

## Soils of Rangelands in the Prairie Region

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### Summary

Twelve million hectares of land within the agricultural part of the Prairie Region is utilized for grazing, generally land of limited capability for arable agriculture. The areas where grazing is the dominant land use include the Dry Mixed Prairie and Mixed Prairie in southwestern Saskatchewan and southeastern Alberta, the Mixed Prairie with Solonchic soils in east-central Alberta, the Fescue Grasslands of the Foothills and Aspen Parkland, forest lands with Gray Luvisol soils, the Interlake and West Lake areas of central Manitoba, and the Sand Hills that occur throughout the whole region. This paper discusses the soils of those rangelands, with attention to the connections between soils and vegetation.

### Introduction

The dominant land use within the Prairies is cropland. Almost all of the land that is suitable for arable cropping (including some of limited capability) has been converted to annual crop production. Land used for grazing or rangeland occurs at the margins of the vast area used for farming. These lands occur at the dry margin where annual precipitation limits the productivity of annual crops, and at the cool margin where the short growing seasons and cool temperatures of forested regions reduce annual cropping opportunities. Many of the rangelands have hilly topography and/or stony soils that make cultivation impractical. Those areas with sandy soils are best suited to maintaining the grassy vegetation and use in low intensity grazing. The Prairie Farm Rehabilitation Administration (PFRA) report entitled *Prairie Agricultural Landscapes* identifies two land practice groups where grazing is the main land use<sup>12</sup>. Areas of ‘dominantly pasture’ occupy nearly 12 million hectares of the Prairie Region (Table 1). The objective of this chapter is to discuss the soils that occur under rangeland, the relationships between soil type and vegetation, and between soils and productivity.

Table 1. Area of land in the ‘Dominantly Pasture’ land practice groups identified by the PFRA<sup>10</sup>.

Land practice group	Area (million hectares)	Rangeland group
Strongly sloping to hilly, mainly glacial till soils	3.57	Mixed Dry Prairie and Mixed Prairie
Well-drained Chernozemic/Luvisolic soils	2.98	Fescue Prairie and Aspen Parkland
Solonchic soils	1.17	Mixed Prairie of east-central Alberta
Imperfectly to poorly drained soils	2.31	Interlake and West-Lake area of Manitoba
Sandy soils	0.85	Sand hills throughout region

### The Mixed Prairie and Dry Mixed Prairie of southwestern Saskatchewan and southeastern Alberta

Rangelands account for much of the Mixed Grassland Ecoregion (including the lands designated as Dry Mixed Prairie in the Atlas of Saskatchewan) of southwestern Saskatchewan and southeastern Alberta<sup>14</sup>. In the moister parts of this region, the dominant vegetation on upland soils, mainly loam-textured soils on glacial till, is a mixture of western porcupine grass and northern wheat grass (Figure 1)<sup>14</sup>.

**Figure 1:** Rich grassland on rolling glacial till with Black Chernozem soils in southeastern Saskatchewan.



Needle-and-thread grass and blue grama grass are more important in areas with warmer and drier climates, as well as on dry sites such as the crests of hills. The level of grazing impact also has a big influence on the composition of the vegetation. Grazing is concentrated on the taller grasses (the speargrasses and wheatgrasses), and overgrazing tends to reduce the abundance of these species. Shorter grasses such as blue grama, June grass and sedges, as well as forbs such as pasture sage, crocus, and scarlet mallow, increase as the taller grasses decline. Droughts, a recurrent feature of this region, also shift the balance from taller to shorter species.

The dominant soils through the Mixed and Dry Mixed Prairie region are Brown Chernozem soils on loam-textured glacial till. While loam-textured soils are normally suitable for cultivation, extensive areas of till have been kept in rangeland because of strongly rolling topography or excessive stoniness (Figure 2).

**Figure 2:** Mixed prairie on a rolling moraine with stony, loamy Brown Chernozem soils.



The glacial deposits are often thin because these are lands of high elevation near the southern limit of glaciation, and strongly influenced by the mixing in of bedrock materials. The soils of the Fife Lake (Brown Chernozem) and Scotsguard (Dark Brown Chernozem) associations, for example, contain fragments of sandstone and coal derived from the underlying Ravenscrag bedrock. The Ah and B horizons generally are thin because of the dry climate, and occurrence on steep slopes and the crests of hills. Bedrock exposures are common, particularly where streams have eroded runways and coulees.

