

Building Strong Nutrient Cycles in Kentucky's Pastures

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Well managed grassland ecosystems are one of the most sustainable forms of agricultural production. Few nutrients are removed from properly managed grazing systems. Instead these nutrients are cycled within the grazing system (Figure 1). In addition, proper grazing management maintains a healthy and vigorous sod that protects the soil from erosion and increases rainfall infiltration. This article will discuss how to build and maintain strong nutrient cycles in Kentucky's pastures.

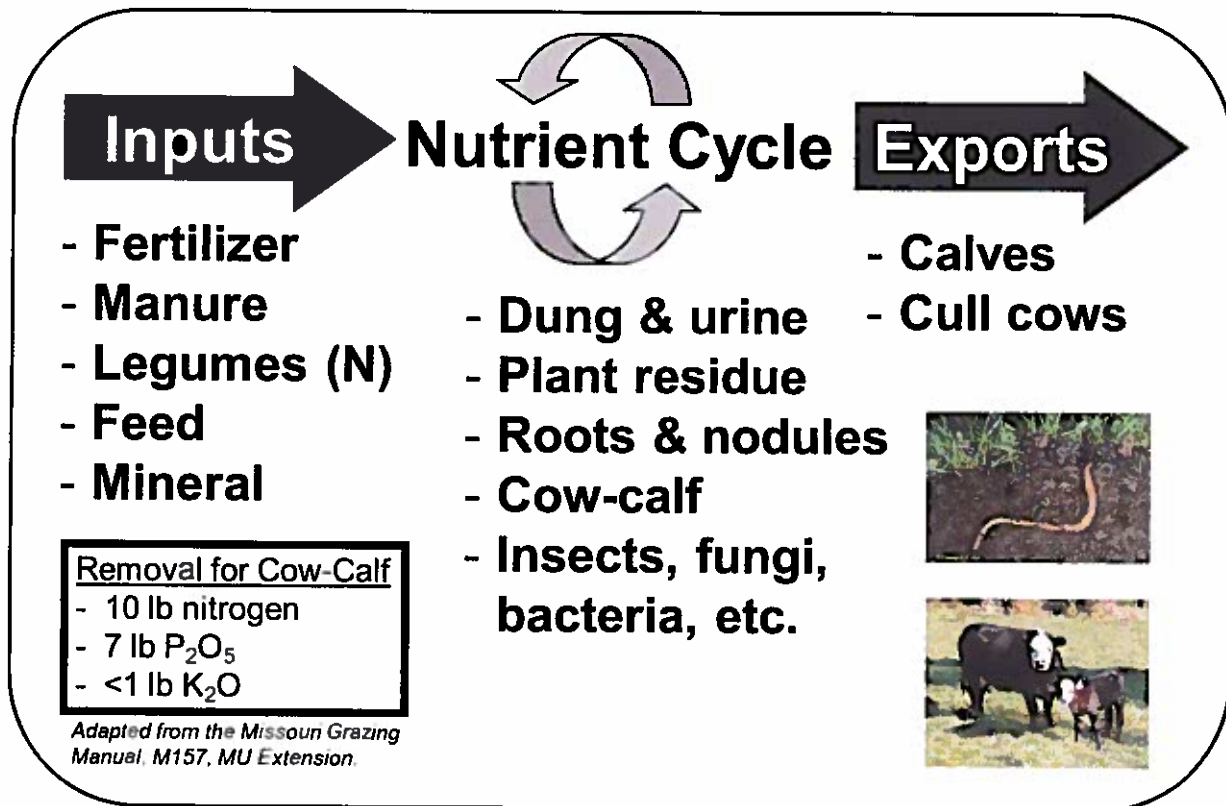


Figure 1. Simplified nutrient cycle for grassland ecosystems. Inputs enter the system in the form of fertilizers and feeds and are cycled within the system through grazing of ruminant livestock and subsequent deposition of dung and urine back onto pastures. Nutrient removal from well managed grazing systems is minimal and many different macro- and micro-flora and fauna are involved in the breakdown of dung, urine, and residual plant materials and the release of plant available nutrients. More information on the role of these different organisms in nutrient cycling can be found in the Soil Biology Primer, available at www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/.

