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"From the Ground Up"

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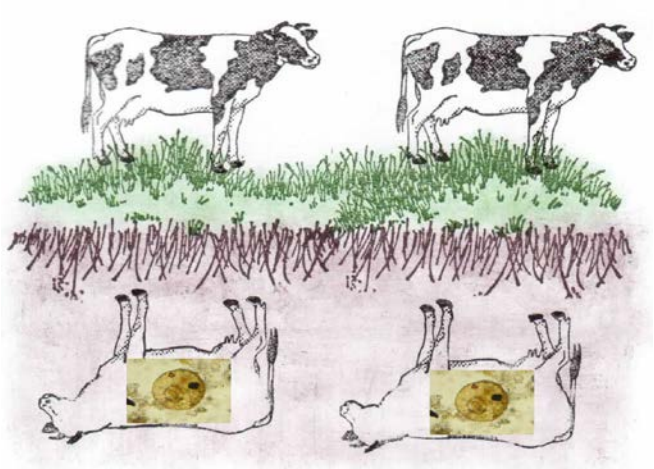
News and Information on natural resource management in western North Dakota

Every Farm Has Livestock

By Jon Stika

Every farm has livestock… trillions of head of them in every acre. That's right; every acre of healthy soil has the equivalent weight of two or more cow's worth of microorganisms living in the soil. And like all livestock, they need to be fed. On the average North Dakota farm of 1,200 acres, that's over 2,400 head of cows-worth of soil life that need something to eat to keep them alive and growing, just as we would expect to keep a herd of cattle alive and growing throughout the year.



An acre of healthy soil has the equivalent of two cows worth of microorganisms living in it. (Illustration by Eve Stika)

What does this underground herd eat? The easiest source of food for soil microbes to eat is the sugar exuded through the roots of living plants. The next easiest food source for soil microbes to utilize is dead plant roots that can be decomposed by soil microbes. Following dead roots on the menu of soil microbes is crop residues: straw, chaff, husks, stalks, flowers and leaves. When root exudates, dead roots, or plant residues are not available, soil microbes will feed on other soil organic matter. One of the most easily digestible portions of soil organic matter is the biologically produced glues that hold soil aggregates together. When soil organic matter is the only source of food available for soil microorganisms, soil organic matter will decline in both quantity and quality. This will lead to a decline in soil aggregate stability, water infiltration and plant nutrient cycling.

This is why it is vital that each field host a diversity of plants that occupy the soil with living roots and cover it from above. A diverse crop rotation, cover crops and no tillage can provide the soil with the food and cover it needs to feed and care for the two cows that live within each acre of soil. Before you leave a field bare or fallowed, think of the underground herd of microbes that need to be fed to keep your soil functioning to support the plants that power the profit of your farm or ranch.

Managing for soil health is like managing for rumen health

By Elin Westover, Montana State University Extension, Fallon/Carter County Agent

Many ranchers are farmers, and many farmers are ranchers. Producers often consider themselves to have expertise in one area, but generally not both. However, similarities in the biological systems of each field mean similar approaches can be used to maximize production in soils and livestock. Soil functions as a plant's stomach, similar to the role of the rumen in ruminant animals (cattle and sheep). Both the soil and the rumen are populated with microorganisms: bacteria, fungi, and protozoa. The function of microorganisms in both systems is dependent on the quality of the environment and availability of nutrients. Health and productivity of rangeland and crops as well as cattle and sheep can be attained by feeding and managing microorganisms and their environment.

1. **Microorganisms eat first.** To maintain healthy ruminant animals, rumen microorganisms must eat first, which in turn will feed the animal. When feed enters the rumen (the second and largest compartment of a ruminant's stomach) microorganisms get access to the food source first and break it down into useable nutrients. For example, rumen microorganisms break down carbohydrates for their use and volatile fatty acids are an end product. In turn, volatile fatty acids are used as an energy source for the host animal. Similarly, the microorganisms in the soil must break down certain materials before plants can

utilize them. Organic forms of nutrients such as nitrogen, phosphorus, and sulfur are present in the soil either as crop residues or manure (organic matter) and must undergo a mineralization process before the nutrients become plant-available.

A group of producers learns about soil health at a tour in Dunn County, ND this summer.

