Cornell University
College of Agriculture and Life Sciences

Pasture and Grazing Management for New York

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Animal Science Mimeograph Series 204 March 1999

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Background

Some of the research information presented in this guide is based on a 12 year collaborative pasture research project conducted by the Cornell University Departments of Animal Science and Agronomy in cooperation with the U.S. Department of Agriculture-Natural Resource Conservation Service (NRCS) and on continuing studies conducted by both Cornell University and the Natural Resource Conservation Service.

For details of the 12 year Cornell pasture research, the reader is referred to the bulletin below available from D.G. Fox, 130 Morrison Hall, Cornell University, Ithaca, NY:

Fox, D.G., R.R. Seaney and D.L. Emmick. 1992. Increasing the productivity of forages and cattle on New York hillside land in New York State. Search:Agriculture. Ithaca, NY. Cornell Univ. Agr. Exp. Sta. No. 35.

Acknowledgment

Thanks to the farmers and extension workers, both in Cooperative Extension and NRCS, who recommended material for this publication based upon their experiences working with grazing systems. A special thank you to Darrell Emmick, NRCS grasslands specialist who shared his knowledge and experiences in helping farmers set up grazing systems across New York, Rob DeClue, NRCS, who shared the knowledge he gained working with fencing watering, and laneways in grazing systems by writing these sections and Kirsten Caminiti who provided the wonderful drawings. We wish to thank Larry Chase and Gary Fick for reviewing this manuscript.

Purpose for this Bulletin

This bulletin was prepared as a revision of the previous bulletin with the same title, in fullfillment of the MPS degree for the first author. We hope this guide will be useful to the many dairy and livestock farms in New York State where a more intensive use of pasture can (with proper planning and management) provide opportunities to significantly improve farm profitability and concurrently reduce environmental degradation.

Grazing systems take time to develop. They evolve as the farmer and land interact. Experienced graziers say that it took them several years to understand how their land responded to grazing and how to best manage the forage and livestock. Experimentation is an important element in this process. Grazing systems will improve as farmers test ideas and retest them. The purpose of experimenting with new ideas is to gain greater understanding of a farm's unique advantages and challenges and to adjust and improve the system (Bunch, 1991).

Observation and reflection are key elements for improving a grazing system. Good observation skills help farmers to see **what** is occurring in all areas of the farm and reflection helps farmers understand why. Allen Nation of the *Stockman Grass Farmer* says that the most valuable time a grazier can spend is in contemplation--thinking about what we are doing and why. These skills help a farmer not only correct his/her mistakes but to also repeat the success again (Nation, 1997).

Why Consider Grazing?

Historical Reasons

Although recently interest in using New York's pasture resources has increased, for many years, agriculturists acknowledged the value of pastures. This is exemplified by Dr. G. F. Warren's statement:

> "The greatest agricultural resource of New York is its exceptional adaptation for the growth of grass. Yet the hay crop has received little attention and pastures have rarely received any care ... It would certainly seem good policy to consider means of increasing the efficiency of our pastures." (Cornell University Agr. Exp. Station Bulletin 280, 1910).

New York State was historically located in the center of the hay and pasture region of the United States because its climate and topography were conducive to growing forage grasses and legumes. As interest in improving pastures increased, pasture research conducted in New York was published in a bulletin entitled, "Pasture Improvement and Management," Cornell Extension Bulletin 383, October 1938, by D.B. Johnstone-Wallace. This bulletin along with other D.B. Johnstone-Wallace's writings were foundational for André Voisin's studies on pasture in the 1950s which influenced the pasture movement of today (Voisin, 1961)

Ecological Reasons

From an agroecological perspective, cool-season grasses and legumes are well adapted to the region's climate, soil, and topography, making pastures and grazing viable options in New York. In some cases this adaptation gives the forages an advantage over other crops (such as corn) that require intensive annual tillage, long growing seasons, or more productive soil types. The conditions in New York where this might be the case would include steep, highly erodible hillsides, poor soil types, areas with a short, cool growing season, and locations with very moist soils. Of course pastures are not limited to these areas, but may be better suited to these conditions than other crops.

Economic and Social Reasons

Grasses and legumes are well-adapted to New York and can be produced relatively inexpensively, giving some farmers an economic advantage by using them. The increased expense in machinery, labor, and energy makes it costly to produce crops unsuited to some of the soils or climates in New York, especially when their production is not optimum. Since pasture is a low cost, high-quality feed, requiring little machinery and few buildings, it significantly contributes to reduced production costs and an increased profit-margin (Baker and Raun, 1989, Bauston, 1996).

People use grazing for many different reasons in addition to economic ones. Some common reasons are that people want to spend more time managing their livestock instead of growing row crops, children are more involved in the farming activities because there is less potentially dangerous equipment used (Welsh, 1996), and grazing requires less capital to start up, enabling new people to start farming with a minimal amount of investment (Lanyon, 1992).

Environmental Reasons

Pastures minimize environmental impact by reducing soil erosion and improving nutrient recycling (nutrients in the plants are released back into the soil through manure, speeding up the natural decay process). Attempts in the past to improve pasture productivity were through agronomic means such as fertilizers, lime, herbicides, and reseeding pastures. Improvement in many cases, can be accomplished by manipulating and controlling the pasture-livestock interaction, reducing the need for machinery, fossil fuels, and potentially harmful chemicals. Pastures often improve wildlife habitat too (Unruh and Fick, 1997).

Interactions within Pastures (Ecology of Pastures)

All crops, including pastures, require some level of management to produce a harvest. In a monocrop system, such as corn, each component is controlled and the treatment is prescribed, for example, how much fertilizer to add or what row spacing to use. Pastures, containing several species, are more complex to manage. They require an understanding of the parts and the interactions between the parts, such as soil fertility, variety selection, and pest control.

One way to do this, is to consider a farm as an ecosystem. Each paddock or field has its own mixture of plants, soils, climate, and history, such as past crops grown or fertilizers applied. In order to understand the ecosystem, two things are needed: a simple biological background of each part and an understanding of how the parts interact together and affect each other (Harris, 1990).

By understanding the biology and interactions within the pasture system, better decisions can be made regarding pasture fertility, improving forage quality, changing the plant species composition within the pasture, and the optimum time to move livestock depending upon the weather, time of year, and growth of plants.

Seasonality

Pastures generally grow faster in spring and fall than they do in mid-summer, which results in a seasonal pattern of forage accumulation as shown in Figure 1. Plant growth generally is twice as fast in May-June as in August-September (Murphy, 1991). Consequently, greatest forage yields occur in the spring and fall, and forage yields are lowest in mid-summer, resulting from the slower growth rates. Forage growth rates at any given point in time are directly related to subsequent forage yield and dry matter availability. In other words, the faster the plant grows, the more forage will be produced in a given amount of time. In addition, even though pastures exhibit large variations in their growth rates from year to year, the general seasonal pattern of production is fairly predictable (Emmick and Fox, 1993).

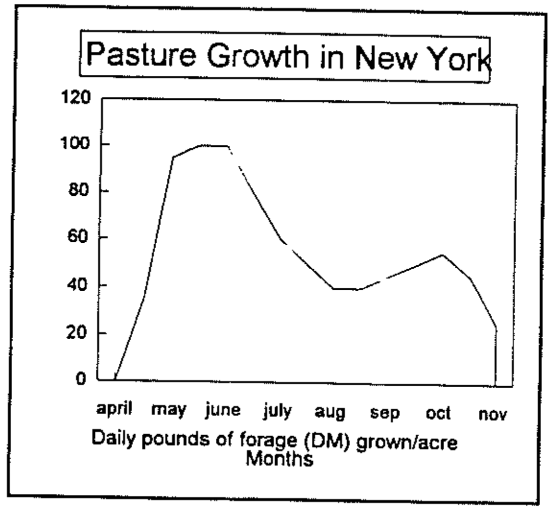

Figure 1. Pasture growth rate in New York.

Actual growth rates measured during 1987 and 1988 on predominantly orchardgrass pasture at the Cornell University Hillside Pasture Research and Demonstration Project averaged over both years of the study. The pastures were managed with a 12-paddock rotational grazing systems, soil fertility was maintained to soil test, and 50% of the paddocks in each treatment received 50 lb/acre of nitrogen. Of the paddocks receiving nitrogen, 50% were fertilized during the 2nd week of April and the remaining 50% were fertilized during the 1st week of August.

Early Spring (April)

As the day lengths increase and the sun's rays warm the soil, pasture plants are one of the first crops to grow. Most pastures in the northeast consist of cool-season grasses such as orchardgrass, bluegrass, and quackgrass mixed with a legume, like white clover. The cool temperatures stimulate cool season plants to grow quickly, causing them to reproduce through seed head production, if not grazed or harvested, by May or early June.

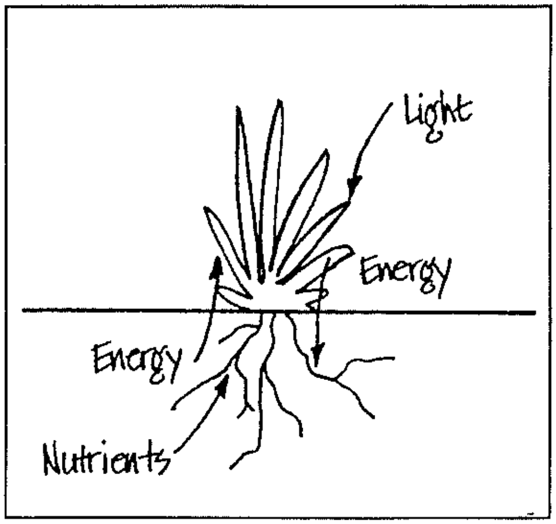

Figure 2. Plant growth.
Through photosynthesis, plants convert light into energy in the form of carbohydrates and sugars. Nutrients are absorbed from the soil via the roots. For good forage growth, a balance must be maintained between the leaf area for photosynthesis and the energy stored in the roots and leaf bases.

To better understand the interactions within a plant, pasture plants can be divided into two main parts: an above-ground portion consisting of leaves and stems, and a below-ground portion comprised of roots and root hairs. The roots and root hairs extract moisture and nutrients from the soil, while the green leaves and stems collect light energy from the sun and convert it into food energy, in the form of carbohydrates, for growth (Figure 2). Energy not used for growth is stored in the roots, stolons, rhizomes, or leaf bases of the plants where it is available to 1) initiate growth in the spring, 2) initiate growth after a defoliation, or 3) provide nourishment for survival over the winter or periods of environmental stress like drought. How and when plants grow is determined by temperature, light, nutrients, and water (Emmick and Fox, 1993).

Cool-season pasture plants begin to grow early in the spring from growing points (buds) located at or near ground level. The energy used for the new plant growth comes from carbohydrates (energy) stored in the roots over the winter. In addition, new plants germinate from seeds, such as durable legume seeds, that survived the winter or were frost-seeded in late winter.

Once the grass buds break dormancy, they begin to produce new side-shoots or tillers. A tiller originates from a bud in the plant's crown (near the soil surface) and produces leaves and new roots. With more leaves and roots, a grass plant makes more carbohydrates through capturing more sunlight and absorbing more water and nutrients (Pinkerton, 1996). Tillering is initiated by light reaching the lower buds (Figure 3). Early in the spring there is more light reaching the lower buds because the plants are short and little shading occurs (Harris, 1978).

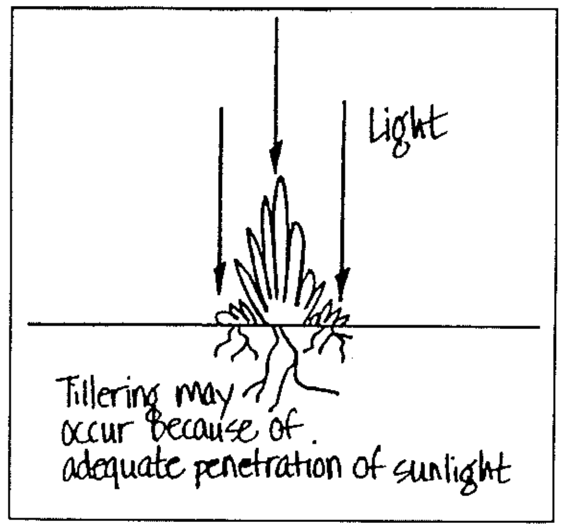

Figure 3. Light initiates tillering.
Light reaching lower buds of grasses initiates tillering. A tiller is a replica of the parent shoot.

Legumes produce new shoots from buds near the base of the plant, as with alfalfa, or through creeping stems called stolons that grow along the ground and produce leaves and roots. An example of a legume with this kind of growth habit is white clover (Langer, 1990).

Spring (May - June)

As spring progresses, each of the individual plants compete with one another for light, nutrients, space, and water. In any ecosystem, there are factors that keep any particular plant or animal from unlimited growth. For example, grasses normally outcompete every other pasture plant, but their growth may be limited by a lack of nitrogen. Once the limiting factor is removed (nitrogen is applied), something else will become the limiting factor (for example water). Pasture productivity can be optimized as more limiting factors are minimized (Harris, 1990).

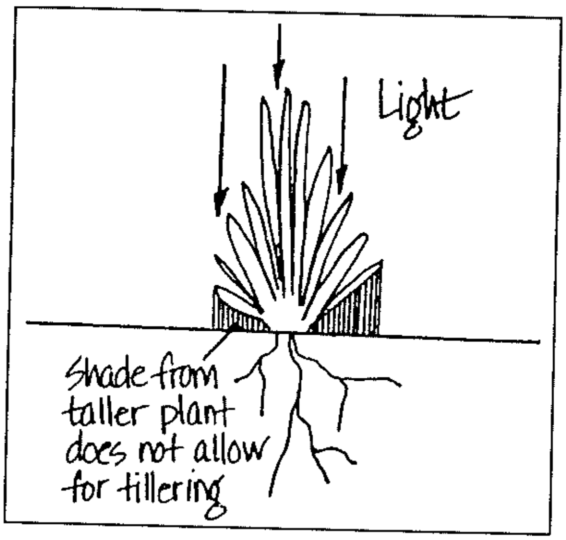

Figure 4. Competition for light.
As plant grows taller, upper leaves shade leaves, buds, and plants below. This may inhibit tillering or reduce the growth of low growing plants like white clover.

Light decreases as it goes through the plant canopy so the tallest plants and leaves absorb the most sunlight, make the most carbohydrates, and grow the most (Figure 4). Plants closer to the ground get less light and thus do not grow as well. These plants may eventually be completely shaded and die. Within the pasture, grasses grow more upright and, if allowed to grow unchecked, will shade clover and their own lower leaves. The shading may reduce or kill the clover.

Shaded lower grass leaves will stop producing carbohydrates for the plant and will turn brown and die (Murphy, 1991).

Plants also compete for nutrients found in the soil. Nitrogen (used in proteins, genetic material, and chlorophyll) is often the main limiting nutrient for grasses. Legumes fix their own nitrogen in areas low in nitrogen, enabling them to outcompete grasses. In areas of high nitrogen, however, grasses are able to outcompete legumes.

