Chapter 1
Overview: Anthropogenic Changes of Canadian Grasslands

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Abstract. Canada's grasslands are located primarily in western Canada within the prairie provinces, but also with significant portions in the interior of British Columbia. Before European contact, their character and distribution were significantly influenced by disturbances from fire and large herbivores, which killed woody plants and produced a more arid environment where grasses were competitive. Aboriginal Indians also influenced these processes, both directly by increasing the number of fires either by accident or for strategic reasons (Lewis 1982) and indirectly through over-hunting (Kay 1994). Anthropogenic impacts were, therefore, present before European contact; whether or not these disturbances could be considered as natural is debatable. However, there is no question that the disturbances introduced through Eurocentric farming practices by settlers beginning early in the 19th century and overtaken within the last 50 years by resource extraction economies were ecologically catastrophic. As a result, most of the grasslands have been cultivated and those that remain have been altered by grazing or severely fragmented by roads, conduits for energy, or urbanization. This chapter deals primarily with anthropogenic changes to the grasslands made since the arrival and establishment of Europeans.

Résumé. Les prairies canadiennes se trouvent principalement dans l'ouest du Canada, dans les provinces des Prairies, mais il en existe également des portions importantes à l'intérieur de la Colombie-Britannique. Avant l'arrivée des Européens, leurs caractéristiques et leur répartition étaient en grande partie définies par l'action du feu et des grands herbivores qui détruisaient les plantes ligneuses et créaient un environnement plus aride, où les herbacées détenaient un avantage concurrentiel. Les autochtones influaient également sur ces processus, soit directement en augmentant le nombre d'incendies — par accident ou pour des raisons stratégiques (Lewis, 1982) —, soit indirectement par une chasse excessive (Kay, 1994). Les incidences anthropiques étaient donc déjà présentes avant l'arrivée des Européens, et la question de savoir si ces effets pouvaient être qualifiés de « naturels » reste matière à débat. Cependant, il est clair que les perturbations provoquées par les pratiques culturales des colons européens à partir du début du XIXe siècle et l'avènement, observé au cours des 50 dernières années, d'une économie fondée sur l'exploitation des ressources, ont eu des conséquences écologiques catastrophiques. Les prairies sont aujourd'hui presque entièrement cultivées, et les portions qui subsistent ont été perturbées par le pâturage ou gravement fragmentées par les routes, les corridors énergétiques ou l'urbanisation. Le présent chapitre traite principalement des changements anthropiques survenus dans les prairies depuis l'arrivée et l'installation des Européens.

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History of Settlement

The Politics of Immigration

European settlement of the prairie was instigated initially by competition for the fur trade between the Hudson's Bay Company and the North West Company, which resulted in rapid expansion of trading posts toward the west so that by 1850, settlers had reached the Rocky Mountains. Expansion was catalyzed by the construction of the Canadian Pacific Railway (CPR) that enabled immigration from eastern Canada. The earliest settlers were farmers who provided meat and vegetables to the trading posts, which were their only markets until the railway was built. Subsequent settlement was strongly influenced by government policy and the economic conditions that followed.

Until 1870, the prairie region was part of Rupert's Land, a large territory defined by the Hudson's Bay drainage system. This area was granted to the Hudson's Bay Company by King Charles II of England in 1670. By the late 1850s, most of the arable land in Canada West (also known as Upper Canada, which was located in what is now southern Ontario) had been sold, and any expansion was restricted toward the west. Consequently, in 1857, Great Britain sponsored expeditions with the intent of determining the value of Rupert's Land. One expedition was led by Captain John Palliser from 1857 to 1860, while a second expedition was led by Henry Youle Hind from 1857 to 1858 (Owram 2007). Palliser spent most of his time within 320 km north of the United States border, a geographical area he classified by its productive potential as either the "fertile belt" or the "Palliser Triangle." The latter was a semi-arid shortgrass prairie "unfitted in all probability to agriculture" (Owram 2007), a view that was supported by Hind. Britain showed little interest in Palliser's report. Expansionists seized on his description of the fertile belt, whereas ranchers used his description of the Palliser Triangle to keep out the farmers.

Expansion into the prairies was made possible with the arrival of the North-West Mounted Police in 1874, the extirpation of the bison (*Bison bison* L.) by 1879, and the relocation of the Aboriginals onto reserves with treaties signed from 1871 to 1877. However, the key to expansion was the building of the CPR, which was begun in 1881, reached Calgary in 1883, and was completed in 1885 with the last spike at Craigellachie, British Columbia. As part of its compensation, the federal government granted the CPR 25 million acres (10 million ha) in Manitoba and what is now Saskatchewan and Alberta (Tyman 1972). The land was located in a checkerboard of 1-section (640 acres) parcels within an economic zone of 32 km on either side of the railway, which it sold to settlers (Fig. 1). The alternate sections continued to be owned by the government, but were gradually sold to settlers in 160-acre parcels (Morton and Martin 1938; Tyman 1972).

The political purpose for building the railway was to unify the country and to assert Canada's claim to the northwest against American competition (Friesen 1984). However, it was the threat from the Northern Pacific Railroad Company to expand into Canada from the United States in 1870, and John Macoun's favourable report on the agricultural potential of the prairies, that determined CPR's decision to build the railway through the southern route. This decision had a tremendous impact on farm settlement and subsequent disillusionment of the settlers during the droughts that followed in the 1920s and 1930s.

John Macoun was recruited in 1872 by Sanford Fleming, chief engineer for the proposed railway, to participate in surveying the railway route and in determining the agricultural potential of the various regions. Macoun's surveys, conducted from 1872 to 1881, corresponded to a period of unusually high rainfall, which was in contrast to the drought experienced by the Palliser expedition. However, Macoun's overstated optimism

Fig. 1. Poster published in 1883 by the Canadian Pacific Railway to induce colonists to settle in Manitoba and the Northwest Territories.

for the region supported the goals of the CPR (Berton 2001) and the 1863 report by Palliser was all but forgotten.

With the completion of the railway and Macoun's unqualified recommendation on the productive potential of the southern prairies, the federal government and the CPR advertised in Europe for prospective settlers. Settlement was needed by the CPR to create business to move grain to the terminals and by the federal government to resist the expansion of Americans into Canada.

Settlements

By the mid-1850s, settlement in the Northwest Territories was clustered in four regions: Two were centred on the fertile soil of the North Saskatchewan River around Edmonton and Prince Albert, one was centred between Moosomin and Moose Jaw in the Assiniboia district, and another in the dry southwest from the Cypress Hills to the Rocky Mountains that was supported primarily by ranching. Ranching in the southwest was greatly influenced by Americans. Texans apparently followed the grass to southern Alberta until the late 1870s (Jordan-Bychkov 2000), and the early ranches were stocked mostly with cattle from the south.

Open-range grazing came to an end through an order-in-council in 1881, which granted to individuals or corporations leases of up to 100,000 acres (40,486 ha) for an annual fee of $0.01 per acre for a period of 21 years. Many of these ranches had absentee landowners living in the east. One of the most prominent among them was Senator Matthew Cochrane, a businessman from Montreal. Many retiring North-West Mounted Police also took up ranching. By 1884, 10 companies controlled two-thirds of the stocked land in the southwest (Breen 1973).

The construction of the railway also increased the threat of immigration, and in 1892 the ranchers received a four-year notice that removed the restriction to homesteads, thus opening up the region for settlement. The ranchers used the reports by Palliser and Hind, suggesting that the southern prairie was too dry to support agriculture, in an effort to keep out farmers. They were able to persuade Ottawa to set aside the major water sources for cattle, thereby maintaining their hegemony because settlers would need water for their livelihood. However, this, too, came to an end for the ranchers with the election of the Liberals in 1896 under Wilfred Laurier, who believed that dryland farming had advanced sufficiently to support a viable farming economy, and water reserves began to be auctioned off. Access to water encouraged an influx of settlers into the arid southern prairies, where they were subjected to its harsh climate and uncertain livelihood, and from where many would eventually retreat (Fig. 2).

The cattle industry was given a major setback in the winter of 1906–1907 when the customary chinook winds failed to appear and up to 80% of the cattle died on some ranches. This marked the end of the last of the large cattle companies and gave rise to the new generation of local ranchers (Evans 1983).

Nature of Human Impacts (Post-European Contact)

The impacts of immigration and industrial development that followed had the effect of destroying, modifying, or fragmenting the native prairie. Destruction was associated primarily with farming practices and urban development; the remaining grassland was altered by grazing and fragmented by fences, irrigation canals, pipelines, and roads.

