

Soil Profile Conditions of Cattle Feedlots¹

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ABSTRACT

Characterization of the conditions that exist in the feedlot surface and soil profile is important to evaluation of the potentials for soil and water pollution. Cattle action and management activities create a dynamic condition in the feedlot. The organic matter surface causes physical and biochemical changes in the soil that are unlike natural or cultivated soils. The feedlot profile can be described as three layers: the organic matter, the interface, and the underlying soil. Measurable characteristics include bulk density, infiltration, and content of organic matter, water, and nitrate-N. Generally, the surface 15.2-cm depth of feedlot soils is compacted and has a high bulk density. Infiltration into the feedlot surface layers is essentially zero. There is no transpiration, and the soil-water content is more uniform through the profile than on cropped land.

Additional Index Words: infiltration, layered soils, organic content.

The beef cattle feeding industry recently has received much attention from the general public and the environmentalists. Their concern with feedlots is mainly from the standpoint of pollution of surface waters from runoff. Of equal, or possibly greater importance in some localities, is the potential for degrading the ground-water quality from nutrients accumulating in the feedlot soil profile.

Most of the beef cattle in the USA are fed in large, open, soil-surfaced feedlots in the Plains and Midwest. Confinement feeding, where cattle are highly concentrated, usually under a roof, is increasing rapidly but accounts for only a small portion of the total animals fed.

Beef animals account for nearly two-thirds of all the red meat consumed in the USA (4). In 20 years, 1950-1970, consumption of beef from grain-fed cattle has increased from about 50% to more than 70%, a fact that reflects the increase in numbers of cattle feedlots.

The availability of feed grain and cattle has influenced the concentration of cattle feeding operations in four major areas of the USA according to Viets (5). About three million head are fed annually in southern California and Arizona. The Texas and Oklahoma Panhandle areas have had spectacular growth with more than five million cattle fed annually. Eastern Colorado, Nebraska, and South Dakota feed about six million annually, twice as many as in 1962. Cattle on feed in the Central Corn Belt numbered almost eight million in 1969.

Agricultural Statistics report 13,911,000 cattle on feed as of January 1, 1972. The January inventory is usually the highest of any period of the year (1). Assuming that the lots are at capacity and using 37.1 m² per head as recommended by the Midwest Plan Service (2), about 53,000 ha are used for feedlots nationally. Higher cattle densities are common in commercial lots, particularly in drier regions. Assuming that 37.1 m² per head is a good estimate, the total feeding area would be less than 490 km² for the entire USA, an area much smaller than an average-size county. The feedlot involves intensive management and a high dollar value. Feedlots also represent

a great pollution potential, but the potential is far greater than the actual contribution to soil and water pollution.

FEEDLOT SURFACES

Three layers develop on and in the top of the soil profile as a result of organic accumulation in a feedlot. A layer of manure soon accumulates on the soil surface of the feedlot. Under continuing use, an interface layer of mixed organic and mineral soil forms under the manure cover. A third layer is the top of the soil profile, which is affected physically by compaction of the animals and chemically by the manure. Mixing of organic matter and soil-mineral material is generally limited to the first few centimeters of soil. Depending on the feedlot management and history, the physical effects may be evident for several centimeters and the chemical effects for several centimeters or meters in the soil profile.

Physical, chemical, and biochemical processes all contribute to formation of the layers in a feedlot surface. As manure is deposited and accumulates, decomposition is going on by physical and microbial processes. Urine and solid manure have high sodium and potassium contents that influence the electrical charges of the clay soil particles and cause them to disperse. At the same time, the trampling of the cattle on the soil surface compacts the dispersed soil particles into a dense, poorly aerated mass. A platy structure forms in some soils and, generally, structure tends to become massive. Observations suggest that after dispersion and compaction, the original soil texture has little effect on water infiltration into the surface of the established feedlot.

The manure containing organic matter serves as a food source for microorganisms. Microbial decomposition produces various byproducts, such as organic gels and polysaccharides that reduce water infiltration by plugging the soil pores. Infiltration of water is controlled by the most limiting layer which in feedlots is the combined effects of the surface and interface layer.

The hydrophilic substances in the manure swell and slow down water movement when the manure is kept wet. However, when the manure dries, these substances shrink and crack, and water may move rapidly through the surface. Water pollution of ground water by nitrate-N can be reduced by keeping the two surface layers moist enough to avoid cracking.