Phosphorous is also important, especially for legumes, and is most available to plants when the soil has a near-neutral pH. Phosphorous plays an important role in energy transfer within a plant.

Potassium is involved in enzyme reactions within a plant and plant hardening for winter. If there is too much potassium in the soil, grasses will readily absorb the excess potassium. This can be a problem for animal health since the potassium can interfere with magnesium uptake increasing the risk of grass tetany (Joost, 1996).

Not only do plants compete with each other, but they also must adapt to being grazed. For many thousands of years in nature, grazing animals and pasture plants survived in the presence of each other. Grazing animals, through defoliation, trampling, and fouling with manure and urine, directly influenced the growth and survival of the plants. Both developed specific adaptations and strategies, and counter-adaptations and counter-strategies that helped them to coexist (Emmick and Fox, 1993).

When an animal takes a bite of grass, especially when the plant is grazed close to the ground, there are immediate changes to the plant. The plant now has fewer leaves to produce energy for plant growth. It also slows down root growth. Carbohydrates previously stored in the roots (in legumes), leaf bases, and stolons (in grasses) are used by the plant to grow new leaves, depleting the energy reserves.

A plant relies on stored energy from two to seven days until enough leaves grow to begin photosynthesizing and producing energy. This depends upon how many leaves remain after grazing, if more remain the plant recovers faster, and the type of plant. Grasses use stored energy for a day or two whereas alfalfa may use it up to a week. Energy reserves slowly build up in the roots and leaf bases again over the next several weeks (Murphy, 1991).

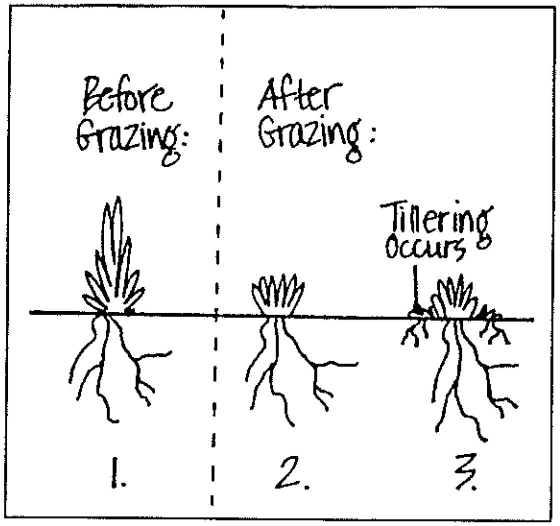

Figure 5. Plant response to grazing. Grazing shortens plants and allows more light to penetrate the canopy. Plants respond by tillering and by transferring stored energy from the roots and leaf bases to the leaves for more leaf growth.

Grazing also affects the microclimate around a plant. More light reaches the ground, warming up soil temperatures and possibly reducing soil moisture. Light reaching the lower leaves and buds of grasses stimulates tillering (Figure 5). In legumes, more light causes growth and branching (Watkin and Clements, 1978). By tillering and branching, the grasses and legumes move horizontally, filling in bare spaces around them. This helps to make a denser stand, or sod, of plants (Murphy, 1991).

Animals eagerly eat the young lush pasture plants, seeking out the most nutritious parts to satisfy their nutrient requirements. They prefer young plant parts over old and leaves instead of stems. As plants get older, they contain more structural lignin, which protects and provides support for the plant but cannot be digested by animals. Stems contain more lignin than leaves. Animals also eat what is easiest to reach, and if plants are tall, they may only eat the tops (Murphy, 1991).

As animals move around the pasture, they have an effect on plants simply by walking on them. Animal hooves damage and bury buds, tillers, and stolons, slowing down the plant's growth (Watkin and Clements, 1978). A traditional proverb says, "A cow eats with five mouths--one in front and its four feet" (Voisin, 1962).

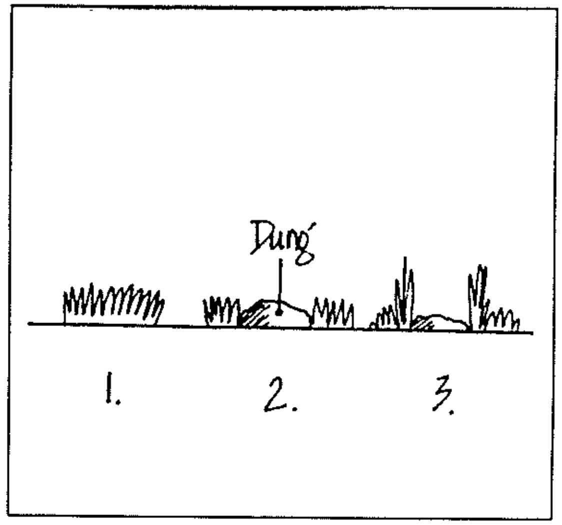

Figure 6. Plant response to animals. Animals affect plants by trampling, eating, and leaving manure. The manure may kill the plants below it, but the nutrients in the manure stimulate plant growth.

Animal manure and urine alter plants through nutrients and coverage (Figure 6). Although manure patties may cover and kill the plants below them, they are important fertilizers. Manure contains phosphorous as well as calcium and magnesium, stimulating more legume growth. Urine predominantly contains nitrogen and potassium, which is quickly utilized by plants, mainly grasses.

The nutrients in the manure release slowly and incorporate into the soil as the manure decays through earthworms, insects, and microbial action. In new pastures, manure does not break down until the following year, but in older pastures, increased insect and microbial action breaks down the manure in two months, recycling the nutrients faster (Murphy, 1991).

Animals return a large portion of the nutrients they remove from the pasture through excretion, although a lot of the nitrogen in the urine volitilizes as ammonia (Joost, 1996). Animals increase nutrient turnover within a pasture by speeding up the decomposition process as they digest the forages and release the nutrients in manure and urine, recycling the same nutrients several times throughout the year (Watkin and Clements, 1978).

Summer (late June - mid September)

As summer progresses, the temperatures rise and rainfall may be reduced. Demand for water in evapotranspiration increases. Cool-season grasses slow down their growth, but legumes, such as white clover, continue to grow if provided with sufficient water.

Low rainfall is detrimental because plants use water for internal needs and depend upon soil water to move nutrients to them. Without rain, the first area to dry out is the soil surface, where most of the nutrients are located. Although plants increase their root growth deeper into the soil to obtain water, their leaves still may not grow because they cannot get the nutrients from the dried top soil layer (Ludlow, 1978). Leaves and tillers may die to reduce the plant's water loss (Figure 7). As a result, there are fewer leaves for animals to eat and fewer leaves absorb sunlight and produce energy for the plants. Since little energy is stored, plants are vulnerable to overgrazing if grazed too soon during low rainfall periods (Murphy, 1991). Drought also reduces legume nitrogen-fixation (Turner and Begg, 1978). Too much rain is detrimental because water logged soils have less oxygen, slowing plant growth (Rayburn, 1987).

By this time of year the pastures are uneven in height and composition because they have already been grazed several times. Since tall plants are lower quality (more stems and lignin), animals select the smaller, more nutritious plants, leaving the taller plants. In addition, animals avoid eating near their manure paddies because of the smell. The plants around the paddies are usually tall because the animals avoided them and because of extra nutrients from the manure.

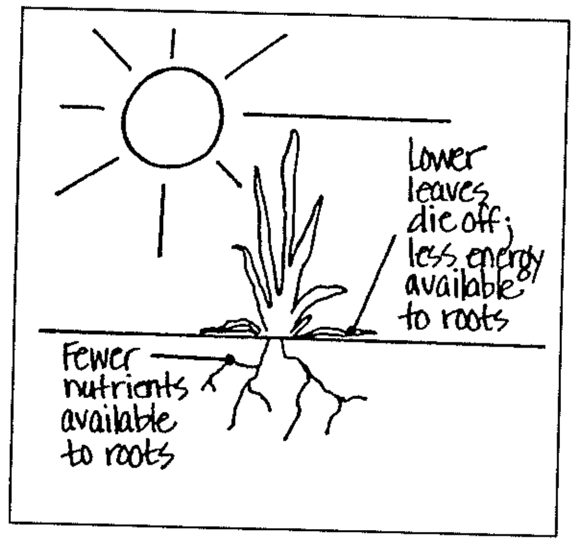

Figure 7. Plant response to drought. Drought reduces the soil moisture, which makes nutrients available to the roots, slowing plant growth. Some leaves may die to conserve moisture. This reduces photosynthesis, and less energy is stored in the leaf bases and roots.

Fall (September - early November)

As the temperatures decrease and rainfall increases, the cool-season grasses (like orchardgrass and perennial ryegrass) begin to grow more vigorously and produce new tillers. Leaves produced from new tillers have a pointed tip. Old leaves from the mother plant will have a flat tip from grazing.

Pasture Management

All crops require planning and management to ensure their establishment and long-term persistence, and also to promote high yield, high quality, and efficient resource utilization. Pasture is no exception (Emmick and Fox, 1993).

In New York State, an unmanaged pasture will undergo ecological succession; in other words, it will slowly become a forest (Figure 8). The moist and cool climate that is good for pasture growth also promotes the growth of trees and shrubs. In fact, many of the forests today were at one time pastures, which were at one time forests cleared for farming. This succession, from pasture to forest, currently takes place all over New York in unmanaged and abandoned pastures with small trees and shrubs growing in them.

Grazing management is the single most important element for efficient pasture use. Forming a management plan for a pasture system can be complex. The system includes management decisions for both maximum forage and livestock production which both occur at the same time and in the same space. A basic understanding of the biology and interrelationships within a pasture (discussed above) will be useful to consider when making decisions on the best management practices.

In order to formulate a grazing plan, the producer must first decide what the overall management goals are for his/her farm. Each farm is a unique combination of human interests, abilities, and management goals as well as resources, attributes, problems, and concerns. As a result, there is not one best method, plan, or system that can be recommended as the best for all pasture situations.

The goals of the farm should be coordinated with the resources of the farm and the needs of the animals. These might include the species of pasture plants; the number, type, and class of livestock; soil types; climate; infrastructure; and topography.

A grazing management plan can then be designed to fit within the goals and resources of the farm. The grazing management plan, taking into account pasture ecology, will help formulate the frequency, intensity, duration, and timing of grazing. It will also decide the method of stocking; the kind, number, and class of animals; and the management objectives for pasture plant communities (Emmick and Fox, 1993).

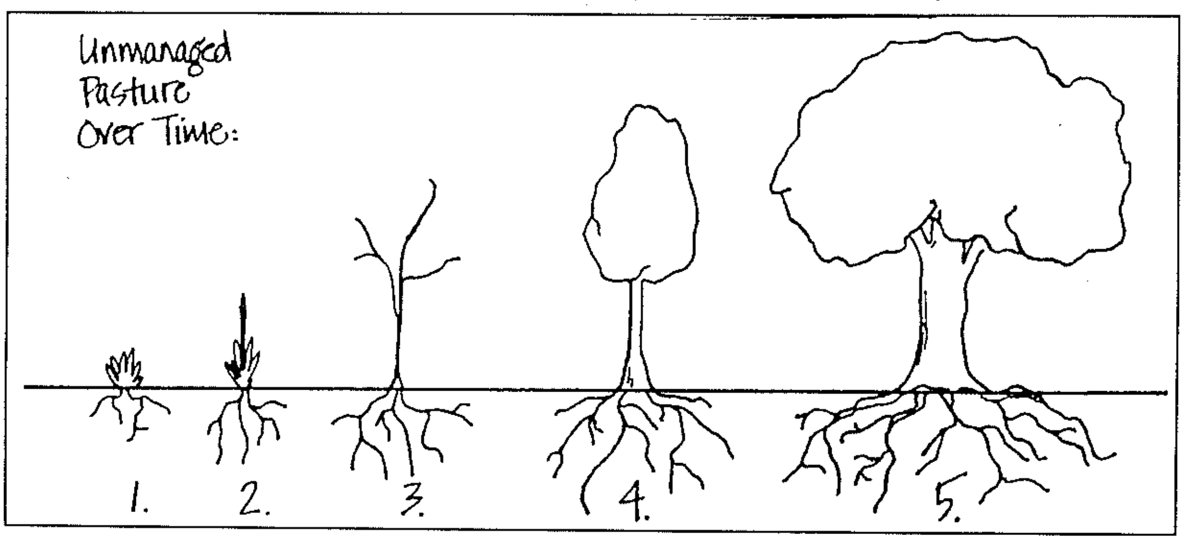

Figure 8. Ecological succession from grassland to forest in an unmanaged pasture.

Components of a Grazing Management Plan:
1) Consider goals of farm
2) List the farm resources
3) Devise grazing plan incorporating 1 and 2.

Impact of Time on Pasture Quality and Yield

Time plays an important role in grazing management because it effects forage quality and yield. There is a trade-off between maximizing the forage yield and having high quality forage.

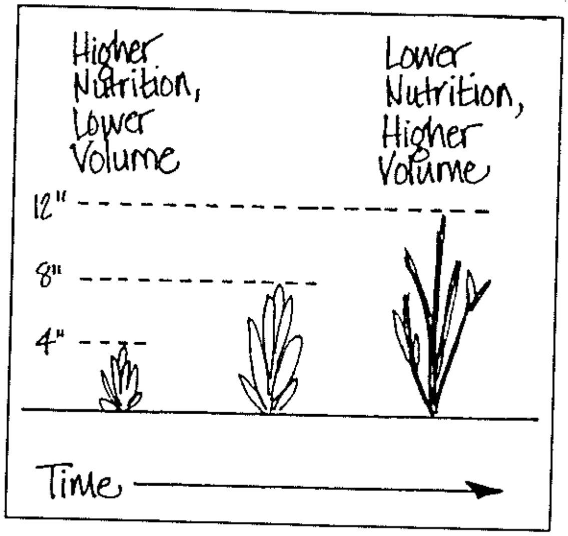

Figure 9. Seasonal pattern of pasture quality vs. yield.
As times progresses, plants grow taller producing more dry matter. Their nutritional quality decreases as they grow taller. Maximum benefit from a pasture is derived at a balance between quality and yield. The optimum height is generally from 6-8 inches.

If a pasture is allowed to grow for too long without being grazed or harvested, it will loose its high nutritional quality Most plants in spring move from the vegetative to the reproductive stage. They progress quickly from high quality green leaves and rapid growth, to low quality stems, slower growth and death of lower leaves. As plants grow older, they add more lignin to their leaves and stems. The lignin provides structure allowing the plant to grow upright. Stems contain the greatest amount of lignin and as a result are the stiffest part of the plant (Van Soest, 1992).

Generally, no new leaves or tillers are produced until after grasses flower or the seed heads are removed (by grazing or mechanical harvest). Once the plants complete their reproductive phases, they resume tillering (Emmick and Fox, 1993).