The introduction of livestock and farming into the Canadian prairies in the last 150 years resulted in the most profound changes during the last 5–10 millennia. In a very short time, the primary land-use activity on the prairie went from predominantly ranching to farming. The rapid transition began after 1896 with the settlement of the more mesic parkland by people from eastern Canada who were of British origin and later by Polish and ethnic Germans from the Ukraine (Carlyle 1994). By 1906 most of the parkland had been settled by immigrants who had travelled from east to west. The more arid grasslands south of Calgary were first occupied by Mormons from Utah who settled in southwestern Alberta in the late 1880s, with the remaining grasslands being settled primarily from 1906 to 1916 (Figs. 2 and 3). During this time, ranchers who had occupied the area retreated to the more remote regions (Evans 1983) as farming transformed the landscape. Roads and fences were constructed and diverse native grasslands were plowed and replaced with

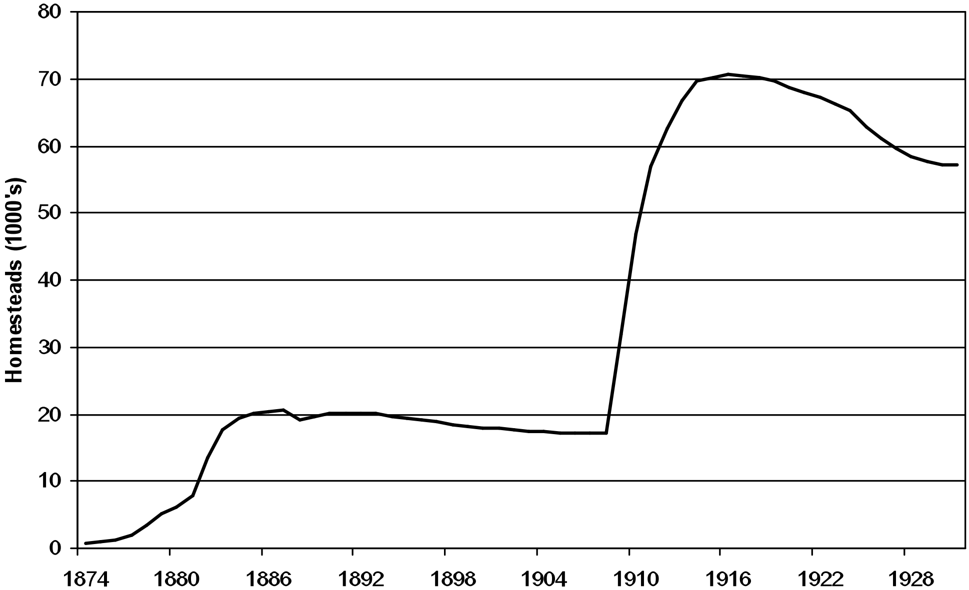

Fig. 2. Net accumulated homesteads (sum of pre-emptions and purchased, less cancellations) in Alberta and Saskatchewan from 1874 to 1931. Adapted from Statistics Canada (2009).

monocultures of annual crops or introduced grasses. Barbed wire, which was invented in 1873, became the visible means of defining property lines and ensured barriers not only to livestock, but to some extent to wildlife, as it does today. Irrigation also was introduced to southern Alberta late in the 19^{th} century, with the St. Mary Project delivering water to Lethbridge by September 1900 (SMRID 2009). Irrigation developed rapidly in Alberta and Saskatchewan, increasing from about 750 km of irrigation ditches in 1901 to about 1,480 km by 1906, 80% of them being in Alberta. The delivery system for irrigation water in Alberta today consists of 7,670 km of main canals and delivery laterals, as well as 17 major and 22 minor reservoirs. The largest reservoir in Saskatchewan is Lake Diefenbaker, which was created by construction of the Gardiner Dam in 1967. When full, this lake is about 225 km long and 58 m deep. Alberta and Saskatchewan draw about 70% of all water used for irrigation in Canada (Rogerson 2009). However, farming was also associated with the loss of wetland habitat through drainage. Of an estimated 80,000 km^2 of wetland in the prairie before European settlement, between 50 and 70% has been destroyed for agricultural development (Hebert 2008).

Production from agriculture represented about 50% of Alberta's revenue in 1935, but only about 15% by 1971, replaced largely by oil and gas. In 2007, agriculture accounted for only about 2% of the gross domestic product, whereas energy represented about 27% (Alberta Finance and Enterprise 2009). Since the discovery of oil at Leduc in 1947, the number of oil wells in Alberta has increased from 502 to 14,168 in 1972 (University of Calgary 2001) and to over 260,000 by the end of 2007 (Sinton 2001). The area affected by well sites and pipelines in the grassland region of Alberta in 1996 was about 2,735 km^2 (Alberta Environmental Protection 1997). Exploration and development have greatly expanded within certain areas of the prairie region. At the Canadian Forces Base (CFB) Suffield, which covers an area of 2,960 km^2 and is one of the few remaining large blocks of native grasslands in Canada, over 14,000 wells have been drilled since 1974. Based on the premise that each well site affects about 1 ha, well-site installation accounts for about 5% of the CFB area. In addition, linear disturbances resulting from pipeline installation and road or trail construction produce considerably more anthropogenic edges. Within the region that includes CFB Suffield, the anthropogenic edge is about 6 $km \cdot km^{-2}$ (Vincent and Mueller 2008) but is as much as 12 $km \cdot km^{-2}$ in certain areas (Bradley 2008).

Industrial activities and infrastructure such as roads and urban development needed to support them have impacted prairie habitat through destruction, conversion, modification, or fragmentation. The effect on the prairie is a reduction in available area and its quality for the support of native species. Several major disturbances and their impact on native wildlife are examined in the following sections.

Farming

The Homestead Act was passed in 1872 by the federal government to encourage settlement in Rupert's Land by eastern Canadians and by foreigners from Europe and the United States. This act gave legal authority for potential settlers to claim 160 acres for a $10 fee and specific improvement to the homestead. Together with the construction of the CPR, the act created opportunity for settlement and, in turn, provided business opportunities for the railway. Therefore, CPR agents operated in western Europe and Scandinavia to promote "The Last Best West," and immigrants were sold packages that included passage on a Canadian Pacific ship, overland travel by CPR, and land for as low as $2.50 an acre. However, the stimulus for immigration came later in the mid-1890s, apparently in response to improved farming practices, including deep plowing and summerfallowing, which reduced the risk of production in the southern prairies (Norrie 1992). This period coincided with a rise in wheat prices, falling transportation costs, and the end of the American frontier when the availability of arable land became exhausted.

The development of Red Fife wheat in 1842 was a key factor that made farming possible. Red Fife was a landrace variety (naturalized), with a high degree of genetic variability and a short growing season. Red Fife led to the development of the Marquis wheat variety in a cross with Hard Red Calcutta, a variety from India. The Marquis variety first became commercially available by 1911 and by the early 1920s made up 90% of all 6.9 million ha seeded to hard red spring wheat on the Canadian prairies (McGinnis 2004).

The population on the prairies increased rapidly from less than 1,000 non-Aboriginal people before 1870 to 56,500 by 1881 and 99,000 by 1891. However, the greatest increase came later when, in Alberta alone, the population increased from 73,000 in 1901 to 374,000 by 1911 (Government of Alberta 2009). The stimulus for immigration was farming. By the early 1900s, wheat was the dominant crop grown by the first settlers and was referred to as "king of the Canadian crops," with the prairie region referred to as the "wheat belt."

The area of farmed land followed the population trends from 1831 to 1856, with about 0.4 ha per person. From 1856 onward, farmland increased greatly from about 3,600 ha to 113,000 ha in 1881 while the area per capita doubled to 0.8 ha. By 1931, there were about 24 million ha of land broken or about 10 ha for each person (Fig. 3). Today only about 20% of the fescue prairie and 33% of the mixed prairie grassland remains intact (Federal, Provincial and Territorial Governments of Canada 2010).