Rangelands also occur on glaciofluvial plains with coarser-textured Chernozemic soils, mostly sandy loams and sands (Figure 3). Many areas on these sand plains were once cultivated, but were returned to perennial grass cover because of their low water-holding capacity and susceptibility to wind erosion. Crested wheatgrass, introduced from Asia, was often seeded on these former fields. Native grasslands on sandy soils are dominated by the needle-and-thread and sand reed grass (Figure 4).

**Figure 3:** Mixed prairie with scattered sagebrush on a sandy glaciofluvial plain.



**Figure 4:** Needle-and-thread grassland on a level area in the Elbow Sand Hills.



Although almost none remains under native vegetation, the Vertisolic soils on clayey glaciolacustrine materials once supported a mixed stand of northern wheat grass and June grass.<sup>2,13</sup> Interestingly, winterfat is a conspicuous shrub on ungrazed native grassland included within the University of Saskatchewan's Matador Prairie. It appears that grazing has a considerable impact on this palatable and nutritious plant that is valued for winter grazing.

Solonetzic soils are common in the Dry Mixed Prairie that occurs south of the Cypress Hills. Solonetzic soils have higher concentrations of sodium that result in the formation of the clayey B horizon (clay pans) and are generally less productive. Western wheat grass is generally more common in the stands growing on Solonetzic soils.

### **The Mixed Prairie of East-Central Alberta**

This part of the Mixed Grassland is distinctive because of the prevalence of Solonetzic soils. The area where rangeland accounts for about 2/3 of land use stretches from north of Medicine Hat to the Battle River area in the north, mainly in the Brown and Dark Brown soil zones. The belt of Solonetzic soils continues into the Black Soil Zone east of Edmonton, with most of the more northern area in cropland. Kjeersgaard, discussing the large proportion of 'abandoned land' (land under native vegetation or reverting to native species, settled in the early 1900s and abandoned in the 1930s) in the Oyen map area considers that a combination of a dry climate and a prevalence of Solonetzic soils were the main reasons.<sup>7</sup>

The occurrence of Solonetzic soils may be attributed to the thin glacial till deposits containing fragments of marine shale from the underlying bedrock. It appears that the presence of minerals that weather to release sodium may be the reason for the high sodium concentrations of Solonetzic soils, particularly under semi-arid climates. In addition, as discussed by Pawluk, the movement of sodium ions into the soil by upward moving groundwater is an additional factor<sup>11</sup>. Certainly, both bedrock shale in road cuts and water-filled dugouts even during dry years are evident when traveling through the area. The main Solonetzic soils in the Oyen area occur on till derived mainly from the underlying shale, occasionally formed on the bedrock itself. The Hemaruka Series, for example, occurs on about 20% of the land in the Oyen Map Area and is a Brown Solodized-Solonetz on till derived primarily from the Horseshoe Canyon and Bearpaw formations.<sup>7</sup>

It is likely that the native grassland on the Solonetzic soils has a higher proportion species such as western wheatgrass than grasslands on Chernozemic soils. The vegetation at a study site in the southern part of this region has been described as Blue grama-Spear grass- Wheatgrass (*Bouteloua-Stipa-Agropyron*), with both western and northern wheatgrass in the stand<sup>10</sup>. In addition, and as mentioned by Kjeersgaard in the soils report for the Oyen area, much of the land now in pasture was once cultivated and then abandoned during the drought of the 1930s, resulting in the common appearance of exotic species such as smooth brome and crested wheat grass.<sup>7</sup>

Grassland productivity on Solonetzic soils is likely to be more strongly affected by drought, because of the presence of the solonetzic B horizons (claypans) that reduce the entry and storage of water and limit rooting depth. There is much variability in the vegetation, ranging from almost bare soil in 'blow-out pits or buffalo wallows' to reasonably productive grass stands only a few metres away.<sup>7</sup>

### **The Rough Fescue Prairie and Aspen Parkland**

The main area of Rough Fescue Prairie is in the Foothills, accounting for about 13% of native prairie in Alberta<sup>3</sup>. This is an area of highly productive Dark Brown and Black Chernozem soils occurring on rolling topography that limits cultivation. The range experimental area near Stavely in the Porcupine Hills has Black Chernozem soils on glacial till overlying sandstone. The dominant species in the Foothills is mountain rough fescue (*Festuca campestris*).

Rough Fescue Prairie is also characteristic of the grassland areas within the Aspen Parkland Ecoregion of Alberta and western Saskatchewan. The dominant species in the Parkland is Plains Rough Fescue (*Festuca hallii*). When used intensively for livestock, overgrazing decreases the proportion of (even eliminating in extreme cases) the rough fescue leaving a mixed-prairie community of spear grasses, blue grama and pasture sage<sup>1</sup>. Rough fescue becomes less common in the Parkland of eastern Saskatchewan and Manitoba, although there are still pockets. It is unclear whether the climate in the east is naturally less suitable for fescue, or it has been eliminated by a longer history of grazing impact in the east.