Soil Fertility Principles for Grassland Ecosystems

Adequate soil fertility in grassland ecosystems is key to increasing pasture production and decreasing the amount of conserved forage (hay) that is fed. This can be accomplished by building and maintaining strong nutrient cycles in our pastures. In the remainder of this article, I would like to talk about how we can improve nutrient cycling grazing systems in Kentucky. In this first section, I will outline basic principles of pasture fertilization and what you need to understand in order to get started building stronger nutrient cycles.

Single nutrients can limit overall pasture production. This is called "Liebig's Law of the Minimum". This principle says that plant growth can be no greater than that allowed by the most limiting of essential plant growth factors. In plain English this means that whatever soil nutrient is the most deficient will hold back overall pasture production, even if the other nutrients are sufficient. This is best illustrated by a barrel model in which each stave represents a different nutrient (Figure 2). No matter how much of the other nutrients that we add to the barrel, the barrel can never fill up (maximum yield) until we fix the lowest stave. The take home message is that fertility programs for pastures need to be balanced and focus on identifying and supplying nutrients that are deficient.

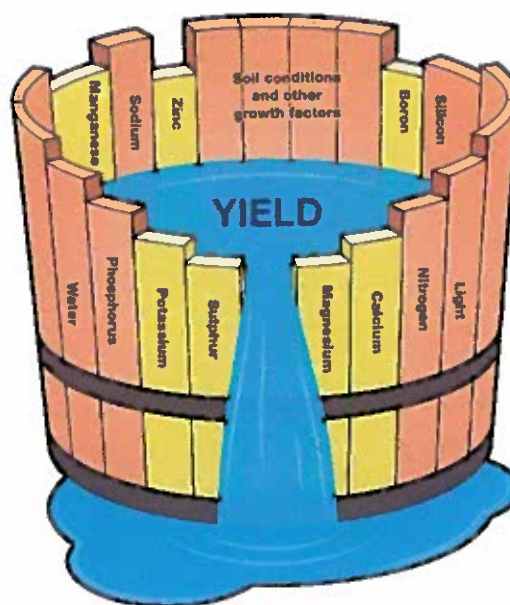


Figure 2. Liebig's barrel illustrates that yield can be no greater than that allowed by the most limiting of plant growth factors.

Grazing animals removing only small quantities of nutrients. Over 80% of the nutrients consumed by livestock are recycled in the form of dung and urine. One cow-calf pair will remove approximately 7 lb phosphate and 1 lb potash per year. If you are stocked at 2 acres per cow-calf unit then our nutrient removal would be 3.5 lb phosphate and 0.5 lb potash per acre per year. It is important to realize that there are other pathways that nutrients are lost from pastures, so even with the limited nutrient removal by grazing livestock, some fertilizer applications will likely be needed over time.

Table 1. Nutrient removal by livestock classes from various production systems. A “-“ preceding the number represents removal and a “+” represents import.

Livestock Class	Nitrogen	Phosphorus as P2O5	Potassium as K2O
Grazing dairy	-84 lb/cow	-34 lb/cow	-28 lb/cow
Confinement dairy	+148 lb/cow	+32 lb/cow	+113 lb/cow
Stocker calf	-10 lb/calf	-3 lb/calf	-0.8 lb/calf
Cow-calf	-10 lb/cow-calf	-3 lb/cow-calf	-0.8 lb/cow-calf
Dry cow	0 lb/cow	0 lb/cow	0 lb/cow

Adapted from J. Lory and R. Kallenbach (2007), *Soil Fertility Management and Nutrient Cycling in the Missouri Grazing Manual*.

Soil pH impacts the availability of nutrients to plants. How acid or alkaline the soil is can have a profound impact on the availability of essential plant nutrients (Figure 3). Maintaining soil pH between 6.0 and 7.0 results in the greatest availability of macro- and secondary-nutrients such as nitrogen, phosphorus, potassium, magnesium, and sulfur. Therefore, applying lime according to soil test recommendations is one of the most important steps that producers can take toward developing strong nutrient cycles in pastures.

Hay and silage remove large quantities of nutrients. In contrast to grazing, making hay or silage removes large quantities of nutrients. These nutrients must be replaced to maintain soil fertility, and stand health and productivity. Each ton of hay that is removed from a field takes with it approximately 15 lb of phosphate and 50 lb potash. In a good year, a tall fescue-clover mix may yield 4 tons per acre and remove 60 lb phosphate and 200 lb of potash (Table 2).