The longer a pasture grows before its initial grazing or between subsequent grazings, the more forage is available for grazing (Figure 9). The amount of forage available increases as the plant size increases until the uppermost leaves on the plants absorb most of the sunlight. As a result, the lower leaves become shaded and die lowering the yield (Harris, 1978). If pastures are grazed at their highest nutritional level (when they are shorter), then the amount of forage available to the livestock will be decreased per grazing.

Pasture Quality and Animal Nutrition

When grazing, an animal attempts to fulfill its nutrient requirements by selecting the most nutritious food. This will be affected by 1) the animal's production level, a higher production level requires more nutritious food, 2) the quality of the forage, 3) the opportunity to select quality forage, and 4) the type of animal (Coleman, 1992).

Animals that are growing or lactating need the high quality forage found in the early spring when the forage is young, short, and leafy or during other times of the year when forage is kept through grazing or harvesting at a shorter height. Other animals at maintenance levels such as dry cows or horses do not need the highest quality forage. In order to keep the forage at its highest quality, pasture may need to be clipped periodically in order to remove the older plants.

Livestock nutrition is directly related to forage quality. This is in turn directly relates to pasture management. Forage quality includes palatability, nutrient concentration, and digestibility. The forage quality in any given pasture is a function of three separate but related factors the kinds of plants present, their stage of maturity, and the time of year (Emmick and Fox, 1993).

In general, leaves are higher in quality than stems. Legumes contain leaves which are lower in fiber and have more soluble carbohydrates. Grass leaves are usually higher in quality than the stems of either legumes or grasses. Stems have more structure and therefore more lignin, so they are less digestible than leaves (Van Soest, 1994).

Maturity also affects forage quality. As a rule, young green leaves and stems are higher in quality than those that are old or dead. Most pasture plants when young and actively growing are mostly leaves. As they grow to maturity, there are more low-quality stems and dead leaf material and fewer high-quality green leaves (Emmick and Fox, 1993).

The time of year and weather affects the nutritional content of plants. Pasture quality tends to be higher in the spring and fall when plants are producing new leaves. Comparatively, in midsummer plants are in the reproductive phase and have more stems and dead leaves. In addition, cool weather promotes more soluble carbohydrates (sugars) and less lignin. More sunshine from longer days will also increase the amount of soluble carbohydrates produced, improving the nutritive value (Van Soest, Mertens, and Deinum, 1978).

The kind of plant, stage of maturity, and time of year will effect the nutritional value of forages for livestock. Figure 10 shows that forage digestibility (if the forage is not grazed or cut) decreases over time. The digestibility decreases primarily because lignin and cellulose (fibrous materials) increase in the plant. This makes plants more difficult for an animal to digest. In addition, some of the energy a plant makes in photosynthesis is used to produce the lignin and cellulose. As a result, older plants have a lower nutritional value for livestock.

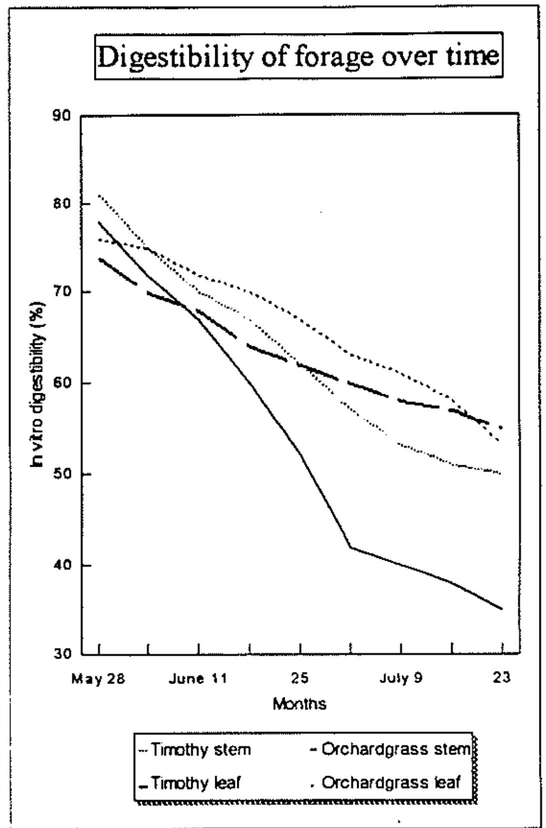

Figure 10. Digestibility of forages over time.
As forage plants mature, they decrease in digestibility. The stems contain more lignin over time, therefore decreasing in digestibility more than the leaves. Lactating and growing animals should consume the forage when it has a high digestibility. Livestock at maintenance can consume a lower digestible forage (Van Soest, 1994).

Forage quality directly affects forage intake which influences animal performance. If the forage is of low quality and animals are not allowed to select the best feed, intake may be reduced along with performance. But of course, even if the forage is of the highest quality, an animal's production will not be optimum if it is not eating enough (Watkin and Clements, 1978).

Pasture density, another indicator of quality, determines an animal's ability to maximize their intake (Figure 11). Since livestock graze a certain amount of time each day, each bite needs to be maximized through forage density and height. Cattle rarely exceed 36,000 bites/24 hours, grazing 7-12 hours/day (although within a species, some animals take more bites than others). This is regardless of the pasture quality or amount of forage available (Murphy, 1991). A dense stand of forages will help to maximize each bite as there will be more plants in an area and more food in each bite (Coleman, 1992). Grazing two different species together may increase animal productivity because the two do not compete with each other. One study showed positive results of pasture use from grazing sheep and cattle together with little negative impact on animal performance (Abaye et. al., 1994).

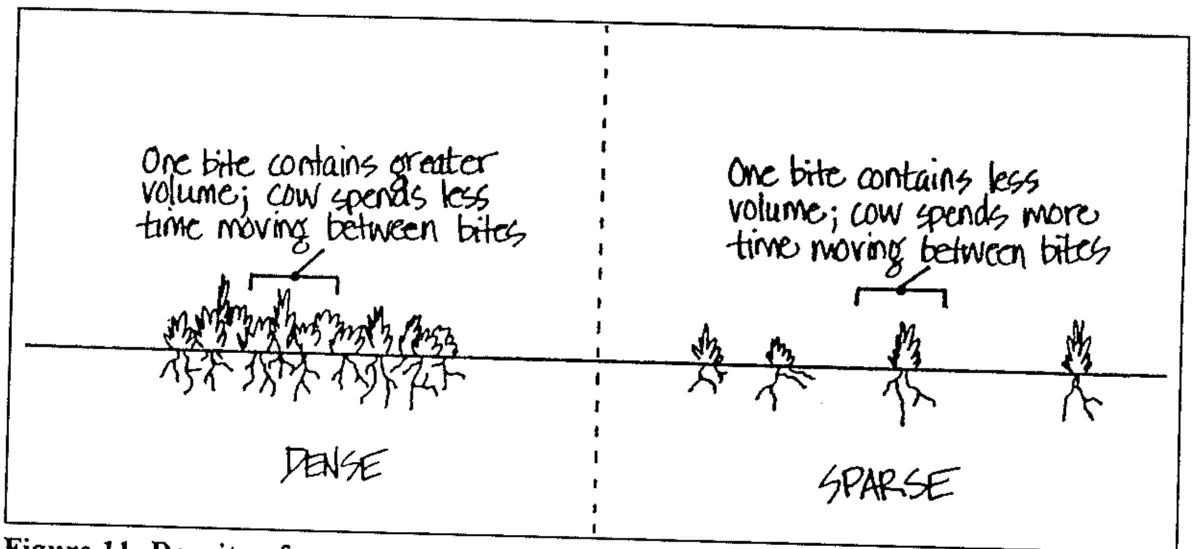

Figure 11. Density of pasture stand.
The denser the stand (or more plants per unit area) the more forage will be available to the animal.

Forage length affects intake. If the pasture is too short, usually below 4 inches, each bite will have less forage than if it is taller. If the forages are too tall and stemmy, however, animals may only eat the top few inches or may reject it all together.

Various species of animals graze differently, depending upon their nutritional requirements. Unlike cattle, sheep and goats have small rumens preventing them from digesting the very fibrous material. As a result, they select the most nutritious parts of a plant with their small nimble mouths. They also graze closer to the ground than cattle and will often select different kinds of plants (Murphy, 1991). Grazing two different

Grazing Management

Animal Impact

Unlike other livestock feeds which are not impacted by livestock as they grow and are harvested, pasture plants are produced with livestock present. Through grazing, pasture plants are subjected to the combined stresses of recurring defoliation, trampling, and manure and urine. Collectively, these influences, when modified by grazing management, allow the grazing animal to exert primary control over what can or cannot survive in any given pasture (Emmick and Fox, 1993).

Plants will respond to being eaten, trampled, or buried in manure and urine by either dying or thriving. The plants that withstand this rough treatment will eventually be the main pasture species.

What determines which species will survive is the frequency, intensity, duration, and timing of grazing, trampling, and fouling. These factors, if controlled, can promote the preferential growth of some species over others.

The key to maximizing pasture yields and reducing losses from animal impacts is to recognize that each plant species has specific tolerances and requirements for growth, and then to plan grazing management around those requirements (Emmick and Fox, 1993).

Frequency of Grazing

In order to optimize the yield and quality of forage produced from a pasture, the pasture must be grazed with a frequency, intensity, and duration that allows the plants to remain both healthy and continually productive (Emmick and Fox, 1993). The goal is to continually produce a high quantity and maintain a high proportion of young green leaves. The basic idea is to allow the animals to graze a section of pasture for a set amount of time, and then remove them and allow the pasture to recover.

Although there are no ideal recovery period lengths, plants should have sufficient time to recuperate from grazing. When animals are absent from the pasture, plants are replenishing stored carbohydrates, growing leaves, and returning to their maximum growth rates. The recovery period should not be so long that pastures become tall, reducing quality. If forage is too tall, animals may reject it because it was trampled and fouled with manure and urine.

Overgrazing occurs if the recovery period is too short (Figure 12) (Karsten, 1996). Overgrazed pastures result from insufficient recovery time, not from being grazed too closely. If the recovery period is too short between grazings, plants will not have stored up enough energy in their leaf bases or roots for new leaf growth. After the animal grazes the plant, the plant makes fewer leaves which in turn reduces root growth. Fewer carbohydrates are stored for the next round of grazing and the plants become progressively weaker (Murphy, 1991).

The tendency is to decrease the recovery period(s) when there is not enough forage

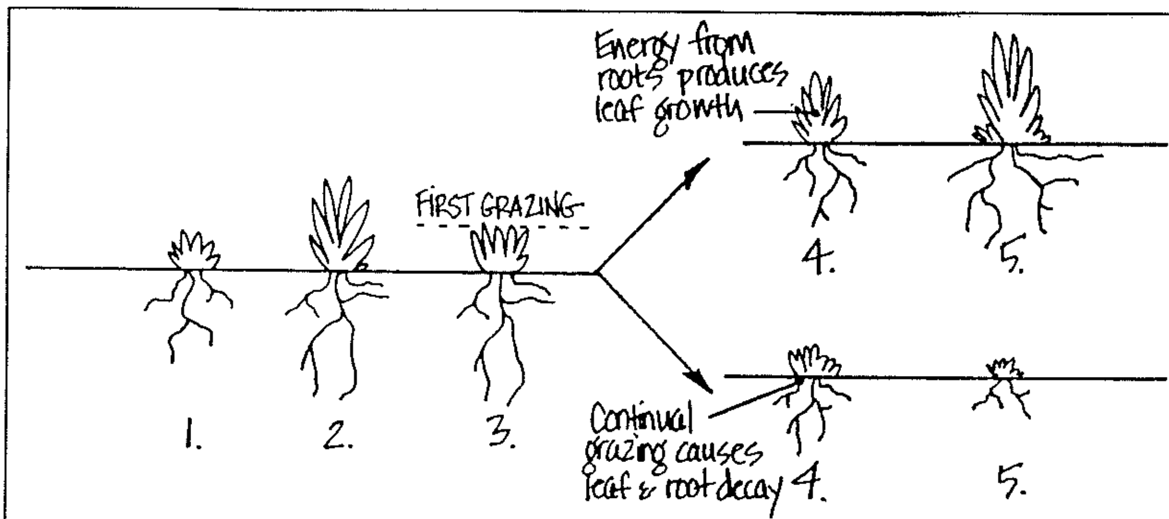

Figure 12. Results of intermittent vs. continuous grazing.
After a plant is closely grazed, stored energy in the leaf bases (grasses) and roots (some legumes) is used to produce more leaves for more photosynthesis. More energy is then stored in the leaf bases and roots. The bottom scenario shows that continuous grazing causes all the stored energy to be depleted, and it is never replenished since the leaves remain small and do not photosynthesize as much. The plant eventually withers away and dies.

for the animals, as is often the case during the summer. This is actually the crucial time to extend the recovery period to allow plants to recover. It is better to take animals off the pastures for a few weeks and feed them hay allowing the pasture to adequately recover (Voisin, 1961).

During the spring of the year, the predominantly orchardgrass pastures at Cornell grew at a daily rate of approximately 100 lb/DM/acre. After a 15 to 20 day growth interval, the forage height reached approximately 8 to 10 inches and contained between 1200 and 2000 lb of DM/acre available for grazing above a two inch residual stubble height. During the summer and early fall months, growth rates averaged approximately one-half of those observed during spring. As a result, it required between 30 and 40 days of growth to accumulate a similar amount of forage during this time period.

Based on the data in Table 1, obtained from actual on-farm experiences, it is recommended that spring rotation lengths (the time for grazing and recovery) be approximately 15 days, extending to 30 days by midsummer, and nearly 40 days for late fall conditions.

The reason behind the recommendations is that forage growth rates change gradually throughout the course of a year and recovery times must be adjusted accordingly. As spring turns to summer, there is a transition from faster to slower growth. Although a rotation length of 15 days may be appropriate the first two times a paddock is grazed, by the third grazing, 18 to 20 days may be required, and during the remainder of the summer, perhaps 25 to 30 days. As summer turns to fall, growth rates generally increase until the lack of sunlight and onset of cold weather slows them back down. Fall rotation lengths may need to be decreased by a few days at first, and then increased to 30 or more days for late fall conditions.

Keep in mind that 15-day spring and 30-day summer rotation lengths are merely guidelines used for planning purposes. In practice, actual rotation lengths will be based on how fast or slow the forage is growing and may vary between 12 and 42 days (Emmick and Fox, 1993).

Intensity of Grazing

Grazing intensity refers to how closely pastures are grazed. The greater the intensity of grazing, the higher the proportion of the pasture forage an animal eats, and the more efficiently the pasture is used.

Grazing intensity management seeks to strike a balance between efficient pasture utilization, maximum animal intake/day, and rapid recovery. Intensively grazed pastures force animals to eat everything available, increasing pasture efficiency, but the plant recovery may be slower and animal intake lower. Less intense grazing allows the plants to recover faster as they have more leaves remaining to photosynthesize the carbohydrates necessary for more growth (Smetham, 1990).

