BIOLOGICALLY EFFECTIVE MANAGEMENT OF GRAZINGLANDS

4th Edition

North Dakota State University
Dickinson Research Extension Center
2014

4015b

North Dakota State University *2014*
Dickinson Research Extension Center
Rangeland Research Outreach Program DREC 14-4015b

Biologically Effective Management of Grazinglands

4th Edition

Llewellyn L. Manske PhD
Research Professor of Range Science

Project Assistant
Sheri A. Schneider

North Dakota State University
Dickinson Research Extension Center
1041 State Avenue
Dickinson, North Dakota 58601

Tel. (701) 456-1118
Fax. (701) 456-1199

CONTENTS

Rangelands of the Northern Plains

Effects of Environmental Factors

Effects of Partial Defoliation

Effects of Grazing Management Treatments

Preface

Biologically effective management of grazinglands places priority with the living components of ecosystems for the purpose of meeting the biological requirements of grassland plants and soil organisms contrary to traditional grazing practices that place priority on the use of grasslands as a source of forage for livestock. The biologically effective twice-over rotation grazing management strategy with complementary domesticated grass spring and fall pastures coordinates partial defoliation by grazing with grass phenological growth stages for the beneficial manipulation of grassland ecosystem biogeochemical processes. Grass plants developed defoliation resistance mechanisms during the period of coevolution with graminivores that help grass tillers withstand and recover from partial defoliation by grazing. These essential biological mechanisms are the scientific basis for biologically effective management strategies; these mechanisms are triggered by partial defoliation by grazing during phenological growth between the three and a half new leaf stage and the flower (anthesis) stage, and these mechanisms are fully activated when 100 lbs/ac soil mineral nitrogen is available from the rhizosphere organisms. The three main mechanisms are: compensatory internal physiological processes within remaining leaf and shoot tissue that increase growth rates of replacement leaves; internal vegetative reproduction from axillary buds that increases secondary tiller density and herbage biomass; and external rhizosphere organism symbiotic activity that increases available mineral nitrogen conversion from soil organic nitrogen; thereby enhancing productivity of grassland ecosystems.

The basic concepts for biologically effective management of grazinglands were developed from research projects conducted in the Northern Plains, however, the resulting grazingland management strategies and recommendations are applicable to all grazingland regions where perennial grass plants reproduce vegetatively and are exposed to frozen soil during the winter season.

RANGELANDS OF THE NORTHERN PLAINS

Northern Plains Rangelands

Llewellyn L. Manske PhD
Report DREC 03-17b
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Northern Plains rangelands are a valuable renewable natural resource that provides a multitude of benefits. Much of the region's economic base is dependent on rangelands, which are the principal land type for the area's recreation, wildlife, and tourism industries and provide the majority of the forage base for the livestock industry. The use of rangelands as grazinglands for domesticated livestock is the premier example of high-value-added sustainable agriculture with low energy input. The vegetation is self perpetuating, and the animals harvest their own forage. Grazing livestock on rangelands converts perennial vegetation that cannot be directly consumed by humans into a high-quality food and provides beneficial secondary products such as fibers, medicines, cosmetics, oils, glues, and base compounds. The vegetation on rangelands provides habitat for wildlife and scarce plants and animals and stabilizes the soil, protecting it from wind and water erosion. Through photosynthesis, the plants reduce the levels of carbon dioxide in the air and release clean oxygen into the atmosphere. Rangelands collect, filter, and store water in aquifers and small basins (pot holes), then slowly release it into streams and rivers by processes that reduce the damaging effects of fast runoff and floods. Rangelands provide clean water for plants, animals, and humans. The open spaces of rangelands are aesthetically appealing and offer opportunities for recreation and sightseeing.

Properly managed, rangelands can be maintained at high levels of production in perpetuity. Rangelands are managed with ecological principles, unlike cropland, which is managed with agronomic principles. Proper management of rangelands requires an understanding of the effects environmental forces have on plant growth and of the complex processes within the plants and ecosystems. Ecological and biological requirements of grass plants can be met by properly timed defoliation by grazing. Rangeland plants have become biologically adapted to grazing. The adaptations are expressed through resistance mechanisms plants have developed in response to the evolutionary selective forces of defoliation. To maintain adequate activity of these biological processes, healthy range plants require annual defoliation by grazing. Management that is focused on a single use and that does not include annual defoliation at the appropriate growth stages cannot sustain a healthy ecosystem over time. Management that places the biological requirements of the plants as the highest priority and facilitates the operation of ecosystem functions at potential levels will sustain healthy, productive rangelands that will remain a valuable renewable natural resource, providing forage for livestock, habitat for wildlife and plants, clean air, clean water, open spaces for recreation and sightseeing, and food, fiber, and energy for people. The greatest attribute of rangelands is that when managed properly, they can provide all of these valuable benefits at the same time.

Physiography, Soil, and Native Vegetation of the Northern Plains

Llewellyn L. Manske PhD
Report DREC 08-3048
Ran ge Scientist
North Dakota State University
Dickinson Research Extension Center

Land resources of the Northern Plains are the source of new wealth generated by livestock agriculture. The land natural resources consist of complex ecosystems with several trophic layers of living organisms that have individual biological requirements and nonliving (abiotic) components that have changeable characteristics. Biologically effective management benefits all living and nonliving ecosystem components by meeting the biological requirements of the plants and soil organisms and by fostering the characteristics of the soil resulting in continuation of ecosystem production at potential sustainable levels. The potential productivity of healthy ecosystems are effected by the same environmental and biological factors that cause changes in physiographic landform characteristics, soil characteristics, and native vegetation types. The characteristics and relationships of the physiography, soil, and native vegetation of the Northern Plains are described in this report.

Physiographic Regions

The Northern Plains are part of the North American Interior Plains that extend from the foot of the Rocky Mountains eastward to the Canadian Shield and Appalachian Provinces and extend from the Athabasca River on the Alberta Plateau southward to the Gulf Coastal Plains (Fenneman 1931, 1946; Hunt 1974; Goodin and Northington 1985). The Interior Plains are divided east and west into the Great Plains and the Central Lowland Physiographic Provinces (Fenneman 1931, 1946). The Northern Plains are separated from the Southern Plains by the North Platte-Platte-Missouri River Valleys (Raisz 1957). The portions of the Great Plains and Central Lowland Provinces that exist in the Northern Plains are separated in North and South Dakota and Saskatchewan by an eroded east facing escarpment at the eastern extent of the Tertiary sedimentary deposits of material eroded from the Rocky Mountains that form a fluvial plain overlaying the Cretaceous bedrock (Hunt 1974). The surface landform feature that shows the location of this boundary is the east escarpment of the Missouri Coteau (Finneman 1931). In eastern Nebraska, the separation of the Great Plains and Central Lowland Provinces is the western limit of older pre-Wisconsin glacial drift which has a mantle of loess (wind deposited silt) (Fenneman 1931).

Great Plains Province

The Missouri Plateau Section and the northern portion of the High Plains Section of the Great Plains Province are separated in southern and eastern South Dakota by the north facing Pine Ridge Escarpment and the southern bluffs of the Missouri River Valley (Fenneman 1931). The portion of the High Plains that extends into the Northern Plains is divided into Pine Ridge, Sand Hills region, Loess Plain, and Goshen Hole Lowland landscape features. The Missouri Plateau, including the Alberta Plain, is divided into three sections: Glaciated, Unglaciated, and Black Hills, along with smaller domed mountains (Fenneman 1931, 1946; Hunt 1974).

Missouri Plateau Section

The Unglaciated section of the Missouri Plateau is north of the Pine Ridge Escarpment in South Dakota, south of the Missouri River in Montana, and west of the Missouri River in North and South Dakota (Fenneman 1931, 1946; Hunt 1974). Portions of this section were undoubtedly glaciated during glacial advances earlier than Wisconsin Age. However, there is little geologic evidence of older glaciation. The important distinction between the Unglaciated and Glaciated sections is the type and age of parent material from which the soil develops. The landscape surface of the Unglaciated section is highly eroded fluvial sedimentary deposits of material removed from the uplifted Rocky Mountains. Most of the deposition occurred from slow meandering streams during the Laramide Orogeny, that formed the mountains, and during the 20 to 30 million years of the late Cretaceous and early Tertiary Periods following the uplift. Intense widespread erosion of these sediments occurred from about 5 to 3 million years ago during the late Pliocene Epoch (Bluemle 2000). The extensive erosion during this period removed about 500 to 1000 feet of sediments (Fenneman 1931). These fluvial Tertiary sediments had great differences in hardness and durability. The soft and unconsolidated material was easily removed and the harder coherent material had greater resistance to weathering and to erosional forces of wind and running water. Differential erosion formed a landscape with well developed integrated drainage systems of broad mature valleys and gently rolling uplands containing widely spaced large hills and buttes with erosion resistant caps raising 500 to 650 feet above the plain (Bluemle 2000).

In addition to the high relief from erosion resistant capped remnant hills and buttes on the landscape, several isolated domed mountain groups with 1500 to 2000 foot rise formed on the Missouri Plateau. These laccolithic mountains developed from the upward push of rising igneous intrusions (molten magma) that did not penetrate through to the surface but caused a diastrophic bulge with a single fold in the uplifted sediments. Differential erosion has since exposed the underlying tilted strata (Froiland and Weedon 1990) and sometimes the intrusive rock (Robinson and Davis 1995). Along with the large dome uplifted Black Hills in South Dakota and Wyoming, which is treated as a separate section, the Sweetgrass Hills, and the Highwood, Bearpaw, Little Rocky, Moccasin, Judith, and Big Snowy mountains in Montana are smaller domed mountain groups (Fenneman 1931, Hunt 1974). The Highwood and Bearpaw domed mountains include extinct volcanoes (Fenneman 1931).

Drainage of the Missouri Plateau during the highly erosional period of the Pliocene (5 to 3 million years ago) was primarily north and northeast towards the Hudson Bay area. The climate became cooler about 2.6 million years ago and, about 700,000 years ago, the climate was cold enough to produce continental glaciers (Bluemle 2000). Early glacial advances blocked the northward paths of the rivers draining the Unglaciated section and diverted water flow into steeper southern routes. The increased gradient of several rivers caused drastic downcutting through areas of poorly consolidated, soft, fine textured sediments resulting in formation of badland regions (Fenneman 1931).

The Glaciated section of the Missouri Plateau is north of the Missouri River in Montana, including the Alberta Plain between the foot of the Rocky Mountains and the Missouri Coteau Escarpment in Canada, and extends southward between the Missouri River and the east escarpment of the Missouri Coteau in North and South Dakota (Fenneman 1931, Hunt 1974). The section has a mantle of glacial and glacier related drift deposited between 70,000 and 10,000 years ago during the Wisconsin Age. The Missouri Coteau has 500 to 600 feet of terminal moraine deposits. The thick deposits of unsorted glacial sediment are a result of the large quantities of additional rock and sediments picked up from beneath the ice and forced upward into the glacier along shear planes that were generated by great internal stress (Bluemle 2000) when the advances of numerous glaciers were forced to progress up the steep escarpment of Tertiary deposited fluvial sediments. Large masses of stagnant ice remained buried under debris on the Coteau area for about 3000 years following the northern retreat of the last continental glacier. As the stagnant blocks of ice melted, the overlying material slumped down forming depressions (Bluemle 2000). The resulting topography is an irregular surface with closely spaced hills of 100 to 150 feet in height enclosing basins, or kettles, that usually contain ponds (Fenneman 1931). The drainage is local and completely unintegrated with only a few short streams.

The glaciated areas north of the Missouri River and on the Alberta Plain have a mantle of till and outwash. The topography is generally rough. The plain is dissected by broad river valleys that have entrenched 200 to 400 feet. The upland areas contain several erosional remnants that have local relief of about 1000 to 2000 feet. The Cypress Hills in Saskatchewan are the highest and have a height tall enough that they were not overriden by glacial ice. The gravel capped Cypress Hills were part of an ancient valley where a thick layer of rock from the Rocky Mountains was deposited by rivers. This heavy gravel layer protected the surface during the severe erosional period of the late Pliocene, while surrounding higher areas were eroded down to levels below the gravel layer forming an inverted topography (Fenneman 1931).

High Plains Section

A small portion of the High Plains Section of the Great Plains Province exists between the Pine Ridge Escarpment in South Dakota and the North Platte-Platte River Valley in Nebraska and is included within the Northern Plains (Fenneman 1931, 1946; Hunt 1974). Contrary to the erosional surface of the Unglaciated section of the Missouri Plateau north of Pine Ridge, the northern portion of the High Plains is primarily a depositional surface. The uplands of Pine Ridge north of the Niabrara River are exposed Tertiary fluvial sediments of the Arikaree Formation deposited during the Miocene and have a gently rolling to nearly flat topography. The Goshen Hole

Lowland located in western Nebraska south of the west end of Pine Ridge is a landform about 50 miles wide and 150 miles long where the North Platte River removed about 700 feet of fine textured clay Tertiary sediments during a period when the river had a relatively steep gradient. The Sand Hills region in Nebraska is located south of the Niobrara River and north of the Platte River. Wind deposited sand covers the Tertiary sediments of the region and forms a sand dune topography. Small areas have active dune movement, however, most of the region has been stabilized by grassland vegetation. Some of the sand hills are several hundred feet high. Lakes, ponds, or wetlands form in the depressions. The Loess Plain in north central Nebraska is located east of the Sand Hills region. Wind deposited silt (loess) about 100 feet thick covers the Tertiary sediments of the area and forms a gently rolling topography (Fenneman 1931).

Central Lowland Province

The Small Lakes Section and the Dissected Till Plains Section of the Central Lowland Province are separated by the age of the glacial till and the degree of development of integrated drainage systems. The Small Lakes Section is located in the northwestern part of the Central Lowland Province and extends eastward from the escarpment of the Missouri Coteau to the Great Lakes Section (Hunt 1974). However, for this report, the Small Lakes Section description extends eastward only to the transition between the Tall Grass Prairie and the Oak Forest in western Minnesota.

