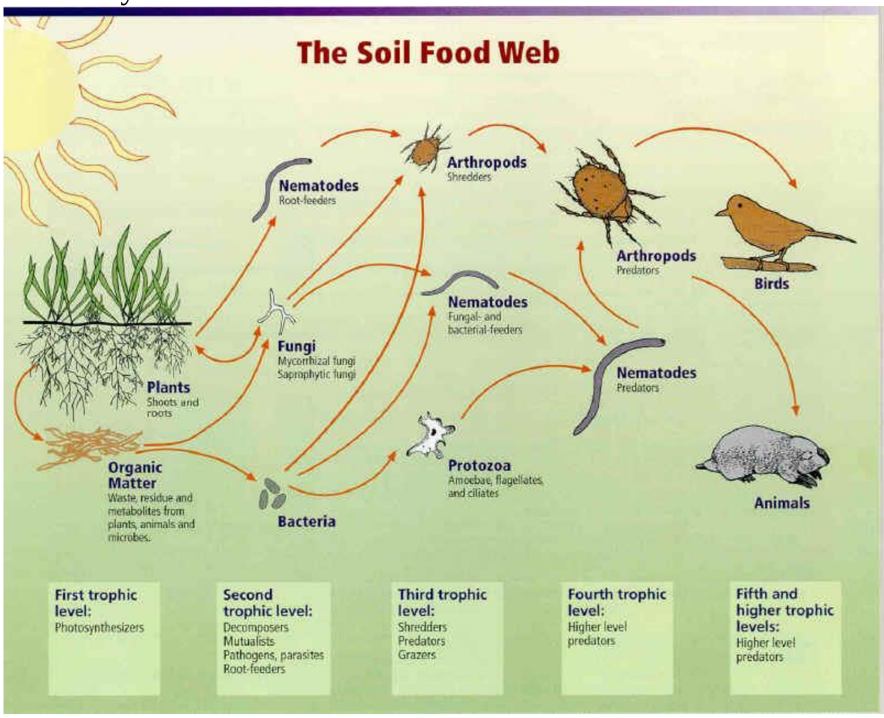
Beetles, such as clover root curculio, eat live plants. Some beetles are predators eating other insects, earthworms, and snails. Carrion and dung beetles feed on detritus. These beetles provide the ecological service of soil aeration, soil inversion and nutrient cycling.

Ants are consumers of live plants and “farm” aphids for their honey dew. They also consume fungus and are predators of other soil organisms. They provide the ecological service of soil inversion, improved soil aeration and water infiltration.

Termites consume dead plant material and are shredders of coarse organic matter. They digest cellulose using gut bacteria similar to a cow and provide soil aeration and soil inversion.

Bacteria are central participants in the nitrogen cycle. As symbiotic partners in root nodules they use sugar provided by the plant as energy to fix nitrogen from the air into ammonia which the plant uses for making protein. Other bacteria are detritus feeders and break proteins down into ammonia while other bacterial convert ammonia to nitrate. Bacteria are food for protozoa and nematodes.

Figure 12. The soil food web depends on solar energy fixed by plants. This energy is provided to the soil community through root death and when leaves and stem are treaded onto the soil surface by livestock.



There are many interconnections within the pasture community both above and below ground. We all are familiar with legumes and their bacteria that fix nitrogen for the pasture ecosystem. We are less familiar with the fungus that help plant take up soil nutrients and even help transfer nitrogen from legumes to grasses (Figure 13).

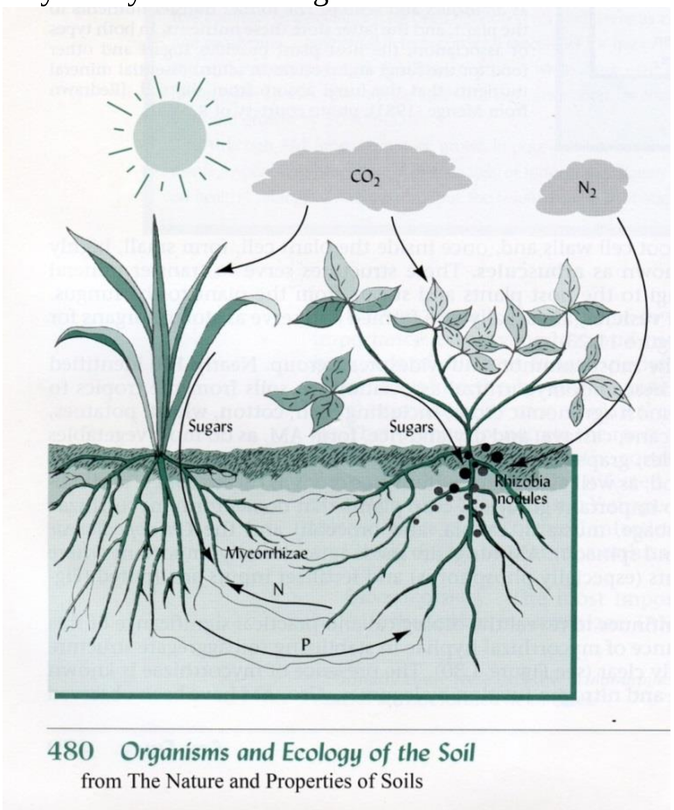
Humans in the pasture ecosystem

Too often we think of the ecosystem as being something apart from us as humans. In reality we are the managers of the ecosystem, either by design or error. For over 10,000 years our ancestors used fire to develop savannas and prairie from forests. These grasslands were used by bison, elk, deer and then cattle and sheep which provided food for the family. Now we use fences, fertilizer, lime, sometimes fire, stocking rate, stock density and the timing and intensity of grazing to achieve our management goals.