ORGANIC MATTER LAYER

The composition of the organic layer varies with depth and stage of decomposition, water content as affected by

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Table 1—Volatile solids by percent weight loss by ignition in surface 7.6 cm of four eastern Nebraska feedlots

Location of feedlot	Soil	No. of samples	Volatile solids	
			Average	Range
			%	
Gretna	Marshall silty clay loam	6	27.8	14 to 42
Springfield	Marshall silty clay loam	4	24.7	12.1 to 41.6
Omaha	Judson silt loam	4	17.9	9.7 to 35.4*
Central City	Volin silt loam	8	30.8	25.1 to 41.1

* 9.7% recently cleaned lot and 35.4% manure mound, other values were 12.6, 14.1 and 17.8%.

feces, precipitation and evaporation, and the ration fed to the cattle. Feedlot management practices including cleaning and animal density affect the surface conditions and control development of the organic matter layer. Swanson et al. (3) report that changes in weather, coupled with cattle trampling, quickly alter the characteristics of the surface layer to greatly affect runoff characteristics and the quality of the runoff water.

Samples from three eastern Nebraska feedlots typify the organic matter layer. The average and range of volatile solids content, percent weight loss by ignition, for the three feedlots are shown in Table 1. Six areas were sampled on the Gretna feedlot. The volatile solid contents were highest near the upper end and near the top of the slope, and lowest along the side of the feedlot opposite the feedbunks.

One composite sample was taken from each of the four pens on the Springfield feedlot site. The pens differed in area, but had about the same number of cattle in each. After the first 2 years of feeding, the pens with the highest cattle densities had the highest surface volatile solids contents.

The Omaha feedlot has a 10 to 15% slope compared to the 6% slopes at the Springfield and Gretna sites. The low volatile solids content was from a recently cleaned lot. The high volatile was from a manure mound. Organic content in a mound decreases as decomposition progresses.

A typical bulk density of an organic matter layer ranges from 0.75 to 0.93 g cm⁻³. The surface bulk density of a silty clay loam ranges from 1.4 to 1.6 g cm⁻³, and that of a silt loam averages 1.2 g cm⁻³. Solids transported from the feedlot surface by runoff are primarily organic, with bulk densities in the range of 0.36 to 0.58 g cm⁻³ and an average of 0.46 g cm⁻³. Runoff can transport materials ranging from the small soil particles up to large aggregates and bits of undigested plant tissue.

Surface materials are removed by wind as well as water. In dry climates and during dry periods, cattle hoof action aids drying and destroys many existing aggregates formed by wetting and drying of the surface. The undigested cellulose fibers have a low density and are readily picked up and moved by wind. Dust in a feedlot also causes cattle health problems that commonly affect eyes and the respiratory system.

THE INTERFACE LAYER

The interface layer is of mixed organic matter and mineral soil of undefined thickness on top of the soil profile, forming as a result of weather, cattle action, and manure accumulation. It appears that the interface starts to form when cattle are first concentrated in an area. Hoof action is severe and the soil surface becomes compacted.

Table 2—Soil bulk density of the surface 7.6 cm of beef cattle feedlots and adjacent cropland

Location	Texture	Bulk density (g cm ⁻³)	
		Cropland adjacent to feedlot	Inside feedlot
Central City	Silt loam	1.2	1.6
Omaha	Silty clay loam	1.5	1.7

As manure accumulates, the organic matter and interface layers develop and the soil is protected.

The interface tends to be massive, without any definite soil structure. When dry, this layer may be hard like pavement. Bulk density, as an indicator of compaction in the feedlot, is shown in Table 2 for two soil types at Central City and Omaha. The top 7.6 cm of silt loam outside the feedlot has a bulk density of 0.4 g cm⁻³ less than the comparable depth inside the feedlot. There was 0.2 g cm⁻³ difference for the silty clay loam. At depths of 30.5 cm, bulk densities were essentially the same inside and outside the feedlot.

Volatile solids by percent weight loss through ignition in the organic layer interface and upper soil profile are shown in Fig. 1. Arbitrary boundaries were assumed for the interface and the samples were segmented by 1-cm depths above and below these boundaries. The values indicate that some mixing of soil and organic matter occurs near the top of the soil profile. The interface layer would be about 5 cm deep or ± 2.5 cm on either side of the assumed boundary (Fig. 1). Under cultivation, the organic matter content would be about 2-3% for this Volin silt loam soil.

Bulk densities through the organic layer, the interface layer, and the top of the soil profile for a silt loam soil are shown in Fig. 2. The bulk density of less than 0.80 g cm⁻³ at the surface increases to almost 1.7 g cm⁻³ in the interface and then decreases slightly. The increased density at 50 cm is attributed to increased clay content at that depth.