The incentive to convert crop land to forage land was derived from circumstance caused by the drought of the 1930s when large tracts of land were seeded to crested wheat grass (*Agropyron cristatum* [L.] Gaertn.) in an effort to stabilize the soil. However, rangeland was also cultivated and seeded to introduced grasses with the promise of increased production—a

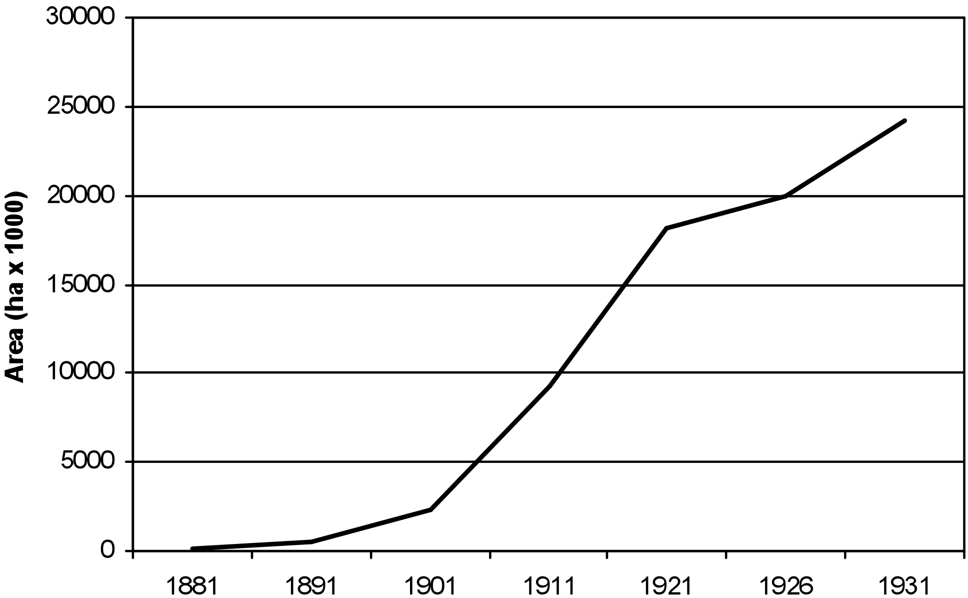

Fig. 3. Cultivated land in the prairie provinces from 1831 to 1931. In 1831, the estimated area that had been cultivated was 871 ha and by 1881 it had increased to 112,910 ha. Adapted from Mackintosh (1934).

promise recognized by its designation as "improved pasture" compared with the term "unimproved pasture" given to native grassland by Statistics Canada. This designation persisted until the 1991 census, after which the terms were revised to more accurately reflect land type as either "tame or seeded pasture" and "natural land for pasture."

Cropping Practices

Although wheat was successfully grown in many regions of the prairies, the first settlers quickly realized that western Canada did not have an ideal climate for crop production. Winters were long and cold, with a relatively short growing season, particularly in the north-central and northern areas of the prairies. The southern prairies had limited growing season precipitation and were often too dry for successful crop production.

Each agroecological region of the prairies is characterized by uniquely different climatic conditions, soil types, and soil fertility conditions and has various problems with weeds, insects, and crop diseases. Farmers within each agroecological region have adapted their cropping practices to deal with the conditions found in each (Table 1).

The practice of clean summerfallow was first introduced to the prairies by Angus MacKay at the Indian Head Experimental Farm in 1890. Summerfallow, also referred to as dust-mulch fallow, leaves land idle for one growing season and was considered an effective means for storing soil moisture and controlling weeds. Summerfallow was initially applied with deep plowing, which increased available soil moisture by improving water infiltration and allowing deeper root penetration (Unger and Howell 2000). The concept of deep plowing was considered of major importance and was rapidly adopted by prairie settlers by the beginning of the 20^{th} century. However, by the 1920s, farmers and researchers realized that plowed land did not increase stored soil moisture. Further, land left in bare condition from plowing and summerfallowing was subject to erosion by both

Table 1. Areas of major crops grown in Alberta (2006), Saskatchewan (2007), and Manitoba (2008).

Crop	Alberta[1]	Saskatchewan[2]	Manitoba[3]	Total	Agroecological Zone(s)[4]
	------------------------Area ('000 ha)------------------------				
Winter wheat	105	210	223	538	Br, DB
Spring wheat	2323	3057	1081	6461	All
Durum wheat	405	2043	-[5]	2448	Br, DB
Oats	285	768	348	1401	All
Barley	1375	1456	330	3161	All
Fall rye	22	56	30	108	Br, DB
Flaxseed	22	501	107	630	DB
Canola	1813	3095	1254	6162	All
Dry peas	247	1255	44	1546	All
Corn (grain)	1	-	79	80	Br (Ir)
Corn (forage)	22	-	34	56	Br, DB (Ir)
Corn (sweet)	1254	-	-	1254	Br (Ir)
Soybeans	25	-	113	138	Br (Ir)
Beans	21	-	52	63	Br, DB (Ir)
Lentils	4	631	-	635	Br, DB
Sunflower seed	-	-	69	69	Br (Ir)
Canary seed	-	146	10	156	Br
Chickpeas	40	42	-	82	Br
Mustard seed	34	113	2	149	Br, DB
Potatoes	23	4	34	61	Br, DB, Bl
Sugar beets	18	-	-	18	Br, DB (Ir)
Hay	2205	1884	992	5081	All
Summerfallow	906	1679	61	2646	

[1] Alberta Agriculture and Food (2007).

[2] Saskatchewan Ministry of Agriculture (2009).

[3] Manitoba Agriculture, Food and Rural Initiatives (2009).

[4] Primary agroecological zones (Fig. 4) where crops are grown (Br = Brown; DB = Dark Brown; Bl = Black; Ir = irrigation).

[5] Zero or negligible amounts; not reported.

wind and water. At this time, farmers shifted from plowed to plowless cultivation, using one-way discs or cultivators, resulting in less soil disturbance that left more crop residue on the soil surface. In the drier regions with wind erosion problems, farmers adopted a practice called strip farming, in which adjacent cropped and fallowed areas run in parallel narrow strips oriented at a 90-degree angle to the prevailing winds to minimize erosion from exposed soil. However, this was an imperfect solution, as strips were useless if the wind was blowing in a different direction.

In 1935, Charles Noble, a southern Alberta farmer, developed a wide cultivator blade that could be used on summerfallow land and would cut just below the soil surface to kill weeds, but leave residue from the previous crop on the soil surface to protect the soil from erosion. This was a major technological advance that was adopted by farmers in the 1940s. The combination of strip farming and cultivation with the Noble blade helped reduce soil erosion. The wheat-fallow rotation was the dominant cropping system across the prairies until the 1960s and is still used as a method for storing soil moisture in the drier regions. However, summerfallow is presently implemented by using chemicals to control weeds, a practice referred to as "chem-fallow." Chem-fallow supports zero tillage and direct seeding, which controls weeds and conserves soil moisture. Direct seeding was first practiced in Manitoba by the mid-1970s and gained widespread acceptance in the more mesic prairies between 1977 and 1985 for winter wheat production (Lindwall 2009).

Farming practices are strongly affected by regional environmental factors defined by the soil zones, which describe agroecological conditions. The more common soil zones of the prairies are Brown, Dark Brown, and Black (Fig. 4). Each zone is characterized by uniquely different climatic and soil conditions.

Brown Soil Zone

The Brown Soil Zone (Fig. 4) is the most arid zone and is characterized by annual precipitation in the range of 275–325 mm. It has high evapotranspiration, frequent droughts, and hot dry winds. The dominant native vegetation is mixed prairie grasses. Soils tend to be brown, indicating a lower level of soil organic matter in the range of 2–3%, and have relatively low soil fertility. Moisture is the primary limiting factor to cultivated agriculture in this region. Only the more favourable soil types within this zone are considered to be arable and much of the annual crop land is in a wheat-fallow rotation. Dryland cropping practices have evolved that provide for moisture and soil conservation. The longer growing season and greater growing degree-days makes this region the most ideal for irrigated crop production on the prairies.

Hard red spring wheat is the most commonly grown wheat type in the dryland areas (Table 1). The majority of the land is direct seeded and cultivation is kept to a minimum to conserve soil moisture and leave protective crop residue on the soil surface. Weeds are controlled by summerfallowing or by chem-fallowing, in which weeds are controlled primarily with the use of herbicides. Some producers have replaced fallow in the cropping system with a lower water-use crop such as peas. The wheat–pea rotation has become more common in recent years in this zone. Other drought-tolerant crops such as mustard are also occasionally grown in rotation with wheat.

The poorer soil areas in this zone that are saline, sodic, or sandy, or that have other physical or chemical limitations, have been left as native rangeland or have been returned to permanent pasture. The highest agricultural use of these sensitive lands is for cattle grazing and production. Careful rangeland management practices are essential to ensure that these soils are conserved and to maintain ecological integrity of the plant community.

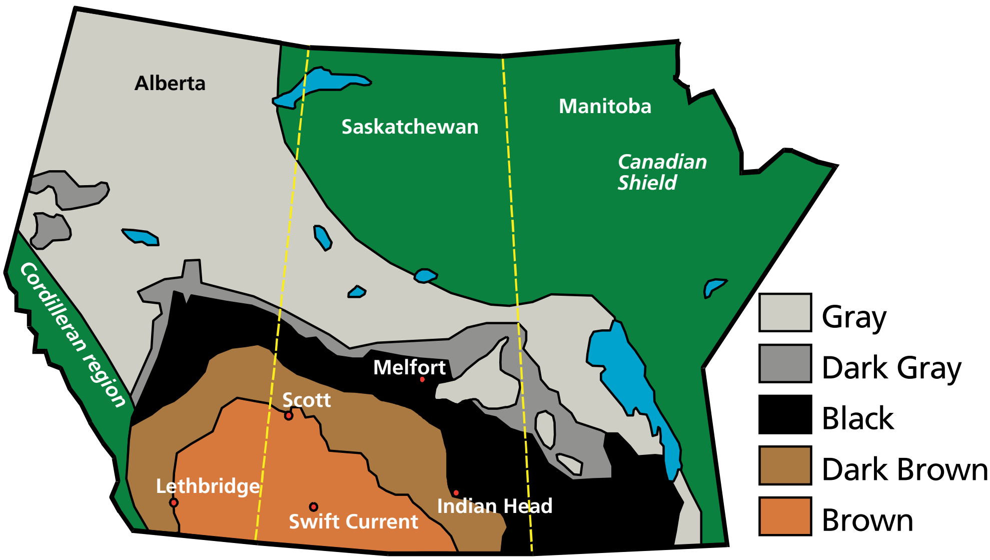

Fig. 4. Major soil zones of the Canadian prairie provinces. The Brown, Dark Brown, and Black Chernozemic soil zones define the extent of the Canadian prairies.

