Optimizing Managed Grazing for Soil Health and Sustainable Production Systems

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Introduction

Well-managed grazing systems are critical to pasture and rangeland sustainability, and necessary for effective resource stewardship, financial stability and profitability, and robust rural communities. Soil health provides the underpinning for forage production, which in turn supports livestock and wildlife populations. According to Wayne Honeycutt, PhD, Chief Executive Officer and President of the Soil Health Institute (SHI), soil health refers to "...a soil's capacity to function as a vital living ecosystem that sustains plants, animals, and humans." The Natural Resources Conservation Service (NRCS) also embraces this definition (e.g., *http://bit.ly/2ndrlyn*). Many things can be described in terms of inherent "quality" – air, water, food, architecture, clothing – but only living things can have health. Soil is very much alive and contains much of the world's biodiversity. As such, soil health influences rangeland productivity, and is an indicator of sustainability and profitability. This definition speaks to the importance of managing soils and grazing lands so that they are sustainable for future generations.

Successful land managers must balance livestock's utilization of plants with ecosystem function, including contributions to and interrelationships with soil nutrients, water infiltration rate and holding capacity, and vegetative growth and production. Managing to optimize these interactions allows ranchers to improve their grazing systems, simultaneously maintaining nutrients in the soil and influencing soil structure, thereby enhancing water availability and forage production. Grazing management supports healthy pastures and rangelands that persist longer into drought, and rebound more quickly afterwards, improving resilience and sustainability of grazing lands for more consistent livestock production. Interrelationships among soil health, forage, and grazing systems formed the foundation for a synergistic Cattlemen's College session at the 2017 Cattle Industry Convention in Nashville. Session speakers delved into the basics of soil health, linkages to pasture and rangeland management, and benefits of managed grazing for soil health and forage production in pasture and rangeland systems.

Significance of Soil Health

Characterizing soil health involves measuring physical, chemical, and biological properties. Soil health influences, and is affected by, the rest of the larger environment. Steve Shafer, PhD, SHI Chief Scientific Officer, emphasizes that crop and livestock management are manipulations of the local environment for desired ends, and can have either a positive or negative impact on soil health. Thus, soil health integrates many aspects of soil science, agricultural management, and natural resources. Maintaining soil health is important to achieve the four goals of a sustainable agricultural system: 1) produce what is intended to be produced; 2) protect for later production the foundation of natural resources; 3) provide economic incentive to keep the

system in production; and 4) support the societal framework that enables it (paraphrased from National Research Council, 2010, Toward Sustainable Agricultural Systems in the 21st Century).

Enhancing soil health in pasture and rangeland systems is essential to addressing numerous agricultural and environmental challenges in the 21st century. Shafer states that healthy soil contributes to producing adequate food for 9 billion people by mid-century; provides resilience to a changing and unpredictable climate, via sequestration of carbon from the atmosphere into the soil, which leads to increased water infiltration and improved water holding capacity; improves retention of sediments and nutrients, making the land more productive and surface waters less contaminated; suppresses plant diseases; and provides other ecosystem services. According to Shafer, improvements in soil health can lower yield variability, reduce production risk, and add to a farm or ranch's profitability. Crop yield during drought years can be increased by improved water-holding capacity. Cover crops and pastures can capture nutrients that represent input costs that would otherwise be lost.

A soil profile supporting a productive grass forage crop. The dark (moist) A and B horizons overlaying the clay subsoil show evidence of water and root penetration throughout the soil.
Photo credit Ken Tate.

Grazing management on pasture and rangelands also contributes to soil health. Shafer points out that compared to continuous grazing, rotational grazing stimulates regrowth of the forage plants, and proliferation and turnover of the plant roots adds carbon to the soil in amounts – and at depths where it can be retained – that improves the condition of grazing lands. Improved forage growth and regeneration contributes further to livestock productivity. In addition, Shafer notes that "moderate" grazing can increase plant biodiversity and suppress invasive weeds.

The critical significance of careful grazing management is emphasized by Shafer as a tool that can enhance soil health over what might be considered a "natural" or a "baseline" condition for a given location. It is a common misconception that "moderate" grazing was what the indigenous American bison did on the range;

however, it is important to note that their numbers, perhaps in the tens of millions, heavily contaminated surface waters with their wastes and in many cases stripped the land of vegetation to the point that the animals starved. Shafer cites research asserting that such grazing was in fact not sustainable in the modern agricultural sense, though it may have gone on, boom and bust, for millennia before Europeans arrived in North America. Proper land management, with an eye toward sustaining and enhancing the vitality of the living soil, will help ensure sustainability and long-term use of soil and the land to meet needs of humans and provide benefits for the overall environment.