Infiltration measurements were attempted in a feedlot using the concentric cylinder technique. Expansion upon wetting of the surface layer was so great that a fixed gage could not be used to determine surface elevation, and infiltration was so slow that appreciable intakes could not

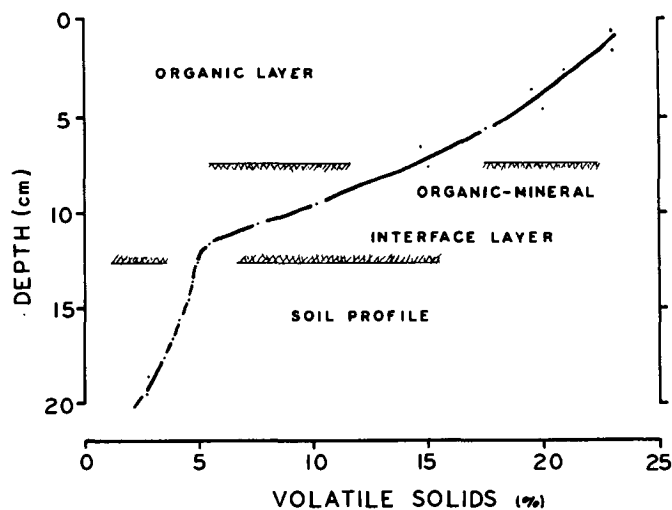


Fig. 1—Volatile solids by percent weight loss by ignition in surface layers of a beef cattle feedlot, Central City, Nebraska.

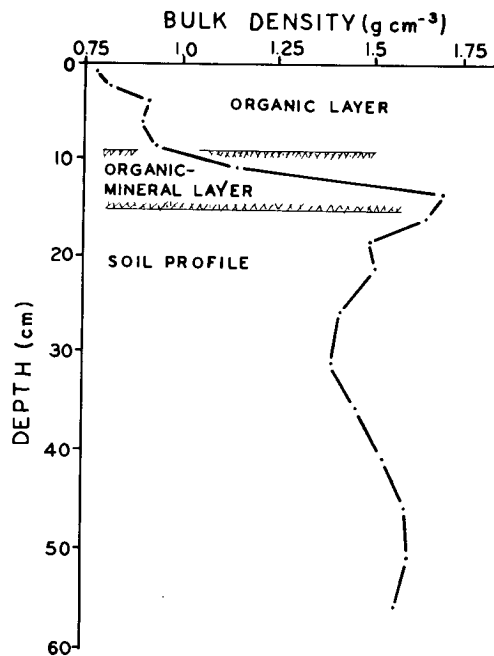


Fig. 2—Bulk density of undisturbed core from feedlot silt loam soil, Central City, Nebraska.

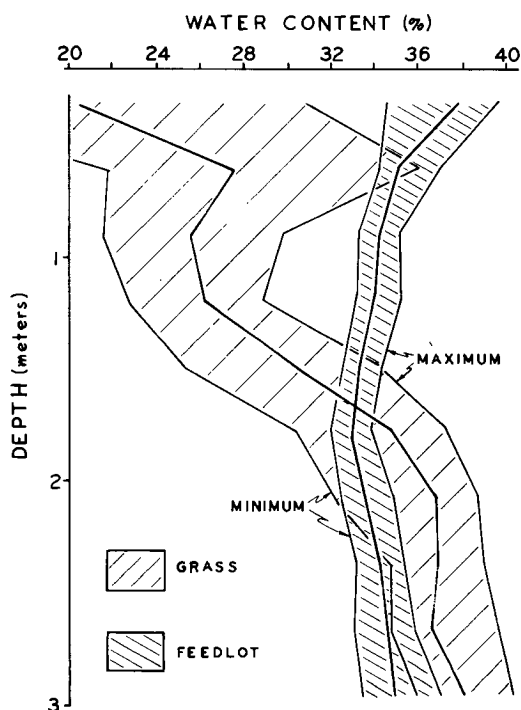


Fig. 3—Yearly range and average soil water content in Marshall silty clay loam soil profile under a feedlot and under grass, Gretna, Nebraska.

be measured even over several hours. The surface materials in a pack can adsorb great quantities of water. Only extremely low rates of actual infiltration into the soil have been observed in the field and in the laboratory using undisturbed soil columns. Unlike research investigations in cultivated fields, measurement equipment in a feedlot requires constant surveillance and protection to guard against destruction by cattle. An apparatus with a vertical