Irrigated crop rotations used in the Brown Soil Zone generally include cereals (wheat and barley), forages, canola, and special crops, including potatoes, sugar beets, beans, and corn. The proportion of special crops grown is higher in the Brown Soil Zone than in the cooler zones because of its longer growing season and higher number of growing degree-days.

Dark Brown Soil Zone

The Dark Brown Soil Zone (Fig. 4) is characterized by annual precipitation in the range of 325–375 mm and has fairly high evapotranspiration, less frequent droughts than the Brown Soil Zone, and warm dry winds. The dominant native vegetation is mixed prairie grasses. Soils are dark brown, indicating a moderate level of soil organic matter in the range of 3–5%, with moderate soil fertility. Moisture is the principal limiting factor to agriculture. Only the more favourable soil types are considered arable. The wheat-fallow rotation is commonly used, however, with the adoption of direct seeding for moisture and soil conservation and significant areas now being continuously cropped. The drier areas of this zone are also well-suited to irrigated crop production. Irrigated cropping systems include fewer special crops than in the Brown Soil Zone and a higher portion of annual and perennial forage crops.

Hard red spring and durum wheat are the most commonly grown wheat types in the drier regions. Other cereal crops such as malt or feed barley are grown in crop rotation. The majority of annually cropped land is direct seeded and cultivation is kept to a minimum to conserve soil moisture and maintain protective crop residue on the soil surface. Many producers have shifted away from the wheat-fallow rotation in favour of more diverse cropping systems and include pulse crops, such as peas, and oilseeds, such as canola or mustard, in their crop rotation. The amount and frequency of land in summerfallow has declined with the adoption of direct seeding.

Black Soil Zone

The Black Soil Zone (Fig. 4) is characterized by annual precipitation in the range of 400–475 mm, evapotranspiration that is lower than the Dark Brown Soil Zone, and hot dry winds that are less frequent than in the Dark Brown Soil Zone. The dominant native vegetation is fescue grasses, with some invasion of deciduous trees after 1880 with the control of fires and extirpation of bison. This region is also referred to as parkland. Soils are black, indicating good levels of soil organic matter in the range of 5–10%. These are the most fertile soils in the prairie region. The vast majority of land is arable and well-suited for annual crop production. Moisture is usually not a limiting factor to agriculture. Wheat, barley, canola, and forages for hay and pasture are the most commonly grown crops, with lesser amounts of pulse crops. Land is normally cropped continuously and summerfallow is not used. Direct seeding or reduced tillage has been adopted by the majority of farmers, but cultivation is sometimes used to control crop residue.

Gray and Dark Gray Soil Zones

These soil zones are characterized by variable annual precipitation ranging from 300 to 500 mm with lower evapotranspiration than in the Black Soil Zone. The dominant native vegetation is mainly woodland with both coniferous and deciduous trees. Gray Soil Zone (Fig. 4) vegetation is often intermixed with moss and sedge bogs (muskeg). Soils in this zone developed under forest vegetation, which added acidic leaf litter to the surface and resulted in moderate to significant leaching. As a result, soils are gray to dark gray, depending on the level of leaching and the amount of soil organic matter. The levels of soil organic matter generally range from 1 to 4%. Soils that are ash gray have low fertility.

The majority of Dark Gray soils are arable and suitable for annual crop production, whereas the majority of Gray soils are less suitable for annual crop production. Moisture can be a limiting factor to agriculture in some areas of these regions. Wheat, barley, canola, and forages for hay and pasture are the most commonly grown crops, with lesser amounts of pulse crops. In some northern areas, the growing season is too short for successful wheat production. Land is normally cropped continuously and the use of summerfallow has become less common. Direct seeding or reduced tillage has been adopted by the majority of farmers.

Ranching

Livestock Grazing

The prairie ecosystem evolved with disturbances from bison and fire, which were integral for maintaining its vegetative character. Their effects were particularly noticeable in the more mesic fringe of the grassland—the forest ecotone—where they challenged tree and shrub encroachment and maintained a favourable environment for grassland vegetation. Disturbances were periodic; fires would not return until the conditions were right, including sufficient fuel continuity and mass. The occurrence of fire likely interacted with bison, which were attracted to the new vegetation after a burn and, in turn, reduced the fuel load where they grazed. Fire in particular, along with grazing by bison, tended to enhance site aridity by removing litter, thereby promoting the tufted grasses; the seasonal timing of these disturbances dictated how the plants might respond to them.

In the fescue prairie, grazing by bison occurred primarily in winter, whereas fires were limited to periods when the grass was dry after the growing season. This timing ensured that the grassland received disturbance at a time when rough fescue (*Festuca campestris* Rydb.), the dominant grass species, was resistant to defoliation and would benefit by litter removal. Conversely, rough fescue is highly sensitive to defoliation during the growing season.

The more arid mixed prairie was grazed by bison primarily in the spring and summer, possibly because they were attracted to the earlier green growth in spring and wanted to escape harassment from flies, which were abundant in the more mesic fescue prairie. The plant species of the mixed prairie are much more resilient than rough fescue to grazing and are highly adapted to moisture deficiency. The relatively low biomass and open plains of the mixed prairie is believed to have encouraged bison to retreat in winter to the shelter and taller grasses of the fescue prairie.

Livestock grazing became the primary disturbance factor on the grasslands following fire suppression and the extirpation of the bison. However, overgrazing was assured when, as a result of inadequate knowledge about the ecosystem and its carrying capacity, a grazing policy of one head of livestock for each 10 acres (4 ha) was established in 1881. This policy was changed to one head per 20 acres in 1888 and then to one head per 30 acres (Johnston 1970). In Alberta, the current recommended stocking rate for the mixed prairie, based on a careful study of the evidence, is one head per 60–100 acres, depending on site characteristics (Adams *et al.* 2005) (Fig. 5).

Although bison would likely have heavily grazed and trampled the grassland when herds were large, they would likely not have returned that year and perhaps not for several years, allowing the grassland to recover. In contrast, livestock grazing is normally conducted yearly on the same area, which is manageable provided that the constraints of the grassland are not exceeded. Overgrazing is defined as heavy grazing pressure and inappropriate season of use.

Overgrazing causes deterioration in the health of grassland by a change in species composition to a dominance of those that are resistant to heavy grazing pressure, an increase in bare soil, and a loss of structural heterogeneity in the plant community. Structural heterogeneity is the variability of plant height, which is closely linked with ecosystem functioning and biodiversity. These changes impair the ability of the grassland to provide goods and services: The hydrological cycle is impaired because snow capture and water retention is reduced; biodiversity is jeopardized, leading to an unstable food web; and site stability is at risk because of accelerated soil erosion and invasion by weedy species. Therefore, beef production also declines.

Overgrazing is expressed in different ways, depending on the plant community, but the impediment to the production of ecosystem goods and services is the same. In contrast, grazing disturbance is essential for maximizing grassland health on most grassland sites. Properly managed grazing can optimize litter levels and discourage tree encroachment on the more mesic sites.

Feedlots

Feedlots have emerged as an efficient way to finish cattle for market by shortening the time to slaughter and producing the quality of meat that consumers desire. However, the feedlot industry places intense demands on the land as a source for feed and a sink for nutrients. In Canada, about 70% of all cattle in feedlots are found in southern Alberta and most feed is produced within a radius of 16 km from a feedlot on irrigated land. However, feed production within the province accounts for only 40% of demand and the remainder is imported (Ramsay and Schmitz 2002). This leaves an imbalance between nutrient uptake by crops and nutrients applied via manure and urine.