In a practical sense, grazing intensities are evaluated based on the relationship between pre-grazing and post-grazing

Table 1. Days for pasture to regrow to a height of approximately 6-8in.

Table 1 shows that the number of days it takes plants to regrow after being cut (simulating grazing) differs depending upon the time of year. The plants grow more slowly in the summer and take almost twice as long to reach the cutting height as in the spring.

Forage type	May	Jun	Jul	Aug	Sep	Oct	Avg.
Grass	18	19	35	38	42	55	42
Mixed mostly grass	19	21	26	29	34	37	29
Mixed mostly legume	--	29	28	34	38	40	34
Legume	--	--	42	37	36	46	40
Average	18	23	28	31	37	46	33

forage heights. These heights indicate plant growth rates and allow forage quality to be maximized. Several factors to consider when establishing grazing heights include the type of pasture plants and their response to grazing, the time of year, and the production objectives of the farm. Forages are often taller than they appear so it is a good practice to double check the height with a ruler or a spot on a boot (Smetham, 1990).

Pastures consisting of tall grasses (bromegrass, timothy, orchardgrass, reed canarygrass) and legumes (red clover, white clover, trefoil, etc.) are generally grazed from an initial forage height of 8 inches down to a residual stubble height of 2 to 2.5 inches. This may depend upon the time of year.

Before grazing begins in early spring, pasture growth rates are extremely high and are fairly uniform across all of the grazing land. If forage heights reach 8 inches prior to the first grazing, a large percentage of the pasture will quickly begin losing quality. Tall and unpalatable plants will be trampled and wasted. Begin the first spring grazing when forage heights reach about 4 to 5 inches, and stop when the pasture is grazed down to a residual stubble height of about 1.5 inches. Grazing at this intensity staggers forage regrowth patterns and allows more light to reach the lower buds promoting new leaf development (tillering). This acts as a "conditioning process" that will help develop and maintain a leafy high quality pasture over a longer period of time

Mixed pastures comprised of low growing plants like bluegrass, ryegrass, fine-leafed fescues, and white clover, should be grazed from an initial forage height of 4 to 6 inches down to a residual stubble height of about 1.5 inches. The first grazing in the spring should be when plants are at about 3 inches tall with grazing down to a residual stubble height of about 1 inch (Emmick and Fox, 1993).

Grazing heights should be adjusted to wet or dry conditions. Wet soil conditions are conducive to punching by animal hooves. In this situation, it is better to let the forage grow taller prior to grazing and not graze so intensively. Although this method protects the soil, it does reduce harvest efficiency and may require the pasture to be clipped once the soil dries. During hot dry weather, leaving more forage in the pasture insulates the soil from heat and helps maintain soil moisture. Allowing plants more recovery time during and after dry spells maintains the pasture productivity (Karsten, 1996).

As a general rule, when in doubt as to whether a pasture should or should not be grazed, give the pasture the benefit of the doubt. It is better to have a little more growth in the pasture and have the grass ahead of the livestock than it is to graze too early and have the livestock ahead of the grass. Do not wait too long, or forage quality will be compromised. The first sign that this is occurring can be found by looking at the tips of the oldest leaves on the plant (those near the bottom of the plant). When the tips of these leaves begin to turn yellow-brown, it is time to graze. When the tips of the youngest leaves (those near the top) begin to turn brown, it is well past time to graze.

Keep in mind that grazing management is a compromise. What may be good for the pasture may not be the best for the animal and, conversely, what may be good for the animal may not be the best for the pasture. This is why it is extremely important to identify the management goals early on (Emmick and Fox, 1993).

Productivity per Animal vs. per Acre

Grazing heights and intensity also relate to the relationship between productivity per animal and productivity per acre of pasture (Figure 13). As more forage in a pasture is utilized, production on a per individual animal basis decreases. This is because the longer and closer livestock graze a pasture, the amount and quality of forage available for grazing declines. Livestock cannot only select the best quality feed; they must eat poorer quality feed as well. As a result, there is less high quality forage eaten, and individual animal performance is reduced.

Increasing the amount of forage utilization through more intensive grazing, however, increases production per acre (for example, pounds of beef or milk per acre). Even though production per animal is lower, a greater number of animals may be supported. As a result, most of the forage produced is converted into livestock production (for example, milk or pounds gained) and little is wasted. If animals are made to stay on a pasture until all the forage is eaten, however, they will not get enough food nor high quality food to eat. Their performance as well as the production per acre will be a reduced. Since it is not possible to maximize production per animal and production per acre at the same time, a compromise must be reached that is consistent with the production objectives of the farm.

Grazing heights can guide the compromise between maximum production per animal and maximum production per acre. They help to control the efficiency of pasture production and utilization. Under most conditions, the above forage height guidelines are a reasonable compromise for maintaining both animal performance and efficient pasture utilization. To optimize animal performance, however, increase the forage stubble heights by approximately 50%. To optimize production per acre, decrease the forage stubble heights by approximately 25% (Emmick and Fox, 1993).

Duration of Grazing

The duration of time livestock have access to a grazing unit or individual paddock is called the residency period. The length of a residency period is determined by seeking a balance between the livestock's forage requirements and the amount of forage in the pasture.

Ideally, residency periods should be long enough for livestock to harvest the forage in a paddock, but not so long as to damage plant growth or reduce intake. Since animals have selective grazing behavior, they consume the highest quality forage first and leave the rest for last. The left-over forage is often trampled and fouled with manure and

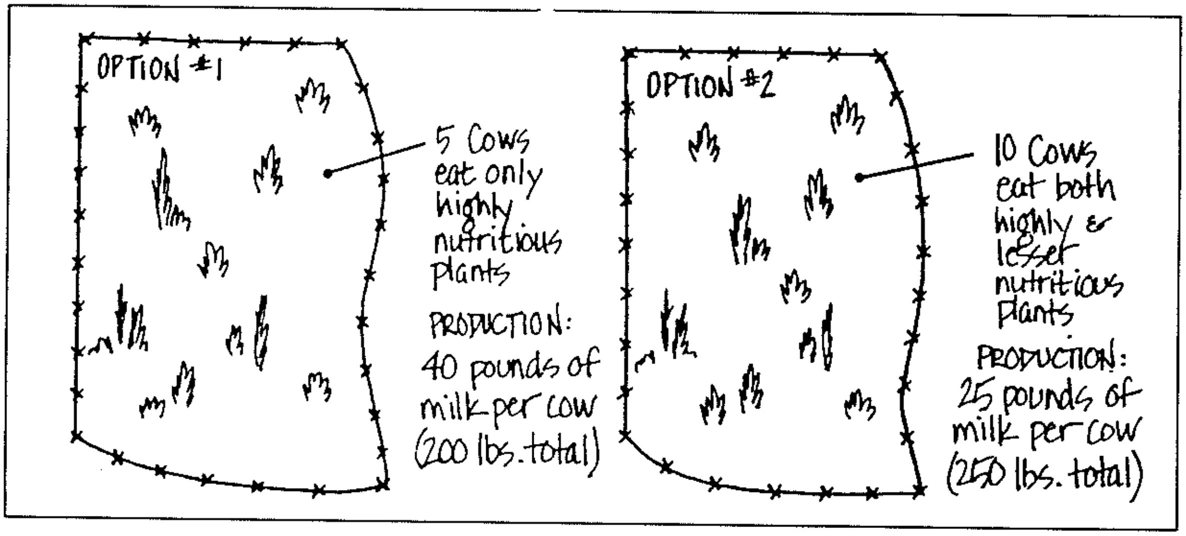

Figure 13. Maximizing productivity per animal vs. per acre.
This example illustrates that productivity can be maximized per animal, but a lot of forage is wasted because they only eat the most nutritious food. Production per acre can be maximized by requiring animals to eat more of the forage present. Although each animal's productivity may drop, overall more is being produced per acre.

urine. As a result, the longer animals remain in a paddock, more forage is wasted and the quality of the remaining feed is lower. If animals are made to eat left-over forage, it will negatively influence their performance.

Depending upon the kind of animal, age, sex, or stage of lactation, nutritional requirements for grazing animals can range from very low to extremely high. For example, although most adult non-lactating animals require only enough feed for body maintenance, a high producing dairy cow at peak milk production has an enormous appetite and needs an extremely high quality feed. Most other kinds of livestock are generally in between these extremes.

Consequently, in order to maintain high and consistent levels of milk production, lactating dairy cows should not remain on any single pasture sub-division for longer than 1 day--some dairy cows are changed every 12 hours. This allows the cows to choose the most nutritious forage. Other classes and kinds of livestock can meet their minimum nutritional requirements with much longer residency periods (including season-long occupancy) provided the total forage supply is adequate and wasting forage is not a concern. Where maximizing forage production and harvest efficiency are indicated as primary concerns, however, residency periods should not exceed 7 days, with 3 to 4 days preferred (Emmick and Fox, 1993).

Acceptable maximum residency time depends upon how quickly the pasture starts to regrow. If animals are allowed to start grazing the regrowth without the pasture having an adequate recovery period, the plants may be severely set back. This may especially be a problem with continuous grazing unless animals are given sufficient forage.

Pasture Fertility

Although poor grazing management is the primary cause of pasture failure, the second most important cause is the lack of fertility management. For a pasture to produce large volumes of high quality feed, there must be an appropriate amount and balance of nutrients available in the soil. If essential plant nutrients are lacking, or unavailable as a result of low pH, plant productivity is reduced. Table 2 gives some general guidelines for pasture fertilization (Emmick and Fox, 1993).

Table 2. General fertilizer recommendations (lb/acre)

	N	P	K
Intensively managed grasses:	80-100	0-50	0-100
Grass/legume mix:	0	0-50	0-150

* These ranges are only recommendations from Cornell Recommends for integrated field crop management (1998). The amount applied to a pasture will depend upon the soil test. If the soil test level is high, the lower end of the range would be applied and vice versa. The fertilizer applications should be timed to the plant's growth cycle.

Nitrogen is often the main limiting nutrient for grasses, but not for legumes since legumes fix nitrogen. When deciding how much nitrogen to apply, there is a trade-off between maximizing nitrogen fixation in legumes and maximizing grass growth. If nitrogen is applied, legumes reduce their nitrogen fixation. For maximum production, grasses need more nitrogen than legumes can provide through decay of their nodules (Russelle, 1992). When applying nitrogen, remember that nitrogen increases plant growth. If the grass is not managed properly, it will get old quickly and be poor quality (Lemaire and Chapman, 1996).

Phosphorous is especially important for legumes, although grasses will compete for it. Phosphorous is most available for plants when the soil has a near neutral pH. Unlike nitrogen, it can build up in the soil over time, especially on fields where a lot of manure has been spread in the past.

Since grasses readily absorb excess potassium from the soil, do not over fertilize with it (Joost, 1996). Micronutrients should not be overlooked. Minerals such as calcium and magnesium, among others, are important to plant growth and animal health (Murphy, 1991).

Don't guess. Do a soil test! Applying fertilizer to a pasture without knowing what it needs can be detrimental to your pasture. Too much of a nutrient can be as bad as too little.

The best way to decide what nutrients are needed is through a soil test. Ideally, soil testing should be done at the same time the grazing system is being planned, and soil nutrients added prior to implementing the system. A pH level near 6.0 should be maintained and phosphorus and potassium levels should be in the medium to high range for grass/legume forages (Emmick and Fox, 1993).

A soil test only estimates the fertility of the pasture. Many microenvironments will exist within a pasture. Nutrient levels increase wherever manure or urine are excreted. In one year, animals spread their manure over 30% of the pasture. Within four years, all areas of the pasture receive manure (Joost, 1996). High concentrations of nutrients, however, occur in "camp" areas--places where animals spend a lot of time (around water tanks, salt blocks, on the tops of hills, or in the shade). Dragging the pasture more uniformly distributes this manure back to the pasture, although this may not be necessary under intensive rotational stocking because animals have fewer chances to camp out (Murphy, 1991).

The timing of fertilizer applications depends upon the growth cycles of the plants, yield goals, temperature, water, and harvest management (Griffith and Murphy, 1996). Adding nitrogen will greatly increase the grass growth. Since grasses grow most in the spring and fall, adding more nitrogen increases the growth rate, resulting in more forage. This may not be desirable in the spring as grasses usually grow faster than they can be consumed by the animals and may be difficult to properly manage (Murphy, 1991). During dry spells (as previously discussed in the pasture ecology section) plants cannot absorb nutrients. If fertilizer is added, then the plants may not be able to utilize it and the nutrients will volatilize or leach beyond the roots of the plant (Russelle, 1996).

Forage Selection

When considering what kinds of forages to select for the pasture, there are certain qualities to look for including persistence, yield, regrowth potential, leaf to stem ratio, toxins, ease of establishment, adaptation, and maturity. Each forage should be evaluated in light of these criteria (J. Cherney, personal communication, October 1,1997). It is important to consider these factors because the plants best suited to a set of conditions will be the ones that persist in a pasture no matter what is initially seeded.

Criteria to consider when selecting a forage:

1) persistence
2) yield
3) regrowth potential
4) high leaf to stem ratio
5) presence of toxins
6) easy to establish
7) adaptation to climate and soils
8) maturity date

When selecting forages, first look at what soil types are in the pasture and their qualities. For instance, some forage species are not tolerant of wet soils, so it would be better not to plant them in heavy clay soils that generally do not drain well. If intolerant species are planted, the better adapted species will outcompete them.

Maturity or heading date is another consideration when selecting grass varieties and species. If possible, several varieties with a range of maturity times should be selected. This will help spread out the highest quality forage over a longer period of time rather than having all the grasses following the same growth pattern (Cornell Forage Web Page).

Table 3 is a partial listing of common grasses and legumes and is in no way exhaustive. There are many new varieties arriving on the market each year. When evaluating new varieties use the above criteria to see if it will work within your goals.

Table 3. List of common pasture grasses and legumes.

Grasses

- **Orchard Grass** - A good grass to consider because it is well adapted to New York, withstands close grazing, and responds well to nitrogen fertilizer. It grows quickly in the spring time and needs to be managed closely so it does not become too mature and unpalatable. There are later maturing varieties. Identify by its dull greenish-blue color, fairly wide leaves, and flat tillers (check towards the base).
- **Perennial Ryegrass** - This grass also withstands grazing pressure, tillers well and responds to nitrogen, but current varieties are not well adapted to New York because they winter kill after three or four years. Identify by medium to small width leaves, deep green color, reddish-purple stem base, with ribs on top and a shiny underside.
- **Timothy** - An easily established grass, but only moderately persistent. It grows a lot in the spring, but late maturing varieties can be planted to stagger the forage maturity and grazing. It does not do well in dry conditions and contains slightly less protein than the other grasses. Identify by light gray-green leaves and rounded tillers or stems.
- **Tall Fescue**- This grass withstands heavy traffic and grows especially well in the fall. It may not be as palatable for animals as other grasses. Identify by large dark-green leaves, that have rough edges and prominent veins.
- **Reed Canarygrass** - A well-suited grass for growing in low, moist areas. It will not "solve" the wet problem (if it is too wet in the spring to graze the cows or to harvest forage, it will still be too wet after planting reed canary grass), but will provide forage in these areas and may provide forage when upland areas stop growing during a dry spell. It can be difficult to establish, but will persist once in place. Reed canarygrass does contain alkaloids, so a low alkaloid variety should be chosen. Identify by its wide leaves and tall growth, if allowed
- **Smooth Bromegrass** - This is a winter hardy grass that grows well early in the spring. Its growing points are raised above the grazing level by late spring. If these points are grazed, the growth of the plant will be set back. The best management is for heavy grazing in the spring and fall and light grazing or mechanical harvesting in the summer. Identify by long, wide leaves and a 'W' marking on the leaf.
- **Kentucky Bluegrass** - It withstands traffic well and forms a dense sod. It is very persistent under grazing, but does not grow very tall, only about 4 inches. Identify by its very narrow bright-green leaves with a shiny underside.