Small Lakes Section

The Small Lakes Section has a mantle of Wisconsin Age glacial till and glacial lake deposits. The Saskatchewan Plain between the Missouri Coteau Escarpment and the Manitoba Escarpment in Canada and the Glaciated Plains (Drift Prairie) east of the Missouri Coteau in North and South Dakota extending into western Minnesota are an undulating plain of ground moraine forming a knob and kettle topography with low to moderate relief (Hunt 1974). Water collects in the lower portions of the landscape forming lakes and ponds or marshes with the size decreasing westward with the decrease in annual precipitation (Hunt 1974). The Small Lakes Section does have a few river systems, however, these rivers are still at the early stages of developing complex integrated drainage systems. Thick glacial deposits forming a hummocky collapsed topography (Bluemle 2000) cover Moose Mountain in Saskatchewan and the Turtle Mountains in Manitoba and North Dakota as a result of shear stress planes developing in the ice as the glaciers advanced over preexisting high relief erosional remnant hills.

Glacial Lake Plains of relatively flat fine sediments and reworked till were formed by glacial lakes that developed when meltwater collected in landscape depressions, along the edge of receding glaciers, or as a result from ice damming drainage routes (Ojakangas and Matsch 1982, Bluemle 2000). Lakes Agassiz, Aitkin, Dakota, Duluth, Minnewaukan, Regina, Souris, and Upham were major glacial lakes that existed for periods sometime between 12,200 and 7,500 years ago. Lake Agassiz was, by far, the largest of the glacial lakes and its western edge is defined by the Manitoba-Pembina Escarpment. This escarpment was formed during the highly erosional period of the Pliocene when artesian ground water from the Cretaceous Dakota sandstone formation and overland water from the Grand, Cheyenne, and White Rivers flowed into the ancestral Red River, cut through the relatively soft Cretaceous sediments down to the west sloping Precambrian igneous rock of the Canadian Shield, and progressively shifted the erosional face westward (Bluemle 2000). These erosional surfaces were later covered with thick layers of glacial till and lake sediments during the Pleistocene glaciation. The exceptionally flat surface of Glacial Lake Agassiz sediments east of the Manitoba-Pembina Escarpment form the Manitoba Plain in Canada and the Red River Valley Plain in eastern North Dakota and western Minnesota.

Dissected Till Plains Section

The Dissected Till Plains Section was not glaciated during the Wisconsin Age. The glacial till of this section is from older glacial advances. The old dissected till deposits extend westward from the Mississippi River across southern Iowa and northern Missouri and narrows northward into southwestern Minnesota and southeastern South Dakota (Fenneman 1946, Raisz 1957). The western limit of the old glacial till occurs in eastern Nebraska. The drainage systems on older till have had longer to develop a complex integrated pattern with closely spaced deep valleys and rounded uplands. There are few lakes and ponds in this section and a younger mantle of about 30 feet of wind blown loess (silt) covers the region (Hunt 1974).

Soil Characteristics

Soil development is effected by climate, parent material, topography, living organisms, and time (Brady 1974). The main climatic factors that affect soil development are temperature and precipitation. Climate determines the type and rate of weathering that occurs. The rates of biogeochemical processes in soil are effected by soil temperature and soil moisture. Climate determines the type of native vegetation and the quantity of biomass production. There is a relationship between the type of native vegetation and the kind of soil that develops. Increases in soil moisture, increase the biomass production and tend to increase organic content of soils. Increases in soil temperature, increase the rate of decomposition and tend to decrease organic content of soils (Brady 1974).

The Northern Plains has a continental climate with cold winters and hot summers. Mean air temperatures increase from north to south changing from about 35° - 40° F (1.7° - 4.4° C) in the north to about 48° - 51° F (8.9° - 10.6° C) in the south. Most of the precipitation occurs during the early portion of the growing season. Total annual precipitation fluctuates greatly from year to year. Periods of water deficiency during the growing season occur more frequently than growing seasons without deficiencies. Drought conditions are common. Mean annual precipitation increases from west to east and increases from north to south. In the northern portion, precipitation ranges from about 12 inches (304.8 mm) in the west to about 24 inches (609.6 mm) in the east. In the southern portion, precipitation ranges from about 14 inches (355.6 mm) in the west to about 32 inches (812.8 mm) in the east.

Evapotranspiration affects the quantity of moisture in the soil and the duration infiltrated water remains available for plant growth. The potential evapotranspiration for most of the Northern Plains is greater than annual precipitation. Potential evapotranspiration demand increases from north to south, and increases from east to west. Along the eastern edge of the Northern Plains, the precipitation is greater than potential evapotranspiration during most years. The region also has several local areas where the combination of stored soil water, precipitation, plus water runin is greater than evapotranspiration. Subirrigated soils where the rooting zone is moist for most of the growing season would be comparable to conditions with greater precipitation than evapotranspiration.

The properties of the parent material that affect soil development include texture and structure, and chemical and mineral composition. The texture and structure of parent material varies from fine to coarse and is related to the type of source material and the degree of weathering. The texture of the parent material determines the texture of the soil and the relative content of clay, silt, sand, and gravel. The texture of the soil controls the downward movement of water. The chemical and mineral composition of the parent material strongly influences the growth of the native vegetation and determines the effectiveness of the weathering forces. Parent material influences the quantity and type of clay minerals that develop (Brady 1974). The parent material on the Northern Plains is eroded Tertiary fluvial sedimentary deposits, unsorted glacial till, sorted glacier related deposits of outwash and lake sediments, and wind deposited sand and silt.

Landform topography modifies soil development by influencing the quantity of precipitation absorbed and retained in the soil, determines aspect to solar radiation, and influences the rate of soil removal by erosion. Water, organic matter, mineral matter, and soluble salts move down slope, whether over the surface or internally. The steeper the gradient, the greater the movement. Soil temperature changes with slope aspect. Increases in soil temperature, increase evapotranspiration and decomposition rates. Upper slope soils tend to have lower soil moisture, less organic matter, and thinner horizon development than lower slope soils from similar parent material (Brady 1974).

Living organisms (including plants, animals, and soil microorganisms) affect soil development by influencing organic matter accumulation, profile mixing, nutrient cycling, and structural stability. The source of soil organic matter is the dead tissue and waste from organisms, decomposition is performed by soil organisms, nutrient cycles are complex processes involving living organisms, burrowing critters mix soil material, and soil aggregation is a result of soil organism secretions (Brady 1974).

Time is required for soils to develop and mature. However, soils do not all develop at the same rate. Conditions that increase soil development are warm humid climate, parent material highly permeable by water, unconsolidated material, low lime content, depression or level topography, good drainage, and forest vegetation. Conditions that retard soil development are cold dry climate, parent material not permeable by water, consolidated material, high lime content, steeply sloping topography, poor drainage, and grassland vegetation (Brady 1974). Some very old soils in the Northern Plains show little or no evidence of horizon development because they exist in dry regions, on steep, actively eroding slopes where the rate of soil removal is as great or greater than the rate of soil development.

The soils that are developing in the Northern Plains fit into the order classification descriptions of Mollisols, Aridisols, and Entisols.

Mollisols are mineral soils that develop under grassland vegetation with a thick mollic epipedon that is “soft”, high in organic matter, and dark colored. The limited leaching results in a high base saturation with a concentration of positively charged exchangeable cations other than hydrogen. Most Mollisols in the Northern Plains have, or are developing, an argillic (clay) layer in an upper subhorizon and have an accumulation of calcium carbonate (lime) at some level of the profile (Soil Survey Staff 1975).

Aridisols are mineral soils that develop in aridic (dry) or torric (hot and dry) climates with a thin ochic epipedon that is low in organic matter and light colored. Soil water is not available to plants for long periods during the growing season. In the Northern Plains, the Aridisols have an argillic (clay) layer in an upper subhorizon and as a result of limited leaching, soluble salts, like calcium carbonate, accumulate in a zone that marks the average depth of moisture penetration (Soil Survey Staff 1975).

Entisols are mineral soils that show little or no evidence of horizon development and have a thin ochic epipedon that is low in organic matter and light colored. In the Northern Plains, considerable retardation of soil development produces Entisols where dry and/or salty medium to fine textured sediments with sparse grass or shrub vegetation are located on gentle to steep, actively eroding slopes with the rate of soil removal as great as the rate of soil development, or where coarse textured, well sorted, wind deposited sand with low water holding capacity and thin grass vegetation become dry and are easily moved by wind (Soil Survey Staff 1975).

Classification of soils into principal suborders is based on differences caused by climate and associated native vegetation. The biological processes in soil are effected by soil temperature and soil moisture. The different climatic characteristics important in soil development are separated into specific soil temperature regimes and soil moisture regimes.

The Northern Plains has two soil temperature regimes based on mean annual soil temperature. The mean annual soil temperature is considered to be the mean annual air temperature plus 1.8° F (1° C) (Soil Survey Staff 1975). The Frigid soil temperature regime has mean annual soil temperatures of less than 47° F (8° C). The Mesic soil temperature regime has mean annual soil temperatures higher than 47° F (8° C) and lower than 59° F (15° C) (Soil Survey Staff 1975). The separation between the Frigid and Mesic soil temperature regimes occurs along a wide irregular belt that extends eastward from central Wyoming along its north border with Montana and continues to north central South Dakota just south of its north border with North Dakota, then extends at a southeasterly diagonal to about the center of South Dakota’s east border with Minnesota, and then extends at a northeasterly angle to the boundary of the Oak Forest.

Soil moisture regimes are based on the soil moisture conditions in the soil. The Northern Plains has four north-south zones of soil moisture regimes that increase in soil moisture from west to east. The soils in the Aridic and Torric soil moisture regime, typically of arid climates, are dry in all parts for more than half the time and the soils are never moist for as long as 90 days during the growing season (Soil Survey Staff 1975). The soils in the Ustic soil moisture regime, typically of semi arid climates, are dry in some or all parts for 90 or more days in most years, but not dry in all parts for more than half the time, and are not dry for as long as 45 days during the 4 months that follow the summer solstice in 6 or more years out of 10 years (Soil Survey Staff 1975). The soils in the Udic soil moisture regime, typically of sub humid climates, are not dry for as long as 90 days. During the summer, the amount of stored moisture plus rainfall is approximately equal to or exceeds the amount of evapotranspiration (Soil Survey Staff 1975). The soils in the Perudic soil moisture regime, typically of humid climates, are rarely dry. During the summer, the precipitation is greater than the evapotranspiration (Soil Survey Staff 1975).

The combination of four soil moisture regimes (Aridic, Ustic, Udic, and Perudic) and two soil temperature regimes (Frigid and Mesic) results in eight distinct soil moisture-temperature regimes in the Northern Plains. The soils in the Aridic-Frigid soil moisture-temperature regime are primarily Aridic Borolls (arid cool Mollisols) and Torriorthents (hot dry recently eroded medium to fine textured Entisols) and support vegetation of short grasses with some mid grasses. The soils in the Ustic-Frigid soil moisture-temperature regime are primarily Typic Borolls (semi arid cool Mollisols) and support vegetation of mid and short grasses. The soils in the

Udic-Frigid soil moisture-temperature regime are primarily Udic Borolls (sub humid cool Mollisols) and support vegetation of mid grasses with some tall grasses. The soils in the Perudic-Frigid soil moisture-temperature regime are primarily Aquolls (humid cool Mollisols that are saturated and absent of oxygen at times for unknown lengths) and support vegetation of tall grasses. The soils in the Aridic-Mesic soil moisture-temperature regime are primarily Argids (arid warm Aridisols with thin horizons, dry for long periods, and have a clay layer) and Aridic Ustolls (arid warm Mollisols) and support vegetation of short grasses. The soils in the Ustic-Mesic soil moisture-temperature regime are primarily Ustipsamments (semi arid warm Entisols that are well sorted wind deposited sands) and Typic Ustolls (semi arid warm Mollisols) and support vegetation of mid and short grasses with lower topographic slopes supporting tall grasses. The soils in the Udic-Mesic soil moisture-temperature regime are primarily Udic Ustolls (sub humid warm Mollisols) and support vegetation of mid grasses and tall grasses. The soils in the Perudic-Mesic soil moisture-temperature regime are primarily Udolls (humid warm Mollisols that do not have a calcium carbonate layer) and support vegetation of tall grasses.

Native Vegetation Types

Development of plant communities and vegetation types is effected by the climatic characteristics of temperature, precipitation, and evapotranspiration demand; the soil characteristics of texture, structure, and chemical and mineral composition; and the landform topographic characteristics of slope, aspect, and elevation. Vegetation of the Northern Plains separates into 10 grassland vegetation types and 7 grassland with woodland or forest vegetation types. The vegetation of the Northern Plains map (figure 1) developed by Dr. W.C. Whitman (Barker and Whitman 1989) is a compilation of information from several sources supplementary to the basic map of potential natural vegetation by Kuchler (1964). Modifications to vegetation type designations, distributions, and boundaries were conflated into the base map from state vegetation maps for Montana (Ross and Hunter 1976, Hacker and Sparks 1977), Nebraska (Kaul 1975, Bose 1977), North Dakota (Shaver 1977), South Dakota (Baumberger 1977), and Wyoming (Shrader 1977). Vegetation type designations and distributions from scientific papers were added for Canada (Clarke, Campbell, and Campbell 1942; Moss and Campbell 1947; Coupland and Brayshaw 1953; Coupland 1950, 1961). A new concept of a plains rough fescue mixture along a portion of the northern border of North Dakota was introduced to the map details by Whitman and Barker (1989).

No living plant species are known to have originated in the Northern Plains. All plant species considered to be native to the Northern Plains originated and developed in other regions and sometime later migrated into the Northern Plains. The plant communities and vegetation types, however, are relatively young and began development in place about 5,000 years ago when the current climate with cycles of wet and dry periods began. Nomenclature of plants in the vegetation types of the Northern Plains followed Flora of the Great Plains (1986) in Barker and Whitman (1989) and, in addition, nomenclature of grass plants follows Flora of North America (2003, 2007) in this report.