The Aspen Parkland Eco-region forms a broad arc from southern Manitoba, northwest across Saskatchewan and Alberta, and then southwards along the foothills. This is an area long recognized as the fertile belt of the Prairies because of the generally moist climate, adequate temperatures and fertile Black Chernozem soils. Most of the land has been cultivated and is used productively for annual crops, including cereals, oilseeds and pulse crops. Native vegetation remains mostly on land too hilly, stony or coarse textured for annual cultivation. Fescue grassland occurs on dry upper- and south-facing slopes, with aspen stands in concave lower slopes and northerly aspects, with willows, balsam poplar and sedges in depressional areas. The balance between aspen and grasslands changes, from aspen only on moist lower slopes, to near continuous stands of aspen as one moves north or up in altitude. Gray Luvisol (gray wooded) soils occur under aspen, with Dark Gray and Black Chernozem soils in grassy areas. About two-thirds of Western Canada's cattle are produced in the Parkland, and more than 80% of the forage crops.<sup>6</sup>

Grazing has long been important in the Aspen Parkland. Bison have used the region for thousands of years, with the dual action of grazing and fire (either started by lightning, or set by Indian people to manage the grassland) keeping the aspen forest from growing out onto the Prairie<sup>13</sup>. With the local extermination of the bison and control of fire as land became settled, it appears that the aspen groves have expanded out into former grassland. One of the authors (Anderson) recall hearing from an elderly farmer in southeastern Saskatchewan that the now continuous cover of aspen on his pasture had gradually taken over what had been open grassland 50 or 60 years earlier.

The aspen forests in the northern part of the Parkland and at the transition to Boreal Forest are not as productive as those further north and are seldom harvested for lumber or pulp. Many of the stands were cleared decades ago, the trees bulldozed into windrows and then burned. These lands are generally seeded to forages, particularly alfalfa and brome, and used for grazing, often in large government-operated pastures<sup>8</sup>. Maintaining productive forage stands is difficult because of the re-growth of aspen from underground suckers, and the gradual invasion by Kentucky bluegrass. Spraying with herbicides, prescribed burning, mechanical brush control, and grazing of aspen suckers by cattle are all used to slow the expansion of the forest onto grassland.

Grazing occurs as well in the aspen forest or bushland. Cattle browse many of the shrubs, particularly saskatoon and chokecherry, aspen suckers, and rose and snowberry, although the latter only when other fodder is in scant supply. Comparisons of vegetation and soil properties on ungrazed, grazed, and land grazed heavily in the past and not for the past decade show the impact of grazing<sup>5</sup>. Gray Luvisol soils on glacial till occurred at the three sites. There were more shrubs in the ungrazed, a recovering shrub layer in the formerly grazed land, and almost no shrubs in the grazed stand. Grassy species were more evident under heavy grazing, probably because of the reduced canopy and more light reaching the forest floor (Figure 5). The surface organic layers (LFH horizons) of the Gray Luvisol soils were thicker in the ungrazed than in the heavily grazed stands. The latter had thin but distinct, dark Ah horizons, perhaps a result of cattle treading on the surface organic layer, working the organic matter into the upper part of the mineral soil. One of the techniques developed for assessing range health in forests is to measure the thickness of the surface organic layer.

**Figure 5:** Grazed aspen forest in the Thickwood Hills of Saskatchewan, with a sparse shrub layer and grassy ground cover.



### **The Interlake-Westlake areas in Manitoba**

This is an area dominated by large farms or ranches with more than 70% of the land in pasture<sup>12</sup>. The area includes the northern and western parts of the Interlake, that is the land between Lake Winnipeg and Lakes Manitoba and Winnipegosis, and the land to the west of the lakes and east of the Riding and Duck Mountains. The vegetation in southern parts is aspen-bur oak parkland, similar to the aspen parkland except for the occurrence of bur oak. Further north the vegetation is mixed deciduous forest, much disturbed by agriculture.