2. **Do not mess with the "bugs."** The contents of the rumen are partitioned into three layers based on their density. The upper region of the rumen contains the gas by-product of microbial fermentation. Grain and fluid-soaked roughage descend to the bottom region, and newly-arrived roughage lies in the middle. There are specific microorganisms associated with each layer due to the degradation process of the specific material. Rumen contractions are continually mixing the contents slowly. If rumen contents were vigorously stirred into one homogenous mixture the animal would not perform normally. The microorganisms' environment would be completely disturbed and it would take time for their environment to be re-established and for the rumen to return to normal. The same idea can be applied to soil, which can be thought of as the plant's stomach. Management tools such as tillage, fertilizer and pesticide applications, and livestock can be used to improve soil productivity or can be detrimental to soil health if not practiced correctly. When management tools are applied incorrectly and does not complement the soil biology, microorganisms must spend time and energy to re-establish equilibrium with the new environment. For example in the short term, tillage helps microorganism break down organic matter, but in the long term this loss of organic matter will hurt soil health and crop yield.

3. **Microorganism populations require time to adapt.** In the rumen, time is needed for microbial populations to develop and function at beneficial levels. Furthermore, each microorganism has a unique function, and depending on the livestock's diet, the populations of microbes may need to shift. Therefore animals must be slowly acclimated to diet changes. It takes roughly 7 days for microorganisms in the rumen to adapt to a new feedstuff. Livestock producers are encouraged to change rations gradually, by introducing a new roughage or concentrate source to livestock incrementally. This allows the bacteria, fungi and protozoa to adapt and shift ensuring the animal remains healthy and receives the maximum amount of nutrients from a feed source. Likewise, changes in soil quality and health will not improve overnight; time is required for microorganism populations to build to a beneficial level.

4. **Carbon: nitrogen ratio is critical.** Health of the soil, like the health of ruminant animals, will be improved when carbon and nitrogen are in balance. Microorganisms break down the protein a ruminant animal consumes and uses the nutrients to their advantage first. The host animal will then receive the nutrients in the form of amino acids or nitrogen, or the protein may by-pass rumen microbial degradation and will be available for digestion in the small intestine. The "bugs" use the nitrogen and carbon from protein to grow and their waste provides a portion of the essential amino acids the animal needs. If there is a shortage of carbon, the nitrogen cannot be utilized and is excreted by the animal. If there is a deficiency of nitrogen, the microorganism activity is reduced and the animal's growth and productivity will suffer. Similarly, the nitrogen waste from the microorganism's digestion of organic matter in the soil is what benefits plants. Digested organic matter can be very beneficial to soil because it helps hold onto mobile nutrients as well as moisture. The carbon: nitrogen ratio is critical in balancing the breakdown of organic matter in a slow release fashion. If the ratio is too high, organic matter is degraded too slowly and the nutrients do not cycle quickly enough between the soil, plants and microbes. Most plant organic matter has a higher carbon: nitrogen ratio which inhibits its breakdown. Too much undigested (or composted) organic matter can rob available nitrogen from live plants as the microorganisms that break down organic matter need relatively large amounts of nitrogen to break down cellulose – the main structural component of plants. If the carbon: nitrogen ratio is too low, the nutrients cycle too rapidly and nothing is left

to supply the plant with nutrients, or oxygen in the soil can be depleted which is necessary for both microbes and crops. Additionally, when degradation of organic matter is occurring too quickly, the soil becomes vulnerable to wind and water erosion, and there is increased evaporation [of water from the soil].

5. **Dead or alive.** Just as microbial activity is important, dead "bugs" have an essential role in the biological system too. As the microorganism population in the rumen dies, they are passed to the lower gastrointestinal tract where they are degraded and utilized as a protein source by the host animal. Microorganisms themselves are a great protein source for ruminant animals. Bacteria, fungi and protozoa generally contain 20 to 60 % crude protein on a dry matter basis with bacteria providing the most at 50% (±5%) crude protein. Similarly, the microorganisms that die in the soil can also be broken down to supply nitrogen and other nutrients plants can utilize. This nutrient cycling is an important facet of soil health and plant nutrition.

Winter Wheat harvest in Golden Valley County, ND on a field with a diverse crop rotation and no tillage for over 20 years.

6. **More is not better.** If you feed cattle more protein than needed, the protein is used as an expensive energy source rather than a nitrogen source. Additionally, there is a point that it starts to cost the animal energy to get rid of the excess nitrogen and can cause infertility due to high pH levels in the uterus. If you add more nitrogen fertilizer to your soil than is needed, it will not be efficiently utilized and often lost through leaching beyond the reach of plant roots or lost as a gas to the atmosphere.