We are the predators (hopefully the only predators) in our pasture ecosystem. We are the managers and through intentional or unintentional control of the animals, fertility, and renovation practices determine the ecological balance in the pasture ecosystem above and below ground.

The pasture manager needs to develop a pasture system that provides for the plants that feed the above and below ground livestock. By optimizing the health of the soil community, we optimize the health of above ground plant community, which feeds our livestock, which feeds the soil with manure, urine and treaded plant parts, and feeds us with meat and milk. So around and around we go in a cycle.

Figure 13. Transfer of nitrogen (N) and phosphorus (P) between legumes, grasses, and soil by way of Mycorrhizae fungus.



A sustainable pasture system needs to be based on a local vision of what is needed by the people, plants and animals dependent on the system; the goals to achieve that vision, plans for achieving the goals, all in tune with the natural and economic environment present in the area.

<u>Summary</u>

Understanding pasture ecology enables us to develop management systems that achieve our goals. Plants grow and store carbohydrates based on the balance of photosynthesis and respiration which is affected by temperature, day length, solar intensity, leaf area and soil moisture. We manage growth and yield by controlling the timing and intensity of livestock defoliating the canopy. The optimal timing of growth and intensity of grazing is depends on the plant community desired and livestock class doing the grazing. Plant species differ in their tolerance to grazing based on their growth habit above and below ground.

Pasture ecology is composed of the interaction of the plants and animals above and in the soil in concert with the climate and season. This is a complex interaction but all the players follow the same biological responses for life. How the plants and animals differ in their needs determines which organisms will be dominant or perform well under a given management system.

The two components of grazing management, timing and intensity of grazing, are **<u>2 independent factors</u>**. Timing of grazing (length of rest interval) needs to be timed with the plant's growth cycle and time of year as it affect the plant's carbohydrate cycle, tiller production, and seed production. The intensity of grazing (plant height at end of grazing) needs to be in balance with the residual leaf area required by the species being managed and the nutritional needs of the livestock being produced. Most often we use the timing and intensity of grazing to optimize plant and animal production. We can also use timing or intensity of grazing to change the species composition of a pasture.

As pasture managers we need to learn more about the above and below ground pasture ecology. The term *ecology* come is derived from the Greek language and means *the study of the house*. As pasture managers it is our house. In a larger sense it is Mother Nature's House. Most of us want to work with nature since we live out in nature every day. We should also want to be on her team since "Mother Nature Always Bats Last"!

<u>Take home lessons</u>

Optimal pasture health and productivity is achieved by providing all needed resources to the organisms above and below ground in the pasture community at an optimal level. Remember Goldie Locks and the Thee Bears.

Optimal pasture yield is achieved by resting plants until they reach a height corresponding to high energy reserves; then grazing the plants to a height which removes much of the forage but leaves adequate leaf area for photosynthesis and energy reserves for rapid growth. The optimal per- and post-harvest forage height depends on the forage species or mixture used and the livestock type being grazed on the pasture.

Examples:

Mixed orchardgrass-clover, cool environment, grow to a 10-inch height then graze to a 2- to 3-inch residual height. This provides high utilization of the standing forage and sets back the orchardgrass just a little, allowing the white clover to be more competitive. If the clover becomes too competitive, leave a 4-inch stubble to favor the orchardgrass. This enables the orchardgrass to have more vigorous growth, shading the clover, and reducing the clover in the stand.

High forage quality is VALUE: <u>v</u>egetative, <u>a</u>vailable, <u>l</u>egumes present, <u>u</u>tilized to correct level, in tune with the <u>e</u>nvironment. Young forage has high cell contents and low but highly digestible NDF. We can increase cell contents (sugar, starch, protein) and reduce NDF (cell walls) by increasing legumes in the stand or by grazing younger forage. Remember ruminants need fiber so to lush a pasture in spring or fall can be suboptimal for animal performance. If this occurs provide animals some long hay.

In the Virginia-West Virginia area: during the summer limit regrowth age to six weeks to maintain VALUE. But don't overgraze during hot summer weather. When stockpiling tall fescue in the fall, growth age can be extended since the cool weather encourages an increase in sugars in leafs and NDF remains digestible due to relatively low lignin production in a cool environment.

When seeding clovers set pasture growth back by grazing the pasture when it has low carbohydrate reserves. First graze the pasture to a low residual height (2-inch stubble) to clear off thatch. Allow the pasture to grow back to half the recommended height; a 5-inch height when we would normally allow it to come back to 10-inches. At this point the energy reserves will be near their lowest point (Figure 3). Graze the pasture again to a 2-inch stubble. This removes the leaf area and there is little reserve energy in the plants. This results in a growth rate about half of what occurs if the stand had high energy reserves. Clover no-tilled seeded into this stand will have less competition and a better chance to establish. Of course this needs to be done when the weather is appropriate for clover germination and establishment.

To open up a tall fescue stand to encourage other forage species to dilute out fescue toxins. Allow the fescue to grow for 60 days or longer. This accumulates a lot of forage which causes self-shading within the stand. The shade causes a thinning of fescue tillers leaving bare ground around the plants. Graze the area using dry cows or yearlings (do not expect high daily gain) at a high stock density to consume the forage and tread residue into the ground. This leaves open spaces for legume, warm-season grass and forb seedlings to establish. Overseed desired species prior to grazing or allow natural establishment from the soil seed bank. The coarse vegetation treaded into the ground will help develop soil organic matter to feed the soil ecosystem. This works best when there is adequate nitrogen in the soil from organic matter, fertilizer or manure.