A scientist examining soil health on annual rangelands piques the interest of the locals. Soil Scientist: Toby O'Geen, UC Davis Department of Land Air and Water Resources.
Photo credit Ken Tate.

Grazing Land Soil Health Specifics

Building on tenets introduced by Shafer, Dennis Chessman, PhD, NRCS Southeast Regional Soil Health Team Leader, expands upon the importance of healthy soils to provide essential functions for agriculture and society as a whole. Among the important agricultural benefits of a functioning soil is its ability to capture and store water for plant growth. The significance of this enhanced water retention was a recurring theme throughout the session. Chessman explains that although soils differ in their capacity to infiltrate water based on their texture or the amount of sand, silt and clay they contain, the management of pasture and rangeland has a significant effect on how surface soil layers in those systems respond to rainfall or irrigation. A review of the Web Soil Survey *(http://bit.ly/2o2kSKZ)* provides information on the advantages and limitations of soils.

Chessman emphasizes that management has a direct effect on soil structure, which is defined as the way the sand, silt and clay particles are stuck together into larger units called aggregates. Good soil aggregation is

essential for water and air movement, root growth, the availability of plant nutrients, and therefore the health and productivity of the plants growing in that soil.

Additionally, according to Chessman, there is a world beneath grazing lands that teems with an incredible diversity and abundance of life. Life in the soil is dependent on carbon that comes through plants' roots and from dead plant material. Much of the carbon that enters plants during photosynthesis is converted to carbohydrates and other organic compounds that provide for the plant's needs. It offers energy to animals that eat the plant, and provides the food that drives the underground living world. If photosynthesis is limited, carbon that can enter the soil is limited. When organic carbon in the soil is limited, life and health in the soil is diminished. Chessman points out that this matters because good soil aggregation is the result of a vibrant soil community. The smallest soil organisms, bacteria and fungi, along with plant roots and the compounds released through roots, provide the glues and physical structures necessary for creation of soil aggregates. Aggregate-forming glues, whether exuded by roots or arising from soil organisms, are carbon-containing substances. Chessman cautions that if grazing lands management disrupts carbon flows into the soil, or leads to a decrease in soil organic carbon, the living soil community is adversely affected. As life in the soil declines, soil aggregates become more fragile or even non-existent, and soil's water infiltration rate and storage capacity decreases. The bottom line is that soils with healthy, diverse communities of organisms can provide more water to plants.

A scientist examines the structure of a soil aggregate for evidence of compaction on a rangeland pasture. Soil structure refers to the arrangement of the soil organic and mineral particles and of the pore spaces located between them.

Photo credit Ken Tate.

Maximizing carbon entry, and the flow of organic carbon through a grazing system, can be achieved with proper management. Chessman suggests that controlling grazing to optimize root growth and development of forage plants helps to ensure that an abundance of roots are present in the soil to provide organic carbon that drives the soil ecosystem. Managing for good root growth below ground means managing what happens above ground. Since carbon that provides energy for the soil system comes from photosynthesis, maximizing the ability of plants to capture sunlight is critical. This means managers must maintain appropriate stock densities, duration of grazing, and adequate non-grazing rest periods for plants. Forage plants that are grazed too heavily or too often for the site and plant species will not be optimally productive, as they could be with less intensive grazing pressure. Chessman cautions that improper grazing management

decreases the photosynthetic capacity of a pasture or range site, and plant root growth is stunted. This results in poor forage production, and inadequate organic carbon to feed the soil system to achieve the water-related benefits of good soil structure.

Optimizing Pasture-based Grazing Systems

Relationships among soil health, water infiltration and holding capacity were a focus throughout the session. Johnny Rogers, M.S., North Carolina State University Amazing Grazing Program Coordinator, grazes livestock between North Carolina and Virginia, and is familiar with low precipitation years. He posits that graziers develop skills by making mistakes, thereby becoming better equipped for future challenges. Many factors that influence the success of livestock operations are beyond graziers' control (weather, markets, government policy, etc.). However, Rogers explains that with good grazing management, graziers can ensure that more of the moisture that falls enters the soil and is retained for plant growth.

Using a grazing stick to measure forage height.
Photo credit University of Idaho Extension.

Effective rainfall is the percentage of rainfall that becomes available for pasture vegetation. Rogers cautions that losses from runoff, evaporation and percolation are expected, but can be managed. While grassland productivity can be improved through fertilization, herbicides, and planting new pasture forage varieties, plant growth will often be limited by plant-available water, regardless of pasture amendments. Therefore, Rogers recommends exploring opportunities to enhance soil health to capture more of the water that falls on pastures.

