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An Ecological Study of Isolated Populus Tremuloides Stands

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AN ECOLOGICAL STUDY OF ISOLATED *POPULUS TREMULOIDES* STANDS

by

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This thesis submitted by Lawrence D. Cordes in partial fulfillment of the requirements for the Degree of Master of Science in the University of North Dakota is hereby approved by the Committee under whom the work has been done.

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INTRODUCTION

In northwestern Minnesota the transition from deciduous forest to prairie is made through an intermediate complex of associations variously known as "aspen parkland", the "aspen grove region", or "brush prairie". Although the *Populus tremuloides* Michx. communities of the Minnesota parkland have been studied by a number of workers, apparently no investigation has been made of the isolated aspen stands throughout the Red River Valley. The objectives of the present investigation were: to describe the vegetation of the aspen stands in the Red River Valley; and to study the relationship between grassland and these aspen stands.

Populus tremuloides was described by Andre Michaux in in 1805. Tidestrom (1911) has also worked on the taxonomy of *P. tremuloides*. The floral morphology of the species has been described by Erlanson and Herman (1927) and Nagraj (1952).

Reproduction of *P. tremuloides* has been studied by a number of workers. Kittredge and Gevorkiantz (1929), Kittredge (1938), Larson (1944), Maini (1960), and Graham et al. (1963) concluded that naturally occurring seedlings are of no great significance and are found quite rarely. Some workers, however, have found that natural seedlings grow well on moist bare soil (Ewing 1924, Faust 1936). Sucker formation appears to be the chief means of reproduction (Ewing 1924, Kittredge and Gevorkiantz 1929, Moss 1932, Lynch 1955, Lutz 1958, Maini 1960, Graham et al. 1963). The effect of soil and fire on sucker formation has been discussed by Shirley (1931), Lynch (1955), and Lutz (1956).

Populus tremuloides has numerous natural enemies including both insects and fungi. The effects of a number of insects on the species have been described by Graham et al. (1963). Various fungi which damage the species have been described (Riley and Bier 1936, Bier 1940, Anderson 1953, Beckwith and Anderson 1956, Graham et al. 1963).

A number of ecological investigations have been made on sections of the aspen parkland in North America (Ewing 1924, Bird 1930, Moss (1932, 1955), Lynch 1955, Buell and Facey 1960, Maini 1960) and on aspen stands in northeastern Minnesota, Wisconsin, and Michigan (Gates 1930, Alway and Kittredge 1933, Kittredge 1938, Heinselman and Zasada, 1955, Graham et al. 1963). The numerous studies of the growth characteristics of aspen include those of Kittredge and Gevorkiantz (1929), Kittredge (1938), Stoeckler (1948), Heinselman and Zasada (1955), Lynch (1955), Maini (1960), and Graham et al. (1963).

The factors responsible for a general lack of trees on the prairies of North America have attracted the attention of a number of scientists. Many have written papers on this controversial subject (Gleason 1912, Cannon 1913, Weaver and Theil 1917, Pool et al 1918, Hanson 1922, Fuller 1923, Ewing 1924, Cowles 1928, Bird 1930, Emerson 1932, Moss (1932, 1955), Carpenter 1935, Transeau 1935, Loomis and McComb 1944, Brink and Farstad 1949, Sauer 1950, Whitford 1951 and 1958, Lynch 1955, Buell and Buell 1959, Buell and Facey 1960, Coupland and Maini 1959, Maini 1960, Wells 1965). Their opinions on the factors determining the treelessness of the Great Plains include among others: precipitation pattern, fire, and edaphic factors as the factor or factors responsible.

LOCATION AND DESCRIPTION OF THE STUDY AREA

Location and Physiography

The study area was located in Grand Forks County, North Dakota and in Polk County, Minnesota. It included about 2080 sq. miles: Grand Forks County and the northwestern 20 townships of Polk County (Fig. 1). This area was approximately 66 miles long from east to west; 36 miles wide in Grand Forks County and 24 miles wide in Polk County.

The study area lies within the limits of the Western Young Drift Section of the Central Lowland (Fenneman, 1938). All the sedimentary rock underlying the area is of Cretaceous origin or older. The youngest stratum is the Pierre Shale which is blue-gray in color, marine in origin, and has a number of thin layers of very fine blue sand in its upper portion (Lum, 1939). Lying beneath the Pierre Shale are three more Cretaceous formations: the Niobrara Shale, the Benton Shale, and the Dakota Sandstone (Laird, 1944).

The sedimentary rocks of the Cretaceous system are covered with a thick layer of glacial drift varying in thickness from 100 to 350 feet (Allison, 1932). This drift outcrops in the western part of the study area and is referred to generally as the Drift Prairie. It is made up of a mixture of ground moraine, recessional moraines, and washboard moraines (Colton et al., 1963). The topography varies from almost level in some places to low ridges with surface depressions in others. The elevation varies from 1150 to 1520 feet above sea level (Kalin, 1964).

The remainder of the study area lies within the Red River Valley. Most of the Valley is very flat due to the fact that it was the bottom of Glacial Lake Agassiz during part of the Pleistocene Period. The land slopes towards the Red River with an average fall of two to three feet per mile and to the north with an average of nine inches per mile (Lum, 1939). Lacustrine deposits of laminated clay, silt, and sand cover most of the valley. In areas these deposits are 50 feet thick, while in others the underlying glacial till is exposed at the surface (Fenneman, 1938). Above this lacustrine material are alluvial deposits of recent streams. This mud, silt, and sand layer is quite thin in most areas but may extend to considerable depths where it has filled up depressions in the lacustrine deposits.

