# Autecology of Plains Rough Fescue on the Northern Mixed Grass Prairie

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Report DREC 17-1161

The autecology of Plains rough fescue, *Festuca hallii*, is one of the prairie plant species included in a long ecological study conducted at the NDSU Dickinson Research Extension Center during 67 growing seasons from 1946 to 2012 that quantitatively describes the changes in growth and development during the annual growing season life history and the changes in abundance through time as affected by management treatments for the intended purpose of the development and establishment of scientific standards for proper management of native rangelands of the Northern Plains. The introduction to this study can be found in report DREC 16-1093 (Manske 2016).

Plains rough fescue, *Festuca hallii* (Vasey) Piper, is a member of the grass family, Poaceae, tribe, Poeae, syn.: *Festuca scrabrella* Torr., and is a native, long lived perennial, monocot, cool-season, mid grass, that is cold hardy and adapted to short growing seasons. Early aerial growth consists of basal leaves arising from crown and rhizome tiller buds. Leaf blades are quite stiff 10-30 cm (4-12 in) long, 0.5-2 mm wide, tapering to a point, strongly ridged above, and scabrous (rough) on both surfaces. Previous years stem and leaf bases are persistent during the following growing season. The split sheaths are mostly open and closed for less than 1/3 their length. The ligule is a short margin with raised ends, 0.1-0.6 mm long, and the margin is fringed with short hairs. The auricles are absent. The numerous short rhizomes form mats of 25-50 cm (10-20 in ) diameter. The extensive fibrous root system has numerous main roots arising from stem crowns and rhizome nodes growing vertically downward to 122 cm (4 ft) deep. Most of the roots are shallow, about 73% are in the top 15 cm (6 in) of soil. Regeneration is primarily asexual propagation by crown and rhizome tillers. Seedling success is low as a result of poor and erratic seed production and competition from established plants. Flower stalks are erect, smooth, 30-60 cm (12-24 in) tall. Inflorescence is a narrow, condensed panicle, 5-15 cm (2-6 in) long. Flower period is from late May to late June. Aerial parts are highly palatable to livestock. Fire top kills aerial parts and crowns continue burning below the soil surface long after the flame front has passed when soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Plains rough fescue was based on works of Stevens 1963, Zaczkowski 1972, Great Plains Flora Association 1986, and Tirmenstein 2000.

**Taxonomic Status**

The rough fescue circumboreal complex, *Festuca scabrella* Torr., indigenous to North America was divided in 1984 into three distinct species separated by several morphological characteristics, rhizome development, ploidy level, growth habit, preferred habitat type, and geographic distribution. The following summary of the taxonomic status of three species from the rough fescue complex was based on the works of Tirmenstein 2000, ITIS n.d., and Barkworth et al. 2007.

Northern rough fescue, *Festuca altaica* Trin., growth form is caespitose bunches, rarely with short rhizomes, produces 5 to 10 culms, 40-60 cm (15.7-23.6 in) tall with 3-5 florets per spikelet, chromosomes are tetraploid, and foliage is yellowish to dark green. Preference is for arctic tundra meadows, taiga, rocky alpine, subalpine forests, and open boreal forest habitats with geographic distribution in Alaska, Northwest Territories, Bristish Columbia, and Alberta.

Mountain (Foothills) rough fescue, *Festuca compestris* Rydb., growth form is large dense caespitose bunches, with no rhizomes, the highly productive tussocks are up to 30 cm (11.8 in) in diameter, produces up to 25 culms, 40-90 cm (15.7-35.4 in) tall with 4-6 florets per spikelet, roots can descend to 120 cm (47.2 in) deep, chromosomes are octaploid, and foliage is bluish gray green with purplish sheaths at the base of leaves. Preference is for subalpine and montane meadows, and high elevation (above 2000 m, 6,526 ft) foothill prairie habitats with geographic distribution in Washington, Oregon, Idaho, western Montana, southern British Columbia, southwestern Alberta, and the plateau of Cypress Hills in southwestern Saskatchewan.

