Breaking Down Soil Compaction: *Does It Increase Forage Production?*

Soil degradation is an important problem of cultivated pastures in Mississippi. One major issue is soil compaction caused by poor grazing management. There is significant interest in aerating pastures among livestock producers to address this compaction issue. Aerating can be beneficial in some instances, decreasing soil compaction and allowing for greater plant root development.

Forage producers often aerate pastures because they believe the soil is compacted. Annual yield losses ranging between 20 and 40 percent have been reported from severely compacted soils, with 20–60 percent of the compaction occurring in moist soils and 40–90 percent in very wet soils. Pastures grown in Mississippi are shallow-rooted—at least 70 percent of roots are in the top 2–5 inches of soil. Recovery of soil physical conditions after heavy or continuous traffic is rather slow, and compacted conditions may persist for 6 months or even years.

Past research studies have addressed using soil aeration to reduce soil compaction, increase forage production, and increase water infiltration. Unfortunately, none of the aeration methods tested have yielded good results. Soil aeration only affects 3–4 inches of the upper layer, while compaction layers are usually 6 inches or more below the root zone.

Three systems interact to make soils productive: physical (texture, structure, compaction, hardpan, porosity), biological (bacteria, fungi, actinomycetes, earthworms, protozoa, and algae), and chemical (fertilizer, lime, pesticides, pH, cation exchange capacity, cations, and anions). The physical characteristics determine how efficiently crops can use the biological and chemical characteristics of the soil.

Compaction makes both wet and dry soil conditions more severe (Figure 1). It decreases water-holding capacity, and impedes root growth and development (expansion, penetration, and distribution). Reduced 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?

Productive soils have good tilth. What does that mean? It means there must be a balance in the relationship between the basic soil elements—minerals, air, water, and organic matter—that allows plant roots to penetrate and thrive.

Three major components cause compaction: equipment traffic, livestock traffic, and rainfall.

Heavy traffic loads, especially in hay production fields, can break down soil particles and squeeze them together; this reduces pore space necessary for water and air movement.

Livestock traffic also compacts soil with repeated heavy pressure in the area resulting from poor grazing management. Although livestock can break the upper layer of the soil with their hooves, deep compaction layers develop over time if left untreated. Soils higher in clay content (medium to heavy textures) are more susceptible to hoof compaction than sandier soils (light textures).

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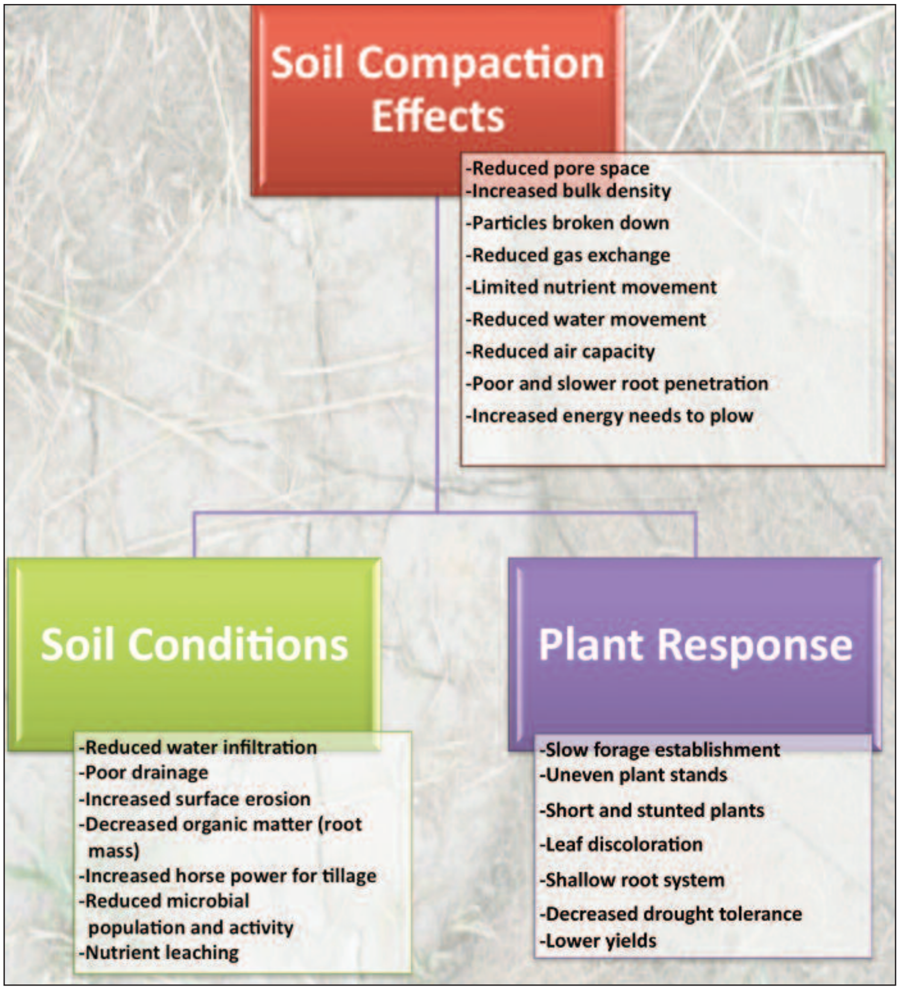