The land used in grazing includes mainly very stony soils on glacial till, and imperfectly to poorly drained areas with grasses and sedges. A ridge and swale landscape is typical. Low ridges composed of highly calcareous (up to 50% calcium carbonate) stony till, often with thin till deposits over limestone, occupy the higher land, and are naturally forested, with mainly aspen<sup>9</sup>. The swales between are dominated by poorly drained Gleysolic soils, some with thin peaty layers, growing mixtures of grasses, sedges and low shrubs. This land was once under Lake Agassiz, a glacial lake that formed at the time of de-glaciation about 10,000 years ago. It is probable that thin silty to clayey materials were deposited in the glacial lake, followed by wave erosion as the lake waters receded. The waves appear to have washed the finer particles from the higher land, resulting in stony and often gravelly soils on the ridges, and concentrating the finer materials in the lower areas or swales.

Most of pasture and hay land in the region occurs on the imperfectly to poorly drained soils of lower areas such as the swales described above. The dominant vegetation on the wetter soils is a mix of sedges and meadow grasses, whereas big and little bluestem (once dominant in the Tall Grass Prairie, to the south) occurs on the better drained or drier soils<sup>9</sup>. Speargrasses grow on the driest sites, especially where thin till overlies limestone bedrock. Forest is the natural vegetation on much of the land, particularly the soils on glacial till. The soils under forest include Brunisolic and Gray Luvisols, with thin A and B horizons because of the influence of the high lime content of the parent material, slowing rates of weathering. Forests have been cleared in many areas and seeded forage species are grown, along with

introduced species such as redtop, smooth brome grass and quack grass. Forests, particularly aspen forests, are often grazed, with grazing effects similar to those discussed for the lands with Gray Luvisol soils in the Foothills and northwestern Saskatchewan.

The high-lime soils of the Interlake include several soil orders in the present classification, but can be grouped as 'Rendzina' soils because of their high content of lime carbonate<sup>4</sup>. Rendzina soils are generally deficient in available phosphorus, because of somewhat lower amounts of phosphorus-containing minerals in the parent material and the complexing of plant-available phosphorus by calcium, resulting in lower yields and phosphorus contents in forage. Forages grown on highly calcareous soils, especially those that are somewhat wetter, are often deficient in copper, zinc and other micronutrients. Mineral supplements are particularly important in livestock nutrition where forages are grown on such soils.

### **The Sand Hills of the Prairie Ecozone**

There are large areas within the Prairie with sandy soils and a dune topography, generally known as sand hills. The parent materials were deposited as streams carrying sediments entered glacial lakes, with the coarse sandy materials settling out first as deltaic materials. It is likely that winds then formed the sand dunes that are characteristic of these areas even today. These lands are covered with vegetation except for parts of the Great Sand Hills in Saskatchewan and a small, non-vegetated area known as the Spirit Sand Hills within the Upper Assiniboine delta (Brandon or Carberry Sand Hills) in Manitoba. There is little doubt that the sand dunes have been active at different times during the past 10,000 years, during long periods of drought, perhaps triggered by related processes such as fire<sup>15</sup>. There is good evidence that dune fields were more active in the 1800s, probably triggered by a decade-long drought between 1790 and 1800<sup>6</sup>. The time of most active dune formation appears to have been about 150 years ago, followed by gradual revegetation of the bare sand. Most active dunes fields in southern Alberta, Saskatchewan and Manitoba have become more stable throughout the last century, with little change since about 1960. One of the indications of past wind activity is the dark, buried layers enriched in organic matter, former Ah horizons, sometimes observed where the subsoils of now stable dunes are exposed in road cuts. Study of these buried soils by radiocarbon dating the organic matter is a way of dating the period of active dunes. These studies are of much interest to those considering the impact of modern-day climate warming trends on soils and vegetation.

There are about 120 dune fields within the boreal and prairie regions of western Canada<sup>6</sup>. Some of those not mentioned earlier include the Middle Sand Hills along the South Saskatchewan River north of Medicine Hat, the Webb Sand Hills in southwestern Saskatchewan, the Manito Sand Hills in west-central Saskatchewan. There are several areas along the South Saskatchewan River, the larger ones being the Dundurn Sand Hills south of Saskatoon, and the Nisbet and Fort à la Corne areas south, north and east of Prince Albert, where jack pine forest covers the dunes. About one-half of the 120 dune fields are in the Prairie Eco-zone, accounting for most of the 850,000 ha of sandy, grazed lands in western Canada (Table 1).