Plains rough fescue, *Festuca hallii* (Vasey) Piper, growth form is short, reduced density caespitose bunches with short rhizomes that can form mats up to 50 cm (20 in) in diameter, produces 3-5 culms, 20-40 cm (7.9-15.7 in) tall with 2-3 florets per spikelet that infrequently develops viable seed, chromosomes are tetraploid, and foliage is bluish or gray green. Preference is for the moist grassland-forest transition zone on lower elevation (below 2000 m, 6,562 ft) foothill grassland habitats with geographic distribution from alpine meadows of northern Colorado, northward into the lower east facing foothills of the Rocky Mountains in Wyoming, western Montana, and southwestern Alberta, and has prehistorically spread eastward from the Alberta foothills into the northern prairieland of Alberta, Saskatchewan, and Manitoba, and then more recently spread southward into the prairieland of North Dakota and eastern Montana.

**Procedures**

**The 1983-2012 Study**

A long-term change in grass and upland sedges species abundance study was conducted during active plant growth of July and August each growing season of 1983 to 2012 (30 years) on native rangeland pastures at the Dickinson Research Extension Center ranch located near Manning, North Dakota. Effects from three management treatments were evaluated: 1) long-term nongrazing, 2) traditional seasonlong grazing, and 3) twice-over rotation grazing. Each treatment had two replications, each with data collection sites on sandy, shallow, and silty ecological sites. Each ecological site of the two grazed treatments had matching paired plots, one grazed and the other with an ungrazed exclosure. The sandy, shallow, and silty ecological sites were each replicated two times on the nongrazed treatment, three times on the seasonlong treatment, and six times on the twice-over treatment.

During the initial phase of this study, 1983 to 1986, the long-term nongrazed and seasonlong treatments were at different locations and moved to the permanent study locations in 1987. The data collected on those two treatments during 1983 to 1986 were not included in this report.

Abundance of each grass and upland sedge species was determined with plant species basal cover by the ten-pin point frame method (Cook and Stubbendieck 1986). The point frame method was used to collect data at 2000 points along permanent transect lines at each sample site both inside (ungrazed) and outside (grazed) each exclosure. Basal cover, relative basal cover, percent frequency, relative percent frequency, and importance value were determined from the ten-pin point frame data. Point frame data collection period was 1983 to 2012 on the twice-over treatment and was 1987 to 2012 on the long-term nongrazed and on the seasonlong treatments. However, point frame data was not collected during 1992 on the sandy ecological sites of all three treatments.

During some growing seasons, the point frame method did not document the presence of a particular plant species which will be reflected in the data summary tables as an 0.00 or as a blank spot.

The 1983-2012 study attempted to quantify the increasing or decreasing changes in individual plant species abundance during 30 growing seasons by comparing differences in the importance values of individual species during multiple year periods. Importance value is an old technique that combines relative basal cover with relative frequency producing a scale of 0 to 200 that ranks individual species abundance within a plant community relative to the individual abundance of the other species in the community during the growing season. Basal cover importance value ranks the grasses, upland sedges, forbs, and shrubs in a community. The quantity of change in the importance value of an individual species across time indicates the magnitude of the increases or decreases in abundance of that species relative to the changes in abundance of the other species.

**Results**

Plains rough fescue increases growth activity shortly after snow melt. Leaf growth in cool season grasses continues very slowly during the entire winter. The top portion of these carryover leaves becomes exposed to low temperatures causing the cell walls to rupture. The lower portion of the carryover leaves have intact cell walls and regreen with active chlorophyll when liquid water becomes available in soil for at least during the daylight hours. The green portions of the carryover leaves provide a large quantity of carbohydrates and fixed energy used in the production of new leaves. Growth of new leaves of Plains rough fescue is usually visible around mid April with active leaf growth occurring during early May (table 1). Tiller growth is rapid during May and June. Like other cool season grasses, Plains rough fescue produces 3.5 new leaves around early June. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial