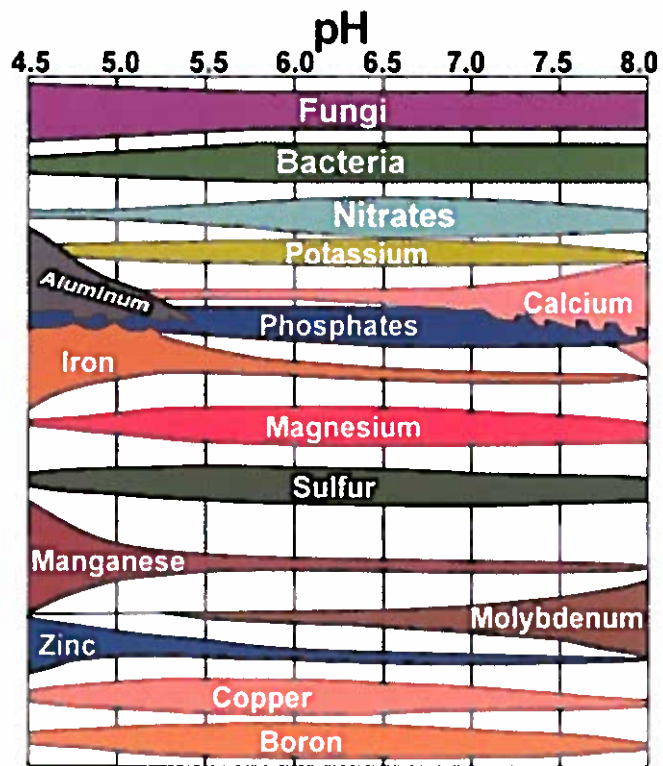


Figure 3. Impact of soil pH on the availability of nutrients to plants.

Table 2. Approximate nutrient removal in pounds per acre for several commonly grown hay types at specified yield levels.

Nutrient	Species and Estimated Yield (tons/acre)			
	Alfalfa @ 5	Tall Fescue @ 3.5	Orchardgrass @ 3	Sorghum-Sudan @ 4
	pounds of given nutrient removed per acre			
Nitrogen (N)	280	135	150	160
Phosphate (P ₂ O ₅)	75	65	50	60
Potash (K ₂ O)	300	185	185	288
Calcium (Ca)	155	30	30	35
Magnesium (Mg)	22	12	15	20
Sulfur (S)	25	14	13	14

Data from Ball et al., 2007, Brown, 1996, Robinson, 1996, and NRCS Animal Waste Management, NEH-651, 1999.

Soil testing provides a starting point to work from. We cannot look at a soil and tell how much lime and fertilizer is needed. Applying fertilizer and lime without a soil test is simply guessing and could lead to an over or under application of nutrients. An over application of fertilizer is bad for your wallet and the environment. An under application of nutrients could lead to lower production and poor stand persistence. Regular soil testing needs to be a part of your grazing system. In most cases pastures should be soil tested every two to three years to help you track your progress. For more information on soil testing recommendations please contact your local extension office or visit <http://www2.ca.uky.edu/aqcomm/pubs/agr/agr1/AGR1.PDF>.

Managing for Legumes

Nitrogen is an important building block of amino acids and proteins and is closely related to both dry matter yield and crude protein concentrations in grasses and non-leguminous forbs. Since nitrogen is highly mobile in the soil, soil testing is not commonly used to make nitrogen fertilization recommendations. In crop production, nitrogen recommendations are commonly based on yield goals. However, in well

managed grasslands strong nitrogen cycles can be developed over time. A key component of these cycles is the use of legumes such as red and white clover and alfalfa (Figure 4).



Figure 4. This pasture sward contains a strong legume component.

Legumes fix nitrogen in the air to a plant available form. The importance of legumes in grasslands has long been recognized. They bring nitrogen into grassland ecosystems via symbiotic nitrogen fixation, improve forage quality and animal performance, and dilute the toxic effects of the endophyte found in tall fescue. It is estimated that commonly used pasture legumes will fix between 50 and 250 lb nitrogen per acre per year (Table 3). This nitrogen is valued at \$35 and 250 per acre per year.

Table 3. The amount and value of nitrogen fixed by commonly used pasture legumes.

