Forage News

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Breaking soil compaction: Does it increase forage production?

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Soil degradation is considered one of the most important problems of cultivated pastures in Mississippi. There is significant interest in aerating pastures among livestock producers. One major issue is soil compaction due to poor grazing management. Aerating can be beneficial in some instances, but the results could be sometimes short-term. In some situations, aeration can decrease soil compaction and allow for greater plant root development.

Probably the most common reason forage producers want to aerate pastures is because they believe the soil is compacted. In the past, studies have been conducted on implementing soil aeration as one of the available methods to reduce soil compaction, increase forage production, and increase water infiltration. Unfortunately, none of the aeration methods implemented have yielded results that could justify any efficacy or improvement. The reason is because soil aeration only affects 3 to 4 inches of the soil upper layer while compaction is usually below 6 inches and under the root zone in the hard pan layer. Annual yield losses ranging between 20 and 40% have been reported from severely compacted soils with 20 to 60% of the compaction occurring in moist soils and 40 to 90% in very wet soils. Pastures grown in Mississippi are shallow rooted with at least 70% of roots present in the top 2 to 5 inches of soil. Recovery of soil physical conditions after heavy or continuous traffic is rather slow and compacted conditions may persist for more than six months or even years.

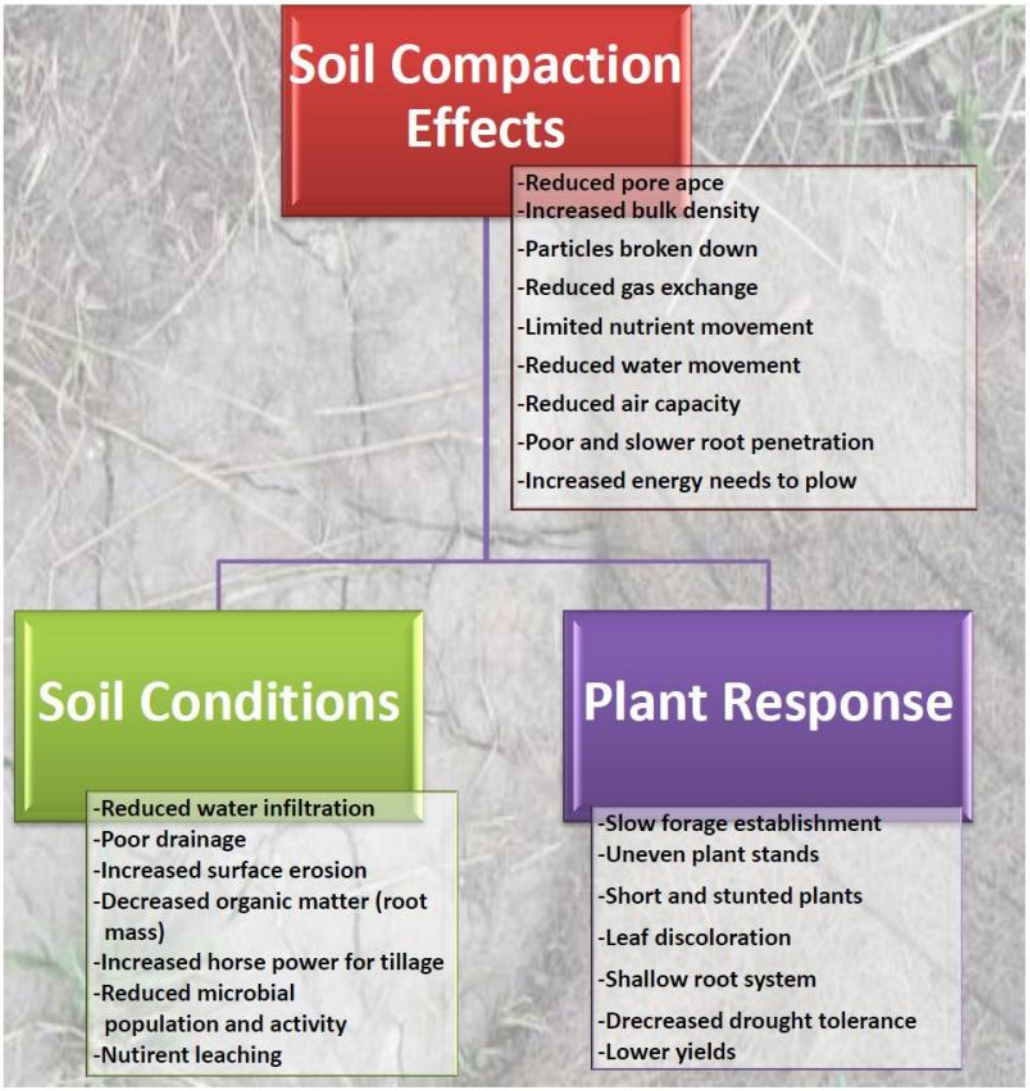

Figure 1. Effect of compaction on soil productivity and plant response.