defoliation of 25% to 33% of the leaf weight by graminivores. During early June, the lead tillers contain 10.1% crude protein (table 1). The flower stalks develop in mid May. The flower period occurs from around late May to mid June. Maximum herbage biomass is produced by the end of June. Seeds develop during late June and seeds are easily shed during mid to late July. Lead tiller digestibility is around 55% during most of June and July. However, the lead tiller crude protein content presumably drops below the requirements of lactating cows during early to mid July (table 2). Senescence of lead tillers occurs rapidly after early August (table 1). Heavy grazing pressure, that removes greater than 50% of the aboveground herbage weight, causes remarkable reductions in Plains rought fescue plant abundance. Plains rough fescue grasslands do not improve with the removal of grazing animals and greatly decrease without the effects from grazing (Slogan 1997).

**Prairie composition with rough fescue**

The descriptions of prairie plant composition with rough fescue required adjustments as a result of the separation of the rough fescue complex into three distinct species. Two of the three rough fescue species grow in the Northern Plains. Northern rough fescue, *Festuca altaica*, prefers habitats at mountain elevations that do not occur in the Northern Plains.

Mountain (Foothills) rough fescue, *Festuca compestris*, is the dominant grass of the Fescue Prairie that lies along the eastern face of the Rocky Mountain Foothills in southwestern Alberta which consists of over 1.3 million ha (3.2 million ac), on rolling, hummocky, dissected glacial till with a subhumid climate and black soils at higher elevations of foothill slopes (Slogan 1997, Henderson 2000, Shorthouse 2010). Mountain (Foothills) rough fescue was also present on the plateau and upper slopes of the Cypress Hills with small open patches among the forest cover on the north facing slopes in southeastern Alberta and southwestern Saskatchewan (Slogan 1997, Shorthouse 2010). The Alberta Fescue Prairie extends southward to the foothill slopes of the Sweetgrass Hills at the Canada-United States border (Shorthouse 2010) and continues south along the higher elevations of east facing foothills through Montana (Thrift et al. 2013) to the Madison Range (Barker and Whitman 1989) which enters Wyoming at the northwestern corner.

Plains rough fescue, *Festuca hallii,* is the dominant grass in patches and small grasslands of the Northern Plains in Alberta, Saskatchewan, Manitoba, eastern Montana, and northern North Dakota (Stevens 1963, Cosby 1965, Barkworth et al. 2007, Shorthouse 2010, Thorpe et al. 2015). The greatest extent of the Plains rough fescue grassland occurs in Canada from west central Alberta through central Saskatchewan to southwestern Manitoba that lies between the Moist (Transition) Mixed Grass Prairie and the Northern Boreal Forest within the Aspen Parkland. The Plains rough fescue grasslands occurs in a subhumid climate on black and dark brown chernozem soils in open areas and as intermittent patches interspersed among the mosaic of trembling aspen groves on dark gray chernozem soils, with groves of bur oak included in the eastern portions. The stands of aspen grade from a groveland to a parkland into a closed woodland (Slogan 1997, Henderson 2000, Shorthouse 2010, Thorpe et al. 2015).

Plains rough fescue grasslands has also developed on the lower south facing slopes of the Cypress Hills and as patches on drier sites of the Turtle Mountain Upland and Pembina Hills (Shorthouse 2010). On the United States side of the Turtle Mountain Upland, patches of Plains rough fescue have been located on the slopes and a grassland has been located at the highest point of St. Paul Butte, Bottineau and Rolette counties, North Dakota (Stevens 1963, Cosby 1965). Patches of Plains rough fescue have been interspersed within the Moist (Transition) Mixed Grass Prairie; Wheatgrass-Bluestem-Needlegrass Type of Saskatchewan, Manitoba, and northern North Dakota as depicted in Dr. Whitman's Map of the Vegetation of the Northern Great Plains (Barker and Whitman 1988, 1989) (see map included). Plains rough fescue has been identified to occur as patches in most of the municipalities of the southern prairieland portions of Alberta and Saskatchewan, and the southwestern prairieland portions of Manitoba within the Tall Grass Prairie with a humid climate and black soils, the Moist (Transition) Mixed Grass Prairie with a subhumid climate and dark brown chernozem soils, the Mixed Grass Prairie with a semiarid climate and brown soils, and the area of dry Mixed Grass (Northern Short Grass) Prairie with a semiarid climate and brown soils (Barkworth et al. 2007).