Legume	Nitrogen Fixed lb/A/yr	Value of Fixed Nitrogen (\$/A/year)		
		N cost=\$0.25/lb	N cost=\$0.50/lb	N cost=\$0.75/lb
Alfalfa	150-250	38-63	75-125	113-188
Red Clover	75-200	19-50	38-100	56-150
Ladino Clover	75-150	19-38	38-75	56-113
Annual Lespedeza	50-150	13-38	25-75	38-113

Adapted from *Southern Forages, Fourth Edition*.

Legumes share nitrogen with grass indirectly. Nitrogen is transferred to grass grown in association with legumes through the ingestion of legumes and subsequent deposition of dung and urine by grazing animals (Figure 3), death and decomposition of above and below ground plant parts including roots, shoots, and nodules, and to a lesser extent direct legume to grass transfer. The sharing of nitrogen is limited during the first growing season after establishment.



Figure 5. Nitrogen from legumes is shared indirectly with grasses through grazing.

Overseeding legumes is not the same as applying commercial nitrogen fertilizer. Mixed stands of grasses and legumes may yield as much or more than grass monocultures fertilized with moderate rates of nitrogen, but a significant proportion of that yield will be made up of the legumes. In other words, legumes not only increase grass growth by supplying nitrogen, but also compensate for lower grass production.

Applying nitrogen fertilizer to mixed stands sifts botanical composition. The addition of nitrogen fertilizer to grass-legumes mixtures tends to sift the composition of the mixture toward grass. It also reduces nitrogen fixation in the legumes since legumes would rather use nitrogen from the soil if it is available.

Improved legumes require good soil fertility to be productive and persistent. Improved legumes such as red and white clover and alfalfa require relatively high soil fertility and pH's above 6.0 to be productive. This means that an initial investment in potash, phosphorus, and lime must be made. These applications need to be based on a recent soil test.

Legumes are most productive when rotationally stocked. Like other forages legumes respond well to improved grazing management. Resting pastures allows leaf area to regrow and carbohydrate reserves to be stored up. In general, tall growing legumes like alfalfa and red clover are more dependent on stored energy for regrowth. This means that they need time to rest and replenish their stored carbohydrates between grazing events. That is the reason that alfalfa does not persist well in continuous grazing systems. Even white clover that tolerates close grazing very well benefits from rest.

Rotational stocking is a tool to manage botanical composition. How we graze our pastures has a profound impact on botanical composition. In grasses, energy for regrowth is dependent on leaf area remaining after grazing. The remaining leaf area is like a solar panel that captures sunlight and converts it into energy (sugars and carbohydrates) that the plant can use to fuel regrowth. The more leaf area we leave, the larger the solar panel, the faster pastures will regrow, and the more competitive the grass will be the tall growing legumes. If we graze closely with a rest period between grazings, we will tend to favor tall growing legumes in the sward since they are more dependent on stored carbohydrates for regrowth.

Mixed stands can be stockpiled for winter grazing. Grass-legumes mixtures can be stockpiled for winter grazing, but they need to be used first since legumes tend to deteriorate before grasses. Save pure stands of grass that were fertilized with nitrogen for late winter grazing.

Overseeding is needed to introduce and maintain improved legumes. Approximately 25 to 30% of the pasture on a dry matter basis should be made up of clover or other legumes. Even improved red clover varieties only last two to three years. Annual lespedeza will sometimes reseed itself, but as a general rule this is not

dependable. A good general mix for overseeding pastures in Kentucky is 6-8 lb medium red clover, 1-2 lb of ladino or grazing type white clover, and in some cases 10 lb of annual lespedeza per acre. At current seed prices this mixture would cost around \$20 to 30 per acre. This cost is the equivalent to applying 20-30 lb of nitrogen per acre.

Grazing Management

The role of grazing management in building stronger nutrient cycles in pastures is often discounted. However, its impact on the establishment and maintenance of strong nutrient cycles in in pastures cannot be understated. Adopting rotational stocking increases pasture productivity, reduces hay feeding, improves nutrient distribution, protects the soil from erosion and increases rainfall infiltration.

Grazing animals will redistribute nutrients in pastures. Overtime grazing animals can move nutrients from one area of the pasture to another through urine and dung deposition. This problem is the worst in large continuously grazed pastures where animals go out and graze then come back to shade and water areas where they urinate and defecate, thereby increasing the nutrient concentrations in these areas (Figure 3).