Figure 1. Effect of compaction on soil productivity and plant response.

Heavy rain can also disturb the smallest particles on the soil surface and create crust layers. Rainfall compaction usually is minimal in pastures with a good ground cover.

Three primary types of soil compaction occur on pastureland: surface compaction, tillage pans (hardpans), and subsurface hardpans.

Surface compaction occurs in the upper 3 inches of the soil from sustained heavy equipment or livestock traffic. In this area, growth is usually limited to seedlings. Surface compaction is easily corrected with a light disking.

Tillage pans, or hardpan compaction, are usually caused by repeated soil disturbance by the same equipment at the same depth (plow, disk, or chisel plow). Soil permeability rates are decreased, and the layers seal and pack tightly. Roots only have access to moisture and nutrients above the compacted layer.

Subsurface hardpans develop over time as leached minerals and clays are deposited at a specific soil depth. Subsurface hardpans tend to re-form after a few seasons, unless they are broken and mixed with porous soil. Breaking a subsurface hardpan is only beneficial if it allows well-developed plant roots to use moisture available at deeper profiles.

How Do You Know if Soil is Compacted?

Compaction can be measured using a penetrometer (penetration resistance), but readings are highly affected by soil moisture. For better assessments of compaction, producers should combine penetration resistance with visual observation of the forage root system, looking for restricted growth both vertically and horizontally.

Also note soil moisture and changes in soil density (bulk density). Soil bulk density is the dry weight of soil divided by its volume. This volume accounts for both soil particles and the pores between the 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.

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
Restricts root growth	> 1.47	> 1.80	> 1.65

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

Indicators of compacted soil include these:

- an accumulation of roots or water just above or within the compacted zone.
- a lack of large pores (identified by "grayed soil," a bluish-gray color caused by long-term waterlogging).
- 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 wet soil with grazing animals left in the paddock for long periods. The degree of damage is usually greater with cattle and horses.

Overgrazing forage plants and allowing livestock to create loafing areas and trails usually leads 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 inches of the soil surface. Grazing systems, such as rotational grazing, that minimize livestock traffic and follow recommended minimum grazing heights reduce bulk density by preventing compaction and providing soil cover.

Hard soil conditions after long drought periods should not be confused with soil compaction. The soil hardness during drought conditions is a natural characteristic of the soil that should not have detrimental or long-term effects on forage production following rewetting.

What Is Soil Aeration?

Aeration is a process by which soil is mechanically disturbed. Soil aeration often is used to renovate established pastures, reducing soil compaction and increasing water infiltration.