Incursions of Plains rough fescue have been identified from counties in North Dakota and eastern Montana by Stevens 1963, Cosby 1965, and Barkworth et al. 2007 (table 3). Incursions into the Tall Grass Prairie with a humid climate and Aquall soils have occurred in Pembina and Walsh counties of North Dakota (table 3). Incursions into the Transition (Moist) Mixed Grass Prairie with a subhumid climate and Udic Boroll soils have occurred in Barnes,

Benson, Bottineau, Burke, Cavalier, McHenry, Renville, and Rolette counties of North Dakota (table 3). Incursions into the Mixed Grass Prairie with a semiarid climate and Typic Boroll soils have occurred in Divide, Mountrail, Ward, and Williams counties of North Dakota and Daniels county of Montana (table 3). Incursions into the Northern Short Grass Prairie with an arid climate and Aridic Boroll soils have occurred in Valley county of Montana (table 3).

Plains rough fescue has made incursions into every prairie ecoregion of Alberta, Saskatchewan, and Manitoba, Canada (Capels n.d, Barkworth et al. 2007) and every prairie type in the United States Northern Plains among the first and second northern tier counties of North Dakota (Stevens 1963, Cosby 1965, Whitman and Wali 1975, Whitman and Barker 1989) and in two first northern tier counties of eastern Montana (Barkworth et al. 2007). Barkworth et al. (2007) has also identified incursions of Plains rough fescue into Barnes county with a fifth tier position in North Dakota. Plains rough fescue no longer appears to retain its habitat requirements of moist, lower elevation foothill grasslands.

Grass species composition in rangeland ecosystems is variable during a growing season and dynamic among growing seasons. Patterns in the changes of individual grass species abundance was followed during the 1983-2012 study on the sandy and silty ecological sites of the long-term nongrazed, traditional seasonlong, and twice-over rotation management treatments (tables 4 and 5).

Plains rough fescue incursions into Dunn County, with a third tier position in North Dakota, were located on Mixed Grass Prairie native rangeland study sites on the Dickinson Research Extension Center (DREC) ranch, operated by North Dakota State University (NDSU), 20 miles north of Dickinson, and west of Manning at latitude 47° 14' N, longitude 102° 50' W.

While collecting vegetative data at the silty site of seasonlong grazing treatment pasture 11, John Urban, Range Research Technician, noticed a different type of grass, Plains rough fescue, during the summer of 2006. During the summer of 2007, John Urban found additional locations of Plains rough fescue growing west of silty site exclosure of seasonlong grazing treatment pasture 11 and growing east of silty site exclosure of twice-over grazing treatment pasture 1. None of the locations were on nongrazed treatments inside the exclosures.

During the growing season of 2010, Plains rough fescue was located on the twice-over rotation grazing treatment silty site with a 1.70% basal cover and located again during the growing season of 2011 on the grazed silty site with a 1.10% basal cover (tables 4 and 5). During the 2011 growing season, Plains rough fescue was also located on the seasonlong grazing treatment silty site with a 0.05% basal cover and on the seasonlong grazing treatment sandy site with a 0.25% basal cover (tables 4 and 5). Plains rough fescue has not been located on any shallow sites or any nongrazed treatment sites.