The soils of the sand hills within the Prairie Eco-zone generally have thin Ah horizons over yellowish sand. There are several reasons for the minimal soil horizon development. The sandy texture combined with a dry climate limit both plant growth (the initial source of organic matter) and the weathering of minerals. The sandy parent material is composed mainly of resistant minerals such as quartz, with little or no clay minerals. Clay minerals, even relatively low amounts, strongly influence water holding capacity and productivity, and the formation of clay-humus complexes. The latter are important to the build-up of organic matter and the development of soil structure. Finally, and often the most important factor, is the short period of soil formation in that most surfaces are much younger than those of more stable landscapes because of periods when vegetation was lost and the soil blown away. Soils of the Regosolic Order are most common, mainly Orthic Regosols with Ah horizons a few centimeters thick and no B horizon (Figure 6). Ah horizons are often thicker in the Aspen Parkland, and the sandy soils are classified as Humic Regosols. Even when soils have Ah horizons thick enough (>10 cm) to be placed in the Chernozemic Order they are not, mainly because the

soils lack the granular structure of Chernozemic Ah horizons. The very sandy Ah horizons have mainly bits and pieces of darkened (humified) plant residues and charcoal, suggesting that fires have occurred in the past.

**Figure 6:** An Orthic Regosol soil on sandy, wind-blown parent material in the Mixed Prairie.



Areas in which the dunes are currently active, or have only recently been stabilized by vegetation, have no detectable Ah horizon, and the soil surface is the yellow colour of the parent material. Bare sand is gradually invaded by pioneer plants such as lance-leaved psoralea and Indian rice-grass. These pioneer plants reduce the wind speed at the surface, allowing other plants which are less tolerant of disturbance to become established. Growth of grasses gradually adds organic matter to the sand, forming the thin Ah horizon as observed on more stabilized dunes. Stabilized sand hills in the Mixed Grassland Ecoregion are usually dominated by needle-and-thread, sand reed grass, and a variety of forbs and shrubs. In the Aspen Parkland Ecoregion, better moisture conditions allow western porcupine grass and occasionally even plains rough fescue to grow on sand hills. Along with the grasses, patches of shrubs such as chokecherry and creeping juniper, as well as aspen stands in the hollows between dunes, are characteristic features of sand hill vegetation. Creeping juniper is a shrub that spreads horizontally over the soil surface, playing an important role in stabilizing dunes. In the driest part of the Mixed Grassland (e.g. the Great Sand Hills), silver sagebrush is scattered through the grassland on sand hills.

A typical catena (a related group of soils along a hillslope) in the Brandon Sand Hills includes Orthic Regosols on upper slopes, Gleyed Regosols on lower slopes, and Rego Humic Gleysols in depressions.<sup>15</sup> The faint to distinct mottles in the subsoil indicates periods when the water table is close to the soil surface. Many of the deep sandy deposits are major aquifers, containing many meters of groundwater. This is important to both the stability of the dune areas, as wet sand supports vegetation and is not eroded by wind, and as a source of high quality water for livestock and people. Access by the roots to near-surface groundwater probably explains the greater abundance of shrubs and trees on sand hills compared to finer-textured soils in the same region.

## Uses of Soil Information in Rangeland Management

While soil surveys have often focused on arable land, soil information is very important to range managers. They divide rangeland into “range ecosites”, landscape types which differ in their physical site characteristics and their ability to produce vegetation. Typically a number of mapped soil associations would be grouped into a single range site. Well-drained Chernozemic soils with textures of loam to clay loam are grouped into the Loam Ecosite, while other ranges of soil texture result in the Clay, Sandy Loam, and Sand Ecosites. Other upland sites include Burnout (on Solonchic soils), Gravelly, Dunes, and Thin (on steep slopes or other naturally eroded sites). A variety of lowland ecosites are defined on moist to wet areas, as well as on saline soils.

For each of these ecosites, the potential plant community that develops under ungrazed to lightly grazed conditions, and the potential stocking rate, are described. For example, in the Dry Mixed Grassland of Saskatchewan, an area of Loam Ecosite has the potential to support a northern wheat grass – needle-and-thread community with a recommended stocking rate of 0.20 Animal Unit Months per acre.

Range ecosites are used in planning a sustainable grazing operation. Range ecosites are mapped, using the available soil map for the area as a starting point, then fine-tuning it with field observations. Survey transects are laid out within range ecosites to measure the species composition of the grassland, as well as other indicators of range health such as litter cover and soil erosion. The results of the survey are compared to information on the potential for that ecosite, to determine how much the area has been altered by grazing impact. A recommended stocking rate is then determined, taking into account the potential stocking rate for that ecosite as well as the level of range health. For example, if the pasture is found to be missing some of the valuable grass species that should occur on that ecosite, or have not enough litter cover to protect the soil surface, or have early signs of soil erosion, then stocking rates are reduced to allow for recovery. Ecosite information is also used in deciding how to divide the pasture with fences (for example, to separate an area of moist to wet ecosites which requires different management), and in selecting grass species for seeding into disturbed areas.

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