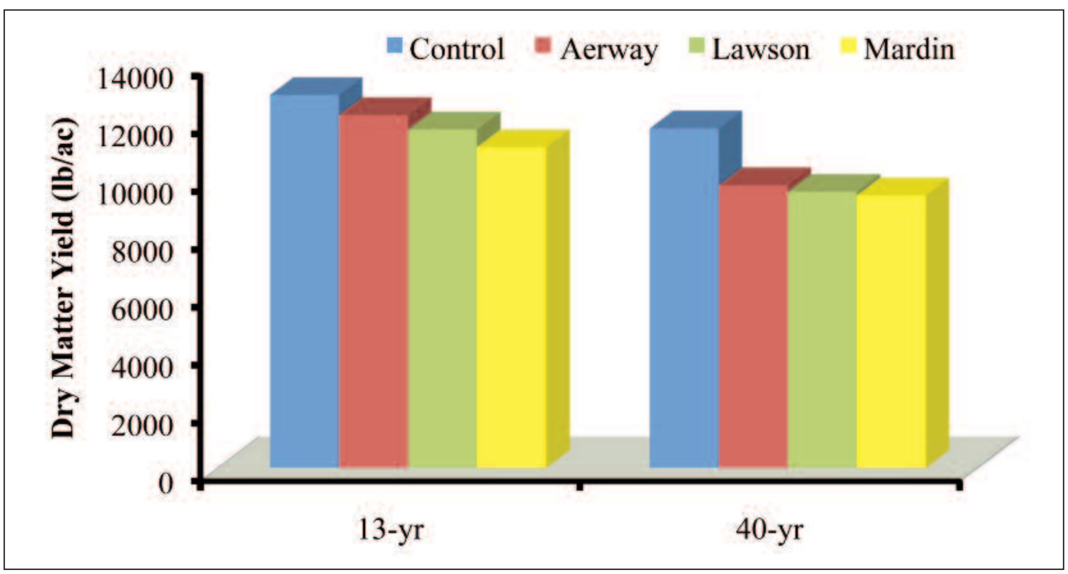

Figure 2. Effect of three soil aeration machines (Mardin HL-7 tandem chopper, Lawson 8 x 16-inch multi-blade pasture aerator, and Aerway model AW118 pasture aerator) on bahiagrass forage production of two stands (13 and 40 years old).
Source: Vendramini and Silveria. 2009. Pasture Aeration. Univ. of Florida Coop Ext. Serv. Pub. SS-AGR-2321.

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 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?

The main objective of aerating pastures is to reduce soil compaction and increase water infiltration. Aeration has very little impact on forage production in established pastures.

Research conducted by the University of Florida using three aerator machines (Figure 2) indicates 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 aeration had no benefits on bahiagrass forage production and even has the potential to reduce forage production.

Similar studies conducted at Mississippi State University found no positive effects on compaction, soil moisture and forage production. The MSU study used an airway, shank renovator, disk, and deep chisel (10 inches) on bahiagrass (Table 2) and bermudagrass (Tables 3 and 4) hayfields with silt and sandy loam soils. Aerated areas produced less forage than the untreated areas in some of these trials.

The only potential benefit of pasture aeration could be faster green-up of the pastures. Soil disturbance may increase microbial activity, causing quicker organic matter decomposition and nutrient release. It is important to keep in mind that this nutrient release after aeration is likely only temporary and not expected to improve long-term or seasonal forage production.

To determine if a specific aeration method could be effective in your farm operation, make sure you are comparing the amount of forage production from aerated and non-aerated strips in the same farm field. Do not compare the yield of the preceding year to the year in which the field is being aerated because fertilizer applications and rainfall patterns were most likely different each year. Even comparing two fields in the same farm might be misleading because of differences in soil texture, water-holding capacity, and nutrient availability.