Tall Grass Prairie

The Tall Grass Prairie, Bluestem-Switchgrass-Indiangrass Type, exists on the eastern margin of the Northern Plains Grasslands and extends from southern Manitoba through eastern North and South Dakota and western Minnesota southward into northwestern Iowa and northeastern Nebraska to the Platte River. The physiography of the region consists of the Manitoba Plain and the Red River Valley Plain of the Small Lakes Section and extends into the Dissected Till Plains Section of the Central Lowland Province. The climate is humid with evapotranspiration lower than precipitation. The soil moisture regime is Perudic and the soil temperature regime is Frigid in the north and Mesic in the south. The soils are primarily Aquolls in the north and Udolls in the south. The major grasses of the Bluestem-Switchgrass-Indiangrass Type of the Tall Grass Prairie (table 1) are big bluestem, porcupinegrass, switchgrass, prairie dropseed, and indiangrass. Cool-season grass species increase towards the northern portions and warm-season grass species increase towards the southern portions. Big bluestem occupies the lower slopes and subirrigated soils in the north and increases in dominance in the south. Prominent forbs are prairie clover, tall blazing star, large beardtongue, stiff sunflower, scurf pea, white prairie aster, white sage, prairie goldenrods, and violets. Major shrubs are leadplant, white spiraea, wild roses, western snowberry, and willows. Most of this vegetation type has been converted to cropland, and only fragments of tall grass prairie vegetation remain. Plant communities with tall grass species exist in several other vegetation types where near equivalent environmental conditions develop from combinations of precipitation, stored soil water, and water runin that are greater than evapotranspiration.

Transition Mixed Grass Prairie

The Transition Mixed Grass Prairie, Wheatgrass-Bluestem-Needlegrass Type (figure 1), exists between the Tall Grass Prairie on the east and the Mixed Grass Prairie on the west and extends from east central Saskatchewan and southwestern Manitoba through east central North and South Dakota and east central Nebraska to the Platte River. The physiography of the region consists of the Saskatchewan Plain and the Glaciated Plains (Drift Prairie) of the Small Lakes Section of the Central Lowland Province and extends into the eastern portion of the High Plains Section of the Great Plains Province. The climate is sub humid with evapotranspiration greater than precipitation over most of the area except for subirrigated soils and topographic slope positions with water runin. The soil moisture regime is Udic and the soil temperature regime is Frigid in the north and Mesic in the south. The soils are primarily Udic Borolls in the north and Udic Ustolls in the south. The major grasses of the Wheatgrass-Bluestem-Needlegrass Type of the Transition Mixed Grass Prairie (table 2) are western wheatgrass, thickspike (northern) wheatgrass, little bluestem, porcupinegrass, needle and thread, and green needlegrass. Cool-season grass species increase towards the northern portions and warm-season grass species increase towards the southern portions. The needlegrasses and thickspike wheatgrass increase in the north. Little bluestem increases in the south. Prominent forbs are white prairie aster, scurf peas, prairie coneflower, purple coneflower, milkvetches, dotted blazing star, white sage, soft goldenrod, curlycup gumweed, hairy golden aster, and stiff sunflower. Major shrubs are wild roses, western snowberry, silverberry, leadplant, white spiraea, and willows. Plant communities change with topographic position. Wetland communities develop in nearly concentric rings around depressions. The salt-affected “pot holes” support saline plant communities. Wet meadow communities develop on subirrigated soils. Upland communities develop on well drained soils and xeric communities develop on shallow soils. Kentucky bluegrass and western snowberry communities have greatly increased in this region as a result of high stocking rates and too early of grazing starting dates.

Mixed Grass Prairie

The Mixed Grass Prairie has a high mid grass component with some short grasses and some tall grasses present and is separated into three vegetation types based on differences resulting from soil texture and soil temperature regime.

The Mixed Grass Prairie, Wheatgrass-Needlegrass Type (figure 1), exists on semi arid cool soils between the Transition Mixed Grass Prairie on the east and the Short Grass Prairie on the west and extends from mid Saskatchewan through western North Dakota and eastern Montana to north central and northwestern South Dakota. The physiography of the region consists of the eastern portions of the Glaciated and Unglaciated sections of the Missouri Plateau Section, including the Alberta Plain, of the Great Plains Province. The climate is semi arid with evapotranspiration greater than precipitation. The soil moisture regime is Ustic and the soil temperature regime is Frigid. The soils are primarily Typic Borolls. The major grasses of the Wheatgrass-Needlegrass Type of the Mixed Grass Prairie (table 3) are western wheatgrass, needle and thread, blue grama, prairie Junegrass, and green needlegrass. Prominent forbs are white prairie aster, scarlet gaura, scarlet globemallow, purple prairie clover, dotted blazing star, purple locoweed, fringed sage, white sage, hairy golden aster, curlycup gumweed, Hood’s spiny phlox, prairie smoke, green sage, and prairie chickweed. Major shrubs are silver sagebrush, buffaloberry, wild roses, western snowberry, broom snakeweed, and creeping juniper. This vegetation type grows in soils developed from glacial till north and east of the Missouri River and grows in soils developed from Tertiary sedimentary deposits south and west of the Missouri River. Soils in the unglaciated section are developing an argillic (clay) layer and accumulating soluble salts in a subhorizon at decreasing depths from east to west.

The Mixed Grass Prairie, Wheatgrass-Grama Type (figure 1), exists on semi arid warm clay soils south of the Wheatgrass-Needlegrass Type and is in southwestern South Dakota. The physiography of the region consists of the southeastern portion of the Unglaciated section of the Missouri Plateau Section of the Great Plains Province. The climate is semi arid with evapotranspiration greater than precipitation. The soil moisture regime is Ustic and the soil temperature regime is Mesic. The soils are primarily clay textured Typic Ustolls. The major grasses of the Wheatgrass-Grama Type of the Mixed Grass Prairie (table 4) are western wheatgrass, blue grama, and buffalograss. This vegetation type is separated from the Wheatgrass-Needlegrass Type because the clay textured soils and warmer soil temperature regime result in near removal of needle and thread and in greatly increasing blue grama and buffalograss.

The Mixed Grass Prairie, Wheatgrass Type (figure 1), exists on semi arid warm dense clay soils south of the Wheatgrass-Needlegrass Type and is in northwestern South Dakota. The physiography of the region consists of the central portion of the Unglaciated section of the Missouri Plateau Section of the Great Plains Province. The climate is semi arid with evapotranspiration greater than precipitation. The soil moisture regime is Ustic and the soil temperature regime is Mesic. The soils are primarily dense clay textured Typic Ustolls. The major grasses of the Wheatgrass Type of the Mixed Grass Prairie (table 5) are western wheatgrass, green needlegrass, and thickspike wheatgrass. This vegetation type is separated from the Wheatgrass-Needlegrass Type because the dense clay textured soils and warmer soil temperature regime result in removal of blue grama and near removal of needle and thread.

Short Grass Prairie

The Northern Short Grass Prairie, Grama-Needlegrass-Wheatgrass Type (figure 1), exists on the western side of the Northern Plains Grasslands and extends from southeastern Alberta and southwestern Saskatchewan through central Montana and southward into northeastern Wyoming. The physiography of the region consists of the western portions of the Glaciated and Unglaciated sections of the Missouri Plateau Section of the Great Plains Province. The climate is arid with evapotranspiration greater than precipitation. The soil moisture regime is Aridic and the soil temperature regime is Frigid in the north and Mesic in the south. The soils are primarily Aridic Borolls and Torriorthents in the north and Argids and Aridic Ustolls in the south. The major grasses of the Grama-Needlegrass-Wheatgrass Type of the Northern Short Grass Prairie (table 6) are blue grama, needle and thread, small needlegrass, western wheatgrass, thickspike wheatgrass, green needlegrass, and buffalograss. Prominent forbs are fringed sage, green sage, milkvetches, Hood's spiny phlox, curlycup gumweed, and prairie chickweed. Major shrubs are big sagebrush, silver sagebrush, rabbitbrush, broom snakeweed, plains prickly pear, greesewood, shadescale, saltbush, and winterfat. Dr. Whitman (Barker and Whitman 1989) continued the separation of this vegetation type from the Wheatgrass-Needlegrass Type because of the notable increase in the shortgrass component and the relative decrease of western wheatgrass and needle and thread. Cool-season grass species increase towards the northern portions and warm-season grass species increase towards the southern portions. The needlegrasses increase in the north. Blue grama and buffalograss increase in the south. Because of the presence of mid cool-season grasses, the Northern Shortgrass Prairie has sometimes been combined with the Northern Mixed Grass Prairie. However, these two vegetation types are distinct and should remain separated. The Grama-Needlegrass-Wheatgrass Type has the appearance of a shortgrass prairie and has an arid soil moisture regime, less soil horizon development, shallower soil depth to the accumulating soluble salts and developing argillic (clay) layer, shallower rooting depth, lower soil water holding capacity, greater evapotranspiration potential, and generally more xeric than the Wheatgrass-Needlegrass Type.

The Northern Short Grass Prairie, Saltgrass Type, exists on salt affected soils distributed in local areas across the Northern Short Grass Prairie region. The major grasses of the Saltgrass Type of the Northern Short Grass Prairie (table 7) are saltgrass, alkali cordgrass, basin wildrye, foxtail barley, little barley, and Nuttall's alkali grass. Few plant species can tolerate the harsh environmental conditions of salt-affected areas. The tolerant species have mechanisms to exclude uptake of salts, or physiologically separate and discharge the undesired salts.

The Southern Short Grass Prairie, Blue grama-Buffalograss Type (figure 1), exists in northwestern Nebraska and extends into east central Wyoming north of the North Platte River. The physiography of the region consists of a small western portion of the High Plains Section of the Great Plains Province. The climate is arid with evapotranspiration greater than precipitation. The soil moisture regime is Aridic and the soil temperature regime is Mesic. The soils are primarily Argids and Aridic Ustolls. The major grasses of the Blue grama-Buffalograss Type of the Southern Short Grass Prairie (table 8) are blue grama and buffalograss. This vegetation type is separated from the Grama-Needlegrass-Wheatgrass Type because the arid soil moisture regime and mesic soil temperature regime severely reduce the mid cool-season grasses and greatly increase the short warm-season grasses. Only a small area of the Southern Short Grass Prairie extends into the Northern Plains.

Sandhills Prairie

The Sandhills Prairie, Bluestem-Sandreed-Grama-Needlegrass Type (figure 1), exists in the north central portion of Nebraska south of the

Niobrara River and north of the Platte River. Other Sandhills Prairie areas exist scattered throughout the Northern Plains. Many areas are too small to map. A large area of Sandhills Prairie exists along the Sheyenne River in southeastern North Dakota and another large area exists near Swift Current, Saskatchewan. The physiography of the Nebraska Sandhills consists of the Sand Hills region of the High Plains Section of the Great Plains Province. The climate is semi arid with evapotranspiration greater than precipitation. The soil moisture regime is Ustic and the soil temperature regime is Mesic. The soils are primarily Ustipsamments. The major grasses of the Bluestem-Sandreed-Grama-Needlegrass Type of the Sandhills Prairie (table 9) are big bluestem, little bluestem, sand bluestem, prairie sandreed, sideoats grama, needle and thread, and switchgrass. Prominent forbs are purple prairie clover, silky prairie clover, scurf peas, goldenrods, sunflowers, white camas, and wild lily. Major shrubs are leadplant, wild roses, western snowberry, willows, creeping juniper, common juniper, eastern red cedar, and yucca. This vegetation type is fundamentally the Tall Grass Prairie vegetation on sand soils. The tall grass species occupy the lower slopes and subirrigated soils while the mid and short grasses occupy the dryer upper slopes. A unique assemblage of grasses grow in blowout areas with active wind erosion and deposition and are blowout grass, sandhill muhly, sand dropseed, indian ricegrass, and Schweinitz cyperus.

Foothills Prairie

The Foothills Prairie, Plains Rough Fescue Type (figure 1), exists as a fringe along the montane forest of the Rocky Mountain foothills from Alberta to south central Montana and along the aspen groveland and aspen parkland bordering the boreal forest zone in Alberta and Saskatchewan and the type mingles with the Wheatgrass-Bluestem-Needlegrass Type extending across Saskatchewan and southwestern Manitoba and into northern North Dakota. The physiography of the region consists of the northern portion of the Glaciated section of the Missouri Plateau Section of the Great Plains Province and the northern portion of the Small Lakes Section of the Central Lowland Province. The major grasses of the Plains Rough Fescue Type of the Foothills Prairie (table 10) are plains rough fescue, Parry's oatgrass, timber oatgrass, bluebunch wheatgrass, slender wheatgrass, western wheatgrass, thickspike wheatgrass, Nelson's needlegrass, and Richardson's needlegrass. Prominent forbs are lupines, tall larkspur, sticky-leaved geranium, and arrowleaf balsamroot. Major shrubs are shrubby cinquefoil and big sagebrush. This vegetation type consists of a high proportion of tussock-forming grass species that are now known to develop on other landforms than Rocky Mountain foothills.

Grassland with Woodland or Forest

The Pacific Bunchgrass Prairie, Bluebunch-Fescue Type (figure 1), exists in the south central portion of Montana. Numerous other areas too small to map exist within the Great Plains. The physiography of the region consists of the Unglaciated section of the Missouri Plateau Section of the Great Plains Province. The major grasses of the Bluebunch-Fescue Type of the Pacific Bunchgrass Prairie (table 11) are bluebunch wheatgrass, Idaho fescue, western wheatgrass, sideoats grama, and little bluestem. Prominent forbs are white prairie aster, western yarrow, American vetch, scarlet gaura, and fringed sage. Major shrubs are western snowberry, silver sagebrush, rabbitbrush, broom snakewood, and plains prickly pear. This vegetation type is commonly associated with big sagebrush and exists as open grasslands between savanna stands of ponderosa pine or Rocky Mountain juniper.