How can graziers improve soil structure? The best method to build pasture soil structure is through intensive forage management. Vegetative ground cover will insulate soil from the sun. Rogers notes that it has been well documented that bare soil can reach temperatures that inhibit soil's microbial activity (i.e. less glues produced, lower nutrient cycling, etc.) and increase soil moisture loss through evaporation. Managing forage heights is important year round, but can become more significant during dry, hot summers.

Additionally, Rogers asserts that pasture rest periods will build soil structure, because rested plants have larger root systems. A thriving root system will feed more soil microbes, and they will produce more glomalin (a.k.a. the glues) needed to maintain soil architecture. Forages must be carefully monitored to determine whether they're fully recovered from past grazing events. A grazing stick can help producers evaluate current conditions to see whether pastures have reached the target height. Rogers states that a properly executed rest rotation system creates a more resilient, drought tolerant forage base.

Potential to create better soil structure through grazing management is paramount to Rogers. The grass height when cattle come off a pasture is critical. Leaving the

soil covered with growing plants prevents the destructive impact of rain drops, which are a source of erosion that can impair soil structure by dislodging soil particles. According to Rogers, erosion damages pastures and carries soil, nutrients, herbicide residues, etc. into surface waters. impact of rain drops, which are a source of erosion that can impair soil structure by dislodging soil particles. According to Rogers, erosion damages pastures and carries soil, nutrients, herbicide

Examining the structure of a soil aggregate for evidence of compaction on a rangeland pasture. Soil structure refers to the arrangement of the soil organic and mineral particles and of the pore spaces located between them. Compaction by excessive hoof action will compress soil aggregates, thus limiting root and water penetration.
Photo credit Ken Tate.

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Additionally, Rogers cautions that equipment traffic and grazing, especially during wet conditions, also can damage soil structure by compacting soil and compressing soil pores. Limited pore space leads to poor water infiltration, root penetration and air movement. Plant growth will be reduced in compacted soils. Graziers can prevent compaction by reducing equipment traffic and pulling cattle off pastures during extended wet periods. A well-drained sacrifice paddock with hay feeding offers an alternative option. Removing cattle is not always feasible and pasture can become pugged during wet conditions. Rogers advises that such pastures should receive extra rest periods during future grazing cycles to repair soil structure. In some cases, producers have added plants species to pastures - e.g. brassica, radishes, turnips, etc. - to alleviate soil compaction.

Rogers concludes that while graziers cannot manipulate the amount of water that falls from the sky, through management they can control what happens to this precious resource once it lands in a pasture. Managed grazing has numerous benefits to pasture-based livestock systems. Critical points for producers to build soil health and increase water infiltration include:

- ✓ Determine the farm or ranch's carrying capacity
- ✓ Maintain a flexible stocking rate at or below carrying capacity
- ✓ Use stock density to build healthy soil
- ✓ Rotate cattle to maintain proper residual in pastures
- ✓ Rest forages to promote root development
- ✓ Monitor the health of the entire pasture eco-system

Managed Grazing to Optimize Sustainability of Rangeland Systems

The points Rogers highlights are reinforced in the context of rangeland systems by Kenneth Tate, PhD, Professor and Russell L. Rustici Endowed Chair in Rangeland Watershed Science at University of California – Davis. Echoing earlier emphases, Tate notes that ranchers must manage the intensity and timing of grazing, as well as — equally important — rest from grazing, to 1) optimize forage and livestock harvest; 2) meet forage plant requirements for growth and vigor; and 3) mitigate potential negative impacts on soils and the environment. He points out that optimal cattle performance in rangeland systems depends upon abundant, nutritious forage – which in turn depends upon healthy forage plants with enough leaf area to capture sunlight, and many deep roots to access abundant soil moisture and nutrients.

Grazing management that removes too much leaf area weakens forage plants. Plants cannot capture enough sunlight for regrowth, and will sacrifice roots and energy reserves to support essential leaf regrowth. With fewer roots, plants cannot fully access soil moisture and nutrients. Tate cautions that weakened forage plants can be displaced by undesired or invasive species. As Rogers notes, poor grazing management on wet, moderate to heavy textured soils will also often compact the soil and limit water, root, and nutrient penetration. This is a dangerous cycle that will not sustain livestock production.