Legumes

- **White Clover** - Many of its seeds have hard seed coats and will still germinate after passing through an animal's digestive system. It can survive in the soil for several years. It is often surprising to find white clover in a new pasture where it was not seeded. This field may, at one time, have been a pasture or hayfield and the seed survived over many years. There are several types of white clover including wild and Ladino, a type of giant clover. The wild white clover is very persistent but small. Ladino is the largest (and currently the most productive) variety and tolerates grazing fairly well. White clover tolerates moist and poorly drained soils. Identify by hairless, serrated leaflets (three to a leaf) with a light colored, crescent-shaped mark on the leaves.

- **Red Clover** - Red clover is less persistent than white clover, although both can be frost seeded in the early spring to increase their density within the stand. Identify by hairy leaves and stem and V-mark on the leaflets.

- **Alfalfa** - Alfalfa is a favorite harvested forage, but its value in a pasture is not as certain. After its growing points on the tips of the stems are cut off through grazing, new shoots must come from the crown of the plant. This is only possible after a lot of carbohydrates are stored in the roots between grazings. This requires a longer recovery time than might be required by other legumes and grasses. If it does not get the required recovery time, it will not persist. More grazing tolerant varieties are available. Alfalfa also requires a near neutral pH and well drained soils.

- **Birdsfoot trefoil** - This legume, unlike other legumes, does not cause bloat. It maintains its nutritional quality into the fall and grows in very poor conditions. The drawback is that it is difficult to establish and can be overgrazed if grazed too closely. Identify by its five leaflets and fine stems.

(Langer, 1992; Robinson, Clare, and Leahy, 1994; Undersander et. al., 1997)

Pasture establishment, improvement, and composition

Pastures can be established by planting a new pasture (possibly from ground previously cropped) or by renovating an existing pasture or hayfield. When improving existing pastures, actually seeding the pasture should be the last step in a three step process (Emmick and Fox, 1993).

The steps to improving a pasture:
1) control the negative influences of grazing animals through a sound grazing management plan
2) soil test and correct deficiencies in soil fertility
3) if necessary, reseed the pasture.

Pasture composition closely reflects the current grazing regime because how a pasture is grazed and the kind of animal grazing it, shifts the competition in favor of some species over others. Through the frequency and intensity of grazing, some plants are able to survive better than others and persist in the pasture (Harris, 1978). Changing compositions in pastures may take several years, but it will change as a response to how it is being grazed (Kemp et. al., 1996).

For example, closely and frequently grazed pastures may have more white clover and less timothy, because the white clover is not shaded by tall plants and withstands close grazing, while timothy cannot tolerate close grazing and dies. If animals do not like to eat tall fescue, it may take over sections of a paddock because the other grasses are too intensely eaten and the fescue can out-compete them. Another example could be that alfalfa after a few grazings will not persist in an old hayfield because it is not given enough recovery time and dies out.

If the pasture does require seeding, then it is important to plan what forage mixture to select (an example of variety mixes and their seeding rates is in Table 4). First, think about the growing conditions, for example the soil type, depth, drainage, and fertility. Second, consider the purpose of the pasture (for example, will it sometimes be cut for hay or be continually grazed) (Robinson, Clare, and Leahy, 1994).

A mix of legumes and grasses is desirable because they complement each other through improved fertility, better growth during the summer, and better nutritional value for the animals. Mixes can be simple, having only two forages, or complex, with multiple forages. The advantages of a simple mix include ease of managing the competition between the plants and high yield preferred for intensive production. An example of a popular mix in New York is orchard grass and Ladino white clover. Inoculating the legume seeds with Rhizobium may boost legume growth.

The main advantage of a complex mixture is that the species mature at different times, extending forage production under different conditions. Mixed pastures require more management, however, to ensure that some varieties do not out-compete other varieties, eventually causing them to die out. Having the right combination of compatible grasses and legumes makes more of a yield difference than just having a large number of species in the mix. An example of a compatible mix might be red clover, alfalfa, ladino white clover, timothy, and orchardgrass (Robinson, Clare, and Leahy, 1994). Considering the grazing conditions and what the pasture will be used for helps determine what forages work best.

When establishing a new pasture, the seeding method, conventional vs. no-till, should be considered. This might depend upon whether the land being seeded into pasture is erodible land, an existing hayfield, or cropland. For new pastures, a companion planting of a grain is often not necessary and will compete with the pasture plants (Robinson, Clare, and Leahy, 1994).

A common way to increase legumes in a pasture stand is to frost seed them onto a pasture in the spring. The planning should begin the fall before. Graze the pasture close to the ground to temporarily set back the pasture. This helps the new young plants to establish in

Table 4. Suggested seeding rates for a variety of forage mixes

Well drained soil		Moderately drained		Poorly drained	
*Orchardgrass	8 lbs/acre	Alfalfa	8 lbs/acre	Ladino clover	2 lbs/acre
Ladino clover	2	Ladino clover	2	Reed canary-grass	8
		Timothy	3.5		
Alfalfa	10				
Orchardgrass	5	Red clover	3.5	Timothy	5
		Ladino clover	2	Ladino clover	2
Alfalfa	8	Timothy	7		
Ladino clover	2				
		Trefoil	8		
Orchardgrass	2.5	Tall fescue	9		
Bromegrass	8				

* This is currently the recommended combination in New York State.
(Robinson, Clare and Leahy, 1994)

the spring without too much competition from existing plants. Broadcast legume seeds at a rate of 2 lb/acre in the spring when the ground freezes at night and thaws in the day--about the same time for collecting maple sap. Although this method does not work for grasses, their numbers can be increased in a pasture stand through simple minimum tillage techniques in the spring (D.L. Emmick, personal communication, December 22, 1997).

Stocking Methods

There are two general methods of stocking used with grazing: rotational and continuous.

The method chosen should be based on a grazier's production and/or management objectives. Each objective modifies the stocking method and requires a somewhat different management approach. Although the method of stocking is an integral part of a grazing management plan, it is secondary to the proper understanding and use of the biological principles and interactions. The most important factors are still the harvest management factors such as the frequency, intensity, and duration of grazing events, and the appropriate kind, number, or class of livestock.

A grazing management plan is only effective in meeting the grazier's objective(s) if it maintains adequate control over the balance between the total amount of forage required by the livestock and the amount of forage available in the pasture. The management plan controls the frequency and intensity of the grazing. These factors influence the forage quality, quantity, and persistence, as well as harvest efficiency, and animal performance (Emmick and Fox, 1993).

Rotational Stocking Method

Rotational stocking methods subdivide pastures into individual grazing units called paddocks. The size and number of paddocks depend upon the level of pasture productivity, stocking rate of livestock, and the desired residency period. Individual paddocks are grazed one at a time, when the forage is ready, with **livestock occupying each paddock long enough to harvest the existing forage but not so long to graze the regrowth**. After each paddock is grazed to the desired forage stubble height (which depends upon the plant species and grazing goals), the pasture is allowed to regrow and regain vigor before again being grazed.

Advantages of rotational stocking are:
1) higher forage yields through controlling the frequency and intensity of grazing
2) easier maintenance of the balance between forage demand and forage supply
3) more uniform levels of forage quality
4) improved harvest efficiencies (a larger percentage of the forage consumed)
5) maximized livestock production per acre of pasture

In a well-managed rotational stocking method, the forage supply is constantly monitored. Adjustments to the stocking rate are made by increasing or decreasing the amount of pasture acreage grazed during a particular time period (Emmick and Fox, 1993).

Management of Rotational Stocking

Generally, rotational stocking methods provide the greatest benefit for lactating dairy cattle and growing livestock. These types of animals need large quantities of consistently high quality feed to maximize their production. Farmers seeking to maximize production per acre of pasture will also benefit from the rotational stocking.

Flexibility in design and implementation is a very important component in any management plan which utilizes rotational stocking because forage growth rates and growing conditions will vary. In addition, plans should not be so costly to develop or complex to manage as to prove impractical. They should be substantive enough in construction and design to facilitate the management required to regulate forage quality, quantity, and harvest efficiencies at critical times during the season (Emmick and Fox, 1993).

Planning for Rotational Stocking

> The rotational stocking method is planned around having enough forage available for grazing during the mid-summer period (when forage is in the most limited supply).
> Several ways to do this are
> 1) set aside 50% of the pasture for hay harvest in the spring and use it as pasture in the summer and fall
> 2) graze twice as many animals in the spring and either sell half or feed them in a barn lot for the remainder of the summer and fall
> 3) do not graze the pasture as close in the spring and rotate through quickly, this helps to stockpile feed for summer and fall. The pastures may need to be clipped to even out patchiness (Murphy, 1991).

There are several different ways to develop a rotational grazing management plan. The following worksheet (Table 6) calculates the minimum amount of acres needed for a set number of animals Another worksheet is in Appendix 1 for calculating the number of animals that can be stocked on a given area of land

Step 1. Estimate the Forage Requirement

The forage requirement is the amount of forage [calculated as dry matter (DM)] an animal needs to eat to maintain itself and grow or produce. One way to estimate the daily forage requirement for an animal is by its weight. As a general rule, producing or growing livestock require 2.5-3.0 % of their body weight in food (dry matter intake requirement) each day. A lactating dairy cow (or other lactating or growing animal) will eat 1½%-2% of her body weight from the pasture. The remaining feed she requires will be supplemented in the barn according to the level of milk production (Emmick and Fox, 1993).

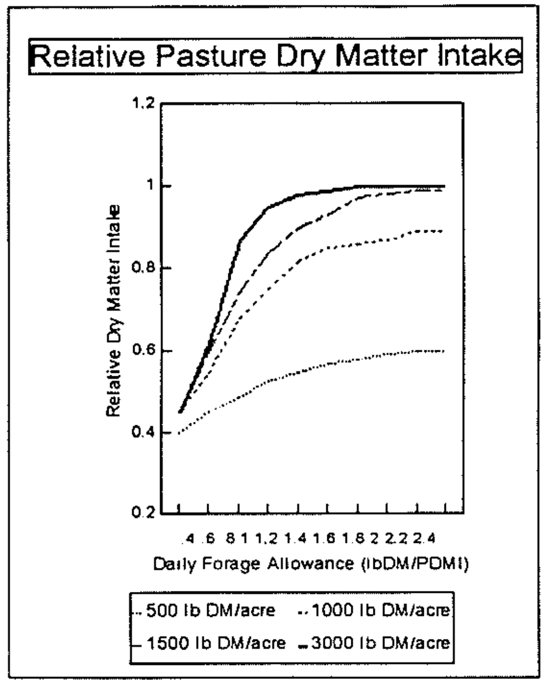

Figure 14. Relative dry matter intake as related to the amount of forage available.

Relative dry matter intake refers to the amount of feed an animal consumes divided by what we predict they can potentially consume [potential dry matter intake (PDMI)]. The daily forage allowance refers to the amount of forage available to a group of animals in the pasture divided by how much forage they would consume (PDMI) if the density and the total amount of forage available allows them to achieve maximum voluntary intake. For example, if the potential intake of a group of animals is 3000 lb DM and we make 4000 lb available to them, then the daily forage allowance will be 4000 lb/3000 lb = 1.33. So Figure 14 shows relative DMI at 1000 lb/acre available will be 80% of maximum voluntary intake. This means that when livestock are given more pasture than they need according to their predicted dry matter intake (PDMI), they have a higher relative dry matter intake. The feed intake from low yielding pastures can be improved by making the pastures larger. Higher yielding pastures, however, will allow for larger DMI (see also Figure 11) (Rayburn).

In Step 1 (Table 6), livestock are allowed access to 2½-3% of their body weight in forage. This allows for an additional amount of forage above what an animal will eat (1½-2%) to keep relative DMI high. The additional amount takes into account that some forage will be lost through trampling and fouling with manure, and gives the animals an opportunity to achieve maximum voluntary DMI. It also helps to prevent overgrazing or damage to pasture plants and allows the high producing and growing animals to select the best forage, not forcing them to eat the low quality old forage. This idea is illustrated in Figure 14.

Nursing beef calves, beef stockers, or dairy heifers start out small at the beginning of the season and get larger. Use their mid-season weight, or combined weight for cow/calf or ewe/lamb, for the calculations (Table 5).

Table 5. Examples of daily pasture dry matter intake requirements

Lactating dairy cow weighing 1300 lb 1300 X 0.03 = 39 lb DM/day
Beef cow/calf pair with a combined weight of 1400 lb at midsummer 1400 X 0.025 = 35 lb DM/day
Ewe/lamb pair with a combined weight of 200 lb at mid-summer 200 X 0.025 = 5 lb DM/day
Steer, heifer, or other growing livestock weight of 650 lb at mid-summer 650 X 0.025 = 16.25 lb DM/day

Step 2. Estimate the Forage Supply

Determining the forage supply is the most difficult part because of the variability in plant species composition and density, and factors, such as climatic conditions, soil type, soil fertility, and the level of management, which control plant growth and yield. Actual measured yields obtained from pasture provide reliable estimates of the available forage supply (see Appendix 2 for instructions) (Emmick and Fox, 1993). A plate meter can be used to determine the bulk density height, or a few samples that are representative of the paddock can be clipped and dried.

The next best option is to estimate the potential total yield of grass-legume hay considering the soil type, fertility level, soil depth, and past harvest data. Hay yield information is available in most county soil surveys which can be provided by either the Natural Resource Conservation Service (NRCS) or Cooperative Extension. Over time, forage yield estimates improve with practice.

Since grazing systems produce more forage than a hay field, the hay yield estimates in the NRCS Soil Survey tend to be lower than what most producers experience in pasture systems. Data from actual on-farm observations are included to provide estimates of what might actually be available based on the predicted hay yields (Emmick and Fox, 1993). For example, Table 7 shows that if the soil survey predicts an annual hay yield of 4.0 ton/acre (8000 lb) on a particular type of soil, a producer using rotational grazing could expect, depending upon conditions, about 1600 lb/acre in every rotation. If the livestock rotated through 6 times during the year, the pasture would produce 9600 lb/acre in a grazing season.