The Badlands and River Breaks, Woody Draw and Savanna Types (figure 1), exist in central Montana along the Missouri and Musselshell Rivers, in western North Dakota along the Little Missouri River, and in southwestern South Dakota along the White River. The physiography of the region consists of the Unglaciated section of the Missouri Plateau Section of the Great Plains Province. The major grasses of the Woody Draw and Savanna Types of the Badlands and River Breaks (table 12) are western wheatgrass, needle and thread, blue grama, green needlegrass, and prairie Junegrass. The grassland communities of this vegetation type exist as open grasslands or understory grasslands associated with thin stands of trees growing in highly eroded badland areas, on steep east and north facing slopes, or in steep, sharply eroded breaks along streams and rivers. The woodlands and savannas consist primarily of ponderosa pine and Rocky Mountain juniper, and the hardwood draws consist of green ash, American elm, boxelder, and hawthorn. Major shrubs are wild roses, Juneberry, chokecherry, skunk bush, western snowberry, and shrubby cinequefoil.

The Pine Savanna, Pine-Juniper-Bluebunch Type (figure 1), exists on rough uplands in south central and southeastern Montana, north central Wyoming, western South Dakota, and southwestern North Dakota. The physiography of the region is the

Unglaciated section of the Missouri Plateau Section of the Great Plains Province. The major grasses of the Pine-Juniper-Bluebunch Type of the Pine Savanna (table 13) are bluebunch wheatgrass, western wheatgrass, thickspike wheatgrass, needle and thread, blue grama, green needlegrass, and little bluestem. The grassland communities of this vegetation type exist as open grasslands or understory grasslands associated with numerous disconnected savanna stands of ponderosa pine and Rocky Mountain juniper growing on eroded uplands with thin soils. Major shrubs are big sagebrush, bitterbrush, western snowberry, skunk bush, rabbitbrush, and common juniper.

The Black Hills Pine Forest, Pine-Spruce-Aspen Type (figure 1), exists in southwestern South Dakota and northeastern Wyoming. The physiography of the region consists of the Black Hills section of the Missouri Plateau Section of the Great Plains Province. The major grasses of the Pine-Spruce-Aspen Type of the Black Hills Pine Forest (table 14) are western wheatgrass, bluebunch wheatgrass, needle and thread, green needlegrass, prairie Junegrass, and blue grama. The grassland communities of this vegetation type exist as open grasslands or understory grasslands associated with the open park stands of ponderosa pine in the higher hills and with the savanna stands of ponderosa pine in the lower hills. Grassland communities are not important in the deep cool canyons with dense, nearly closed stands of white spruce and paper birch, in the dense secondary growth of aspen and paper birch, or in the dense deciduous forest stands of green ash, bur oak, American elm, boxelder, and hackberry along streams. Important shrubs are beaked hazelnut, Juneberry, chokecherry, willows, big sagebrush, sand sagebrush, and mountain mahogany.

The Montane Forest, Pine-Fir-Spruce Type (figure 1), exists on the Sweetgrass Hills, and the Highwood, Bearpaw, Little Rocky, Moccasin, Judith, and Big Snowy mountains in Montana and the Cypress Hills in Saskatchewan. The physiography of the region consists of the laccolithic domed mountains in the Unglaciated section and the erosional upland remnant in the Glaciated section of the Missouri Plateau Section of the Great Plains Province. The major grasses of the Pine-Fir-Spruce Type of the Montane Forest (table 15) are bluebunch wheatgrass, Idaho fescue, Nelson's needlegrass, spike fescue, prairie Junegrass, needle and thread, and spike oatgrass. The grassland communities of this vegetation type exist as open grasslands and understory grasslands associated with open stands of ponderosa pine and Douglas fir on the lower elevations of the domed mountains. Prominent forbs are arrowleaf balsamroot, lupine, sticky-leaved geranium, bluebells, and prairie smoke. Major shrubs are western snowberry, white spiraea, and bearberry. Grassland communities are not important at the higher elevations with closed forest stands of subalpine fir, Douglas fir, and Engelmann spruce. Grassland communities are associated with the open forest stands of lodgepole pine, white spruce, paper birch, and aspen on the Cypress Hills.

The Upland Woodlands, Aspen-Ash-Oak-Juniper Types (figure 1), exist as scattered areas with various types of trees, shrubs, and grasses in North Dakota, Manitoba, and Saskatchewan. The physiography of the region consists of upland positions of the Small Lakes Section of the Central Lowland Province and of upland positions of the Unglaciated section of the Missouri Plateau Section of the Great Plains Province. The major grasses of the Aspen-Ash-Oak-Juniper Types of the Upland Woodlands (table 16) are roughleaf ricegrass, little ricegrass, and long-beaked sedge. Grass plants of these vegetation types are part of the understory community. Prominent forbs are northern bedstraw, wild strawberry, violets, anise root, and black snakeroot. Major shrubs are beaked hazelnut, western snowberry, Juneberry, chokecherry, red raspberry, bittersweet, gooseberry, wild plum, and northern hawthorn. The aspen woodlands contain trembling aspen, balsam poplar, paper birch, green ash, and sometimes bur oak. The ash woodlands contain green ash, American elm, boxelder, and occasionally hackberry. The oak woodlands contain bur oak, green ash, American elm, boxelder, aspen, and occasionally ironwood. The juniper woodlands contain Rocky Mountain juniper.

The Riparian Woodlands, Cottonwood-Ash-Elm Type (figure 1), exists along the floodplains of the larger rivers and streams and as small groves along minor drainage ways located throughout the Northern Plains. The major grasses of the Cottonwood-Ash-Elm Type of the Riparian Woodlands (table 17) are Canada wildrye, slender wheatgrass, Virginia wildrye, prairie sandreed, needle and thread, green needlegrass, marsh muhly, reed canarygrass, prairie cordgrass, bottlebrush grass, and mountain ricegrass. The grassland communities of this vegetation type exist as understory grasslands associated with open woodlands and sometimes fairly dense forest stands of cottonwood, green ash, boxelder, American elm, hackberry, peach-leaved willow, and occasionally bur oak. Prominent forbs are false solomon's seal, dogbane, wild licorice, fringed loosestrife, and meadow rue. Major shrubs are western snowberry, wild roses, skunk bush, g olden currant, gooseberry, dogwood, poison ivy, bittersweet, wild grape, thicket creeper, and western clematis.

The environmental and biological factors that affect development of plant communities and vegetation types are the same factors that affect soil development. Soil moisture regimes affect distribution of plant species affiliations. The species affiliations that are the major vegetation types in the Northern Plains; Tall Grass Prairie, Transition Mixed Grass Prairie, Mixed Grass Prairie, and Short Grass Prairie; coincide with the four soil moisture regimes; Perudic, Udic, Ustic, and Aridic; respectively. The four soil moisture regimes are further separated into two soil temperature regimes; Frigid in the northern portions and Mesic in the southern portions. Soil temperature regimes affect composition and distribution of cool-season and warm-season grasses within the vegetation types. In the northern Frigid temperature regime, warm-season grass species decrease and cool-season grass species increase. In the southern Mesic temperature regime, cool-season grass species decrease and warm-season grass species increase.

Changes in elevation, slope, and aspect resulting from the various physiographic landforms in the Northern Plains affect plant species topographic distribution and plant community productivity by causing differential distribution and retention of soil water. Lower slopes have greater soil water than upper slopes. East and north facing slopes retain more soil water longer than south and west facing slopes. Lowland landscape slopes have soil water in amounts greater than precipitation levels because of water runin from upper slopes. Upland landscape slopes have soil water in amounts similar to precipitation levels because water runin and water runoff occur in low quantities and are about the same. Xeric landscape slopes have soil water in amounts less than precipitation levels because of restricted water infiltration, low water holding capacity, high evapotranspiration demand, and/or high water runoff.

Some slope positions have sufficiently low evapotranspiration demand and/or receive sufficient quantities of water runin for woodland and forest plant communities to develop. Woodlands and forests also develop along rivers and streams and at higher elevation positions that receive greater quantities of precipitation.

Enhancement of the Land Natural Resources

Generating greater new wealth with livestock agriculture requires enhancement of the land natural resources. These essential changes are doable and not the herculean task that they first appear to be. A few small catalyzing changes correctly timed can have remarkable effects.

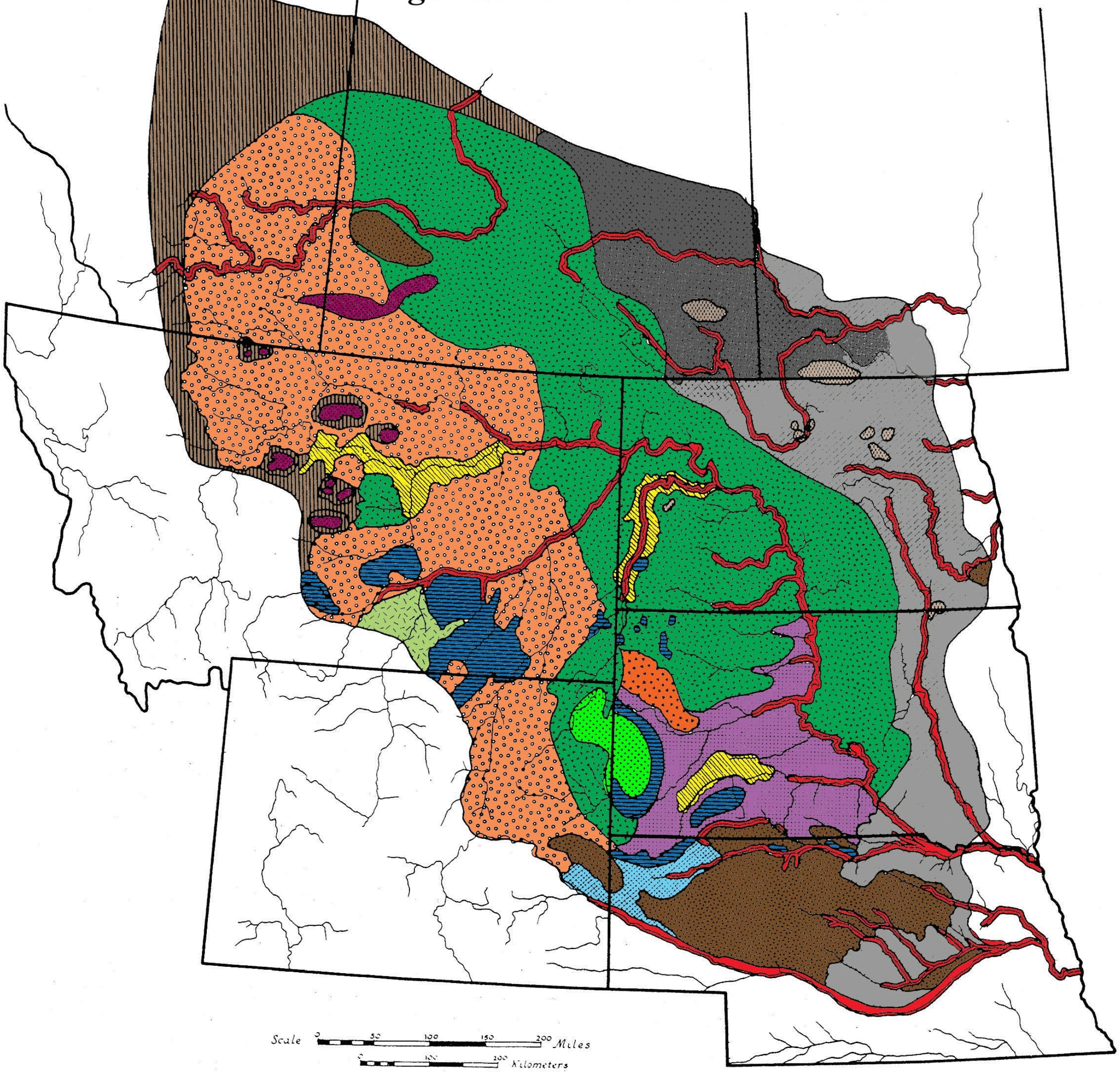
The forces that change hills into valleys, rocks into clay, and forests into grasslands work slowly over thousands and millions of years. The physiographic landform characteristics have changed little during the past 10,000 years. The current climate with wet and dry periods, and the current soil moisture and soil temperature regimes have been operational for about 5,000 years. The native plant species completed development of their physiological processes and defoliation resistance mechanisms in conjunction with early herbivore evolution millions of years ago.

By contrast, the soils, plant communities, and vegetation types in the Northern Plains are relatively young and their development is still ongoing. These developmental processes can be manipulated through implementation of biologically effective management that benefits all living and nonliving ecosystem components by meeting the biological requirements of the plants and soil organisms which causes improvements in the biogeochemical processes, ecosystem health, soil quality, plant community composition, and vegetation type affiliations. These important improvements enhance the quality and productivity of the land natural resources and result in generation of greater new wealth.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables.