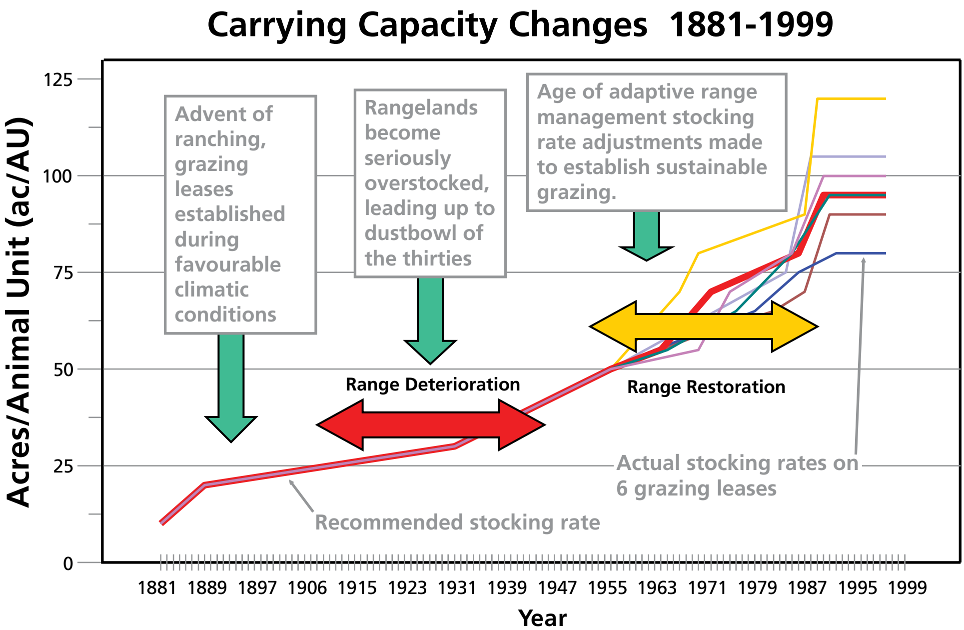

Fig. 5. Trends in recommended stocking rates from 1881 to 1999 and actual stocking rates from 1955 to the present on a selection of six large grazing leases in southeastern Alberta. Adapted from Adams *et al.* (2004).

Feedlots can be a point source for pollution with pathogens and nutrients, whether these substances are carried as runoff or as aerosols. Good feedlot management can eliminate pollution, but manure disposal continues to be a challenge.

Manure transportation for disposal is expensive because of its weight and the large mass that is produced. Feedlot animals produce an average of 1.76 kg manure (dry weight) daily (Gilbertson et. al 1974; Erickson *et al.* 2003), or about 640 kg per year, because the feedlots are normally kept stocked. This manure is usually incorporated into cropland. However, the amount of manure can exceed the nutrient demand from locally grown crops because most feed is imported. Therefore, there has been a tendency to apply excessive manure, which results in the buildup of nutrients with the potential to contaminate surface and groundwater. As knowledge of this concern has increased in the last decade, better nutrient management has been adopted so that soil nutrient concentrations are in balance with crop demand. Practices such as composting manure, or at least reducing the water content, have made transportation economically more viable as the cost of transporting manure beyond the local forage supply perimeter decreases.

In 2006 in southern Alberta, there were 196 feedlots supporting 1,000-plus head of cattle, 12 of them having a capacity of 20,000 or more (Alberta Cattle Feeders Association 2010). In 2009, Alberta had 1.6 million feeder cattle, 56% of all feeder cattle in Canada (Statistics Canada 2009). Of the feeder cattle, about 75% were finished in 100 of the largest feedlots (Alberta Beef Producers 2010), with most found in southern Alberta north of Lethbridge. This region, with its high density of feedlots in an area of about 500 km^2, has been referred to as “feedlot alley.” The area is serviced by irrigation, which provides high yields for the production of animal feeds that consist mainly of oats, barley, and hay.

Intervention

Poplar Encroachment

The prairie is characterized by summer drought, which ensures that trees are disadvantaged and that those that encroached on the prairie at its ecotone were readily controlled by periodic fires and disturbances from bison. Since the suppression of fires and the extirpation of bison, encroachment by aspen poplar (*Populus tremuloides* Michx.) has been mostly unchecked except by use of one or more aggressive measures such as mechanical treatment, herbicide application, or burning. On a local scale, evidence of the ecotone is described as the encroachment of aspen poplar into the surrounding grassland. Aspen poplar favours the more mesic potholes and northern aspects of slopes in the Aspen Parkland and Fescue Grassland ecoregions, from where it encroaches at rates varying from 0.05 to 0.75% of total area (Bailey and Wroe 1974). However, under constant conditions, the rate of infilling would be expected to increase exponentially as the edge of the poplar groves increases in length. In the absence of disturbance, encroachment appears to follow a pulsed event triggered by conditions favourable to suckering in poplar. Fire alone may not eliminate poplar because of its suckering capability, but its mortality is significantly increased when fire is combined with browsing (Fitzgerald and Bailey 1984). Presumably, historical disturbances from a combination of fire and bison prevented poplar encroachment and confined its distribution to the fringes of the potholes. However, drought episodes may have enhanced the effects of fire and bison by increasing the flammability of fuel and increasing the palatability of poplar suckers relative to that of grass.

Drought and the Introduction of Crested Wheat Grass

Drought may be defined as an extended period when soil moisture is deficient, resulting in extensive damage to crops and yield loss. However, the occurrence of damage is defined much differently among farmers, ranchers, and the Aboriginals who occupied the land before European settlement. According to Roberts *et al.* (2006), droughts occur once every three years across the prairies, with about 40 droughts recorded in the last 100 years on the Canadian prairies (Marchildon *et al.* 2007). However, none were as severe as the drought of the 1930s, which actually began in 1928. This drought was significant because it was prolonged—lasting until 1938—and coincided with an economic depression, which resulted in numerous farmers abandoning the land and moving north to less drought-prone areas. About 7,000 farmers abandoned their farms from 1930 to 1938 with the help of the federal government.

This drought provoked the intervention of the federal government to create the Prairie Farm Rehabilitation Administration (PFRA) in 1935, whose responsibility was to assist the farmers in managing the effects of drought by introducing water and soil conservation measures. One measure that had unintended consequences was the seeding of crested wheat grass on abandoned and eroded land; by 1954, PFRA had seeded about 77,000 ha (Knowles 1956).

Crested wheat grass was introduced from Russia to the United States in 1898 and to Canada in 1911 (Lorenz 1986). The species was ideally suited for stabilizing eroded lands in semi-arid areas because of its rapid establishment, high seed production, and drought resistance. It exhibits early growth in spring, which makes it desirable for spring grazing. However, these attributes make crested wheat grass extremely competitive with the native flora on the Northern Great Plains. In this region, crested wheat grass tends to produce a monoculture where it is seeded (Schuman *et al.* 1982) and invades native grasslands (Hull and Klomp 1966; Henderson 2005).

The aggressive competitiveness of crested wheat grass has also been exploited to replace noxious weeds on rangeland (Brooks and Minnich 2006; Whittaker and Jensen 2008) and to replace native grasslands to improve forage production for livestock grazing. In Canada, crested wheat grass was used to control knapweed in the Palouse prairie in the interior of British Columbia (Berube and Meyers 1982), but was not used on the prairie for weed control. However, it has been seeded on about 1.3 million ha for forage production and on about another 0.4 million ha on secondary sites such as roadsides and well sites (Henderson 2005). Although these seedings were planned, they were also the source of crested wheat grass invasion onto native grassland, as much as 4 million ha yr^{-1} (Marlette and Anderson 1986), the median among sites being 0.21 million ha yr^{-1} (Henderson 2005). Its rate of spread depends on the length of the crested wheat grass edge and the orientation of the edge to the wind because, as a tufted species, it depends on wind for dispersal. Because roads and small disturbances associated with oil and gas development were often seeded with crested wheat grass, these sites present the greatest threat to the remnant native grassland (Henderson 2005). At CFB Suffield, crested wheat grass has expanded to 3.2 times its original seeded area (Vincent and Mueller 2008). It also seems to depend on the soil and climatic characteristics of the site because its propensity to spread seems considerably greater on Dark Brown soils than on Brown soils, whereas it is incapable of invasion onto more mesic sites with Black soils (W.D.W. pers. obs.).

The ecological impact of seeding crested wheat grass is immediate: elimination of native species and severe reduction of species richness and diversity, with their concomitant values. Although the future effect of crested wheat grass on the remnant native prairie is difficult to predict, it is certain that this species will continue to invade and dominate an increasing area.

The contribution of crested wheat grass to forage production, relative to native grassland, is not necessarily an improvement (Willms *et al.* 2009). In fact, wheat grass monocultures reduce ecosystem biodiversity and may reduce soil quality (Dormaar and Smoliak 1985). Further, crested wheat grass can be a reservoir for Russian wheat aphid, *Diuraphis noxia* (Mordvilko) (Hemiptera: Aphididae) (Donahue *et al.* 2000) and can promote population explosions of herbivorous insects (Lattin *et al.* 1994) that would normally be maintained at low levels in a more diverse community. Some populations of non-game birds (Reynolds and Trost 1981; McAdoo *et al.* 1989) and small mammals (Koehler and Anderson 1991) are attracted to stands of crested wheat grass, but a greater number of bird and mammal species occur in adjacent native communities.