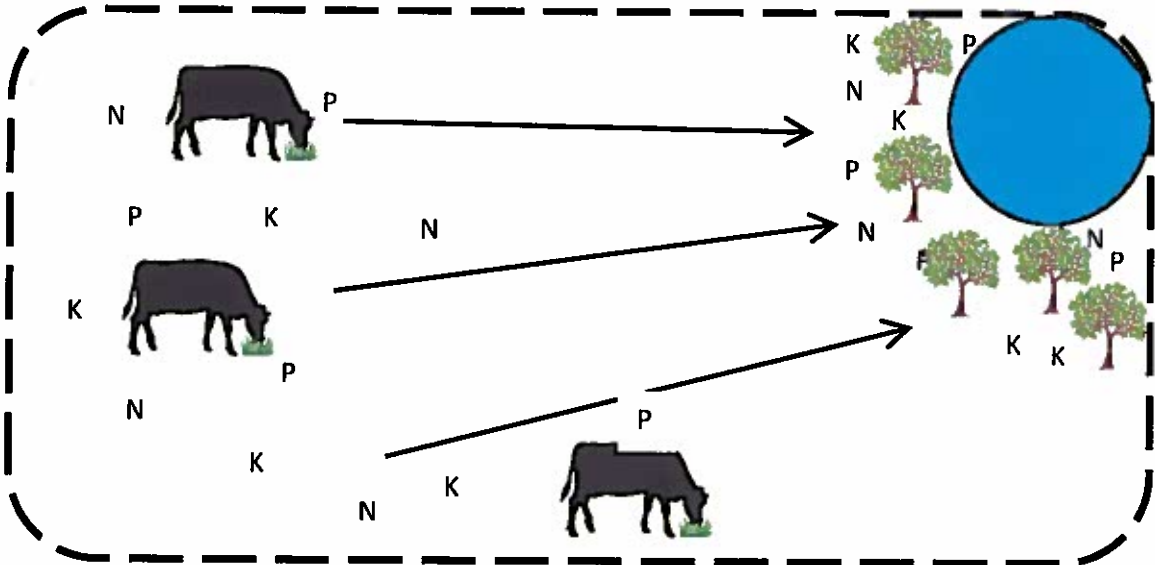


Figure 3. In a large continuously stocked pastures, grazing livestock will move nutrients from grazing areas and concentrate them around shade, water, and feeding areas.

Increasing stocking density improves nutrient distribution. Subdividing pastures and utilizing rotational stocking results in a more uniform deposition of urine and dung within a grazing system. Research conducted at the University of Missouri found that under continuous stocking it would take more than 25 years for a dung pile to be deposited in every square yard of the pasture compared with 8 years for a pasture that

was rotated on a 14-day schedule. Rotating on a 2 and 4-day schedule resulted in a dung pile being deposited in every square yard of pasture in 2 and 4.5 years, respectively. I truly hope that everyone appreciates the contributions of the poor graduate student who worked on this project!

Healthy pastures are more efficient at harvesting rainfall and using nutrients. Allowing pastures to rest between grazing events helps to maintain a healthy and vigorous sod with a strong root system. This increases water infiltration, reduces erosion, and allows plants to more efficiently utilize soil nutrients.

Buying and feeding hay and concentrates imports nutrients into grazing systems. Each ton of hay contains nitrogen, phosphorus, and potassium along with organic matter (Table 1). At today's fertilizer prices these nutrients are worth than \$35 per ton of hay. Buying hay and feeding it on your worst paddocks may be a cost effective way to build fertility in your grazing system over time. However, it is important to realize that this approach will be much slower than applying commercially available fertilizer or poultry litter.

Hay feeding can be used to redistribute nutrients within a grazing system. Hay can be produced on paddocks or in fields that contain high levels of nutrients and then fed in areas that are low in fertility. Overtime nutrients can be transferred from areas of high concentration to areas of low concentration.

Conclusion

One of the most exciting things about ruminant livestock production is the sustainability of well-managed grazing systems. In comparison to crop and hay production, relatively small quantities of nutrients are removed, better insulating graziers from the wide variations in fertilizer prices. It is always important to remember that change within a grazing system comes slowly. In fact, it can take three to five grazing seasons to see measurable changes. So develop a long-term grazing plan, implement it, and be patient!