**Discussion**

Plains rough fescue, *Festuca hallii*, is a North American native, perennial, cool season, mid grass, monocot, of the grass family that is not common in the Northern Plains Mixed Grass Prairie. Plains rough fescue is common as incursion patches in the Moist (Transition) Mixed Grass Prairie and as grasslands interspersed among the mosaic of trembling aspen groves in the Aspen Parkland north of the prairieland of Canada. Plains rough fescue typically grows in moist, cool, areas on low elevation foothill grasslands. Something has happened in the not too distant past to permit Plains rough fescue to develop as incursion patches in the Tall Grass Prairie, the Transition (Moist) Grass Prairie, the Mixed Grass Prairie, and the Northern Short (dry portion of Mixed) Grass Prairie of the Northern Plains in Alberta, Saskatchewan, and Manitoba of Canada and eastern Montana and North Dakota of the United States. Only a few other grasses can survive on all the prairie types of the Northern Plains, blue grama, needle and thread, prairie Junegrass, and western wheatgrass.

Early season activity for Plains rough fescue starts with regreening with active chlorophyll portions of the carryover leaves that have intact cell walls from the previous growing season vegetative tillers, secondary tillers, and fall tillers. The green portion of the carryover leaves provides large quantities of carbohydrates and fixed energy for the production of new leaves. New leaves of Plains rough fescue are usually visible around mid April. Plains rough fescue lead tillers are derived from carryover vegetative tillers, with active leaf growth starting in early May, and producing 3.5 new leaves around early June. Lead tillers at the 3.5 new leaf stage are physiologically capable of positive response to partial defoliation of 25% to 33% of leaf weight by graminivores. The lead tillers contain 10.1% crude protein during early June. The flower stalks are developing around mid May, with a short flower

period from late May to mid June. Seeds are developing between late June and mid July and seeds are shed from mid to late July. However, Plains rough fescue develops viable seed infrequently. Lead tillers drop below the crude protein requirements of lactating cows during early to mid July. The lead tiller digestibility remains around 55% during most of June and July. Leaf senescence occurs rapidly during early August. Plains rough fescue grasslands degrade from heavy grazing that removes greater than 50% of the aboveground herbage weight and from nongrazing after the removal of grazing animals. Plains rough fescue, like all other grasses, produces double the leaf mass than the plant needs for normal growth and development. However, if half the leaf mass is not removed through partial defoliation by graminivores, this extra leaf material becomes a detriment. The incursions of Plains rough fescue into prairie types that it previously had not been part of the plant community have occurred too recently to determine whether the results will have a beneficial or negative outcome.

Acknowledgment

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

Table 1. Festuca hallii, Plains rough fescue, conjectural percent crude protein and phenological growth stages in Northern Mixed Grass Prairie.

| Growing Season Date | | Crude Protein % | Phenological Growth Satges |
|---|---|---|---|
| Apr | early | | |
| | mid | | early leaf greenup |
| | late | | |
| May | early | 12.0 | active leaf growth |
| | mid | 13.7 | flower stalk developing |
| | late | | |
| Jun | early | 10.1 | flower period |
| | mid | | |
| | late | | seeds developing |
| Jul | early | | |
| | mid | | seeds shed |
| | late | | |
| Aug | early | 7.0 | |
| | mid | 6.6 | |
| | late | | |
| Sep | early | | |
| | mid | 4.7 | cured |
| | late | | |
| Oct | early | | |
| | mid | 4.5 | |
| | late | 4.2 | weathered |