There are three systems that work together to make a soil productive: physical (texture, structure, compaction, hardpan, and porosity), biological (bacteria, fungi, actinomycetes, earthworms, protozoa, and algae), and chemical [fertilizer, lime, pesticides, pH, cation exchange capacity, cations (+), and anions (-)]. The interaction

and the soil physical conditions will determine how efficient the biological and chemical conditions of the soil are to make forage crops productive and persistent. Compaction makes both wet and dry soil conditions more severe (**Figure 1**). Some of the effects on compaction include decrease in water holding capacity and impediment of root growth and development (expansion, penetration and distribution). Reduction in water holding capacity makes pastures more susceptible to stand loss under drought stress. Compaction also inhibits drainage, making wet conditions more troublesome.

What are the causes of compaction? For a soil to productive, it needs to have a good tilth. What that means? It means that there has to be a balance between the between the basic soil elements: minerals, air, water, and organic matter. There are usually three major components in that cause compaction: (1) equipment traffic, (2) livestock traffic, and (3) rainfall. Heavy traffic loads, especially in hay production fields can break down soil particles and squeeze them together and in this way reducing pore space need for water and air movement. Livestock traffic also develops soil compaction due to repeated pressure in the area due to poor grazing management. Although livestock can break the upper layer of the soil due to hoof action, deep compaction layers develop overtime if left untreated. Soils that are higher in clay content are more susceptible to hoof compaction than sandier soils. Heavy rain can also disturb the smallest particles on the soil surface and creating layers of crust. Rainfall compaction is usually very minimal in pastures with a good ground cover.

There are at least three primary types of compaction on pastureland: surface compaction, tillage pans (hardpans), and subsurface hardpan layer. Surface compaction results for sustained heavy equipment of livestock traffic. It usually occurs in the upper 3" of the soil. In this area, growth is usually limited to seedlings. Surface compaction could be easily corrected because it can be broken with a light disking. Tillage pan is usually caused by repeated soil disturbance by the same equipment at the same depth (plow, disk, or chisel plow). This type of compaction decreases soil permeability rates and the layers seal and pack tightly. Roots will only have access to moisture and nutrients above the compacted layer. Subsurface hardpans have developed over time as leached minerals and clays are deposited at a specific soil depth. They tend to reform after a few seasons unless they are broken and mixed with porous soil. Breaking a subsurface hardpan is only beneficial if it allow well developed plant roots to capitalize on soil moisture available at deeper profiles.

How can it be determined if soil compaction is present? Compaction could be measured using a penetrometer (penetration resistance), but readings are highly affected by soil moisture. To get a better assessment of compaction, producers should combine penetration resistance with visual observation of the forage root system (especially restricted growth and how far they extend into the ground), soil moisture, and changes in soil density (bulk density). Soil bulk density is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles. Bulk density is typically expressed in g/cm^3. **Table 1** provides changes on bulk density across soil textures that could affect plant growth. Grazing systems such as rotational grazing that minimizes livestock traffic and adhere to recommended minimum grazing heights reduce bulk density by preventing compaction and providing soil cover.

Table 1. Relationship between soil texture, bulk density, and plant growth.

	Soil Texture		
Bulk Density	**Clayey**	**Sandy**	**Silty**
	g/cm^3		
Ideal for plant grow	< 1.10	< 1.60	< 1.40
Restrict root growth	> 1.47	> 1.80	> 1.65

Source: USDA-NRCS. 2008. Soil quality indicators.

Compacted soil may be indicated by an accumulation of roots or water just above or within the compacted zone. It may also be apparent by a lack of large pores, by the existence of "greyed soil" (a bluish-grey color caused by long-term waterlogging), or by the absence of roots and earthworm activity within the compacted soil and/or high density of that soil. Soils with poor drainage are particularly susceptible to compaction because they remain wet for a long time after rainfall. Some degree of compaction damage will occur on any soil when it is wet and grazing animals are left in the paddock. The degree of damage is usually greater with cattle and horses.

Producers need to be careful not to confuse hard soil conditions after long drought periods with soil compaction. The soil hardness is during drought conditions is a natural characteristic of the soil known as soil aggregation and it is not expected to have detrimental or long-term effects on forage production since soil often returns to its common physical conditions when soil moisture is restored through rainfall.