Vegetation of the Northern Plains



map from Barker and Whitman 1989

- Wheatgrass-Bluestem-Needlegrass
- Wheatgrass-Needlegrass
- Wheatgrass-Grama-Needlegrass
- Wheatgrass-Bluestem-Needlegrass (Rough-Fescue Mixed)
- Wheatgrass-Grama grass
- Wheatgrass
- Sandhills Prairie
- Grama-Buffalograss
- Foothills Prairie (Rough Fescue)
- Pacific Bunchgrass
- Badlands and River Breaks
- Pine Savanna
- Black Hills Pine Forest
- Montane Forest
- Upland Woodlands
- Riparian Woodlands

Table 1. Major Grasses of the Tall Grass Prairie; Bluestem-Switchgrass-Indiangrass Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Big bluestem	Andropogon gerardii	Andropogon gerardii
Porcupinegrass	Stipa spartea	Hesperostipa spartea
Switchgrass	Panicum virgatum	Panicum virgatum
Prairie dropseed	Sporobolus heterolepis	Sporobolus heterolepis
Indiangrass	Sorghastrum nutans	Sorghastrum nutans
Northern reedgrass	Calamagrostis stricta	Calamagrostis stricta inexpansa
Prairie cordgrass	Spartina pectinata	Spartina pectinata
Sideoats grama	Bouteloua curtipendula	Bouteloua curtipendula
Slender wheatgrass	Agropyron caninum majus majus	Elymus trachycaulus trachycaulus
Bearded wheatgrass	Agropyron caninum majus unilaterale	Elymus trachycaulus subsecundus
Kentucky bluegrass	Poa pratensis	Poa pratensis
Needle and thread	Stipa comata	Hesperostipa comata
Little bluestem	Andropogon scoparius	Schizachyrium scoparium scoparium
Mat muhly	Muhlenbergia richardsonis	Muhlenbergia richardsonis
Needleleaf sedge	Carex eleocharis	Carex duriuscula
Sun sedge	Carex heliophila	Carex inops heliophila
Woolly sedge	Carex lanuginosa	Carex pellita

Table 2. Major Grasses of the Transition Mixed Grass Prairie; Wheatgrass-Bluestem-Needlegrass Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus
Little bluestem	Andropogon scoparius	Schizachyrium scoparium scoparium
Porcupinegrass	Stipa spartea	Hesperostipa spartea
Needle and thread	Stipa comata	Hesperostipa comata
Green needlegrass	Stipa viridula	Nassella viridula
Bearded wheatgrass	Agropyron caninum majus unilaterale	Elymus trachycaulus subsecundus
Slender wheatgrass	Agropyron caninum majus majus	Elymus trachycaulus trachycaulus
Sideoats grama	Bouteloua curtipendula	Bouteloua curtipendula
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Prairie Junegrass	Koeleria pyramidata	Koeleria macrantha
Prairie sandreed	Calamovilfa longifolia	Calamovilfa longifolia
Big bluestem	Andropogon gerardii	Andropogon gerardii
Kentucky bluegrass	Poa pratensis	Poa pratensis
Needleleaf sedge	Carex eleocharis	Carex duriuscula
Threadleaf sedge	Carex filifolia	Carex filifolia
Sun sedge	Carex heliophila	Carex inops heliophila

Table 3. Major Grasses of the Mixed Grass Prairie; Wheatgrass-Needlegrass Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Needle and thread	Stipa comata	Hesperostipa comata
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Prairie Junegrass	Koeleria pyramidata	Koeleria macrantha
Green needlegrass	Stipa viridula	Nassella viridula
Plains reedgrass	Calamagrostis montanensis	Calamagrostis montanensis
Little bluestem	Andropogon scoparius	Schizachyrium scoparium scoparium
Prairie sandreed	Calamovilfa longifolia	Calamovilfa longifolia
Sandberg bluegrass	Poa sandbergii	Poa secunda
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus
Slender wheatgrass	Agropyron caninum majus majus	Elymus trachycaulus trachycaulus
Small needlegrass	Stipa curtiseta	Hesperostipa curtiseta
Bluebunch wheatgrass	Agropyron spicatum	Pseudoroegneria spicata
Buffalograss	Buchloe dactyloides	Buchloe dactyloides
Kentucky bluegrass	Poa pratensis	Poa pratensis
Threadleaf sedge	Carex filifolia	Carex filifolia
Sun sedge	Carex heliophila	Carex inops heliophila

Table 4. Major Grasses of the Mixed Grass Prairie on Clay Soils; Wheatgrass-Grama Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Buffalograss	Buchloe dactyloides	Buchloe dactyloides
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus
Green needlegrass	Stipa viridula	Nassella viridula

Table 5. Major Grasses of the Mixed Grass Prairie on Dense Clay Soils; Wheatgrass Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Green needlegrass	Stipa viridula	Nassella viridula
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus
Associated Grass		
Needle and thread	Stipa comata	Hesperostipa comata

Table 6. Major Grasses of the Northern Short Grass Prairie; Grama-Needlegrass-Wheatgrass Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Needle and thread	Stipa comata	Hesperostipa comata
Small needlegrass	Stipa curtiseta	Hesperostipa curtiseta
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus
Green needlegrass	Stipa viridula	Nassella viridula
Buffalograss	Buchloe dactyloides	Buchloe dactyloides
Associated Grasses		
Red threeawn	Aristida purpurea robusta	Aristida purpurea longiseta
Indian ricegrass	Oryzopsis hymenoides	Achnatherum hymenoides
Plains muhly	Muhlenbergia cuspidata	Muhlenbergia cuspidata
Bluebunch wheatgrass	Agropyron spicatum	Pseudoroegneria spicata
Threadleaf sedge	Carex filifolia	Carex filifolia
Deteriorated Grassland		
Cheatgrass	Bromus tectorum	Bromus tectorum
Japanese brome	Bromus japonicus	Bromus japonicus

Table 7. Major Grasses of the Northern Short Grass Prairie on Salty Soils; Saltgrass Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Saltgrass	Distichlis spicata stricta	Distichlis spicata
Alkali cordgrass	Spartina gracilis	Spartina gracilis
Basin wildrye	Elymus cinereus	Leymus cinereus
Foxtail barley	Hordeum jubatum	Hordeum jubatum jubatum
Little barley	Hordeum pusillum	Hordeum pusillum
Nuttall's alkali grass	Puccinellia nuttalliana	Puccinellia nuttalliana
Common squirreltail	Sitanion hystrix	Elymus elymoides elymoides
Tumblegrass	Schedonnardus paniculatus	Schedonnardus paniculatus

Table 8. Major Grasses of the Southern Short Grass Prairie; Blue grama-Buffalograss Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Buffalograss	Buchloe dactyloides	Buchloe dactyloides
Associated Grasses		
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Needle and thread	Stipa comata	Hesperostipa comata

Table 9. Major Grasses of the Sandhills Prairie; Bluestem-Sandreed-Grama-Needlegrass Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Big bluestem	Andropogon gerardii	Andropogon gerardii
Little bluestem	Andropogon scoparius	Schizachyrium scoparium scoparium
Sand bluestem	Andropogon hallii	Andropogon hallii
Prairie sandreed	Calamovilfa longifolia	Calamovilfa longifolia
Sideoats grama	Bouteloua curtipendula	Bouteloua curtipendula
Needle and thread	Stipa comata	Hesperostipa comata
Switchgrass	Panicum virgatum	Panicum virgatum
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Blowout Areas		
Blowout grass	Redfieldia flexuosa	Redfieldia flexuosa
Sandhill muhly	Muhlenbergia pungens	Muhlenbergia pungens
Sand dropseed	Sporobolus cryptandrus	Sporobolus cryptandrus
Indian ricegrass	Oryzopsis hymenoides	Achnatherum hymenoides
Schweinitz cyperus	Cyperus schweinitzii	Cyperus schweinitzii

Table 10. Major Grasses of the Foothills Prairie; Plains Rough Fescue Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Plains rough fescue	Festuca scabrella	Festuca hallii
Parry's oatgrass	Danthonia parryi	Danthonia parryi
Timber oatgrass	Danthonia intermedia	Danthonia intermedia
Bluebunch wheatgrass	Agropyron spicatum	Pseudoroegneria spicata
Slender wheatgrass	Agropyron caninum majus majus	Elymus trachycaulus trachycaulus
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus
Nelson's needlegrass	Stipa columbiana	Achnatherum nelsonii nelsonii
Richardson's needlegrass	Stipa richardsonii	Achnatherum richardsonii
Needle and thread	Stipa comata	Hesperostipa comata
Prairie Junegrass	Koeleria pyramidata	Koeleria macrantha
Idaho fescue	Festuca idahoensis	Festuca idahoensis
Spike oatgrass	Helictotrichon hookeri	Avenula hookeri
Kentucky bluegrass	Poa pratensis	Poa pratensis
Threadleaf sedge	Carex filifolia	Carex filifolia
Deteriorated Grassland		
Cheatgrass	Bromus tectorum	Bromus tectorum
Japanese brome	Bromus japonicus	Bromus japonicus

Table 11. Major Grasses of the Pacific Bunchgrass Prairie; Bluebunch-Fescue Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Bluebunch wheatgrass	Agropyron spicatum	Pseudoroegneria spicata
Idaho fescue	Festuca idahoensis	Festuca idahoensis
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Sideoats grama	Bouteloua curtipendula	Bouteloua curtipendula
Little bluestem	Andropogon scoparius	Schizachyrium scoparium scoparium
Red threeawn	Aristida purpurea robusta	Aristida purpurea longiseta
Needle and thread	Stipa comata	Hesperostipa comata
Plains muhly	Muhlenbergia cuspidata	Muhlenbergia cuspidata
Prairie Junegrass	Koeleria pyramidata	Koeleria macrantha
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus

Table 12. Major Grasses of the Badlands and River Breaks; Woody Draw and Savanna Types.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Needle and thread	Stipa comata	Hesperostipa comata
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Green needlegrass	Stipa viridula	Nassella viridula
Prairie Junegrass	Koeleria pyramidata	Koeleria macrantha
Plains reedgrass	Calamagrostis montanensis	Calamagrostis montanensis
Kentucky bluegrass	Poa pratensis	Poa pratensis
Sandberg bluegrass	Poa sandbergii	Poa secunda
Buffalograss	Buchloe dactyloides	Buchloe dactyloides
Small needlegrass	Stipa curtiseta	Hesperostipa curtiseta
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus
Little bluestem	Andropogon scoparius	Schizachyrium scoparium scoparium
Bluebunch wheatgrass	Agropyron spicatum	Pseudoroegneria spicata
Saltgrass	Distichlis spicata stricta	Distichlis spicata

Table 13. Major Grasses of the Pine Savanna; Pine-Juniper-Bluebunch Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Bluebunch wheatgrass	Agropyron spicatum	Pseudoroegneria spicata
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus
Needle and thread	Stipa comata	Hesperostipa comata
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Green needlegrass	Stipa viridula	Nassella viridula
Little bluestem	Andropogon scoparius	Schizachyrium scoparium scoparium

Table 14. Major Grasses of the Black Hills Pine Forest; Pine-Spruce-Aspen Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Bluebunch wheatgrass	Agropyron spicatum	Pseudoroegneria spicata
Needle and thread	Stipa comata	Hesperostipa comata
Green needlegrass	Stipa viridula	Nassella viridula
Prairie Junegrass	Koeleria pyramidata	Koeleria macrantha
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Hairy grama	Bouteloua hirsuta	Bouteloua hirsuta
Buffalograss	Buchloe dactyloides	Buchloe dactyloides
Needleleaf sedge	Carex eleocharis	Carex duriuscula
Threadleaf sedge	Carex filifolia	Carex filifolia

Table 15. Major Grasses of the Montane Forest; Pine-Fir-Spruce Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Bluebunch wheatgrass	Agropyron spicatum	Pseudoroegneria spicata
Idaho fescue	Festuca idahoensis	Festuca idahoensis
Nelson’s needlegrass	Stipa columbiana	Achnatherum nelsonii nelsonii
Spike fescue	Hesperochloa kingii	Leucopoa kingii
Prairie Junegrass	Koeleria pyramidata	Koeleria macrantha
Needle and thread	Stipa comata	Hesperostipa comata
Spike oatgrass	Helictotrichon hookeri	Avenula hookeri
Sandberg bluegrass	Poa sandbergii	Poa secunda

Table 16. Major Grasses of the Upland Woodlands; Aspen-Ash-Oak-Juniper Types.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Roughleaf ricegrass	Oryzopsis asperifolia	Oryzopsis asperifolia
Little ricegrass	Oryzopsis micrantha	Piptatherum micranthum
Long-beaked sedge	Carex sprengelii	Carex sprengelii
Kentucky bluegrass	Poa pratensis	Poa pratensis
Associated Grasses		
Western wheatgrass	Agropyron smithii	Pascopyrum smithii
Bluebunch wheatgrass	Agropyron spicatum	Pseudoroegneria spicata
Thickspike wheatgrass	Agropyron dasystachyum	Elymus lanceolatus
Blue grama	Bouteloua gracilis	Bouteloua gracilis
Porcupinegrass	Stipa spartea	Hesperostipa spartea
Little bluestem	Andropogon scoparius	Schizachyrium scoparium scoparium

Table 17. Major Grasses of the Riparian Woodlands; Cottonwood-Ash-Elm Type.		
Standardized Common Name	Flora of the Great Plains 1986	Flora of North America 2003, 2007
Canada wildrye	Elymus canadensis	Elymus canadensis
Slender wheatgrass	Agropyron caninum majus majus	Elymus trachycaulus trachycaulus
Virginia wildrye	Elymus virginicus	Elymus virginicus
Prairie sandreed	Calamovilfa longifolia	Calamovilfa longifolia
Needle and thread	Stipa comata	Hesperostipa comata
Green needlegrass	Stipa viridula	Nassella viridula
Marsh muhly	Muhlenbergia racemosa	Muhlenbergia racemosa
Reed canarygrass	Phalaris arundinacea	Phalaris arundinacea
Prairie cordgrass	Spartina pectinata	Spartina pectinata
Bottlebrush grass	Hystrix patula	Elymus hystrix
Mountain ricegrass	Oryzopsis racemosa	Piptatherum racemosum
Kentucky bluegrass	Poa pratensis	Poa pratensis
Yellow sedge	Carex pensylvanica	Carex pensylvanica
Long-beaked sedge	Carex sprengelii	Carex sprengelii

Literature Cited

Barker, W.T., and W.C. Whitman. 1989. Vegetation of the Northern Great Plains. North Dakota State University Experiment Station Research Report #111. Fargo, ND. 26p.

Baumberger, R. 1977. South Dakota rangeland resources. Old West Regional Commission. Society for Range Management, Denver, CO. 150p.

Bluemle, J.P. 2000. The face of North Dakota. Third Edition. North Dakota Geological Survey. Educational Series 26. 205p.

Bose, D.R. 1977. Rangeland resources of Nebraska. Old West Regional Commission. Society for Range Management, Denver, CO. 121p.

Brady, N.C. 1974. The nature and properties of soils. MacMillan Publishing Co., Inc., New York, NY. 639p.