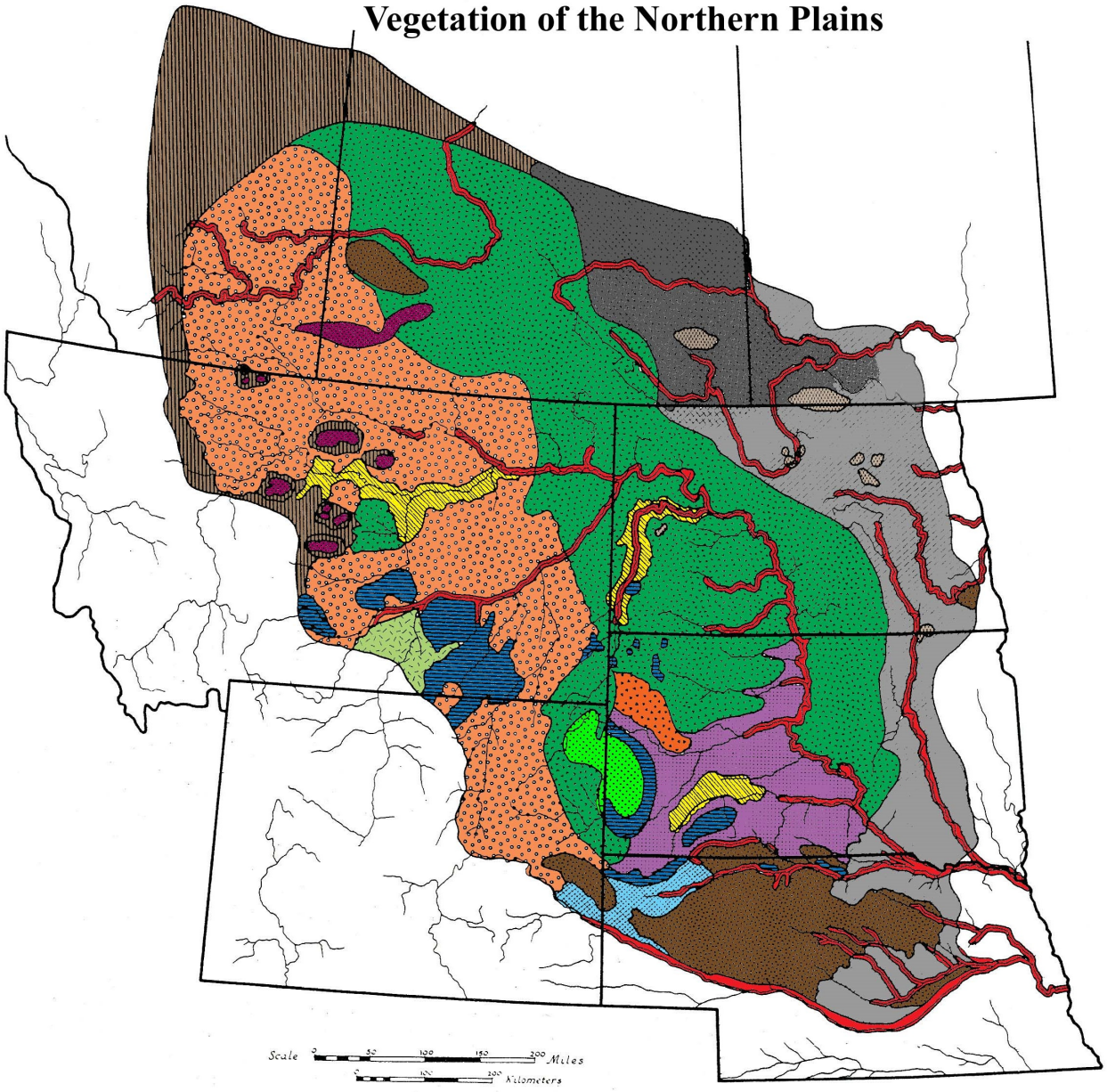
Partial Data Sets from Campbell et al. 1956 and Tirmenstein 2000.

Table 2. Intake nutrient requirements as percent of dry matter for range cows with average milk production.

| | Dry Gestation | 3rd Trimester | Early Lactation | Lactation (Spring, Summer, Fall) |
|---|---|---|---|---|
| 1000 lb cows | | | | |
| Dry matter (lbs) | 21 | 21 | 24 | 24 |
| Crude protein (%) | 6.2 | 7.8 | 10.5 | 9.6 |
| Phosphorus (%) | 0.11 | 0.15 | 0.20 | 0.18 |
| 1200 lb cows | | | | |
| Dry matter (lbs) | 24 | 24 | 27 | 27 |
| Crude protein (%) | 6.2 | 7.8 | 10.1 | 9.3 |
| Phosphorus (%) | 0.12 | 0.16 | 0.19 | 0.18 |
| 1400 lb cows | | | | |
| Dry matter (lbs) | 27 | 27 | 30 | 30 |
| Crude protein (%) | 6.2 | 7.9 | 9.8 | 9.0 |
| Phosphorus (%) | 0.12 | 0.17 | 0.19 | 0.18 |

Data from NRC 1996.