Crested wheat grass is implicated in loss of soil quality (Dormaar *et al.* 1995; Lesica and DeLuca 1996). This effect may be the result of producing a smaller amount of exudates from the roots than some common native species do (Biondini *et al.* 1988), of early spring growth that removes soil moisture that limits microbial activity, or of cultivation, which mixes soil and stimulates mineralization. According to Dormaar *et al.* (1995), soils in the crested wheat grass community had significantly less soil organic matter and higher NO_3-N, chemical index, urease activity, and available phosphorus than did soils in the native community. However, as with most comparisons, the conclusions are influenced strongly by site and the character of the native community.

It seems reasonable to conclude that the early planting of crested wheat grass was needed to conserve the soil but that the subsequent "improvement" of rangeland with the species was based on insufficient knowledge of the value provided by native grasslands. In other words, large-scale seeding was a mistake with much broader implications for the ecosystem than was first recognized. Much of this mistake was the responsibility of federal government scientists and the PFRA, whose exuberant promotion of range improvement was flawed by bias and ignorance of the functioning of grassland ecosystems.

Invasive Species

Most of the invasive plant species (weeds) in western Canada are native to Europe and were introduced either accidentally or as ornamentals that escaped. Similarly, many of the invasive insect pest species on the Canadian prairies originated in Europe and became established following accidental introductions. De Clerck-Floate and Cárcamo (see Chapter 12) discuss many of these invasive species, as well as the arthropods deliberately introduced into Canada as biological control agents for these invasive species.

Industrial Footprint

Over the past decades, rangeland ecologists have focused primarily on the effects of livestock grazing on rangelands to reduce detrimental impacts and to improve rangeland health in support of other values such as wildlife habitat. Given development pressures on rangelands, considerable interest has been focused on the impact of other forms of disturbances on plant community integrity, reclamation, and restoration, including land-use activities such as oil and gas development, road construction, vehicle traffic, development of transportation corridors, wind power, and country residential access. Resource managers are primarily concerned with two forms of impact. One is the primary footprint, which is the area of a well site, roadway access, or pipeline right-of-way where vegetation is destroyed by blading and by vehicle traffic. Significant effort and cost may be required to reclaim and restore these disturbed sites to an acceptable plant community that will support the ecological goods and services provided by the original native cover. In many cases, the reclamation technology and practices are not currently available (e.g., fescue prairies of southwestern Alberta) and disturbed land may become colonized by invasive plant species that include noxious weeds or invasive agronomic species.

A secondary footprint develops when the primary disturbance is not effectively reclaimed and where invasive species have been introduced through contaminated seed stocks or poor species selection. The invasive species may then move off of the primary disturbance into the surrounding native vegetation (shadow effect), resulting in a loss of plant community integrity.

The primary and secondary footprints eventually have a cumulative impact, resulting in landscape fragmentation and reduced habitat effectiveness. The principal tool applied to limit fragmentation in the grasslands of Alberta is described as minimum disturbance practices, in which industry is encouraged to avoid disturbing native prairie vegetation through pre-site evaluation and planning. Where avoidance is not possible, disturbance of native vegetation cover must be minimized through the use of the best available technology and practices.

The following examples are likely expressions of secondary footprints:

- Of 1,686 sites surveyed in the Central Parkland Natural Subregion of Alberta, 582 (34.5%) were dominantly non-native communities. Plains rough fescue (*F. hallii* [Vasey] Piper) occurred at 549 (32.6%) sites and, of these, only 211 (12.5%) had plains rough fescue communities (Holcroft-Weerstra and Biota Consultants 2003). Invasive non-native plants were found in 41.8% of the plains rough fescue communities. Invaders were predominantly smooth bromegrass (*Bromus inermis* Leyss) and Kentucky bluegrass (*Poa pratensis* L.) and most frequently occurred in rough fescue grasslands that were in poor condition (Holcroft-Weerstra and Biota Consultants

2003). These data suggest that there is widespread invasion of agronomic grasses into plains rough fescue grasslands in central Alberta and that conversion to grasslands dominated by non-native species is continuing.

- In the northern parts of the Special Areas, which are the Central Parkland Natural Subregion and the Northern Fescue Natural Subregion, smooth brome has invaded many sites of native vegetation (BA, pers. obs.). As these sites age, the bromegrass tends to lose productivity and become vulnerable to invasion by shrubby species.

- Only 10% of foothills rough fescue cover remains today, inside an ungrazed range exclosure (65 m × 40 m), following contamination by bromegrass hay 15 years ago. One foothills rough fescue grassland range exclosure in the Castle River drainage area in southwest Alberta, which had little non-native species cover in 1953, was co-dominated by agronomic grasses by the mid-1970s. The relative cover of foothills rough fescue increased during the drought years of the mid-1980s, but lost competitive advantage to Kentucky bluegrass and timothy (*Phleum pratense* L.) in the wet years that followed (Willoughby and Alexander 2007).

Oil and gas development affects the grassland by physically disturbing the vegetation and soil through the construction of well sites, pipelines, and roads, as well as through secondary effects produced by landscape fragmentation and vehicular traffic that provides a vector for invasive weeds (Gelbard and Belnap 2003; Von der Lippe and Kowarik 2007) and disturbs or kills wildlife near or on the road. The effects of oil and gas development are highly variable and depend on the installation methods used, the nature of their reclamation, the time since disturbance (which interacts with the previous factors), and their density. The more recent installations are based on minimal disturbance and natural recovery, which produces a more aesthetically and ecologically satisfactory effect than earlier projects did, where soil disturbance was high and agronomic species were seeded for reclamation. Crested wheat grass was the agronomic species most commonly seeded on the mixed prairie, which further exacerbated the disturbance effect of the installations.

The effects of anthropogenic disturbances on animals depend on their habitat requirements and the nature of the disturbance (Koper and Schmiegelow 2006). Of particular concern is the effect of oil and gas development on species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). For example, of the listed species at CFB Suffield, the body condition of Ord's kangaroo rat (*Dipodomys ordii* Woodhouse) was reduced in anthropogenic sites, presumably by lower quality food, cooler burrows, and less protection from predation caused by agronomic monocultures, reduced litter mass, and soil compaction (Teucher 2007). Sprague's Pipit (*Anthus spragueii* Audubon), another listed species, avoids bare ground, which is increased with oil and gas development. This bird requires non-fragmented patches with a minimum area that ranges from 69 to 314 ha (Sutter *et al.* 2000) and has been found to decrease in population with an increase in road density. This response may also have contributed to a 23% reduction in population when well density doubled to one well per 16 ha (EnCana data reported in Vincent and Mueller 2008). Prairie rattlesnakes (*Crotalus viridis* Melli; LaDuc, 2000) and bullsnakes (*Pituophis catenifer sayi* Schlegel) are particularly vulnerable to being killed on roads, which they cross during their annual migration that can be as far as 24 km from their hibernacula (Vincent and Mueller 2008).

Roads and the resulting traffic negatively affect pronghorn antelope (*Antilocapra americana* Ord) by increasing their vigilance and reducing their foraging time (Gavin and Komers 2006). Therefore, antelope appear to view roads as a risk and a disturbance that needs to be avoided, which reduces the habitat area or at least the quality of remnant habitat. Fences also impede antelope movement; antelope are poor jumpers and will crawl through or under fences rather than jumping over them. Consequently, barbed wire that is strung too low to the ground or is too narrowly spaced will impede their movement and restrict their mobility in their search for food or when fleeing predators (Yoakum 1975). In the worst case, barbed wired fences can trap the animal. Current recommendations are to use double-strand smooth wire that is raised 46 cm above the ground to provide safe and rapid movement for antelope.

The cumulative effect of linear disturbances is greater than the area that is actually occupied and would normally include a buffer of diminishing effect from the edge, whether it is for animal or plant species. For plants, the buffer is dictated by the invasiveness of aliens into the landscape or the effect of the disturbance on modifying the adjacent environment. A common example of an alien is crested wheat grass, for which the buffer is constantly expanding. Roads or shelterbelts affect the environment of the edge by concentrating soil moisture through runoff or snow trapping, shading, or wind abatement. For animals, Vincent and Mueller (2008) recommend a buffer of 100 m for wetlands and roads, but buffer width should be as wide as the species with maximum requirement. For the Ord's kangaroo rat, this could be 250 m.

Fences produce a very narrow edge effect, but can have a large impact on certain wildlife populations. Wolfe *et al.* (2007) reported that collisions with fences produced about 33% of all lesser prairie-chicken (*Tympanuchus pallidicinctus* Ridgway) mortality on grasslands in Oklahoma and New Mexico. Baines and Andrew (2003) recorded fence collisions by 13 bird species in England that resulted in up to 70% mortality in red grouse (*Lagopus lagopus scoticus* Lath.). Fences can also snare large ungulates, including deer, antelope, and elk, and cause their death (Harrington and Conover 2006).

