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Manure Application and Nutrient Balance on Rangeland

The expansion of the intensive livestock industry in recent years in Alberta has increased producer interest in applying manure to the vast native rangelands in the province. Rangelands may be viewed as a convenient place for disposing of manure and may serve to increase forage production. The assumption may be that rangelands are low in nutrients and therefore grassland production could be increased with application of manure.

However, the application of livestock manure to native range has significant effects on the cycling of plant nutrients in soil and can result in artificially raising nutrient levels, causing a dynamic shift in dominant plant species. To understand the effects manure can have on native range, an understanding of how native range soils have developed and how nutrients cycle in soil is essential.

The application of livestock manure to native range has significant effects

Range soil development

Soils under native rangeland in the Northern Great Plains of North America have taken between 5,000 and 10,000 years to form and develop, ultimately reaching a steady state. In Alberta and Saskatchewan, native grasslands are located in the Brown, Dark Brown and Black soil zones. Grasses and soil types in each zone are uniquely different.

The Brown soils formed under short prairie grass vegetation in an arid climate, and those in the Dark Brown soil zone formed under mixed grasses and fescue grass vegetation. The Black soils formed under fescue grasses in a moist climate.

These soils have a surface soil layer (top soil) called the A horizon, which varies from 7.5 to 25 cm (3 to 10 inches) in depth. The material these soils formed on is the C horizon (subsoil), generally 30 to 60 cm (12 to 24 inches) beneath the soil surface.

The A horizon of Brown soils is characterized by a light brown color with about 2 to 3 per cent organic matter, and a Dark Brown soil is medium to dark brown with 3 to 4 per cent organic matter (Figure 1). Black soils have soil organic matter levels of 5 to 10 per cent and are black. Generally, as soil organic matter levels increase, soil color becomes darker.

Significant acreages of grassland soils were broken in the early part of the twentieth century and have remained under cultivated agriculture. However, there are approximately 9 million acres of native grassland in the Brown and Dark Brown soil zones in Alberta and Saskatchewan that have not been broken. These areas were not broken or were returned to grassland due to one or more of the following factors:

- low rainfall
- rolling or rough landscape
- sandy soil
- stony soil
- salt affected soil
- soils with a hard pan below the soil surface

Significant areas of rangeland are dominated by Solonetzic soils (Figure 2). These soils are characterized by a hardpan layer below the A horizon. The hardpan layer generally has high levels of sodium, coupled with an accumulation of clay. The combination of high sodium and clay results in a very hard B horizon layer. These soils often have an uneven soil surface.