# 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 3. Incursion of Plains rough fescue into Counties of North Dakota and eastern Montana.

| Stevens, 1963<br>field work 1909-1950 | | Cosby, 1965<br>field work 1958-1964 | | Barkworth et al. 2007<br>Flora of North America, Vol. 24 | |
|---|---|---|---|---|---|
| North Dakota | | North Dakota | | North Dakota | |
| 1st Northern Tier Co. | | 1st Northern Tier Co. | | 1st Northern Tier Co. | |
| Burke | B. | Bottineau | B. | Bottineau | B. |
| Rolette | B. | Burke | B. | Burke | B. |
| | | Divide | C. | Cavalier | B. |
| 2nd Northern Tier Co. | | Pembina | A. | Divide | C. |
| | | Renville | B. | Rolette | B. |
| Benson | B. | Rolette | B. | | |
| | | | | 2nd Northern Tier Co. | |
| | | 2nd Northern Tier Co. | | | |
| | | | | Benson | B. |
| | | Benson | B. | Mountrail | C. |
| | | McHenry | B. | Ward | C. |
| | | Mountrail | C. | Williams | C. |
| | | Walsh | A. | | |
| | | Ward | C. | 5th Northern Tier Co. | |
| | | | | Barnes | B. |
| | | | | Montana | |
| | | | | 1st Northern Tier Co. | |
| | | | | Daniels | C. |
| | | | | Valley | D. |

Key to Vegetation Types of the Counties.

A. Tall Grass Prairie; Bluestem-Switchgrass-Indiangrass Type.
B. Transition Mixed Grass Prairie; Wheatgrass-Bluestem-Needlegrass Type.
C. Mixed Grass Prairie; Wheatgrass-Needlegrass Type.
D. Northern Short Grass Prairie; Grama-Needlegrass-Wheatgrass Type.

| Table 4. Autecology of Festuca hallii, Plains rough fescue, with growing season changes in basal cover, 1983-2012. | | | | | |
|---|---|---|---|---|---|
| Ecological Site Year Period | Nongrazed | Seasonlong | | Twice-over | |
| | | Ungrazed | Grazed | Ungrazed | Grazed |
| Sandy | | | | | |
| 1983-1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1988-1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1993-1998 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1999-2003 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2004-2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010-2012 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 |
| Shallow | | | | | |
| 1983-1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1988-1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1993-1998 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1999-2003 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2004-2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010-2012 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Silty | | | | | |
| 1983-1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1988-1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1993-1998 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1999-2003 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2004-2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010-2012 | 0.00 | 0.00 | 0.05 | 0.00 | 1.40 |

Table 5. Autecology of Festuca halii, Plains rough fescue, with growing season changes in basal cover importance value, 1983-2012.

| Ecological Site Year Period | Nongrazed | Seasonlong | | Twice-over | |
|---|---|---|---|---|---|
| | | Ungrazed | Grazed | Ungrazed | Grazed |
| Sandy | | | | | |
| 1983-1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1988-1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1993-1998 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1999-2003 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2004-2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010-2012 | 0.00 | 0.00 | 2.04 | 0.00 | 0.00 |
| Shallow | | | | | |
| 1983-1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1988-1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1993-1998 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1999-2003 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2004-2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010-2012 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Silty | | | | | |
| 1983-1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1988-1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1993-1998 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1999-2003 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2004-2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010-2012 | 0.00 | 0.00 | 0.42 | 0.00 | 7.35 |

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