Summary

Maintaining a healthy and vigorous pasture should be a major objective of grazing management, but it should also be used as a tool for maintaining acceptable soil physical conditions. Compaction is not visible and is often undetected. Both grazing livestock and agricultural equipment put pressure on the ground, leading to potential soil compaction issues. Tillage and pasture renovation are difficult to use in continuous grazing or permanent pastures, providing little opportunity to improve poor soil physical conditions.

Although compaction may be measured in the upper 6 inches of the soil, compaction at greater depths could have more of an impact on 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.

Soil aeration is unlikely to be of economic benefit since yield increases have been observed on a very limited number of soil types with hard pans and compacted layers. The cost of aerating could be as high as $15 per acre including 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. Other limiting factors, such as pH or nutrient deficiencies, may be affecting forage production. Diagnosing and addressing those factors could be more beneficial.

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 yields, other practices, including careful soil sampling, fertilizing or liming according to soil test-based recommendations, or subdividing pastures, could give better results for less cost.

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

	Location[1]		
Treatment[2]	Brown Loam	White Sands	
	1993	1993	1994
	lb/ac		
Control	3373	4763	3880
Aerway	3373	5488	3908
Disk	2477	4129	4331
Deep Chisel (10″)	3324	5082	5166
Shank renovator	2701	3751	3759
LSD0.05	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 year previous to data collection.
Source: Ingram et al. 2009. Influence of spike-tooth aeration on permanent pastures in Mississippi. MAFES. Tech. Bull. 220.

Table 3. Influence of timing of pasture aeration on dry matter yield of bermudagrass across three locations in Mississippi in 1994 and 1995.

	Location[1]		
Treatment[2]	Brown Loam[3]	Coastal Plains[4]	White Sands[5]
	lb/ac		
Control	12138 (7260)6	9081 (10059)	8584 (7815)
Spring	12427 (7659)	8466 (9839)	9351 (7808)
Summer	12452 (7398)	8312 (9786)	9001 (7788)
Spring + Summer	11457 (8136)	8057 (9641)	8971 (8183)
LSD0.05	NS (NS)	NS (NS)	NS (NS)

[1]Bermudagrass varieties at each location were: Brown Loam (Coastal), Coastal Plain (Tifton 78), and White Sands (Alicia).
[2]The spike-tooth pasture aerator was used in this study.
[3]Treatments applied: spring (4/25/94) and summer (8/16/94).
[4]Treatments applied: spring (4/27/94) and summer (7/30/94).
[5]Treatments applied: spring (4/26/94) and summer (6/29/94).
[6]Yields in parenthesis are for the 1995 growing season.
Source: Ingram et al. 2009. Influence of spike-tooth aeration on permanent pastures in Mississippi. MAFES. Tech. Bull. 220.

Table 4. Dry matter yield of bermudagrass as affected by aeration timing at three locations in Mississippi in 1995.

	Location[1]		
Treatment[2]	Brown Loam[3]	Coastal Plains[4]	White Sands[5]
	lb/ac		
Control	8546	9214	6882
Spring only	7224	9244	7184
Spring + every harvest	7950	8802	7395
Spring + summer	8091	9415	7684
Spring + second harvest	7119	8522	7639
Spring 2X	8134	8287	6939
LSD0.05	NS	NS	NS

[1]Bermudagrass varieties at each location were: Brown Loam (Coastal), Coastal Plain (Tifton 78), and White Sands (Alicia).
[2]The spike-tooth pasture aerator was used in this study.
[3]Treatments applied: spring (4/4); summer (6/9); first (6/6), second (7/31) and third harvest (10/31).
[4]Treatments applied: spring (4/10); summer (6/6); first (6/5), second (8/1) and third harvest (10/12).
[5]Treatments applied: spring (5/5); summer (5/29); first (5/29), second (7/14) and third harvest (8/17).
Source: Ingram et al. 2009. Influence of spike-tooth aeration on permanent pastures in Mississippi. MAFES. Tech. Bull. 220.

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