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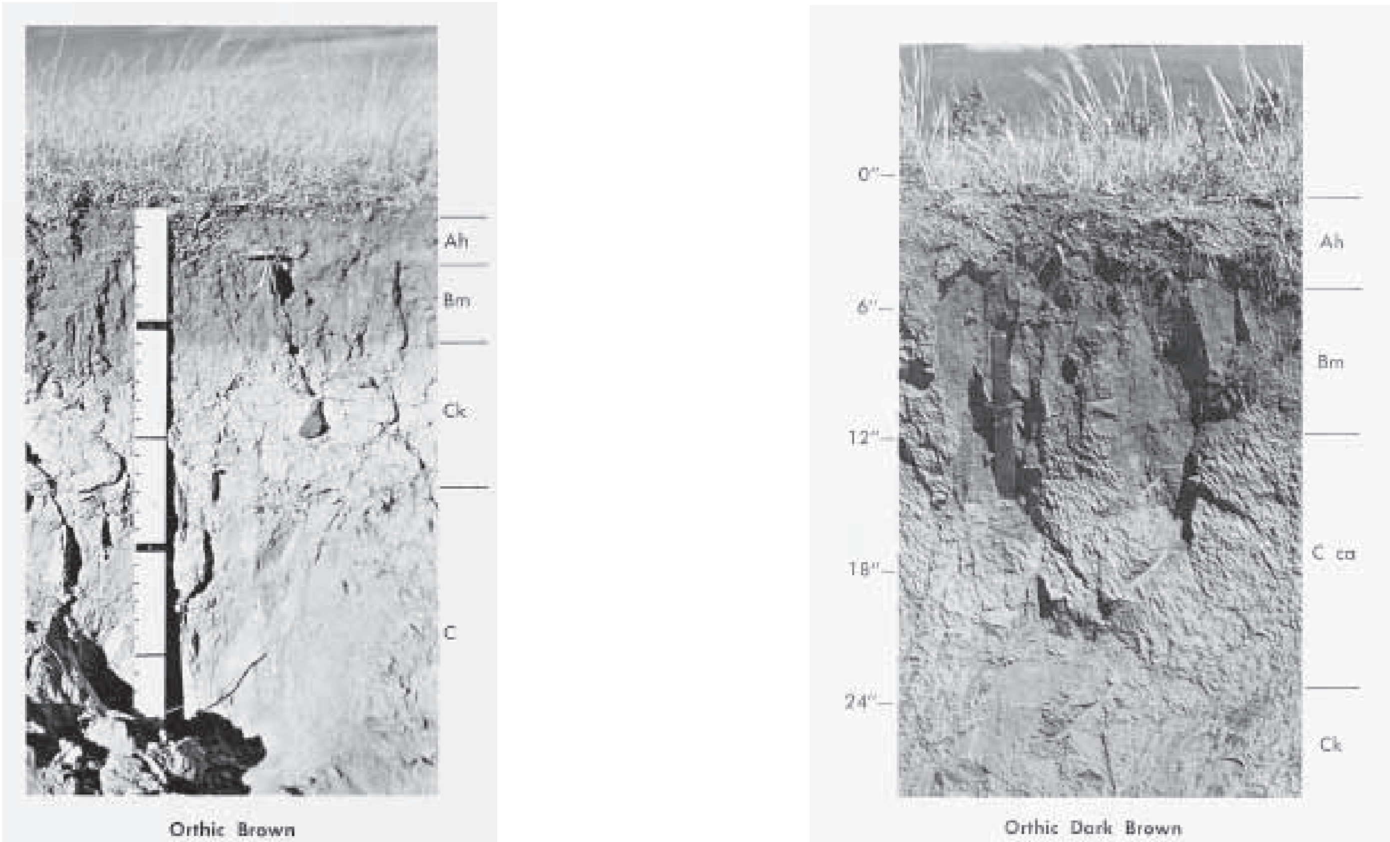

Figure 1. *Typical soil profiles of Brown and Dark Brown soils of the southern prairies of western Canada.*