Clarke, S.E., J.A. Campbell, and J.B. Campbell. 1942. An ecological and grazing capacity study of the native grass pastures in southern Alberta, Saskatchewan, and Manitoba. Division of Forage Crops Dom. Experiment Station. Technical Bulletin 44. Swift Current, SK. 31p.

Coupland, R.T., and T.C. Brayshaw. 1953. The fescue grassland in Saskatchewan. Ecology 34:386-405.

Coupland, R.T. 1950. Ecology of mixed prairie in Canada. Ecological Monographs 20:271-315.

Coupland, R.T. 1961. A reconsideration of grassland classification in the Northern Great Plains of North America. Journal of Ecology 49:135-167.

Fenneman, N.M. 1931. Physiography of western United States. McGraw-Hill Book Company, New York, NY. 534p.

Fenneman, N.M. 1946. Physical divisions of the United States. USDI Geological Survey. Map.

Flora of North America Editorial Committee, eds. 2003, 2007. Flora of North America. Oxford University Press, New York, NY. Vols. 24-25.

Froiland, S.G., and R.R. Weedon. 1990. Natural history of the Black Hills and badlands. The Center for Western Studies, Sioux Falls, SD. 225p.

Goodin, J.R., and D.K. Northington (eds.). 1985. Plant resources of arid and semiarid lands. Academic Press, Inc., Orlando, FL. 338p.

Great Plains Flora Association. 1986. Flora of the Great Plains. University Press of Kansas, Lawrence, KS. 1392p.

Hacker, P.T., and T.P. Sparks. 1977. Montana rangeland resources. Old West Regional Commission. Society for Range Management, Denver, CO.

Hunt, C.B. 1974. Natural regions of the United States and Canada. W.H. Freeman and Company, San Francisco, CA. 725p.

Kaul, R.B. 1975. Vegetation of Nebraska (Circa 1850). Conservation and Survey Division, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, NE. Map.

Kuchler, A.W. 1964. Potential natural vegetation of the conterminous United States. American Geographical Society. Special Publication No. 36. New York, NY. 116p. + Maps.

Moss, E.H., and J.A. Campbell. 1947. The fescue grassland of Alberta. Canadian Journal of Research. 25:209-227.

Ojakangas, R.W., and C.L. Matsch. 1982. Minnesota's Geology. University of Minnesota Press, Minneapolis, MN. 255p.

Raisz, E. 1957. Landforms of the United States. Copyrighted Erwin Raisz Map.

Robinson, C.S., and R.E. Davis. 1995. Geology of Devils Tower National Monument. Devils Tower Natural History Association, WY. 96p.

Ross, R.L., and H.E. Hunter. 1976. Climax vegetation of Montana based on climate and soils. USDA, Soil Conservation Service. Bozeman, MT. 64p.

Shaver, J.C. 1977. North Dakota rangeland resources. Old West Regional Commission. Society for Range Management, Denver, CO. 118p.

Shrader, J.A. 1977. Wyoming rangeland resources. Old West Regional Commission. Society for Range Management, Denver, CO. 87p.

Soil Survey Staff. 1975. Soil taxonomy. USDA Agriculture Handbook No. 436. Washington, DC. 754p.

Whitman, W.C., and W.T. Barker. 1989. Mapping North Dakota's natural vegetation. Proceedings of the North Dakota Academy of Science. 43:4-5.

Seasonal Weather Patterns of the Northern Plains

Report DREC 03-3024

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Precipitation Pattern

The current climate of the Northern Plains has existed for the past 5,000 years (Bluemle 1977, Bluemle 1991, Manske 1994, Bluemle 2000). The seasonal distribution of precipitation (figure) is classified as the Plains Precipitation Pattern (Humphrey 1962), in which most of the precipitation occurs during the growing season (85%) and the smallest amount occurs in winter (10%). Total precipitation for the 5-month nongrowing season of November through March averages less than 2.5 inches (63.5 mm) (15%) of precipitation. The greatest amount of precipitation occurs in spring and early summer (60%). The precipitation received in the 3-month period of May, June, and July accounts for over 50% of the annual precipitation, and June has the greatest monthly precipitation (22%).

Weather Air Mass Pattern

The weather of the Northern Plains is controlled by three major air masses that dominate at different times of the year (Redmann 1968). The Pacific air mass dominates the region from September through January, a period that is generally dry because the orographic effect of the Rocky Mountains causes a rain shadow as the air mass moves east. The mean monthly precipitation during this dry period is less than 1.0 inch (25.4 mm). The Polar air mass dominates the region from February through May, a period with mean monthly precipitation between 1.0 and 2.0 inches (25.4 mm and 50.8 mm). Throughout June, combinations of Gulf, Polar, and Pacific air masses mix and produce a relatively rainy period with a monthly precipitation average around 3.5 inches (88.9 mm). The summer months of July and August are dominated by the Gulf air mass, with little mixing of other air masses and a reduction of monthly precipitation to about 2.0 inches (50.8 mm), which comes generally in intermittent thunderstorms. The change from the dominance of one air mass to the next results in transition periods, which can vary annually. Differences in the transition periods contribute to the variation in conditions from year to year.

Literature Cited

Bluemle, J.P. 1977. The face of North Dakota: the geologic story. North Dakota Geological Survey. Ed. Series 11. 73p.

Bluemle, J.P. 1991. The face of North Dakota. Revised edition. North Dakota Geological Survey. Ed. Series 21. 177p.

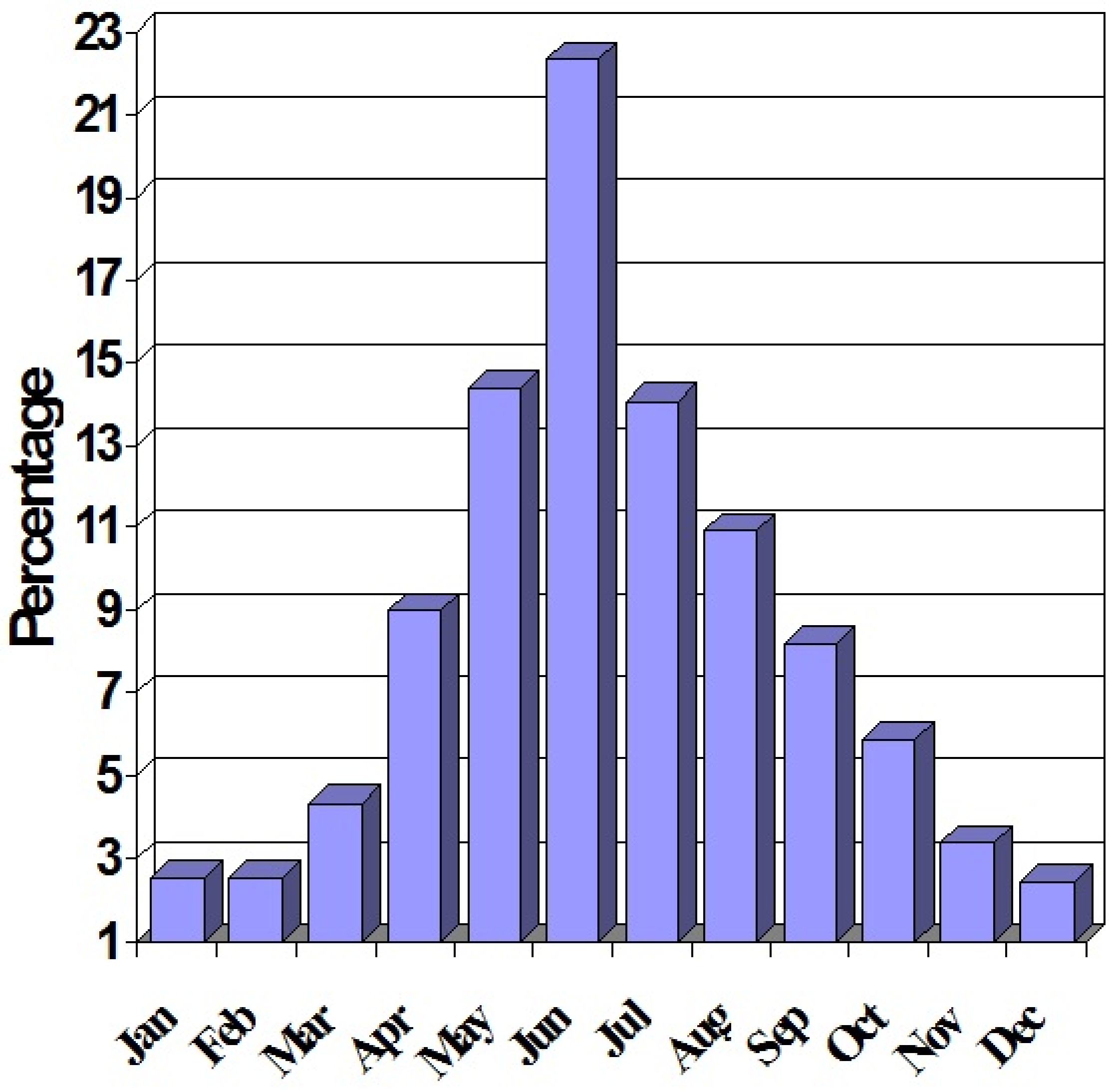
Bluemle, J.P. 2000. The face of North Dakota. 3rd edition. North Dakota Geological Survey. Ed. Series 26. 206p. 1pl.

Humphrey, R.R. 1962. Range ecology. The Ronald Press Company. New York, NY. 234p.

Manske, L.L. 1994. History and land use practices in the Little Missouri Badlands and western North Dakota. Proceedings-Leafy spurge strategic planning workshop. USDI National Park Service. Dickinson, ND. p. 3-16.

Redmann, R.E. 1968. Productivity and distribution of grassland plant communities in western North Dakota. Ph.D. Thesis, University of Illinois. IL. 153p.

Seasonal Precipitation Distribution of the Plains Precipitation Pattern



Soil Formation in the Unglaciated Northern Plains

Llewellyn L. Manske PhD
Report DREC 03-3023
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Soil is the medium in which grassland plants grow. Major variations in soil properties result from differences in the type of parent material and in the soil developmental processes. Plant community dynamics and plant growth potentials are affected by the changing characteristics occurring during the continuous progression of soil formation, and soil, climate, and plants have complex cause-effect relationships regulating soil formation. Management practices affect these relationships and can enhance or impair soil developmental processes.

Parent Material from Sedimentary Deposits

The unglaciated region of the Northern Plains is part of a large geologic depression, which has been filled over a period of 515 million years with accumulations of sedimentary rocks deposited in off-shore shallow seas and in near-shore marine environments or by running water on floodplains or deltas. For about the last 5 million years, running water and wind have been eroding the generally flat-lying sedimentary deposits in the unglaciated region. These erosional forces have been selective in their action because hard, relatively resistant sandstone, limestone, scoria, chert, or other erosion-resistant materials were present in some of the sedimentary deposits and have remained as protective caps, while the soft, weakly consolidated, less resistant silt and clay layers have been easily washed or blown away. The landforms that have resulted from uneven sediment removal are gently rolling to hilly plains intermingled with buttes, which have flat tops and steep slopes. Over the last 600,000 years, badlands topography has developed near some streams and rivers from erosional forces that accelerated sediment removal when glacial ice blocked the northward flow of the drainage systems. The diverted routes to the east were shorter and steeper, and the water flowing in the drainage systems caused deep, rapid erosion that resulted in badlands landforms (Hunt 1974, Bluemle 1977, Trimble 1990, Bluemle 1991, Bluemle 2000).

Soil Development from Sedimentary Deposits

Soils in the unglaciated region have been developing from weathered sedimentary deposits of soft shale, siltstone, and sandstone. Soil formation is a long, slow, continuous process. Temperatures and precipitation levels of the area have been important in the development of the regional soils. The climate has determined the type of vegetation and the amount of annual growth, which, in turn, have influenced the amount of soil organic matter accumulated.

Temperature affects the rate of oxidation of organic matter. Higher temperatures promote rapid oxidation of organic matter, and soils in regions with long periods of high temperatures contain little organic matter. Little or no oxidation of organic matter occurs in frozen soil. Organic matter has accumulated in the soils in the Northern Plains because the climate has cold periods during which little chemical activity takes place. In most years, soils in the unglaciated region have frost penetration to a depth of 3 to 5 feet for a period of approximately 120 days (Larson et al. 1968), a condition that contributes to soil organic matter accumulation. The dark surface layer of most soils in the region has an accumulation of 2 to 5% organic matter (Larson et al. 1968, Wright et al. 1982).

Temperature and precipitation have influenced the amount and kinds of physical and chemical weathering of the region's parent material. High temperatures and high precipitation have encouraged rapid weathering and clay formation during the summer, while low temperatures during fall, winter, and early spring have caused cracks, fissures, and breaks in the parent material and developing soil as a result of the expansion and contraction forces of frost.

Precipitation level has influenced the amount of water in the soil. The amount of water that has entered the soil has not been the same as the precipitation level, and the amount of soil water has not been the same on all parts of the landscape. The amount of soil water has been less than the amount of precipitation received in areas that have had rain run off, and the amount of soil water has been greater than the amount of precipitation received in areas that have had rain run in. The amount of soil water present has affected the rate of leaching. The depth of the downward movement of the water has not been uniform for the soils on different topographic positions on the landscape.

Soil water has dissolved calcium carbonate (lime), soluble salts, exchangeable sodium, and clay particles from the upper horizons of the soil and moved them downward into a lower horizon. The amount of these dissolved materials in the soil profile has been dependent on the amount present in the weathered parent material. The depth to which they have been moved has varied with the amount of soil water. The layer where the dissolved material has accumulated indicates the approximate average depth of downward water movement. The depth of the accumulation layer decreases when the precipitation decreases. Soils with a high lime content have developed a layer of natural cement (hardpan) that restricts plant root penetration. Soils high in soluble salts and/or exchangeable sodium have developed accumulation layers containing sufficient amounts of these chemicals to impair plant growth. Soils high in soluble salts have developed into saline soils; soils high in exchangeable sodium have developed into sodic soils; and soils high in both have developed into saline-sodic soils (Omodt et al. 1968, Soil Survey Staff 1975, Foth 1978).