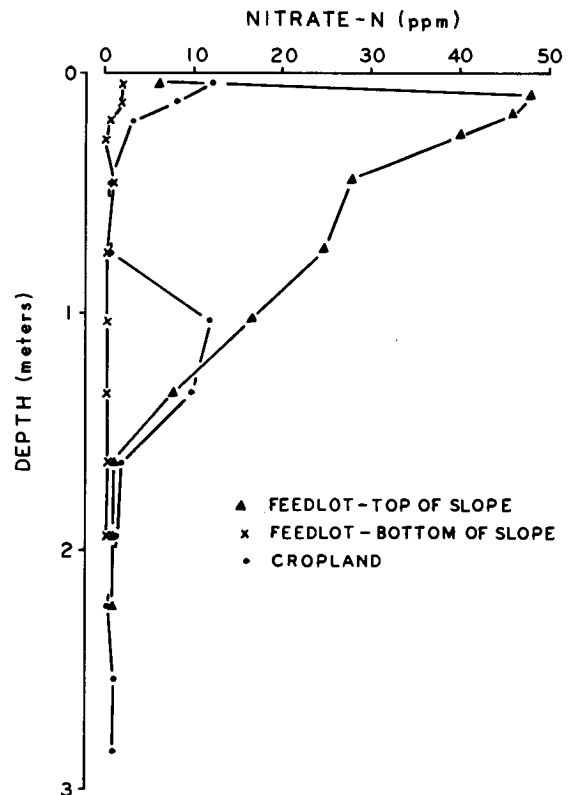


Fig. 4—Content of nitrate-N in Marshall silty clay loam for feedlot and cropland, Omaha, Nebraska.

supply tank, check valve and float, and concentric infiltration cylinders was used in the Gretna feedlot. The test was necessarily isolated from the animals, but no measurable infiltration was evident from the supply tank water elevation over a 20-day period. Most precipitation that falls on the feedlot either leaves as runoff or is adsorbed for later removal by evaporation or sublimation in the case of snow and ice.

SOIL PROFILE

The feedlot soil profile is unique in that there is no extraction of soil water by plant roots. The interface layer almost completely restricts water movement into or out of the profile. However, any water entering the profile could act as a transport medium to move chemicals in solution.

Access tubes 5.1 cm in diameter were installed in the Gretna feedlot and an adjacent grassed area. Soil-water contents were measured at monthly intervals for three seasons inside and immediately outside the feedlot on the Marshall silty clay loam site. Fig. 3 shows the range and average of soil-water contents at various soil depths for six access tubes inside the feedlot and for four access tubes under grass outside the feedlot in 1970. The range of soil-water content over the season was narrow for the feedlot profiles and remained relatively constant through the profile. In contrast, the seasonal soil-water content under the grass fluctuated widely, particularly in the root zone. The top 1.7-m depth of soil was wetter in the feedlot than under grass, but the feedlot soil tended to be drier

below that depth. Patterns were similar during 1969, 1970, and 1971.

The narrow range of soil-water contents in the feedlot soil profile include, and may be essentially accounted for, by variation in equipment calibration. Lower values at deeper depths as compared with those under the grass indicates that wetting fronts do not move through the feedlot profile.

Nitrate-N levels in the soil profile under feedlots tend to vary widely among locations. Nitrate-N levels in three soil profiles, two under a feedlot and the other under alfalfa (*Medicago sativa* L.), are shown in Fig. 4. The two soil cores from the feedlot were taken from a selected pen. All portions of this pen had received the same management and had been used continuously for more than 30 years. The surface slope was 13%, except that it decreased toward the lower end of the pen. One core was taken from the profile on the steeper slope. The nitrate-N was high in the top 0.6 m of soil and then decreased to about the same as in the cropland at the 1.7-m depth. The second core was taken from the soil profile at the lower end of the slope where soil and manure had been deposited. Very little nitrate-N was found in this profile. This condition is similar to that found under manure mounds. Where manure is mounded or has naturally accumulated to several inches, conditions are favorable for denitrification.

CONCLUSIONS

The texture of the soil profiles under the feedlots investigated appears to have little effect on the water movement into the profile or runoff characteristics for a mature feedlot. The bulk density of the interface (organic-mineral) layer in the feedlot is greater than in the cropland at the same depth. Organic-matter content is higher in the interface layer and the combined effects of soil particle dispersion and compaction provide a barrier to water movement. The surface layer may adsorb appreciable water, but actual infiltration into the soil is minimal. Where an interface exists and a cover of manure is present, nitrate-N is less likely to accumulate in the profile.

LITERATURE CITED

1. Agricultural Statistics. 1972. U. S. Dep. of Agr. U. S. Government Printing Office, Washington, D. C.
2. Midwest Plan Service. 1968. Beef housing and equipment handbook. MWPS-6 Midwest Plan Serv., Iowa State University, Ames, Iowa.
3. Swanson, N. P., L. N. Mielke, J. C. Lorimor, T. M. McCalla, and J. R. Ellis. 1971. Transport of pollutants from sloping cattle feedlots as affected by rainfall intensity, duration, and recurrence. p. 51-55. *In* Livestock waste management and pollution abatement. Amer. Soc. Agr. Eng., St. Joseph, Michigan.
4. U. S. Department of Agriculture. 1970. Cattle feeding in the United States. Agr. Econ. Rep. No. 196.
5. Viets, F. G., Jr. 1971. Cattle feedlot pollution. Agr. Sci. Rev. 9(1):1-8.