Table 6. Calculating the stocking rate for rotational stocking.

Calculating the Rotational Stocking Rate

1) Estimate the Forage Requirement (see comments above)

Animal weight X 0.025 (or 0.03 for lactating dairy cows) = Daily Forage Requirement/animal (lb DM/day)

Daily forage requirement/animal X number of animals = Daily herd(flock) Forage Requirement (lb DM/day)

2) Estimate the Forage Supply (see comments above and table below)

Table 7. Forage availability estimates for Rotational Stocking

Hay yield, annual tons/acre as predicted in the NRCS Soil Survey	5.5	5.0	4.5	4.0	3.5	3.0	2.5	2.0	1.5
Actual observed forage availability lb DM/acre each rotation	2200	2000	1800	1600	1400	1200	1000	800	600

3) Determine the Paddock Residency Period

Table 8 provides general guidelines for selecting residency periods to optimize livestock production and harvest efficiency with different kinds or classes of livestock. Lactating dairy cows, having the highest nutrient requirements, have the shortest residency periods.

Table 8. Recommended Residency Periods

Kind of Livestock	Number of Days
Lactating Dairy Cattle	one-half to 1
Milking Sheep or Goats	1 to 2
Growing Stock (Steers, Heifers, Lambs)	3 to 4*
Beef Cow/Calf, Ewe/Lamb, Deer/Fawn	3 to 4*
Most Adult Non-Lactating Stock	4 to 7*

* may also be grazed season long with proper planning

4) Calculate the Paddock Size

(Herd forage requirement ÷ forage supply) X residency period = Paddock size (acres)

continued on next page

5) Determine the Number of Paddocks Required

The number of paddocks required for a grazing plan is based on having enough forage available during the slowest growth period of summer. The combined experiences of many producers across New York State indicate that a 30 day regrowth interval for a paddock provides a reasonable compromise between maximizing forage quality and promoting maximum yield. This may depend upon soil type, rainfall, and forage species.

(30 ÷ residency period) + 1 = Number of paddocks needed

6) Estimate the Number of Acres Required

Paddock size X number of paddocks = Number of acres planned

(Emmick and Fox, 1993)

Paddock Designs

There are as many ways to design a rotational stocking system as there are farms and each farm may consider several options. This section will contain the basic principles that guide these designs and give some examples.

A common way to design a grazing system is to fence the perimeter of the pastures and then use flexible fencing to subdivide them into paddocks. The subdivisions are important because variable pasture growth and livestock number requires the paddock size to be flexible. Another reason is that in order to intensify grazing, livestock need to be confined to a small paddock so they eat most of the forage in a short time. The livestock should then be moved so the paddock can recover after grazing.

As mentioned in the previous section, forage requirements for rotational systems are based around having enough forage in the summer, which is when the forage grows the slowest. As a result, there is twice as much forage in the spring to manage. One way to harvest the extra forage in the spring is to cut and harvest it mechanically. Half of the pasture area should be set aside for mechanical harvest in the spring (the secondary pasture) and half should be designated as the grazing area (the primary pasture) during the spring and rest of the year. After the hay is harvested, the fields become part of the grazing rotation during the summer.

Hayfields should be managed to enhance the grazing system. Since it takes about 6 weeks (under optimal conditions) for a cut hayfield to be ready for grazing, stagger the cuttings to coincide with grazing needs. For instance, rather than cutting all the paddocks at once, paddocks to be grazed in mid July should be cut for hay in early June and paddocks grazed in late July should be cut in mid June (G.W. Fick, personal communication, December 19, 1997).

One possible system for dividing pastures is to divide the primary grazing pasture into five subdivisions using permanent or semi-permanent wire (Figure 15). Each subdivision should provide three days worth of grazing (or three paddocks). Use the planning process above to calculate the number of acres required for one day's worth of grazing, and then multiply by three to determine the acres needed for each subdivision. If the system operates as planned, by the time all five subdivisions have been grazed, approximately 15 days will have passed since the first paddock was grazed (Emmick and Fox, 1993).

For most livestock, each subdivision can be used as the paddock for three days. For a dairy herd, or other animals with high nutritional demands, however, each major subdivision would be further subdivided into three paddocks with temporary fencing, like electric fence, and allocated to the herd one paddock at a time for each of the three days. Using temporary fencing allows the paddock size to be flexible since conditions change throughout the season. Should the paddocks be too large (more forage available than the livestock can consume in three days) they can be made smaller. Should the paddocks be too small (not enough forage available for the livestock) they can be made larger (Emmick and Fox, 1993). This is just one possible paddock design and others may be more appropriate depending upon the circumstances.

Pastures cut for hay could also be subdivided with semipermanent fencing. The hay fields should be fenced and laid out in a way the allows easy access for the harvesting equipment. The paddocks can then be fenced with temporary fencing within the subdivisions when grazed.

During the spring, this paddock design allows the primary pasture to be grazed on a rotation length of 15 days. Remember though, a calendar should not tell the producer when to move the livestock. The condition of the pastures is what is important. After the hay or silage is taken from the secondary pasture area, it can then be subdivided into paddocks with temporary fence and be grazed as necessary.

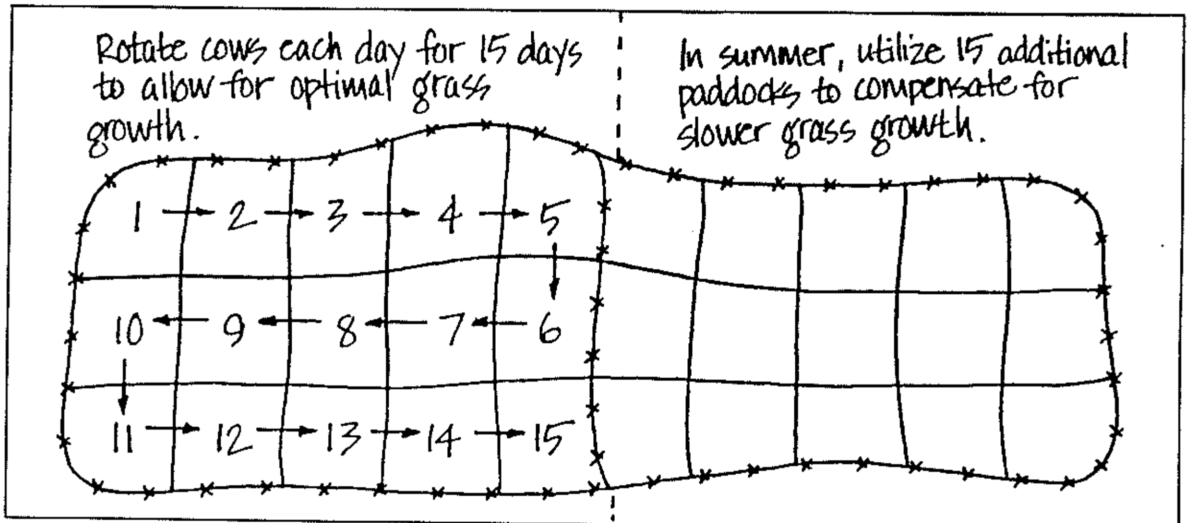

Figure 15. Paddocks for rotational stocking depending upon seasonal forage growth. Because of fast forage growth in the spring, a complete rotation through the paddocks can be made in approximately 15 days. Slower forage growth in the summer requires a longer rotation of approximately 30 days. To accommodate the longer rotation, add more pasture. The additional pasture could be hayfields that are harvested in the spring and grazed in the summer.

During the summer because of the slower grass growth, the rotation length may increase from 15 days in the spring, when 50% of the planned acreage is utilized, to a maximum of 30 days when the entire system is grazed. Actual rotation lengths will depend on forage growth rates (Emmick and Fox, 1993).

Paddock Management

Clipping pastures should be done as needed, but do not clip just to make the pasture look pretty (Figure 16). Even with the best management some of the pasture may get ahead of the livestock and become over mature, or there may be a problem with weeds. In addition, if the livestock reject the forage the first time they came into contact with it, chances are they will reject it the second time as well. In these instances, clipping is not only desirable, it is a key to maintaining high quality pastures (Emmick and Fox, 1993). Clip as low as possible to keep the stubble below the grazing level. Tall stubble makes it more difficult and uncomfortable for animals to graze.

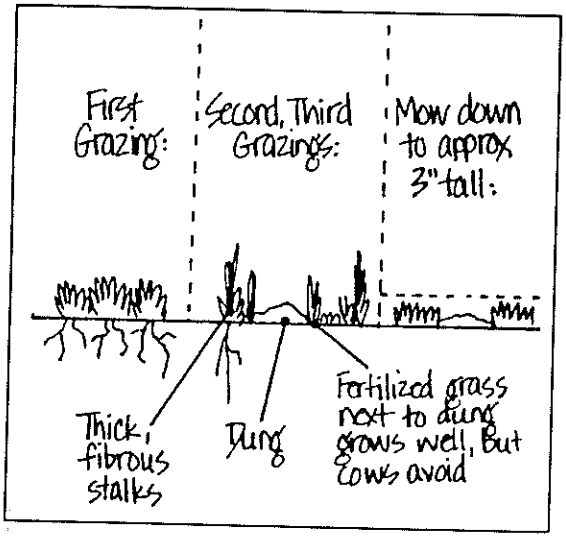

Figure 16. Pasture clipping.
Over time a pasture becomes uneven and livestock refuse to eat tall and coarse forage. Clipping removes this unpalatable forage

An alternative to clipping is to intermix different livestock species or have one group of animals follow another in the grazing sequence. For instance, sheep and cows consume different plants and sheep will eat around cow manure, maintaining a more evenly grazed pasture. Another possibility would be to graze high producing dairy cows in a pasture allowing them to eat the highest quality feed. The next day, follow them with dry cows or heifers who will eat the remaining lower quality forage (Murphy, 1991).

Continuous Stocking Method

As commonly practiced, the continuous stocking method requires a minimum amount of management. A set number of animals are turned out on a given number of acres of pasture and allowed to graze for as long as the forage supply lasts. Advantages are that it requires less rigorous management and less work, it can be productive under the right circumstances and it has fewer development costs for water and fencing when compared to rotational stocking. It is generally best for animals with lower nutritional requirements.

As long as there is an adequate supply of forage, gains per animal are often equal to or greater than those obtained from more intensively managed rotational stocking methods. Animals under continuous stocking are able to select a diet that is higher in overall quality because they have more forage to choose from. Unfortunately, the forage that is left behind is wasted, and it is this non-utilized feed that accounts for the reductions in liveweight gains per acre. As a result, the continuous stocking method is not very productive in terms of liveweight gains per acre or in maximizing the length of grazing season.

Although continuous stocking over time weakens or eliminates many of the more productive plant species, this can be a benefit if there are certain species a producer wants to remove from the pasture. Forages such as birdsfoot trefoil, red clover, alfalfa, bromegrass, timothy, and orchardgrass do not survive well under close continuous grazing. As a result, pasture yields are often reduced along with a loss of quality. However, once the plant community is weakened or suppressed, the pasture can be overseeded with a more desirable plant species.

One caution, however, is that it is extremely difficult to control the grazing events. This makes it difficult to maintain an effective balance between forage demand and forage supply. When stocking rates are high, animal nutritional requirements are not met because there is not enough highly nutritious feed for all of them. When stocking rates are low, forage is wasted and production per acre is reduced. In either case, the result is often a highly variable forage quality and an inefficient conversion of forage into a salable product (Emmick and Fox, 1993).

Continuous stocking management - variable forage growth during the grazing season will cause pasture stocking rates to vary accordingly. In the spring, 100% of the livestock can graze the pasture. In the summer, only 50% can remain while the other 50% can be sold or pastured on hayfields.

Management of Continuous Stocking

Managing continuous grazing requires that the animal's requirements be matched with the available forage supply throughout the entire grazing season. This takes into account that forage production is seasonal, more in the spring and early summer and less in the summer and fall.

One way of matching the requirements and also protecting the pasture from overgrazing is to manipulate the stocking rate. The pasture should be stocked in the spring with approximately twice the expected summer stocking rate (Figure 17). A worksheet for calculating the stocking rate is found in Table 9.

Then as the forage growth rates slow in midsummer, the stocking rate should be reduced by at least 50%. When the numbers are reduced in the summer, animals can either be sold, placed in feedlots, or fed off additional pasture. This last method is particularly effective if there are hay lands available which can be grazed after the first cutting of hay is taken.

For example, during the spring of the year, livestock are on pasture or pastures grazed with a continuous stocking method. As the forage growth rate declines in the summer there is not enough forage available for the entire herd or flock. As a result, some, but not all of the animals move to the hayfields after the first or second cutting. The pasture is still being grazed (continuously stocked) with a reduced number of

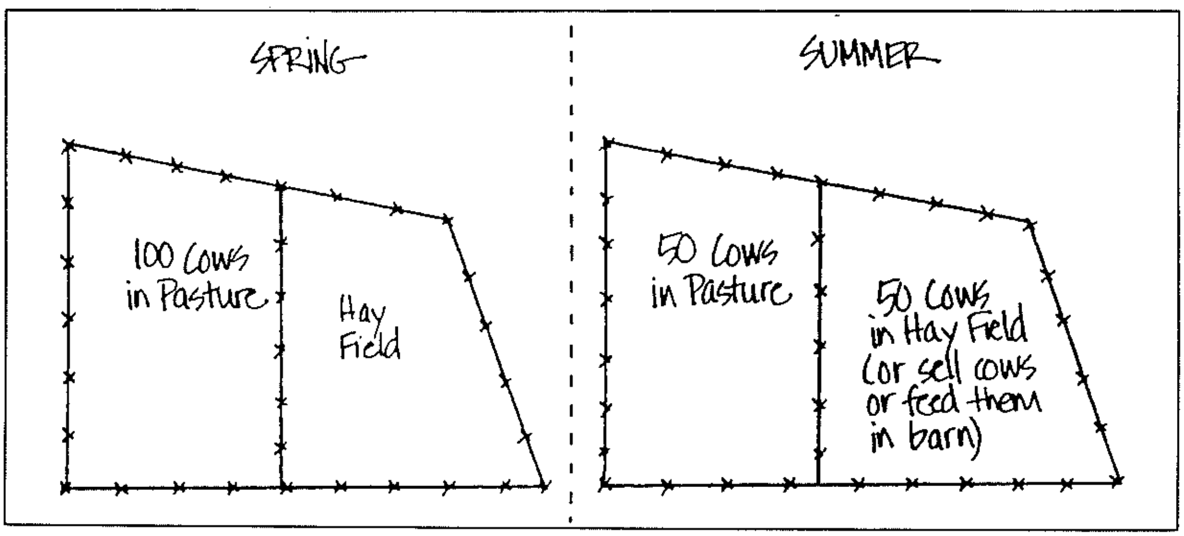

Figure 17. Continuous stocking pasture plan.
Because of the difference in forage growth rates from spring to summer, pastures are able to support approximately 50% fewer livestock in the summer than the spring. The herd can be split and a portion either put on additional pasture, fed in a feedlot, or sold.

animals and the hayfields become the pasture for the other group of livestock.