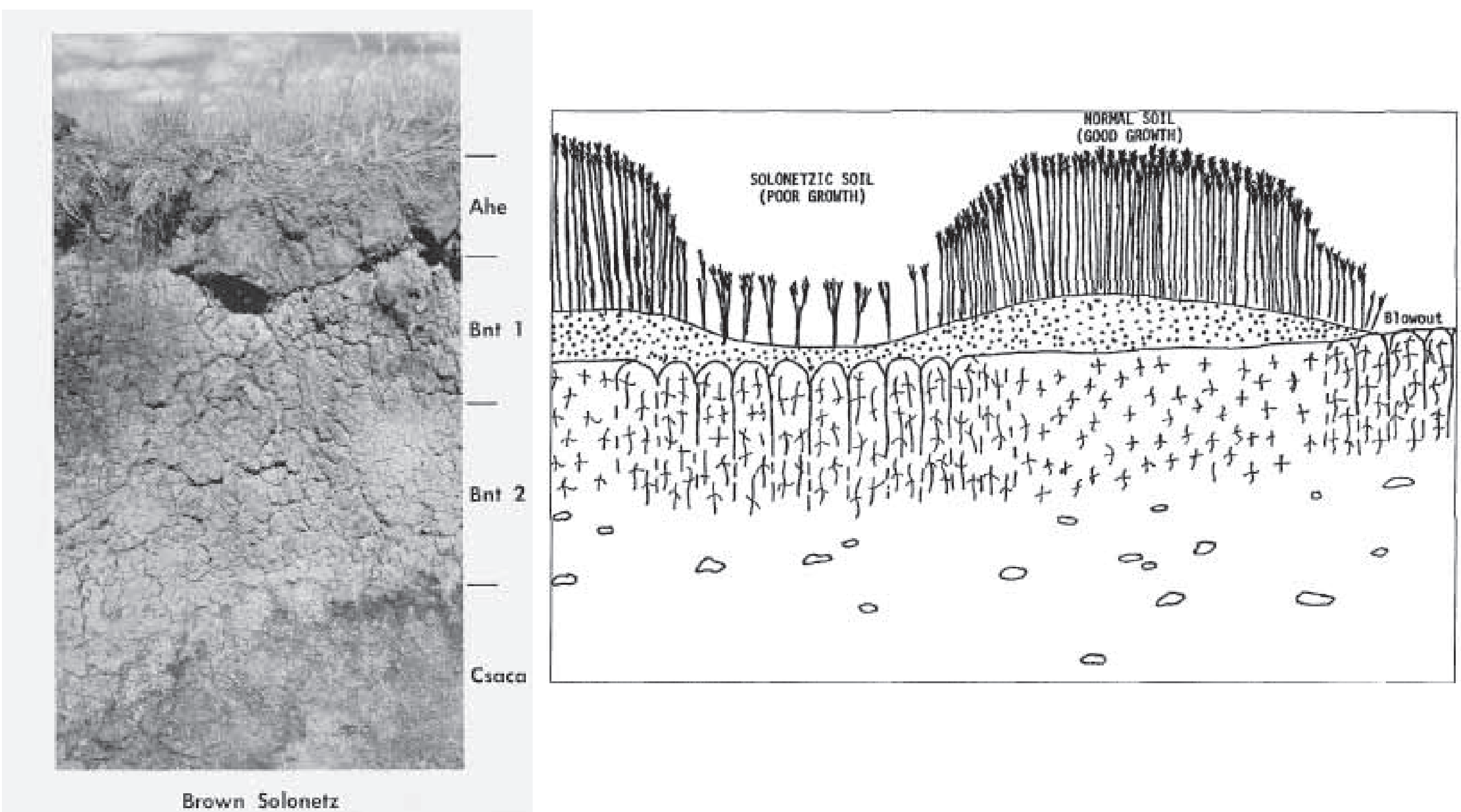

Figure 2. *Typical profiles of a Solonetzic soil.*

Generally, when land was not broken, the soils were identified as having a low potential for cultivated agriculture. From a soil conservation standpoint, early pioneers were wise to leave these lands in their native state. Most land that remains as native rangeland is fragile and very sensitive to changes in management.

Nutrient cycling in rangeland soils

Rangeland should be viewed as a natural ecosystem in which nutrient levels in soil are in a steady state or dynamic equilibrium. This description means that the nutrient levels are in balance within the soil, vegetation, animals and climatic effects. Essential nutrients such as nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) are in a steady state.

Virtually all nitrogen in soil is stored in the soil organic matter. Nitrogen required for plant growth comes from the natural breakdown of soil organic matter. Soil organic matter is composed of a number of different fractions that have different rates of breakdown and decomposition. Additional N added to the soil comes from fixation by native legume species and atmospheric additions by lightning storms.

For soil P, about half the P in surface soil on rangeland is contained in the organic matter, with the remaining P tied up in soil minerals. Much of the P for plant growth comes from the breakdown and decomposition of organic matter and a small amount from release by soil minerals. Approximately 75 to 90 per cent of the nutrients consumed by grazing animals are cycled back to the soil in urine and feces. Only a small amount of consumed nutrient is removed from a field with the animal.

Native grasses are generally low-yielding species that are adapted for survival in semi-arid to sub-humid climate on soils low in available nitrogen. Native prairie grasses do not respond to fertilizer like cultivated species.

The organic matter in rangeland soils should be viewed as a "complex soup." Organic matter provides significant amounts of nutrient for plant growth. If nutrients are added to soil, this addition results in changes to the organic matter dynamics.

Additional nutrients added in the form of livestock manure or inorganic fertilizer result in a shift in the ecosystem balance, and the soil is no longer in equilibrium. The increased level of nutrients affects forage production as well as forage quality and causes shifts in the dominant plant species.

Added manure affects forage yield and quality

An application of 12 ton/ac of manure can result in the doubling of the forage yield of a Stipa-Bouteloua grass prairie, and the yield increase can persist for a number of years. Higher rates of manure of 20 to 30 ton/ac have shown even greater yield increases and increased crude protein content in the year of application. Manure applied to Stipa-Bouteloua grass significantly boosts both forage production and crude protein.

Clearly, the application of livestock manure can improve native grassland production. However, the application of manure can have negative effects by shifting species composition and may overload the soil with nutrients.