Soil water has also dissolved clay particles and moved the clay downward. When the soil water with dissolved clay has hit areas of dry soil, the water has been withdrawn and the clay particles have been deposited. Over time this clay film layer has built up to form what is called an argillac horizon. Low amounts of argillac horizon in a soil can be beneficial because the clay helps increase the amount of water and nutrients stored in that zone; however, when the clay accumulation becomes great, the effects can be detrimental because water movement and plant root penetration are severely restricted. Soils that have a well-developed argillac horizon are called clay-pan soils (Omodt et al. 1968, Soil Survey Staff 1975, Foth 1978).

The depth of the layer where the dissolved material accumulates is very important because it determines the thickness of the plant growth medium; the soil above the layer of accumulation holds the nutrients and soil water needed to sustain plant life. Shallow soils restrict plant growth. The depth of the accumulation layer decreases westward with the reduction in precipitation and ranges from 6 inches to 4 feet. Most soils in western North Dakota have formed the accumulation layer between 15 and 24 inches below the soil surface (Larson et al. 1968, Omodt et al. 1968, Soil Survey Staff 1975, Foth 1978, Wright et al. 1982).

Literature Cited

Bluemle, J.P. 1977. The face of North Dakota: the geologic story. North Dakota Geological Survey. Ed. Series 11. 73p.

Bluemle, J.P. 1991. The face of North Dakota. Revised edition. North Dakota Geological Survey. Ed. Series 21. 177p.

Bluemle, J.P. 2000. The face of North Dakota. 3rd edition. North Dakota Geological Survey. Ed. Series 26. 206p. 1pl.

Foth, H.D. 1978. Fundamentals of soil science. John Wiley and Sons. New York, NY. 436p.

Hunt, C.B. 1974. Natural regions of the United States and Canada. W.H. Freeman and Company. San Francisco, CA. 725p.

Larson, K.E., A.F. Bahr, W. Freymiller, R. Kukowski, D. Opdahl, H. Stoner, P.K. Weiser, D. Patterson, and O. Olsen. 1968. Soil survey of Stark County, North Dakota. U.S. Government Printing Office. Washington, DC. 116p.+plates.

Omodt, H.W., G.A. Johnsgard, D.D. Patterson, and O.P. Olson. 1968. The major soils of North Dakota. Department of Soils. Bulletin No. 472. North Dakota State University. Fargo, ND. 60p.+map.

Soil Survey Staff. 1975. Soil Taxonomy. Agriculture Handbook No. 436. USDA Soil Conservation Service. U.S. Government Printing Office. Washington, DC. 754p.

Trimble, D.E. 1990. The geologic story of the Great Plains. Theodore Roosevelt Nature and History Association. Medora, ND. 54p.

Wright, M.R., J. Schaar, and S.J. Tillotson. 1982. Soil survey of Dunn County, North Dakota. U.S. Government Printing Office. Washington, DC. 235p.+plates.

Prehistorical Conditions of Rangelands in the Northern Plains

Llewellyn L. Manske PhD
Report DREC 08-3015b Ran ge Scientist
North Dakota State University
Dickinson Research Extension Center

An accurate representation of the Northern Plains rangelands does not match the static romantic image of a vast, ageless, pristine grassland in excellent health, with large herds of free-roaming bison accompanied by elk, antelope, wolves, and grizzly bears in idealistic harmony. The present grassland assemblage of communities and ecosystems in the Northern Plains started to develop only about 5,000 years ago, and the plants that migrated into the region respond to environmental changes dynamically, with shifts in species composition and biological status. Populations of plants and animals in grassland ecosystems experience peaks and crashes in cycles of variable highs, lows, and duration, in response to the complex set of interrelated forces in the environment. Grassland ecosystems have never been static nor can they be managed to remain at an idealistic static goal. Most idealistic static management goals for grasslands are based on a perceived image of "presettlement conditions" that evokes strong nostalgia but does not provide a complete set of guidelines on which to base sound grassland management. To formulate an accurate representation of the integral parts of the Northern Plains grasslands and to develop an understanding of these interrelated processes we must look further back in time at the environmental forces and the processes within the plants and the ecosystems.

Climate

The climate of the Northern Plains has changed several times during geologic history. A major climate change resulted when the Rocky Mountains began to uplift about 70 to 80 million years ago, forming a barrier that prevented humid Pacific Ocean air masses from flowing eastward. The Plains became much drier. Two million years ago the climate became cooler and more humid, with several periods of glaciation. Glacial advances occurred during periods when the winter snow accumulation on top of the glacier was greater than the amount of ice melted during the summer. The periods of glacial advance were cool and humid, the interglacial periods warmer and drier.

The changes in climate since the last glaciation period, which occurred between 100,000 and 10,000 years ago, have strongly influenced the present conditions of the region. The last ice sheet reached its maximum advance between 14,000 and 12,000 years ago. About 10,000 years ago, a sudden change in the climate to drier and warmer summers but colder winters occurred. This major change accelerated the melting of the glacial ice. A spruce-aspen forest developed in the cool, moist conditions at the ice margin; this community graded into a deciduous forest, which graded into a grassland south of the Northern Plains. The climate was much drier and warmer for the period between 10,000 and 5,000 years ago. During the period between 8,500 and 4,500 years ago, the vegetation was a sage and short grass plant community similar to vegetation in parts of Wyoming, and the region experienced frequent summer droughts and extensive soil erosion from wind (Bluemle 1977, Bluemle 1991).

The climate changed about 5,000 years ago to conditions like those of the present, with cycles of wet and dry periods (Bluemle 1977, Bluemle 1991, Manske 1994). The wet periods have been cool and humid, with greater amounts of precipitation. A brief wet period occurred around 4,500 years ago. Relatively long periods of wet conditions occurred between 2,500 and 1,800 years ago and between 1,000 and 700 years ago. Recent short wet periods occurred from 1905 to 1916, 1939 to 1947, and 1962 to 1978. During the wet periods, the vegetation changed, with increases in taller grasses and deciduous woodlands. The dry periods have been warmer, with reduced precipitation and recurrent summer droughts. A widespread, long drought period occurred between 1270 and 1299, and more recent drought periods occurred in the 1860's and from 1895 to 1902, 1933 to 1938, and 1987 to 1992 (Manske 1994). During the dry periods, the vegetation changed, with decreases in woodlands and increases in grasslands, and the plant composition shifted from taller grass species to shorter grass species. This climatic pattern with cyclical changes in amounts of precipitation oscillating between wet and dry periods has caused noticeable changes in the plant species composition as it shifted from deciduous woodland species to tall grass, mixed grass, short grass, and desert shrub plant communities, then reversed the cycling process, returning to increases in taller grasses and woodland plants.

Vegetation

The plant species in this region originated in other areas and migrated into the Northern Plains by different mechanisms and at different times and rates. The present vegetation has plant species with affinities to the tall grass, mixed grass, and short grass prairies, deciduous and coniferous forests, and Rocky Mountain and desert shrub plant communities (Zaczkowski 1972). This wide mix of plant species in the Northern Plains formed from remnants of plant communities that reached periods of greater development during the periods of wet and dry cycles when conditions favored these various plant community types. The diversity of plant species in our native plant community permits it to respond dynamically to changes in climatic conditions by increasing the plant species favored by any set of conditions.

The grass plants that migrated into the Northern Plains had previously developed biological mechanisms to exist and thrive with defoliation by grazing herbivores. This evolutionary process started millions of years ago. The earliest grass fossils appeared in the late Tertiary Period during the time when the earth's climate was becoming cooler and drier as a result of the build up of an ice cap at the south pole on Antarctica. The earth's lush tropical and subtropical forests diminished and moved southward, and grasslands expanded and moved northward. Grass species evolved quickly during the lower Miocene Epoch, 20 million years ago, developing characteristics that are similar to those of present grasses and that identify these plants to modern genera.

Grass plants and grazing mammals evolved together (Manske 1994). During the period of coevolution with herbivores, grasses developed defoliation resistance mechanisms like hormonal growth regulation and symbiotic soil organism relationships as compensatory processes to grazing. Close cropping of plants by herbivores exerted selective pressure that improved the survival of grasses over that of other plants and promoted grassland expansion.

Herbivores

Grazing mammals appeared in the fossil record at about the same time as grass plants. The early grazing mammals had cecal fermentation digestive systems (small horses, rhinoceroses, tapirs, brontotheres, and chalicotheres) and primitive ruminant digestive systems (camels and oreodonts). Herbivore characteristics changed and improved in response to changing characteristics in grasses. Grass plants developed a complex chemical composition and deposited silicates in their tissue, rendering it tough and nearly indigestible. Herbivores developed deep, hard teeth with enamel ridges on the crowns and digestive systems with improved effectiveness. Increased predatory pressure on open grasslands led to herbivores' development of longer legs with horny hooves, and increases in overall body size. The latest and most successful group of herbivores to evolve during this coevolutionary process was the bovine (deer, sheep, cattle, and antelope), which have advanced true ruminant digestive systems, long legs, and hard, moon-shaped cusps on their teeth. Bison are an advanced bovine with a true ruminant digestive system, fast legs, and hard teeth. Early bison migrated to North America from Asia about a million years ago. The early populations remained small in response to competition. Bison have changed form several times, with a gradual decrease in body and horn size.

Several large mammals became extinct in North America between 10,000 and 8,000 years ago, after the sudden climatic change that set off ecological changes in the vegetation communities. Most paleontologists believe that these large mammals could have adjusted to the climate change had extra pressure from human hunters not altered the birth-death ratios and had increased competition for forage resources not disadvantaged territorial animals and given herding animals a survival advantage. The mastodon, mammoth, camel, tapir, sloth, horse, large long-horned bison, middle-sized bison, and dire wolf became extinct during this time. Caribou, musk oxen, and the small bison survived the climate change, hunting pressure, and forage competition. The dramatic success of the bison following this period resulted in part from the extermination of previous prairie competitors. The small bison was the dominant herbivore between 5,000 and 115 years ago (Manske 1994). Domestic cattle have been the dominant herbivore on Northern Plains rangelands for over one hundred years.

Humans

The early human inhabitants of the Northern Plains were descendants of Asian immigrants who moved across the Bering Land Bridge between 19,000 and 14,000 years ago (Snow 1989, Wormington 1957). They later moved into this region at the time of the retreating ice sheet. These people lived in small family groups, traveled and traded over long distances, and do not appear to have claimed territories. They had fire for warmth and cooking, used well-made stone-tipped spears to hunt large game animals, and conducted hunting as an efficient, coordinated group activity. These people used fire intentionally as a hunting aid to change the vegetation to attract herds of game animals to a desired region (Bryan 1991, Holder 1970). During the early portion of human occupation in the Northern Plains, many types of large herbivores roamed the region and were used for food. Following a climate change about 10,000 years ago, the availability of game animals decreased for several thousand years, and the humans made a noticeable shift in their diet by increasing the use of plants. During this period, humans intentionally distributed seeds of food plants across the territory. Starting around 2,250 years ago, the inhabitants cultivated large plots of arable land for production of domesticated food plants (Manske 1994).

Conclusion

The rangelands of the Northern Plains are highly advanced, complex ecosystems that function similarly to living organisms, with response and feedback processes. Defoliation by herbivores is a process grass plants require at specific growth stages if healthy productive rangelands are to be maintained. Attempting to develop modern grazing management practices that emulate a perceived model of bison movement is naive. Grass plants developed their biological processes of defoliation resistance mechanisms 20 million years ago in areas outside the Northern Plains and in conjunction with early herbivores that are now extinct. Grass plants migrated from numerous types of environments into the Northern Plains and initiated development of dynamic plant communities only about 5,000 years ago, when the present climatic pattern started. The modern small bison did not coevolve with the grass species of the Northern Plains but migrated from Asia to North America about a million years ago. The large herds did not develop before 5,000 years ago. The bison has played a role in plant community dynamics and plant species composition, but it was not a part of the fauna when the grasses developed their biological mechanisms in resistance to defoliation. The 5000-year tenure of the bison on Northern Plains grasslands has the same relationship to the 20-million-year age of the grass plants as 6.8 days has to the age of a 75-year-old person. In order to be successful and maintain a healthy productive grassland ecosystem in the Northern Plains, modern grazing management practices must meet the grass plants' biological requirements as the first priority.

Management Implications

A. The present rangeland ecosystems have existed in the Northern Plains for only about 5,000 years, and the plant communities are still developing.

B. The normal Northern Plains climatic pattern is cyclical between wet and dry periods and causes changes in plant species composition, with periodic increases and decreases in woody plants and increases and decreases in taller and shorter grasses.

C. Plants on the Northern Plains rangelands originated elsewhere and migrated into the region, developing dynamic plant communities in place.

D. Plants developed defoliation resistance mechanisms during coevolution with herbivores prior to migration into the region and require defoliation at specific growth stages to remain healthy and productive.

E. The early herbivores that coevolved with grass plants in North America are extinct. All extant herbivores require control of grazing patterns so that plant requirements are met.

F. Humans lived in the Northern Plains prior to the development of the present rangeland ecosystems and have used various techniques and practices to manipulate herbivore movement and plant growth. The inhabitants distributed seeds of food plants across the region and cultivated arable land for food plant production from about 2,250 years ago.

Acknowledgment

I am grateful to Amy M. Kraus and Naomi J. Thorson for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript.

References

Barker, W.T., and W.C. Whitman. 1988. Vegetation of the Northern Great Plains. Rangelands 10:266-272.

Bluemle, J.P. 1977. The face of North Dakota, the geologic story. North Dakota Geological Survey. Ed. Series 11. 73p.

Bluemle, J.P. 1991. The face of North Dakota: revised edition. North Dakota Geological Survey. Ed. Series 21. 177p.

Branson, F.A. 1985. Vegetation changes on western rangelands. Society for Range Management. Denver, CO. 76p.