In order to reduce the amount of forage that is wasted and provide some control over the nutritional quality of the pasture, it is recommended that the height of the forage in the pastures should not be allowed to exceed 6 inches nor decrease to less than 3.0 inches (Emmick and Fox, 1993).

Table 9. Calculating the stocking rate for continuous stocking.

Calculating the Continuous Stocking rate

1) Estimate the Total Forage Requirement

Animal weight X 0.025 or 0.03 = daily forage requirement/animal

Daily Forage requirement/animal X number of animals = daily herd (flock) forage requirement

2) Estimate the Forage Available For grazing

The amount of forage available for grazing with continuous stocking is based on the total annual hay yield in tons/acre minus 40% for losses due to trampling, fouling with manure and urine, and reduced growth. Table 10 estimates the amount of forage available for grazing based on grass-legume hay yield estimates. For example, a hay field that annually produces 3.5 tons/acre of forage could be expected to annually produce 4200 pounds/acre under continuous grazing.

Table 10. Forage availability estimates for continuous stocking.

Hay Yield, annual tons/acre	5.5	5.0	4.5	4.0	3.5	3.0	2.5
Annual Forage Availability pounds/acre	6600	6000	5400	4800	4200	3600	3000

3) Determine the Grazing Period

In most parts of the northeast, the period of grazing will range between 150 to 215 days depending on the local environmental conditions. Grazing might start in mid April and go until early November.

4) Calculate the Number of Acres Required

[Daily herd (flock) forage requirement X number of days in the grazing period] ÷ forage supply (per acre) = number of acres needed

(Emmick and Fox, 1993)

Infrastructure

(Sections on Fencing, Watering, and Laneways are contributed by Rob DeClue)

Managing livestock and forage resources is the backbone of a successful grazing system. These resources are more easily and efficiently managed, however, when the proper infrastructure is in place on the farm and is matched to the grazing system. Infrastructure in this section includes fencing, watering systems, and laneways and will be described in further detail in this section.

Infrastructure will probably be the most costly and permanent part of a grazing operation. Consequently, it is important to **plan ahead** before putting posts in the ground and laying down piping for watering. Most farms do not start planning a grazing system with bare fields, but rather have existing fences and buildings to work around. A new high-tensile fence or watering system is not a prerequisite for starting to graze, but invariably as grazing management improves, most facilities on a farm will be enhanced or expanded.

Fencing

Even when livestock are provided with ample and high quality forage while grazing, it is unrealistic to expect them to remain, on their own accord, in the area allocated for them. Proper fencing provides better control and ease of handling when containing, excluding, and moving livestock. In order to accomplish this, fencing should be effective, durable, economical, and easy to maintain

Traditional approaches to fencing relied upon barbed wire, conventional smooth electric, or woven wire. Thankfully, more advanced fencing technologies are currently on the market and offer superior performance, dependability, and adaptability. There are basically two classifications of modern fencing used in grazing systems: permanent and temporary. Each grazing system should contain a balance of both permanent fencing (to ensure overall integrity) and temporary fencing (to provide flexibility for changing conditions of forage production and/or livestock requirements).

Currently, the best choice for permanent fencing is electrified high-tensile fencing. This is used in perimeters, laneways, and for major pasture subdivisions. High-tensile wire yields about 3.5 times the breaking (i.e. tensile) strength of equivalent gauged barbed wire and does not stretch when pulled. These two characteristics permit spacing of line posts upwards of 75 feet on straight runs. Maintenance is straightforward and negligible. Tensioning devices are permanently installed on each strand and set for between 150 - 250 pounds per strand. On very short runs, springs are also included.

Two critical requirements for this type of fencing are 1) allowing all wires to "float freely" at every contact point except at the ends, and 2) providing solid attachments at ends, gates, and corners. Achieving the latter requirement involves using a hydraulic post driver to set larger blunt bottomed posts (min. 6" dia.) deeper (at least 3.5') into the ground. Depending on how many strands are needed for effective animal control, further bracing may be warranted for ends, gates, and corners. Live trees should not be used for line posts since they rarely line up straight and the trunk's growth will inevitably engulf the strands (unless preventative measures are taken and are perpetually maintained).

High-tensile fencing can be constructed by either a qualified and experienced contractor or the farmer. Built properly with suitable components and materials, high-tensile fences last well over 20 years. For more information, consult with fencing dealers, contractors, manufacturers, USDA Natural Resources Conservation Service, county Soil and Water Conservation Districts, and

Cornell Cooperative Extension for further guidelines, standards, and specifications.

Temporary fencing, used to divide pastures into individual paddocks, can be constructed of portable electric twine and/or ribbon. The electric twine or ribbon is composed of a polyethylene chord interlaced with 6 or more very thin metal wires. As opposed to high-tensile wire, used as a physical barrier, the electric fence is strictly a psychological barrier. It must be electrified in order to provide an unpleasant shock when an animal challenges the fence. This material is held off the ground at the proper height by either light-weight fiberglass or molded plastic posts, both of which are self-insulating. A reel is a convenient way to store and dispense the portable electric twine or ribbon. Due to its small conductors, electric twine or ribbon should only be deployed in reaches of about 1000 - 1500 feet within the confines of a permanent fence.

place a suitably deterring charge on the wires. Fortunately, along with the recent advent of improved fencing materials has come a new generation of fence energizers, described generically as "low impedance." This breed of energizers is vastly superior to the archaic "weed choppers" which became worthless when loaded down by weeds or branches, and occasionally caused brush fires. Low impedance energizers emit a different type of electrical pulse capable of passing beyond (i.e. not impeded by) even a moderate plant load on the fence line.

Electric fencing systems are like other electrical circuits requiring a complete, low resistance pathway to function properly (Figure 18). One segment of the circuit is the hot (electrified) wires on the fence. Another part is the grounding wire which also must permit easy passage of the electric pulse. When an animal touches the live wire, its body conducts the pulse from the fence to the ground. The pulse travels through the ground to

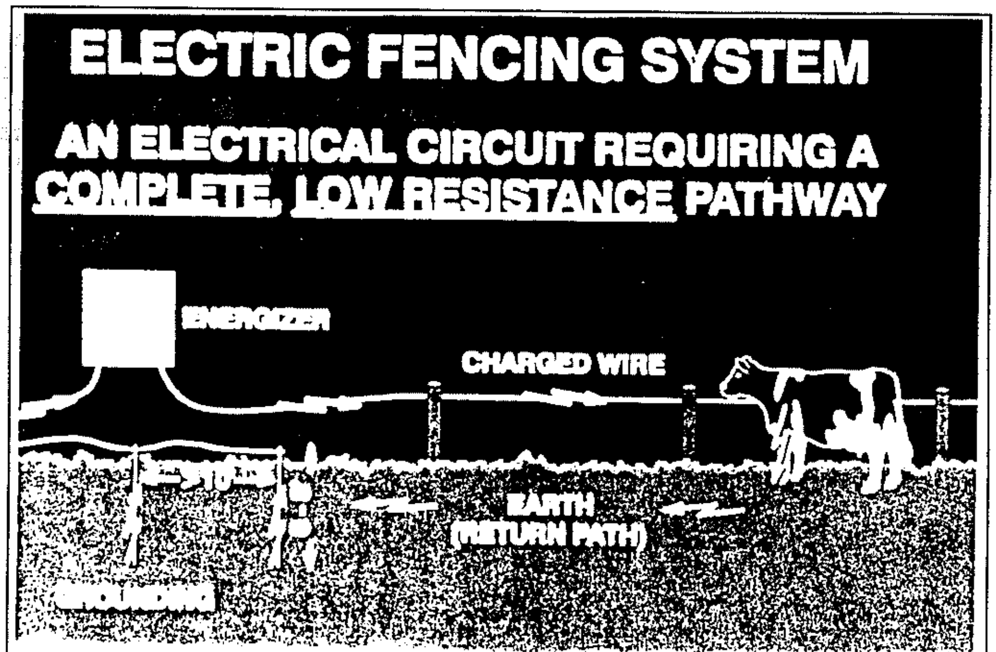

Figure 18. Electrical pathway in an electric fencing system.

Since both high-tensile and portable twine/ribbon are electrified, a fence charger or "energizer" is necessary to

the grounding wire. To complete the circuit, the energizer must have excellent contact with the ground.

The importance of an adequate grounding system cannot be over emphasized. Most energizer manufacturers stipulate a minimum of three 8' long by 5/8" dia. ground rods spaced at least 10' apart and fully embedded in the ground.

Isolate the energizer from lightning strikes coming from both the fence and electric utility. This can be accomplished with a surge protector at the 115 VAC outlet in combination with a lightning arrestor, choke, and separate grounding system appropriately placed and wired.

Choose electric carrying fencing components of the same composition; otherwise a process known as electrolysis will occur between dissimilar metals, ultimately causing a corroded (i.e. high resistance) connection. For livestock inexperienced with electric fences, a brief training period should be given under highly controlled conditions (e.g. barnyard, pen, corral, etc.) to imprint a healthy respect for such unfamiliar fencing.

Watering

Animal performance in any production system is intricately tied to providing water of adequate quality, quantity, and ready accessibility.

> Water for livestock should be
> 1) good quality
> 2) sufficient quantity
> 3) easy for livestock to access

To ensure good quality, periodically test the water for contaminants or pathogens If these are in a large concentration, they may contribute to poor livestock health or reduced water intake. A veterinarian or Cornell Cooperative Extension can provide guidelines for thresholds

When determining the quantity of water to be provided on pasture, consider the livestock's total daily requirements and the different ways they may obtain it.

Between free choice water available in the housing or milking facility, contained in the tissue of the fresh forage (up to 80% water), and dew on the plants, a large part of the daily needs can be met (Figure 19). The remaining balance of their water needs should be provided for in the pasture. If animals go right to water tanks as they return to the barn, they may not be getting enough water in the pasture.

A fully integrated watering system is comprised of **1) a water source, 2) a distribution network, and 3) a dispensing site(s).** Whether the source is a pond, stream, spring, or well, it should not only provide high quality water but yield dependable quantity throughout the entire grazing season. Generally, streams are not good water sources due to inconsistent quality and potential for livestock to pollute the stream. Ponds, streams, and springs should always have livestock excluded and be protected from incompatible land uses. Drilled wells that provide water for the farmstead are the favored source where available because they are high quality, reliable, and furnish sufficient pressure. The pressure must be enough to overcome any lift when distributing water from the source to higher watering points in the pasture.

Most farmers choose black (clear allows algae growth) polyethylene water pipe placed on top of the ground (the water will be fairly cool once vegetation grows over the pipe) at the base of fencelines to distribute the water to the paddocks. Metal or heavy plastic protective sleeves protect the pipe at heavy animal and/or equipment traffic sites like gates or laneway crossings. To supply water outside of the typical growing season, pipes have to be trenched below the frost line and connected to either "energy-free" or electrically heated water troughs.

Pipelines, fittings, and valves must be large enough to reduce friction loss out to the furthest reach. For example, a 3/4" pipe may allow good water flow at the pump, but the further the water travels the more friction builds up. At 500 ft. from the pump, a trickle of water will come out. Increasing the pipe size to 1" or greater alleviates this problem. Water dispensing sites consist of a valved connection to the water line, a section of durable garden hose, and a light-weight water trough outfitted with a full-flow water level control device. Light-weight

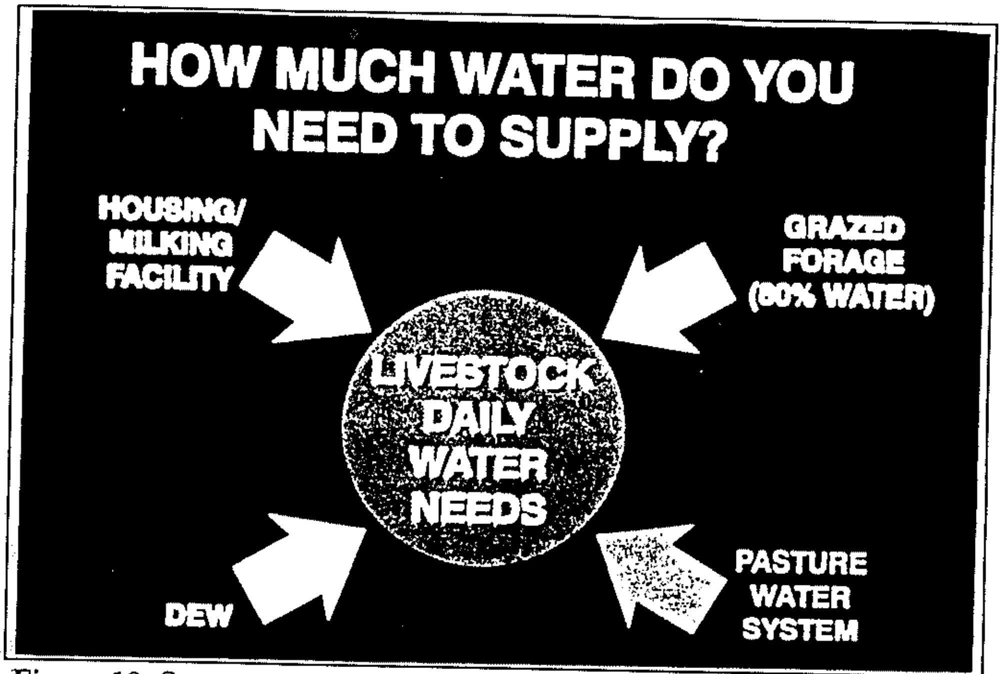

Figure 19. Sources of water for livestock.

water troughs can easily be moved to different spots to reduce trampling and manure concentration in one spot. Make sure that all parts of the system (pipes, pipe connectors, and float valves) have similar pipe sizes because the overall flow rate (gallons/minute) will be regulated by the smallest pipe opening For example, all the pipes leading up to a float valve may allow for a 5 gal/minute flow, but the float valve has a small opening allowing 2 gal/minute. Consequently, the amount of water flowing into the water tank will be 2 gal/minute.

An alternative to laying out a system of pipeline is to harness a large capacity tank onto the running gear of a wagon. Fill it up at some reliable source, tow it to the site where livestock are grazing, and park it. A short section of high capacity hose links the tank with a trough outfitted with a full-flow water level control device. This setup is typically referred to as a water wagon. It is a temporary means to provide water to a new or expanded grazing system until a more permanent means of getting water to the livestock is available. It can be used on a long term basis for a small portion of the grazing system that may be in an area a permanent water system cannot service. While providing water in this way is usually low cost, it is very labor intensive.