Effects of nutrient application on rangeland plant species

Fertilization of native rangeland has been successful with relatively pure stands of native grasses. However, in mixtures of grasses, forbs and shrubs, 30 per cent or more of the fertilizer applied can be used by unpalatable forbs and shrubs.

Manure applications alter plant species composition. In ungrazed rangeland, study has shown the effect was to reduce the abundance of ground cover species in favor of a few dominant grasses, especially western wheatgrass. Western wheatgrass is a productive species when soil moisture is adequate; however, under drought conditions, it is less productive and palatable than native species it replaced.

Studies found that nutrient additions on grazed rangeland resulted in the increase of weedy species. Moderate to heavily grazed rangeland tends to respond with increased growth of early successional weedy species that respond to the increased nutrient supply.

Changes in species composition may occur because of the way the species use nutrients, which can change the nutrients available to the plant. For example, weedy species tend to prefer nitrate nitrogen ($N0_3^-$), which is in limited supply on rangelands in a steady state, while the native grasses prefer ammonium nitrogen (NH_4^+).

The maintenance of biodiversity is an important goal for rangeland managers and is an emerging priority on crown rangelands. Though there is little long-term research available concerning the effects of manure applications to native grasslands integrity, considerable anecdotal evidence suggests that manure applications will cause undesirable species shifts. For this reason,

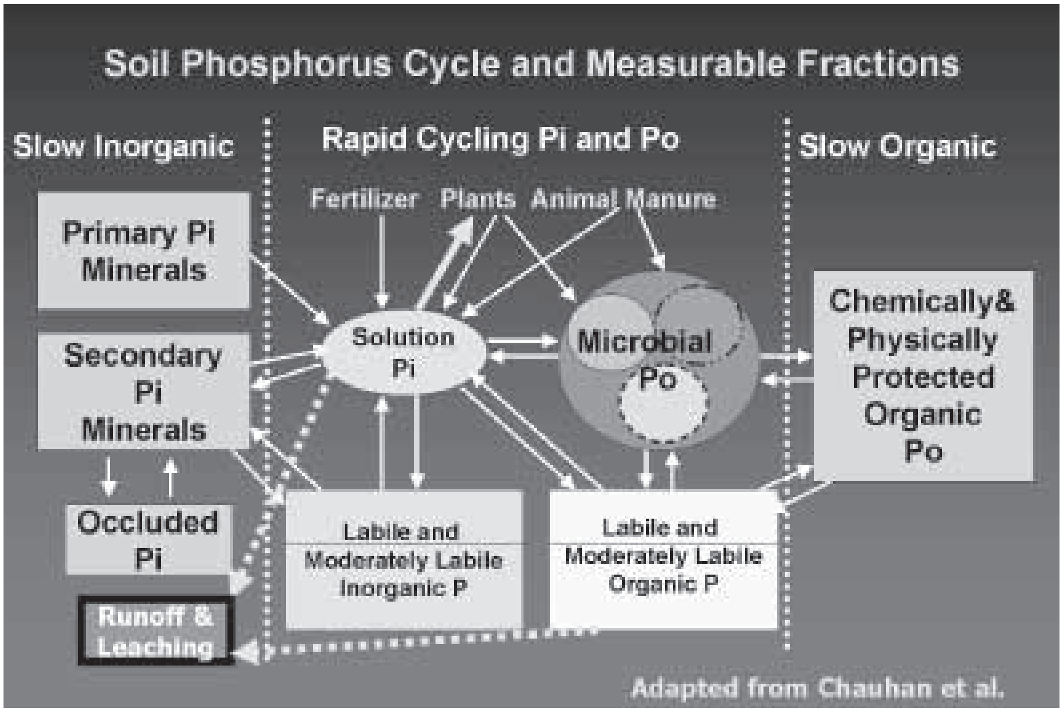

Figure 3. *Fractions of P in soil.*

manure application is not permitted on crown rangelands and is viewed as an undesirable disturbance to native plant communities.

Also, guidelines to limit the expansion of exotic species normally stress the avoidance of management actions that lead to moisture or nutrient enrichment in grassland communities. This concern is particularly true in the fescue grassland and aspen parkland where exotic species have already had a major negative effect on native plant community integrity.