Conclusion

The Canadian prairies were settled by immigrants from eastern Canada and Europe within the last 150 years. The early attraction for settlement was the fertile soil, which supplied all the nutrients necessary for crop production for several decades before supplemental nitrogen was needed. Farming resulted in the most fertile land being cultivated while a large portion of the remaining grassland was developed for urban housing or industry. The residual rangeland is constantly under threat from extraction economies with short-term rewards. Although private landowners can be tempted to exploit resources, the same is not true for public lands. As a result, the largest blocks of contiguous native grassland occur in southeastern Alberta, where they are anchored by federal lands under the jurisdiction of the Department of National Defence at Suffield and of Agriculture and Agri-Food Canada at Onefour, Alberta.

The first settlers brought with them European farming practices, which were soon modified in response to the semi-arid climate. Drought defined the risk for crop production, but farming practices were developed to reduce the effects of drought and allow a greater variety of crops to be grown. Irrigation probably expanded crop diversification more than any other innovation, whereas the adoption of continuous cropping had the greatest impact for soil conservation and sustainable farming.

A powerful tool for protecting the remaining native grassland has been the *Species at Risk Act* (SARA), which is a commitment by the federal government to prevent wildlife species from becoming extinct and to develop a strategy for their recovery. Because the security of a population is intimately linked with its habitat, the act also provides protection for certain grasslands from disturbances that threaten the species. Hall *et al.* (see Chapter 13) discuss SARA and species on the Canadian prairie that are protected under its legislation.

Our grasslands can never resemble those that existed before European contact, but we can hope to manage the remnant in a manner that optimizes their function in the supply of goods and services, which includes beef production and non-tangible values such as biodiversity. In Canada, rangeland health is judged from a composite of several criteria, including species composition, vegetation structure, hydrological properties, site stability, and the presence of invasive weeds. As such, it provides a robust index of how the grassland is functioning relative to its potential. On the basis of these criteria, the health of public rangeland in western Canada is generally considered to be good, and in Alberta, less than 10% of rangeland is considered to have problems. Although our grasslands are well managed, it is their future status that must be guarded for the benefit of future Canadians.

References

Adams, B.W., Carlson, J., Milner, D., Hood, T., Cairns, B., and Herzog, P. 2004. Beneficial Grazing Management Practices for Sage-Grouse (*Centrocercus urophasianus*) and Ecology of Silver Sagebrush (*Artemisia cana*) in Southeastern Alberta. Public Lands and Forests Division, Alberta Sustainable Resource Development, Lethbridge, Alberta. Publication No. T/049.

Adams, B.W., Poulin-Klein, L, Moisey, D., and McNeil, R.L. 2005. Range Plant Communities and Range Health Assessment Guidelines for the Dry Mixedgrass Natural Subregion of Alberta. Public Lands Division, Alberta Sustainable Resource Development, Lethbridge, Alberta. Publication No. T/040.

Alberta Agriculture and Food. 2007. Agriculture Statistics Yearbook 2006. Alberta Agriculture and Food, Economics and Competitiveness Division, Statistics and Data Development Unit, Edmonton, Alberta.

Alberta Beef Producers. 2010. Industry: Beef Production. Available from http://albertabeef.org/industry/beef-production-chain/ [accessed 9 April 2010].

Alberta Cattle Feeders Association. 2010. Facts and Statistics. Available from http://www.cattlefeeders.ca/industry/stats.aspx [accessed 9 April 2010].

Alberta Environmental Protection. 1997. The Grassland Natural Region of Alberta. Available from http://tpr.alberta.ca/parks/heritageinfocentre/docs/Grassland_Natural_Region_of_Alberta_Report.pdf [accessed 18 August 2009].

Alberta Finance and Enterprise. 2009. Highlights of the Alberta Economy. Available from http://www.albertacanada.com/documents/SP-EH_highlightsABEconomyPres.pdf [accessed 5 January 2009].

Bailey, A.W., and Wroe, R.A. 1974. Aspen invasion in a portion of the Alberta Parklands. Journal of Range Management, **27**: 263–266.

Baines, D., and Andrew, M. 2003. Marking of deer fences to reduce frequency of collisions by woodland grouse. Biological Conservation, **110**: 169–176.

Berton, P. 2001. The Last Spike: The Great Railway, 1881–1885. Anchor Canada, Toronto, Ontario.

Berube, D.E., and Myers, J.H. 1982. Suppression of knapweed invasion by crested wheat grass in the dry interior of British Columbia. Journal of Range Management, **35**: 459–461.

Biondini, M., Klein, D.A., and Redente, E.F. 1988. Carbon and nitrogen losses through root exudation by *Agropyron cristatum*, *A. smithii* and *Bouteloua gracilis.* Soil Biology and Biochemistry, **20**: 477–482.

Bradley, C. 2008. Presentation to Joint Review Panel Regarding the EnCana Shallow Gas Infill Development Project in the Suffield National Wildlife Area. Available from http://www.ceaa-acee.gc.ca/050/documents/29407/29407E.pdf [accessed 5 January 2009].

Breen, D.H. 1973. The Canadian Prairie West and the "harmonious" settlement interpretation. Agricultural History, **47**: 63–75.

Brooks, M.L., and Minnich, R.A. 2006. Southeastern deserts bioregion. *In* Fire in California's Ecosystems. *Edited by* Neil G. Sugihara, Jan W. van Wagtendonk, Kevin Eugene Shaffer, Joann Fites-Kaufman, and Andrea E. Thode. University of California Press, Berkeley. pp. 391–415.

Carlyle, W.J. 1994. Rural population changes on the Canadian Prairies. Great Plains Research, **4**: 65–87.
Donahue, J.D., Brewer, M.J., and Burd, J.D. 2000. Relative suitability of crested wheatgrass and other perennial grass hosts for the Russian wheat aphid (Homoptera: Aphididae). Journal of Economic Entomology, **93**: 323–330.
Dormaar, F.F., Naeth, M.A., Willms, W.D., and Chanasyk, D.S. 1995. Effect of native prairie, crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) and Russian wildrye (*Elymus junceus* Fisch.) on soil chemical properties. Journal of Range Management, **48**: 258–263.
Dormaar, J.F., and Smoliak, S. 1985. Productivity of Russian wildrye and crested wheatgrass and their effect on prairie soils. Journal of Range Management, **38**: 403–405.
Evans, S.M. 1983. The end of the open range era in western Canada. Prairie Forum, **8**: 71–87.
Erickson, G.E., Auvermann, B., Eigenberg, R.A., Greene, L.W., Klopfenstein, T., and Koelsch, R. 2003. Proposed Beef Cattle Manure Excretion and Characteristics Standard for ASAE. *In* Proceedings of the Ninth International Animal, Agricultural and Food Processing Wastes Symposium. *Edited by* R.T. Burns. American Society of Agricultural Engineers Publication Number 701P1203. pp. 269–276.
Federal, Provincial and Territorial Governments of Canada. 2010. Canadian Biodiversity: Ecosystem Status and Trends 2010. Canadian Council of Resource Ministers, Ottawa, Ontario.
Fitzgerald, R.D., and Bailey, A.W. 1984. Control of aspen regrowth by grazing with cattle. Journal of Range Management, **37**: 157–158.
Friesen, G. 1984. The Canadian Prairies: A History. University of Toronto Press, Toronto, Ontario.
Gavin, S., and Komers, P. 2006. Do pronghorn (*Antilocapra americana*) perceive roads as a predation risk? Canadian Journal of Zoology, **84**: 1775–1780.
Gelbard, J. L., and Belnap, J. 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. Conservation Biology, **17:**420–432.
Gilbertson, C.B., Nienaber, J.A., Ellis, J.R., McCalla, T.M., Klopfenstein, T.J., and Farlin, S.D. 1974. Nutrient and Energy Composition of Beef Cattle Feedlot Waste Fractions. The Agricultural Experiment Station, IANR, University of Nebraska, Lincoln. Research Bulletin 262.
Government of Alberta. 2009. About Alberta: History. Available from http://alberta.ca/home/182.cfm [accessed 18 August 2009].
Harrington, J.L., and Conover, M.R. 2006. Characteristics of ungulate behavior and mortality associated with wire fences**.** Wildlife Society Bulletin, **34**: 1295–1305.
Hebert, P.D.N. 2008. Wetland regions in Canada. *In* The Encyclopedia of Earth. *Edited by* D. Langdon. Available from http://www.eoearth.org/article/Wetland_regions_in_Canada [accessed 15 February 2010].
Henderson, D.C. 2005. Ecology and Management of Crested Wheatgrass Invasion. Ph.D. dissertation, University of Alberta, Edmonton.
Holcroft-Weerstra, A.C., and Biota Consultants. 2003. Plains Rough Fescue **(***Festuca hallii***)** Grassland Mapping – Central Parkland Natural Subregion of Alberta. Report prepared for Resource Data Branch, Alberta Sustainable Resource Development, Edmonton, Alberta.
Hull, A.C., and Klomp, G.J. 1966. Longevity of crested wheatgrass in the sagebrush-grass type in southern Idaho. Journal of Range Management, **19**: 5–11.
Johnston, A. 1970. A history of the rangelands of western Canada. Journal of Range Management, **23**: 3–8.
Jordan-Bychkov, T.G. 2000. Does the border matter? Cattle ranching and the 49th parallel. *In* Cowboys, Ranchers and the Cattle Business: Cross-Border Perspectives on Ranching History. *Edited by* Simon M. Evans, Sarah Carter, and Bill Yeo. University of Calgary Press, Calgary, Alberta. pp 1–10.
Kay, Charles E. 1994. Aboriginal overkill: the role of native Americans in structuring western ecosystems. Human Nature, **5**: 359–398.
Knowles, R.P. 1956. Crested Wheatgrass. Canada Department of Agriculture, Publication. No. 986.
Koehler, D.K., and Anderson, S.H. 1991. Habitat use and food selection of small mammals near a sagebrush/crested wheatgrass interface in southeastern Idaho. Great Basin Naturalist, **51**: 249–255.
Koper, N., and Schmiegelow, F.K.K. 2006. A multi-scaled analysis of avian response to habitat amount and fragmentation in the Canadian dry mixed-grass prairie. Landscape Ecology, **21**: 1045–1059.
Lattin, J.D., Christie, A., and Schwartz, M.D. 1994. The impact of non-indigenous crested wheatgrasses on native blackgrass bugs in North America: a case for ecosystem management. Natural Areas Journal, **14**: 136–138.
Lesica, P., and DeLuca, T.H. 1996. Long-term harmful effects of crested wheatgrass on Great Plains grassland ecosystems. Journal of Soil and Water Conservation, **51**: 408–409.
Lewis, H.T. 1982. A Time for Burning. Boreal Institute for Northern Studies, University of Alberta, Edmonton. Occasional Publication No. 17.