7. **Create the ideal environment.** Moisture and temperature affect microbial activity while pH affects the food availability for the microorganisms. Consequently, it is critical to understand and manage the environment of the rumen and the soil. The rumen is an effective fermentation vat as long as the environment is anaerobic (without oxygen) with a constant temperature, pH and moisture content. It is important to note the environment can change as a result of diet (grain versus roughage diet), but as long as it is changed over a period of time, the microorganisms can adapt. Diet changes consequently alter the proportion of volatile fatty acids produced. Like the rumen, soil can be thought of as a semi-aquatic environment. "Bugs" in the soil are most active in moist, warm conditions. Each species of microorganism functions best at a specific temperature and pH. Keeping the soil covered at all times with a crop or crop residue is one method to help regulate temperature and avoid extremes. Applications of lime, acid-forming fertilizers, and other soil amendments can shift soil pH. A soil pH of 7 or "neutral" allows for the best exchange of soil nutrients and plant roots – too acid and nutrients leach into the groundwater or streams and too alkaline and nutrients are tightly chemically bound and are unavailable to plants. It is always a good idea to test your soil before spending lots of money to amend it or potentially harm it. Furthermore increasing the diversity of the organisms in the soil will provide balance and stability to soil pH in the rhizosphere, the area immediately surrounding plant roots where soil organisms are concentrated.

8. **Papillae/ villi = Root Hairs.** Much like a shag carpet, the rumen wall is lined with finger-like projections called papillae. Likewise, the inner surface of the small intestine is covered with finger-like projections called villi. The size and amount of villi and papillae change as the diet changes. The function of papillae and villi is to increase the surface area and therefore increase absorption of nutrients and water. Similarly, root hairs are very important to plants and help absorb water and minerals from the soil. Root hairs are small lateral extensions of a mature root and are visible with the naked eye. Root hairs serve as the primary nutrient and water uptake mechanism for plants. Plants' association with mycorrhizal fungi can also increase the volume of soil that can be accessed by plants. Fungal hyphae are like a second set of roots that explore the soil for water and nutrients. The water and nutrients that the

fungi capture from the soil are provided to the host plant in exchange for sugars the plant produces through photosynthesis.

Corn is planted without tillage on a farm in Hettinger County, ND.

9. **Diversity.** All microorganisms have a specific role and utilize specific organic matter. The diversity of microorganisms in the rumen allows the animals to get nutrients from the feed consumed. Additionally, ruminant animals perform better when on a diverse, non-monoculture diet that provides the microorganisms and animal with a complete diet of nutrients, including vitamins and minerals. A diverse crop rotation which utilizes all four crop types (cool-season grasses and broadleaf plants and warm-season grasses and broadleaf plants) can be very beneficial. One of the benefits of crop rotations and diversified planting is array of root structures to scavenge nutrients and water from different levels in the soil and make them available. Increasing plant diversity increases soil health and soil function by providing the soil food web with nutrient, energy and water cycling.

10. **Continual and Consistent.** Cattle and sheep need access to a continual and consistent food supply in order to perform to their genetic potential. Furthermore, the rumen microorganisms are unable to function to their potential when their feed source is inconsistent. Likewise, when there are live plants in the soil, the biology has its preferred food. Organic matter in the soil provides soil microorganisms with a feed source to break down for the plant. Plants do not thrive in soils that are low in organic matter because microorganisms have limited access to feed. Both rumen microorganisms and soil microorganisms suffer from intermittent feed availability.

Managing the soil as microbial habitat is critical to the functioning capacity of the soil, just as managing the rumen as microbial habitat is critical to the health of a cow or sheep. To be profitable and sustainable, producers must realize that the soil, like the rumen, is a biological system and must be managed accordingly.

Using Technology to Benefit Biology

In a recent article in the No-Till Farmer, Dr. Dwayne Beck emphasizes that biological problems in cropping systems require biological solutions that can be facilitated with the thoughtful application of technological tools. One of those tools is a cover crop. Beck says that; *"Cover crops and forage crops provide no-tillers an opportunity to increase the intensity and diversity of their system when and where the production of a cash crop would be impossible, unprofitable or excessively risky"*.

A cover crop in Slope County, ND.

Cover crops can be utilized to help balance the diet of the soil food web to keep it well fed and diverse. This also reduces the risk of plant nutrients, such as nitrogen, from leaching below the root zone of annual crops. Leached nitrogen is not only a hazard to groundwater supplies, but a waste of money when the nitrogen is no longer available to a crop.

Paying attention to the details of how no-till equipment is operating to achieve the goal of placing seed correctly is also important. Producers may need to make adjustments or modifications to planters/drills to be successful no-tillers. Read the entire article in the No-Till Farmer here.