Effect of surplus nutrients on rangeland soils and plants

Surplus nutrients applied to soil in manure will encourage non-native, nutrient loving invading plant species at the expense of native plants. This change results in a decline in rangeland biodiversity.

When manure is applied to the surface of rangeland, up to half the nitrogen in the manure is lost to the atmosphere by volatilization. This outcome is very inefficient. Best management practices for manure include the application to soil, followed by incorporation to minimize N losses to the air.

Remaining organic N in manure will convert to nitrate nitrogen. When excess levels of nitrate accumulate in soil, there is the potential for the downward movement of nitrate into the subsoil and eventually into groundwater.

Therefore, if manure is applied to rangeland, the rates must be very light to ensure excess levels of nitrate will not accumulate in soil for possible movement into groundwater. For example, if large amounts of manure are applied to rangeland, significant amounts of P will be added and could potentially be lost in runoff water.

The phosphorus content of manure tends to be relatively high. Each ton of feedlot manure contains up to 33 kg (30 lb) of P. A 40 ton/ac application of feedlot manure would add 1,320 kg of P_20_5/ha (1,200 lb of P_20_5/ac) to the soil. This amount would greatly increase soil P levels and affect how soil P fractions cycle in soil (Figure 3).

Generally, much of the P in the manure would remain near the soil surface. The addition of P from manure to rangeland can result in warehousing P in soil. When manure is applied to soil, the plant available P levels will substantially increase. High soil P levels may also contribute to shifts in plant diversity.

Inorganic and organic P on the soil surface may move into surface waters, which can cause serious water pollution. One part per million of P in water will produce up to 225 kg (500 lb) of blue green algae. Therefore to prevent contamination, it is critically important to ensure that manure not be applied near surface water.

Effects of manure application on saline or solonetzic soils

Manure tends to contain moderate levels of salt. In particular, hog manure may often contain significant amounts of sodium. Repeated applications of manure can raise salt levels in soil. Rangeland soils that are saline or Solonetzic could be negatively affected as a result of salt or sodium additions, which reduce the productivity of these soils. So it is important that manure not be applied to saline or Solonetzic rangeland soils.

Runoff contributes to surface water contamination

Manure is surface-applied to rangeland and remains on the soil surface. When large amounts of manure are applied on lands that are moderately rolling or near surface water bodies, there is a risk that nutrients in the manure could be transported in runoff water to the surface water, especially after unusually heavy rainfalls. This situation would result in the contamination of surface water that may also be used as a stock-watering source.

Therefore, if manure is to be applied to rangeland, it should only be applied on land with relatively uniform topography and not applied near surface water or water wells. In addition, the use of light rates of composted manure for rangeland application is suggested, as the majority of weed seeds are no longer viable after the composting process.

Manure affects livestock grazing

The application of manure on rangeland can affect livestock distribution and grazing patterns. The initial manure application will increase plant productivity, resulting in overgrazing of manured areas.

Manure additions may result in rank growth similar to remnant plants near manure pats on grassland. Generally, these plants are not consumed by livestock, resulting in reduced rangeland plant production.

Summary

Manure application on native rangeland is not a recommended practice. Native rangelands are very fragile, with diverse eco-systems that have taken centuries to evolve to their present day steady state.

Proper stocking rates coupled with careful grazing management of native grassland have proven to be a successful and sustainable management regime. The application of manure to this regime will negatively affect the rangeland bio-diversity by:

- affecting nutrient cycling in soil
- overapplication of nutrients to soil so that the soil stores excess nutrients
- changing the rate of natural decomposition of soil organic matter
- adding salts and sodium to soils that may already have higher salt levels
- affecting livestock grazing patterns, leading to over and undergrazing of pastures.

In addition, the application of manure onto the soil surface will result in a significant loss of nitrogen by volatilization to the atmosphere as ammonia. Organic nitrogen will convert to nitrate and will leach through subsoil to groundwater when there is too much in the soil.

In summary, the productivity of rangeland is self-maintained. Plant nutrients are naturally recycled and reused, but remain in equilibrium. When manure is applied beyond what is naturally applied by grazing animals, the natural self-sustaining system is disrupted.

Rangeland is a natural eco-system that works! Rangeland managers must carefully consider the potential consequences of disrupting successful, productive rangeland eco-systems by the application of manure.

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