Lindwall, W. 2009. Engineering Breakthroughs in Conservation Tillage/Direct Seeding Technology. Proceedings of Landscapes Transformed: The Quiet Triumph of Conservation Tillage and Direct Seeding. Available from http://www.kis.usask.ca/CTConf/proceedings/Lindwall.pdf [accessed 1 March 2010].

Lorenz, R.J. 1986. Introduction and early use of crested wheatgrass in the Northern Great Plains. *In*: Crested Wheatgrass: Its Values, Problems, and Myths. Symposium Proceedings. *Edited by* K.L. Johnson. Utah State University, Logan. pp. 9–20.

Mackintosh, W.A. 1934. Prairie settlement, the geographical setting, Vol. 1. *In* Canadian Frontiers of Settlement. *Edited by* W. A. Mackintosh and W.L.G. Joerg. Macmillan, Toronto, Ontario. p. 244.

Manitoba Agriculture, Food and Rural Initiatives. 2009. November Estimate of Production of Principal Field Crops, 2008. Industry Intelligence Section, Knowledge Management, Manitoba Agriculture, Winnipeg, Manitoba.

Marchildon, G.P., Kulshreshtha, S., Wheaton, E., and Sauchyn, D. 2007. Drought and Institutional Adaptation in Alberta and Saskatchewan, 1914–1939. Available from http://www.parc.ca/mcri/pdfs/papers/iacc040.pdf [accessed 18 August 2009].

Marlette, G.M., and Anderson, J.E. 1986. Seed banks and propagule dispersal in crested wheatgrass stands. Journal of Applied Ecology, **23**: 161–175.

McAdoo, J.K., Longland, W.S., and Evans, R.A. 1989. Nongame bird community responses to sagebrush invasion of crested wheatgrass seedings. Journal of Wildlife Management, **53**: 494–502.

McGinnis, A. 2004. The Wheat that Won the West: The Impact of Marquis Wheat Development. Available from http://www.wdm.ca/skteacherguide/WDMResearch/MarquisWheatPaper.pdf [accessed 16 February 2010].

Morton, A.S., and Martin, C. 1938. History of Prairie Settlement (by Arthur S. Morton); "Dominion Lands" Policy (by Chester Martin). MacMillan, Toronto, Ontario.

Norrie, K.H. 1992. The National Policy and the rate of prairie settlement: a review. *In* The Prairie West: Historical Readings. *Edited by* R.D. Francis and H. Palmer. University of Alberta Press, Edmonton. pp. 243–263.

Owram, D. 2007. The promise of the west as settlement frontier. *In* The Prairie West as Promised Land. *Edited by* R.D. Francis and D. Kitzan. University of Calgary Press, Calgary, Alberta. pp. 1–28.

Ramsay, L., and Schmitz, A. 2002. A Profile of Alberta's Beef Industry: Lessons for Saskatchewan? Centre for the Study of Agriculture, Law, and the Environment, University of Saskatchewan, Saskatoon. Working paper #6.

Reynolds, T.D., and Trost, C.H. 1981. Grazing, crested wheatgrass, and bird populations in southeastern ldaho. Northwest Science, **55**: 225–234.

Roberts, E., Stewart, R.E., and Lin, C.A. 2006. A study of drought characteristics over the Canadian Prairies. Atmosphere-Ocean, **44**: 331–345.

Rogerson, R. 2009. Irrigation along the Oldman River. Available from http://www.uleth.ca/vft/Oldman_River/Intro.html [accessed 18 August 2009].

Saskatchewan Ministry of Agriculture. 2009. Agricultural Statistics Fact Sheet. Policy Branch, Saskatchewan Ministry of Agriculture, Saskatoon, Saskatchewan.

Schuman, G. E., Rauzi, F., and Booth, D.T. 1982. Production and competition of crested wheatgrass-native grass mixtures. Agronomy Journal, **74**: 23–26.

Sinton, H.M. 2001. Prairie Oil and Gas: A Lighter Footprint. Alberta Environment, Edmonton, Alberta.

SMRID. 2009. The Saint Mary Project. Available from http://www.smrid.ab.ca/history.html [accessed 2 December 2010].

Statistics Canada. 2009. Section L: Lands and Forests, Table L42–45. Available from http://www.statcan.gc.ca/pub/11-516-x/sectionl/4147441-eng.htm#1 [accessed 18 August 2009].

Sutter, G.C., Davis, S.K., and Duncan, D.C. 2000. Grassland songbird abundance along roads and trails in southern Saskatchewan. Journal of Field Ornithology, **71**:110–116.

Teucher, A.C. 2007. Factors Affecting Ord's Kangaroo Rats (*Dipodomys ordii*) in Natural and Anthropogenic Habitats. Unpublished M.Sc. thesis, University of Calgary, Calgary, Alberta.

Tyman, J.L. 1972. Patterns of Western Land Settlement. Department of Geography, Brandon University Manitoba Historical Society Transactions, Series 3, No. 28. Available from http://www.mhs.mb.ca/docs/transactions/3/landsettlement.shtml [accessed 1 April 2010].

Unger, P.W., and Howell, T.A. 2000. Agricultural water conservation - A global perspective. Journal of Crop Production, **2**: 1–36.

University of Calgary. 2001. The Oil and Gas Frontier: 1913–Present. Available from http://www.ucalgary.ca/applied_history/tutor/calgary/oil.html [accessed 18 August 2009].

Vincent, M., and Mueller, D. 2008. Joint Review Panel Established by the Alberta Energy and Utilities Board and the Canadian Environmental Assessment Agency. EnCana Shallow Gas Infill Development Project Suffield National Wildlife Area, Alberta. Submissions of the Government of Canada, Ottawa, Ontario.

Von der Lippe, M., and Kowarik, I. 2007. Long-distance dispersal of plants by vehicles as a driver of plant invasions. Conservation Biology, **21**: 986–996.

Whittaker, A., and Jensen, S.L. 2008. Effects of Fire and Restoration Seeding on Establishment of Squarrose Knapweed (*Centaurea virgata* var. *squarrosa*). USDA Forest Service Proceedings RMRS-P-52. pp. 77–79.

Willms, W.D., Entz, T., Beck, R., and Hao, X. 2009. Do introduced grasses improve forage production on the Northern Mixed Prairie? Rangeland Ecology Management, **62**: 53–59.

Willoughby, M.G., and Alexander, M.J. 2007. Rangeland Health for Native and Modified Plant Communities in the Rough Fescue Ecological Site of the Montane Subregion. Alberta Sustainable Resource Development, Lands Division, Edmonton, Alberta.

Wolfe, D.H., Patten, M.A., Shochat, E., Pruett, C.L., and Sherrod, S.K. 2007. Causes and patterns of mortality in lesser prairie-chickens *Tympanuchus pallidicinctus* and implications for management. Wildlife Biology, **13**(Suppl. 1): 95–104.

Yoakum, J.D. 1975. Antelope and livestock on rangelands. Journal of Animal Science, **40**: 985–993.