What is soil aeration? Aeration -- a process by which soil is mechanically disturbed -- is commonly used to renovate established pastures with the objective of reducing the soil compaction and increasing water infiltration. Aerator machines include coulters, which make narrow slits in the soil, rollers with spikes that make indentations in the soil, and prongs, which function like a mini sub-soiler. These machines can also be used for purposes other than pasture aeration, such as for weed control and for incorporating fertilizer, lime or seeds of annual, cool-season forages. Based on data, the best time to aerate is in the spring or early summer when grasses are growing most actively. Do not aerate when soils are wet.

Does soil aeration increase forage production? Although the main objective of aerating pastures is to reduce soil compaction and increase water infiltration, aeration has shown to have very little impact on increasing forage production in established pastures. Studies addressing soil aeration have indicated a great variability. Research conducted at University of Florida using three aerator machines indicated that water infiltration rates and compaction were affected immediately after the application, but the effect was not present at 3,6, and 12 months after aeration. The results indicated that aeration has no benefits on bahiagrass forage production and in most cases can potentially reduce forage production. Similar studies conducted at Mississippi State University on silty and sandy loam soils using an airway, shank renovator, disk, and a deep chisel (10") on bahiagrass (**Table 2**) and bermudgrass hayfield at different times of years indicated no positive effects on compaction, soil moisture and forage production. In some of these trials, aerated areas produced less forage than the untreated areas.

The only possible benefits of pasture aeration could be a faster green up of the pastures since soil disturbance could increase microbial activity causing quicker organic matter decomposition and nutrient release. It is important to keep in mind that this nutrient release after aeration might be only temporary and not expected to improve long-term or seasonal forage production.

Table 2. Effect of aeration treatments on dry matter yield of bahiagrass across two locations in Mississippi.

Treatment[2]	Location[1]		
	Brown Loam	White Sands	
	1993	1993	1994
	lb/ac		
Control	3373	4763	3880
Aearway	3373	5488	3908
Disk	2477	4129	4331
Deep Chisel (10")	3324	5082	5166
Shank renovator	2701	3751	3759
$LSD_{0.05}$	NS	866	NS

[1]Soil types at locations were: Brown Loam (Loring silt), and White Sands (Malbis fine sandy loam).
[2]Treatments were applied in October of the previous year to data collection.
Source: Ingram et al. 2009. Influence of spike-tooth aeration on permanent pastures in Mississippi. MAFES. Tech. Bull. 220.

Overgrazing forage plants, and allowing development of livestock loafing areas and trails usually can lead to soil compaction. Livestock activity can modify soil properties by degrading soil structure, increasing soil bulk density, and reducing infiltration rate. A 10-year study in the tall-grass prairie region of Oklahoma using a low, medium, and high stocking density indicated that long-term livestock grazing increased compaction and bulk density values, but only in the upper 4" of the soil surface.

To determine is a specific aeration method was effective and paid off in your operation, make sure that the amount of forage production from aerated and non-aerated strips in the same farm field are compared. Do not compare the yield of the preceding year to the year in which the field was aerated because fertilizer applications and rainfall patterns could have not being the same in both years. Even comparing two fields in the same farm might be misleading due to changes in soil texture, water holding capacity, and nutrient availability.

Summary - Grazing livestock usually put pressure on the ground comparable to agricultural equipment and making them vulnerable to compaction. Because of continuous grazing and permanent pastures, there is little opportunity to improve poor soil physical conditions through tillage and pasture renovation. Although compaction has been measured in the upper 6" of the soil, compaction to a greater depth could have a greater effect in soil physical properties, especially on heavy soils. The response of pastures to the poorer soil conditions caused by grazing or hay production is difficult to determine. Maintaining a healthy and vigorous pasture should be a major objective of grazing management, but it should also be used as tool for maintain acceptable soil physical conditions.

Soil aeration is unlikely to be of economic benefit since yield increases have been observed on a very limited number of soil types that have hard pans and compacted layers. The cost of aerating could be as high as $15 per acre, factoring in fuel and time. If soil compaction is suspected, test the soil with a soil penetrometer and look at root distribution before going to the expense of aerating and wasting fuel and time pulling expensive equipment across the pasture or hay fields. There might other limiting factors that could be affecting forage production such as pH or nutrient deficiencies and addressing those factors could usually have better returns. Compaction is not visible and is often undetected. Producers need to observe the effects of lower production, more undesirable plants, greater surface runoff and increased soil erosion as indicators of possible compaction. Soil and grazing practices must be carefully planned and integrated into the total forage management system. Aeration should be at the bottom of the priority list in pasture management plans. If the goal of aerating is to increase yield, there are other practices like careful soil sampling, fertilizing or subdividing pastures that will allow having greater results for less cost.

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