Bryan, L. 1991. The buffalo people. University of Alberta Press. Edmonton, Alberta. 215p.

Carstensen, V. (ed). 1968. The public lands, studies in the history of the public domain. University of Wisconsin Press. Madison, WI. 522p.

Dary, D.D. 1974. The buffalo book. Avon Books. New York, NY. 374p.

Daubenmire, R. 1968. Plant communities, A textbook of plant synecology. Harper and Row. New York, NY. 300p.

Daubenmire, R.F. 1974. Plants and environment, A textbook of plant autecology. John Wiley and Sons, New York, NY. 422p.

Davis, K.P. 1976. Land use. McGraw-Hill Book Co. New York, NY. 324p.

Dill, C.L. 1990. Early peoples of North Dakota. State Historical Society of North Dakota. Bismarck, ND. 63p.

Eyre, S.R. 1963. Vegetation and soils, a world picture. Aldine Publishing Co. Chicago, IL. 324p.

Fenneman, N.M. 1931. Physiography of western United States. McGraw-Hill Book Co. New York, NY. 534p.

Foster, J.E., D. Harrison, and I.S. MacLaren. 1992. Buffalo. University of Alberta Press. Edmonton, Alberta. 244p.

Gard, W. 1968. The great buffalo hunt. University of Nebraska Press. Lincoln, NE. 324p.

Gilmore, M.R. 1991. Uses of plants by the Indians of the Missouri River Region. University of Nebraska Press. Lincoln, NE. 125p.

Great Plains Flora Association. 1986. Flora of the Great Plains. University Press of Kansas. Lawrence, KS. 1392p.

Heidenreich, V.L. (ed). 1990. The fur trade in North Dakota. State Historical Society of North Dakota. Bismarck, ND. 73p.

Hibbard, B.H. 1965. A history of the public land policies. University of Wisconsin Press. Madison, WI. 579p.

Holder, P. 1970. The hoe and the horse on the plains. University of Nebraska Press. Lincoln, NE. 176p.

Humphrey, R.R. 1962. Range ecology. The Ronald Press Co. New York, NY. 234p.

Hunt, C.B. 1974. Natural regions of the United States and Canada. W.H. Freeman and Co. San Francisco, CA. 725p.

Hyde, G.E. 1959. Indians of the high plains. University of Oklahoma Press. Norman, OK. 234p.

Lowie, R.H. 1963. Indians of the plains. Natural History Press. Garden City, NY. 258p.

MacNeish, R.S. 1973. Early man in America. W.H. Freeman and Co. San Francisco, CA. 93p.

Manske, L.L. 1994. History and land use practices in the Little Missouri Badlands and western North Dakota. Proceedings-Leafy Spurge Strategic Planning Workshop. USDI National Park Service. Dickinson, ND. p. 3-16.

McHugh, T. 1972. The time of the buffalo. University of Nebraska Press. Lincoln, NE. 339p.

Morgan, L.H. 1993. The Indian journals, 1859-1862. Dover Publications Inc. New York, NY. 273p.

Quigg, J.M., and J.H. Brumley. 1984. Stone circles. State Historical Society of North Dakota. Bismarck, ND. 183p.

Ruhe, R.V. 1969. Quaternary landscapes in Iowa. Iowa State University Press. Ames, IA. 255p.

Sandoz, M. 1954. The buffalo hunters. University of Nebraska Press. Lincoln, NE. 372p.

Shiflet, T.N. (ed). 1994. Rangeland cover types. Society for Range Management. Denver, CO. 152p.

Snow, D.R. 1989. The archaeology of North America. Chelsea House Publishers. New York, NY. 143p.

Stevens, O.A. 1963. Handbook of North Dakota plants. North Dakota Institute for Regional Studies. 324p.

Stevens, O.A. 1965. Plants used by Indians in the Missouri River Area. North Dakota History 32:101-106.

Taylor, C.F., and W.C. Sturtevant (ed). 1991. The native Americans. Smithmark. New York, NY. 256p.

Thornbury, W.D. 1969. Principles of geomorphology. John Wiley and Sons. New York, NY. 594p.

Trimble, D.E. 1990. The geologic story of the great plains. Theodore Roosevelt Nature and History Association. Medora, ND. 54p.

Whittaker, R.H. 1962. Classification of natural communities. The Botanical Review. 28:1-239.

Whittaker, R.H. 1975. Communities and ecosystems. MacMillan Publishing Co. New York, NY. 385p.

Woodhead, H. (ed). 1992. The first Americans. Time Life Books. Alexandria, VA. 183p.

Wormington, H.M. 1957. Ancient man in North America. Denver Museum of Natural History. Denver, CO. 322p.

Zaczkowski, N.K. 1972. Vascular flora of Billings, Bowman, Golden Valley, and Slope Counties North Dakota. Ph.D. Thesis. North Dakota State University. Fargo, ND. 219p.

Range Management Practices Addressing Problems Inherent in the Northern Plains Grasslands

Llewellyn L. Manske PhD
Report DREC 08-3002c
Ran ge Scientist
North Dakota State University
Dickinson Research Extension Center

Range management practices that are biologically effective address the inherent problems and conditions of the geographic region in which the practices are implemented. In the Northern Plains grassland ecosystems, the vegetation is characterized by three major features that have implications for animal production: 1) plant growth is limited by several environmental factors, 2) ungrazed grasses are low in nutritional quality during the latter portion of the grazing season, and 3) plants grazed too early in the growing season or late in the growing season suffer negative effects. The twice-over rotation grazing system on native rangeland with complementary domesticated grass spring and fall pastures was developed with consideration of these features and has been successfully implementated on the Northern Plains.

In this region, the most important of the environmental factors limiting plant growth (Manske 1998) are moderate annual precipitation, limited distribution of precipitation during part of the growing season, cool temperatures in the spring and fall, and hot temperatures in summer. The seasonal precipitation pattern is characterized by a period of maximum precipitation in late spring and early summer, tapering off to a moderately light amount during fall and winter. Periods with precipitation levels sufficiently low to place plants under water stress and limit growth occur frequently. Herbage production within grassland communities is also limited by temperature. The frost-free period is usually short, from 120 to 130 days. Perennial grassland plants can sustain growth for longer than the frost-free period, but they require temperatures above the level that freezes water in plant tissue and soil. Plant growth is greatly limited by low air temperatures during the early and late portions of the growing season and by high temperatures, high evaporation, drying winds, and low precipitation during mid summer.

The growing season for perennial grasses covers about six months, from mid April to mid October. However, because favorable precipitation and temperature conditions occur during May, June, and July (Manske 1998), most plant growth in height is attained within this three-month period (Goetz 1963). Peak aboveground herbage biomass is usually reached during the last ten days of July. Herbage biomass of ungrazed plants increases in weight during May, June, and July; after the end of July the weight of the herbage biomass decreases because the rate of senescence (aging) of the grass leaves exceeds growth and the cell material in aboveground structures is being translocated to the belowground structures. This translocation causes a decrease in the nutritional quality of the aboveground structures. Ungrazed plants of the major upland sedges, cool-season grasses, and warm-season grasses drop below the 9.6% crude protein level around mid July (Whitman et al. 1951), as they attain maximum growth in height and weight.

The nutritional quality of the native vegetation during the latter portion of the grazing season is a limiting factor in animal performance. A 1000-pound lactating cow requires a crude protein level of at least 9.6% (NRC 1996). Most ruminant animals require a daily dry matter intake of about 2% (1.5-3.0%) of their body weight (Holechek et al. 1989). Cows may be able to compensate for lower-quality forage for a short time by increasing intake and/or selecting plant parts higher in nutritional quality than average plant parts. However, cows on seasonlong and deferred grazing systems lose weight from early or mid August to the end of the grazing season (Manske et al. 1988). The loss of weight does not hurt the animals but does cause decreased milk production (Landblom 1989) and a subsequent reduction in the daily gain of calves (Manske 1996).

The negative effects suffered by plants on a seasonlong system with grazing begun too early include great reductions in herbage biomass production, which cause reductions in stocking rates and animal production per acre. Data from three studies indicate that if seasonlong grazing is started in mid May on native rangeland, 45-60% of the potential peak herbage biomass will be lost and never be available for grazing livestock. If the starting date of seasonlong grazing is deferred until early or mid July, nearly all of the potential peak herbage biomass will grow and be available to the grazing livestock, but the nutritional quality of the available forage will be at or below the crude protein levels required by a lactating cow. If the starting date is deferred until after mid July, less than peak herbage biomass will be available to grazing livestock because of senescence and the translocation of cell material to belowground parts (Campbell 1952, Rogler et al. 1962, Manske 1994a), and the crude protein levels of the available forage will be insufficient to meet the nutritional requirements of a lactating cow.

The phenological growth stage of the grass plants is the best indicator of appropriate grazing starting dates. Grazing plants before the third new leaf stage causes negative effects in grass growth, while starting grazing after the third new leaf stage stimulates tiller production, a process that leads to increased aboveground herbage biomass and increased nutritional quality of available herbage. Most native cool-season grasses reach the third new leaf stage around early June, and most native warm-season grasses reach the third new leaf stage around mid June. This phenological development indicates that within each management system, starting grazing on each pasture sometime between early June and early July would produce the fewest negative effects on herbage biomass production and nutritional quality of the available forage. Seasonlong grazing management systems on native rangeland should wait until mid June to begin grazing, but rotation grazing systems could start in early June.

Continuation of grazing late in the season can also produce detrimental effects on plants. Severe defoliation of grass plants during fall and winter reduces herbage production of the grasslands the following growing season. Late-stimulated tillers remain viable over winter and continue growth the following growing season. Cool-season species initiate tillers the previous fall and continue growth the following season. Defoliation of late-stimulated tillers and cool-season tillers during fall and winter reduces their contribution to the ecosystem the following season.

The twice-over rotation system on native rangeland with complementary domesticated grass spring and fall pastures times grazing to maximize vegetation and animal performance. A spring pasture of crested wheatgrass is grazed during May. The twice-over rotation grazing management system uses three to six native rangeland pastures. Each of the pastures in the rotation is partially defoliated by grazing for 7 to 17 days during the first period, the 45-day interval from 1 June to 15 July when grasses are between the third new leaf stage and flowering (anthesis) stage. The length in number of days of the first grazing period on each pasture is the same percentage of 45 days as the percentage of the total season's grazable forage each pasture contributes to the complete system. During the second grazing period when lead tillers are maturing and defoliation by grazing is only moderately beneficial, after mid July and before mid October, each pasture is grazed for double the number of days it was grazed during the first period. A fall pasture of Altai wildrye is grazed by cows and calves from mid October until weaning in mid November.

The twice-over rotation system with complementary domesticated grass pastures has a grazing season of over 6.5 months, with the available forage above, at, or only slightly below the requirements for a lactating cow for nearly the entire grazing season. It requires fewer than 12 acres per cow-calf pair for the entire 6.5-month grazing season on grassland that when grazed for 6.0 months seasonlong requires 24 acres per cow-calf pair. The cow-calf weight performance on the twice-over rotation grazing system with complementary domesticated grass pastures is improved over the performance on other systems (Manske 1994b, Manske 1996).

It is possible that no range management practice can address all the problems inherent in an ecosystem, but successful practices will incorporate adjustment for the most serious problems. The twice-over rotation system with complementary domesticated grass pastures is one system that has been shown to be well adapted to the conditions of the Northern Plains grasslands and to produce positive results in vegetation and animal performance.

Acknowledgment

I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript.

Literature Cited

Campbell, J.B. 1952. Farming range pastures. Journal of Range Management 5:252-258.

Goetz, H. 1963. Growth and development of native range plants in the mixed grass prairie of western North Dakota. M.S. Thesis, NDSU. Fargo, ND. 165p.

Holechek, J.L., R.D. Pieper, and C.H. Herbel. 1989. Range management principles and practices. Prentice Hall. NJ. 501p.

Landblom, D.G. 1989. Brood cow efficiency management study. 39th Livestock Research Roundup. Dickinson Research Center. Dickinson, ND. Sec.I. p. 20-34.

Manske, L.L. 1994a. Problems to consider when implementing grazing management practices in the Northern Great Plains. NDSU Dickinson Research Extension Center. Range Management Report DREC 94-1005. Dickinson, ND. 11p.

Manske, L.L. 1994b. Ecological management of grasslands defoliation. p. 130-136. *in* F.K. Taha, Z. Abouguendia, and P.R. Horton (eds.). Managing Canadian rangelands for sustainability and profitability. Grazing and Pasture Technology Program, Regina, Saskatchewan, Canada.

Manske, L.L. 1996. Economic returns as affected by grazing strategies. p. 43-55. *in* Z. Abouguendia (ed.). Total Ranch Management in the Northern Great Plains. Grazing and Pasture Technology Program, Saskatchewan Agriculture and Food. Regina, Saskatchewan, Canada.

Manske, L.L. 1998. Environmental factors to consider during planning of management for range plants in the Dickinson, North Dakota, region, 1892-1997. NDSU Dickinson Research Extension Center. Range Research Report DREC 98-1018. Dickinson, ND. 36p.

Manske, L.L., M.E. Biondini, D.R. Kirby, J.L. Nelson, D.G. Landblom, and P.J. Sjursen. 1988. Cow and calf performance on seasonlong and twice over rotation grazing treatments in western North Dakota. Proceedings of the North Dakota Cow-Calf Conference. Bismarck, ND. p. 5-17.

National Research Council. 1996. Nutrient requirements of beef cattle. 7th ed. National Academy Press. Washington, DC.

Rogler, G.A., R.J. Lorenz, and H.M. Schaaf. 1962. Progress with grass. N.D. Agr. Exp. Sta. Bul. 439. 15p.

Whitman, W.C., D.W. Bolin, E.W. Klosterman, H.J. Klostermann, K.D. Ford, L. Moomaw, D.G. Hoag, and M.L. Buchanan. 1951. Carotene, protein, and phosphorus in range and tame grasses of western North Dakota. N.D. Agr. Exp. Sta. Bul. 370. 55p.