Water should easily accessible for the livestock. Where watering sites are available nearby, livestock tend to visit the trough in smaller numbers and return to grazing once their thirst is quenched. This is in stark contrast to traditional pasture watering scenarios where only one or two fixed sites are available and once a single animal decides to head for a drink, the entire group follows in hot pursuit.

A general rule of thumb is to have water available no further than 300 linear feet away for lactating dairy cows and within 800 linear feet for all other classes and kinds of livestock. It is better to have the water closer than these recommend maximum distances. Every paddock, however, does not requires its own individual water trough. By thoughtful planning and placement, a single trough can readily support livestock using three, four, or more paddocks without having the animals walk too far.

There are two ways to set up the tank system. One way is to have a smaller tank, but provide quick recharge. Without quick recharge, the animals will quickly drink it dry and probably knock it over. The other way is to have slow recharge, but a large tank. The goal is to always provide water for the animals when they want it.

The site chosen for dispensing water to livestock receives considerable abuse from animal traffic and manure buildup creating the potential for this area to turn into a mud hole. There are a various factors which affect its suitability such as native soils, topography, type and class of livestock, and intensity and duration of use. Portable water troughs are easily relocated between grazings to a slightly different location. This will disperse the impact. For permanent troughs, development of a durable base may be necessary if the existing site cannot provide long term support.

Where conventional means of obtaining water are not practical or cost-effective, a wide assortment of alternative pumps are currently available on the market These include hydraulic ram, sling, nose, solar and gasoline powered pumps, and windmills. Each has its own unique advantages, limitations, and requirements. A thorough evaluation of these options is essential to determine which most appropriately matches the farm's needs and resources.

Laneways

Indispensable to effective grazing management is the capability to reliably and simply move livestock to different paddocks, water dispensing sites, barns and other facilities on the farm. A laneway facilitates these moves.

The laneway is generally located in the central part of the grazing system, enabling it to serve the greatest acreage for the least distance. When planning the specific path of the laneway, try to keep it on high ground or at least avoid swales, draws, and known seeps. Once the alignment is determined, attempt to preserve natural drainage patterns and take preventative measures to keep erosion in check.

Laneways should be no wider than absolutely necessary to allow unrestrained passage of livestock. If field equipment cannot access the pastures by some other route (for example, gates in the interior fences), then the laneway should also be wide enough for your equipment. Whenever a laneway serves this dual role, the greater impact to the lane requires extra attention to avoid developing a problem with erosion or mudholes.

When streams must be crossed, two basic approaches are available: above-grade or at-grade crossings. Smaller streams and creeks can be crossed by installing culverts or bridges. By keeping animals out of the stream, the lane and animals stay drier and manure is kept out. This approach, however, is too costly for wide streams. Instead, a spot in the stream where the banks are low is selected. A shallow sloping ramp is dug out of the banks on either side and stabilized with gravel or concrete so livestock can safely advance to and cross the stream bed. When planning the laneway, it is best to cross the stream in only one place.

Especially for dairy operations, the laneway by the barn gets the most traffic in and out of the barn. Since this area is often a quagmire, it should be the first part of the laneway to be improved. At a minimum this involves capturing roof and surface water coming into the area and redirecting it to a less troublesome spot. More often than not a concrete pad with board fencing will also be required.

The section of the laneway directly off the barnyard would be the next most heavily trafficked area. It is important to establish a reliably firm surface for the animals to travel on. They will be cleaner and it is easier for them to travel to the pasture. Improving the lane surface may require hauling in gravel (building up the base on top of geotextile material) toping it with lime dust, and finally packing it down. The geotextile material keeps the mud from coming up through the gravel, improving drainage (Figure 20).

A less expensive solution if the site includes hardpan, is to have a bulldozer

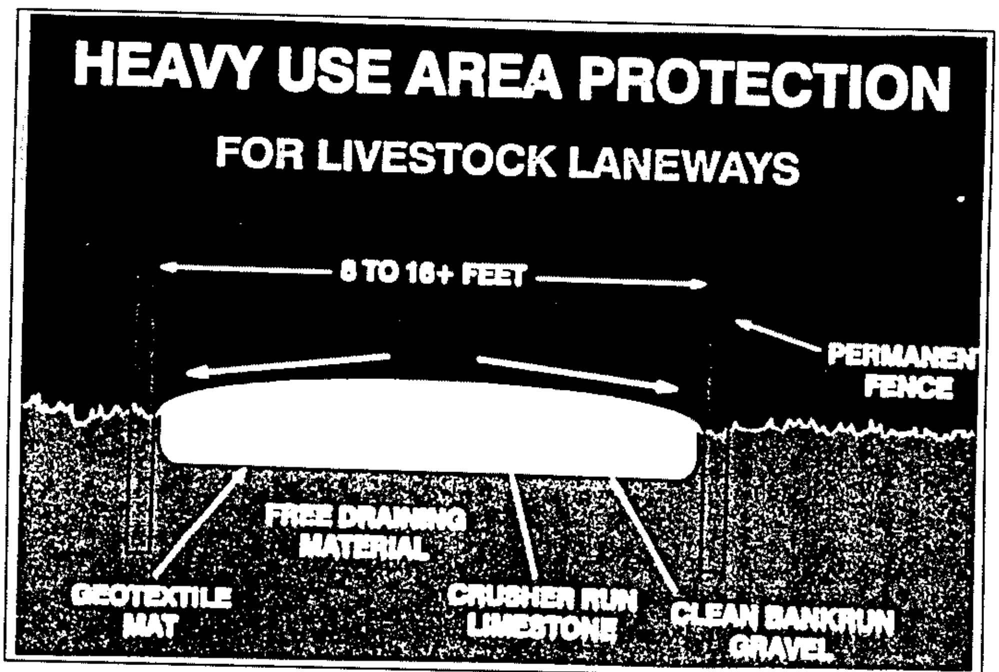

Figure 20. Cross-section of laneway construction.

mound up the subsoil into a berm and then compact it. An important consideration on any laneway improvement is to make the final surface crowned, permitting it to shed water to the sides, keeping it dry. This is true even for laneways composed of gravel or crushed stone. Manure is very effective at plugging up the pores of even the coarsest material, despite their well drained characteristics. Further out on the laneway as the frequency of animal traffic diminishes, there is less need to make costly improvements and there are more management options to deal with troublesome spots.

Shade and Trees

As a general consideration, under normal New York State conditions, there are very few days during the summer when shade is necessary. In fact, providing shade for lactating dairy cows may do more to harm milk production than to help. Livestock are a lot like people in that sometimes things are done, not out of necessity, but out of desire. When a lactating dairy cow stands in the shade on a 75° to 80° day with a cool breeze blowing, it is not because she needs to. It is because she wants to. Unfortunately, while she is standing in the shade she is not eating and, as a result, milk production is reduced. During those few days when temperatures exceed 85° and there is little or no breeze blowing, dairy cows can still graze mornings and nights. During the heat of the day they can be put in the barn or on a pasture with shade. As far as other classes and kinds of livestock are concerned, providing shade may make the producer feel better, but livestock probably do not actually need it in a typical New York summer (Emmick and Fox, 1993).

Moderate amounts of trees may be useful in pasture systems, however, because in addition to supplying shade, they also recycle nutrients and provide food. A tree's deep roots absorb nutrients in the soil that leach beyond the grass roots. When their leaves fall and decay, they return the nutrients to the soil surface where grass roots can absorb them. Some trees like the honey locust have nutritious pods that gradually drop and can be consumed by animals (Daly, 1990).

Paddock Shape and Orientation

Livestock like to cruise fence lines to locate their boundaries or escape points. While doing so, they trample and waste forage. To reduce these impacts, paddocks should be as square as possible. Rectangular paddocks are also acceptable as long as they are no more than four times as long as they are wide. Avoid fencing from tree to tree, and making circles or triangles. Just because a fence is already in place does not mean that it is in the best place.

Paddocks should be oriented according to the pasture characteristics and topography. Since forage growth rates, forage availability, and forage utilization are impacted by differences in forage type, topography, climate, and soil type, paddocks need to be oriented to reduce variability. For example, a single paddock should not include steeply sloping hillsides with hilltops and flatlands because the soil types will vary due to wetness, stoniness, and fertility and the forage species will differ in growth characteristics. As a result, paddocks should not be oriented up and down hillsides, but rather on the contour (Emmick and Fox, 1993).

Paddocks should also be orientated in relation to favorite livestock "camping" spots, water, laneways, and shade. For instance, if the water supply is located at the bottom of a hill, livestock will overgraze the lower slope and undergraze the upper slope. If a paddock includes the side and top of a hill, the livestock will overgraze the top of the hill because they like to "camp out" on hilltops.

Gate Location

Gates need to be located so they do not interfere with the natural movement of livestock as they travel to and from the barn or water. Generally, gates should be located in the corner of the paddock that is closest to the direction the livestock need to travel. If they are not, although some of the livestock will find their way out of the paddock, there will always be a few that will end up trapped in a gateless corner trying to figure out how to destroy a fence.

Conclusion

The information in this bulletin explains some of the ecological relationships between the environment, plants, and animals. This information, coupled with experience, will well-equip any grazier to begin grazing for the first time or to make changes to an established system as the opportunity and need arise.

Every farm and grazing system differ since each farm has its own distinctive qualities (including climate, soils, topography, water resources, etc.) and its own ecosystem. Depending upon these qualities and the goals of the farmer, grazing may supply most or just a small part of the livestock feed and may serve different functions on different farms. The possible combinations are endless because each farm blends the farmer's assets and interests, and the farm's resources. Consequently, a grazing system that functions best is one that is tailored to fit the farm.

Additional sources of information

Resource people

Local Natural Resource Conservation Service (NRCS) office

Local county Cornell Cooperative Extension office

Graze NY - 1(800)472-0399
- A statewide organization that promotes grazing, sponsors local pasture improvement meetings, and provides information about grazing.

Appropriate Technology Transfer for Rural Areas (ATTRA) - 1(800)346-9140
- ATTRA is the national sustainable farming information center. They provide most of their information free of charge on many farm-related topics and have several publications about grazing.

Organizations

The New York Pasture Association - 5840 Perry Center Rd. Warsaw, NY 14569.
- In addition to other events the association holds, there is an annual grazing conference in the early spring. Membership includes a subscription to Pasture Talk.

Grazing publications

Pasture Talk - P.O. Box 620732, Middleton, WI 53562. Phone: 1(800)831-3782.
- A monthly publication that is the "Northland's grass-based dairy and pasture beef publication.

The Stockman Grass Farmer - P.O. Box 9607, Jackson, MS 39286-9607.
Phone: 1(800)749-9808
- A monthly magazine that is dedicated to the "art and science of turning pasture into profits."

Computer E-mail Listserv

GRAZE-L - To subscribe, send an email message to: listserv@taranaki.ac.nz , in the body of the message type only subscribe GRAZE-L .
- This is an electronic bulletin board that lets people interested in grazing post questions, learn about grazing techniques in other parts of the country and world, and learn about the latest information

Computer Software

Cornell Net Carbohydrate and Protein System for Evaluating Cattle Diets version 3.1. A spreadsheet that is used to predict requirements of cattle, evaluate the adequacy of their feeding programs, and design whole herd feeding programs.

Cornell Cattle Systems 5. A stand alone program for predicting performance and profits of growing cattle. Animal Science Mimeo. 115.

Beef Cowherd. A stand alone program that is used to predict requirements, costs and returns for a beef herd with various forage and herd combinations. Animal Science Mimeo. 114.

Dairy Rt 4. A Lotus spreadsheet for balancing rations for grazing lactating dairy cows.

These programs are available, with a user's guide, through Beef Cattle Extension, Cornell University, 130 Morrison Hall, Ithaca, NY 14853.

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Appendix 1

Calculating how many animals can be grazed on a given amount of land.

1) Determine total pasture acreage (PA) for the season.

2) Estimate average pasture yield (PY) per acre.

3) Estimate the length of your grazing season (GS) in days.

4) Estimate the average weight (AW) of the animal for the season.

$$\text{Average weight (AW)} = \frac{\text{(beginning weight + final weight)}}{2}$$

5) Estimate the maximum animal numbers (AN) which can be grazed on your pastures during an entire season:

$$\text{Number of animals (AN)} = \frac{(PA) \times (PY)}{(0.03) \times (AW) \times (GS)}$$

(0.03 refers to the amount of pasture dry matter an animal eats or needs to have access to as a percentage of their body weight.)

(Undersander et. al., 1997)

For example, if you have 20 acres of pasture that produces 4000 lb/acre of forage and you want to pasture ewe/lamb pairs (about 200 lb) for 153 days, then the calculations would be as follows:

$$\frac{\text{20 acres x 4000 lb/acre}}{\text{0.03 x 200 lb x 153 days}} = \text{87 ewe/lamb pairs can be supported by the 20 acres}$$

Note: If animals are allowed to waste forage by trampling or the pasture is not managed well, a 4% (0.04) figure may be used for the amount of forage an animal needs to have access to per day. If we redo the calculations, we see that 20 acres only supports 65 ewe/lamb pairs. **Good management is the key to increasing stocking rates and productivity.**

$$\frac{\text{20 acres x 4000lb/acre}}{\text{0.04 x 200lbs. x 153 days}} = \text{65 ewe/lamb pairs}$$

Appendix 2

A method for estimating the amount of forage available in a pasture is as follows:

1) Clip the forage in 1 square yard of pasture (clip at the height to which the pasture and forage species should be grazed).

2) Weigh all of the forage collected (in pounds) and record the number (in lbs./yd^2).

3) Determine the % forage dry matter (DM):

a) weigh an empty paper plate,
b) take an approximately 1/2 lb. subsample of the forage and weigh on the plate,
c) place sample on paper plate into the microwave with a cup of water on high for 3 minutes,
d) remove the sample and weigh it,
e) place the same sample on paper plate and put in microwave again for 1 minute and weigh it,
f) compare the weight of sample after microwaving for 3 minutes to the weight after microwaving for 1 minute; if the weight did not change go to step 'g', if it did change repeat steps 'e-f' until the weight does not change (at this point the sample is dry),
g) calculate the % forage dry matter (DM) as

$$\text{\% forage dry matter (DM)} = \frac{\text{(final weight of subsample) - (weight of plate)}}{\text{(original weight of subsample) - (weight of plate)}}$$

For example:

$$\frac{\text{(3 oz.) - (1 oz.)}}{\text{(9 oz.) - (1 oz.)}} = 0.25 \text{ (or 25\% forage DM)}$$

4) Determine pasture yield (lbs./acre) as

$$\text{Pasture yield (lbs./acre)} = \frac{\text{(total weight of sample) x (\% forage DM) x (43,560 ft}^2\text{/acre)}}{\text{(9 ft}^2\text{/yd}^2\text{)}}$$

For example:

$$\frac{\text{(2.07 lb/ yd}^2\text{) x (0.25) x (43,560 ft}^2\text{/acre)}}{\text{(9 ft}^2\text{/yd}^2\text{)}} = 2505 \text{ lbs./acre}$$

(Undersander et. al., 1997)