Tate acknowledges that fortunately, ranchers are well aware that such management is a road to nowhere. Research and on-the-ground experience show that effective grazing management creates win-win outcomes. Management that supports growth and vigor of desired forage plants, as well as root and water penetration throughout the soil, will result in:

- ✓ Optimal forage production and quality
- ✓ Optimal animal performance
- ✓ Pasture resilience to drought, weed invasion, and other stresses
- ✓ Return on investments in herd genetics, reproduction, health, supplementation, and infrastructure
- ✓ Healthy and productive soil and environmental conditions

Many grazing strategies can sustain forage plant vigor and soil health. Tate emphasizes that continuous and rotational grazing strategies at moderate stocking rates in rangeland systems can sustain high levels of soil function, forage production, and livestock performance. However, recent surveys of 765 California and Wyoming ranchers show that two-thirds of respondents use extensive rotational grazing strategies, with livestock movements every few weeks and moderate stocking rates — ranchers see on-the-ground and on-the-hoof benefits from pasture rest and rotation of grazing animals.

Tate advises that underperforming rangeland pastures should be investigated, particularly in heavy soils commonly grazed during wet periods. Grab a shovel, and dig a pit 1 foot deep by a couple feet long. Look 3 to 6 inches below the surface for a band of compacted, platy, massive soil with little root penetration. Look for fine plant roots stacked on top of this layer. Presence indicates you might have a “cow-pan”. For additional information on this and other grazing management issues, soil, forage, and livestock expertise is available within university Cooperative Extension, as well as through NRCS. In most cases, Tate assures that small adjustments in intensity and timing of grazing will allow rooting and natural soil processes to break down compaction and improve soil structure within a few years – allowing increases in water infiltration, soil health, forage and cattle production.

Conclusions

Grazing management in pasture and rangeland systems is sustainable when it promotes profit as well as environmental health over the long term. Speakers in this Cattlemen’s College session asserted what ranchers have known for generations – if you take

care of the land, it will take care of you. Optimizing grazing involves appropriate stock densities, duration of grazing, and adequate non-grazing rest periods for plants. Soil health is a key component of a sustainable operation. Rogers notes the importance of keeping the soil covered to maintain temperatures for microbial activity and prevent erosion. Effective management of aboveground resources benefits the belowground community, and Rogers mentions the importance of microbial activity for aggregate formation to improve soil structure. Similarly, Shafer and Chessman emphasize that improving soil health and soil structure positively impacts water infiltration and water holding capacity, enhances water availability, increases resilience, and reduces production risks over the long term.

Rogers and Tate highlight the importance of monitoring to inform management decisions. This may involve using a grazing stick to evaluate forage height, or digging a hole to assess soil compaction and root penetration.

Soil profile under a grazed annual grassland on California's north coast. The white pins demark the different soil layers within this profile. The zone between the top two pins is where one would look for evidence of soil compaction from grazing ("cow-pan"). Grass roots should be penetrating this layer to access nutrients and moisture in the lower layer. If roots are not penetrating this zone, then compaction may be limiting forage and livestock production.
Photo credit Ken Tate.

Monitoring data may indicate need for management changes and adaptations, such as adjusting stocking rates or grazing duration. Rogers and Tate recommend minimizing soil erosion and compaction to optimize forage productivity. Soils with intact aggregate structure and biological activity offer a growth medium for a healthy forage base to support livestock production. As session speakers note, a grazing system including moderate stocking rates, rest periods, and rotation contributes to both the financial and environmental health of an operation. According to Rogers, improving productivity of a system through management may be more effective than costly amendments, since plant-available water can be most limiting. Optimizing grazing management involves enhancing soil health to benefit forage productivity, while also potentially reducing expenses and increasing profitability. As Tate states, producers' on-the-ground experience and scientific research show that optimal grazing management benefits all aspects of sustainability, socio-economics as well as grazing land health.

The complete Cattlemen's College *presentation videos for each session are available on NCBA's website.* The Basics for Soil Health in Pasture *and* Rangeland Systems, *with Dr. Steven Shafer and Dr. Dennis Chessman, is available at at* http://bit.ly/2nIqhq1, *and* Managed Grazing to Optimize Sustainability in Pasture and Rangeland Systems, with Johnny Rogers and Dr. Kenneth Tate, *is linked at* http://bit.ly/2o7nOqg. *Article authors are listed in order of appearance in these session presentations. Presenters' summaries were integrated and edited for this article by Dr. Kristie Maczko.*

Moving a large herd of yearling steers at the USDA-ARS Central Plains Experimental Range to start the summer grazing season. This herd will be adaptively rotated among 10 pastures using decision-triggers developed by an 11 member Stakeholder Group comprised of ranchers, environmental and non-government conservation organizations, and state/federal land managers to achieve soil, vegetation, livestock and wildlife objectives in a shortgrass steppe ecosystem.

Photo credit Matt Mortenson (USDA-ARS).