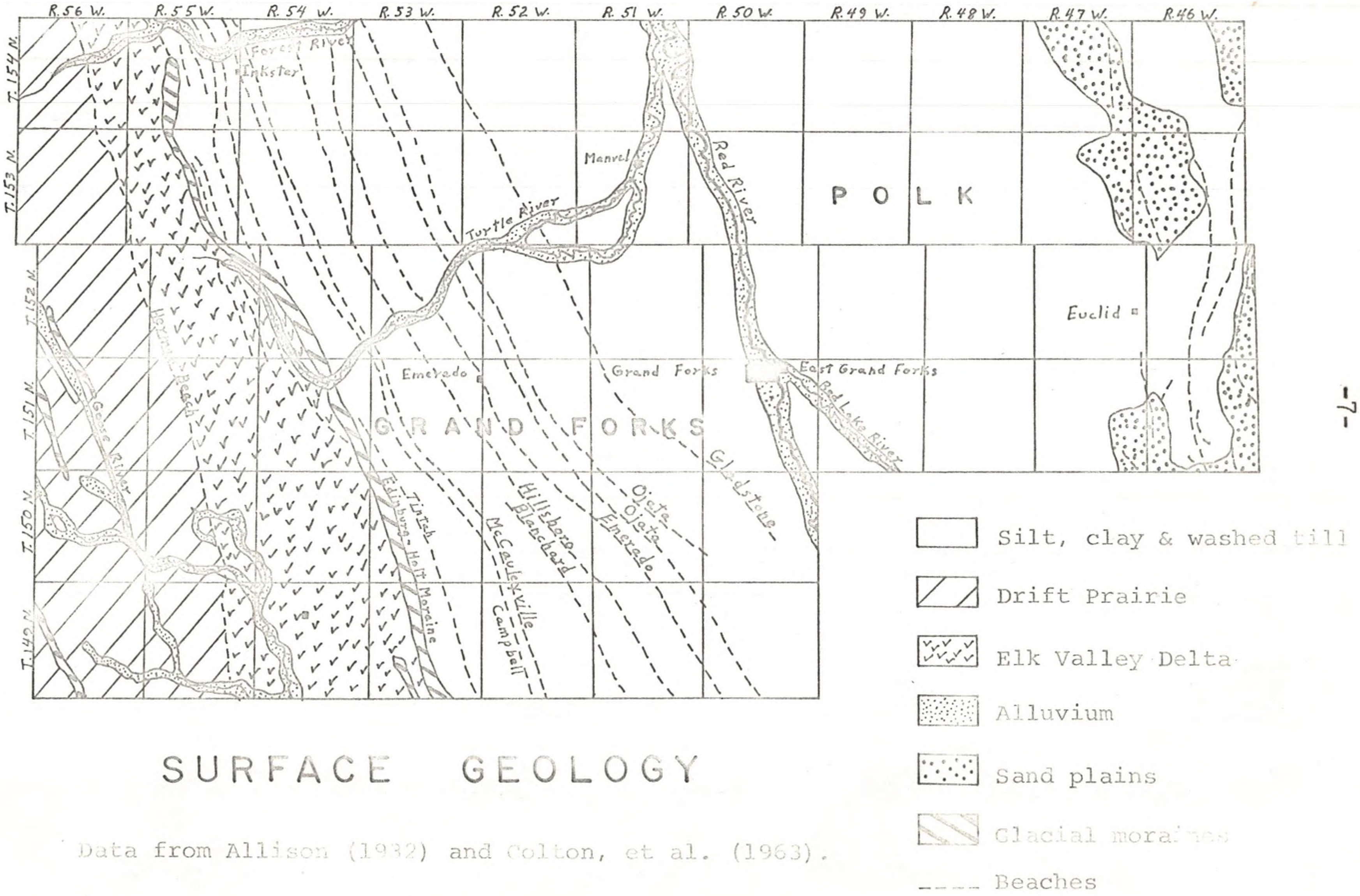
Located along both sides of the Valley are a number of beaches which were formed during different water levels of Lake Agassiz (Fig. 1). These beaches are low rounded ridges usually 300 to 400 feet in width, standing 10 to 30 feet above the surrounding land and with the steepest side in the direction of the old lake bed (Laird, 1944). The Herman beach is the highest and runs through the western part of the study area at an elevation of about 1150 feet. Other beach elevations in Grand Forks County are: Campbell, 1000 feet; McCauleyville, 980 feet; Blanchard, 960 feet; Hillsboro, 930 feet; Emerado, 900 feet; and Ojata, 870 feet. From the Ojata beach the land drops about 100 feet to the Red River which is 770 feet above sea level at the north boundary of the study area. Most of these beaches are east of the study area on the Minnesota side of the Valley. The beach ridges are not always continuous due to original irregular deposition (Laird, 1944). This is especially true on the eastern side of the Valley.

Associated with the beaches on both sides of the Valley are sand plains and areas of lake washed sandy till. The sand plains, which are nearly as flat as the silt and clay deposits, are quite extensive on the Minnesota side of the valley (Fig. 1). The areas of sandy till were formed from glacial till that had been reworked in the shallow offshore part of Lake Agassiz, leaving the till sandier with less clay present (Laird, 1944). This type of deposit covers a large part of the land area in the beach zone.

East of the Herman beach is a large deposit of fine sand and silt which is called the Elk Valley Delta. Opinions vary as to whether the Delta was formed from a glacial river (Upham, 1895) or from outwash in front of a moraine (Leverett, 1932). The rolling surface of the Delta lies about 30 feet above the old lake bottom at an elevation between 1050 and 1100 feet. Due to the sandy nature of the Delta, it "blows" badly when exposed to strong winds.

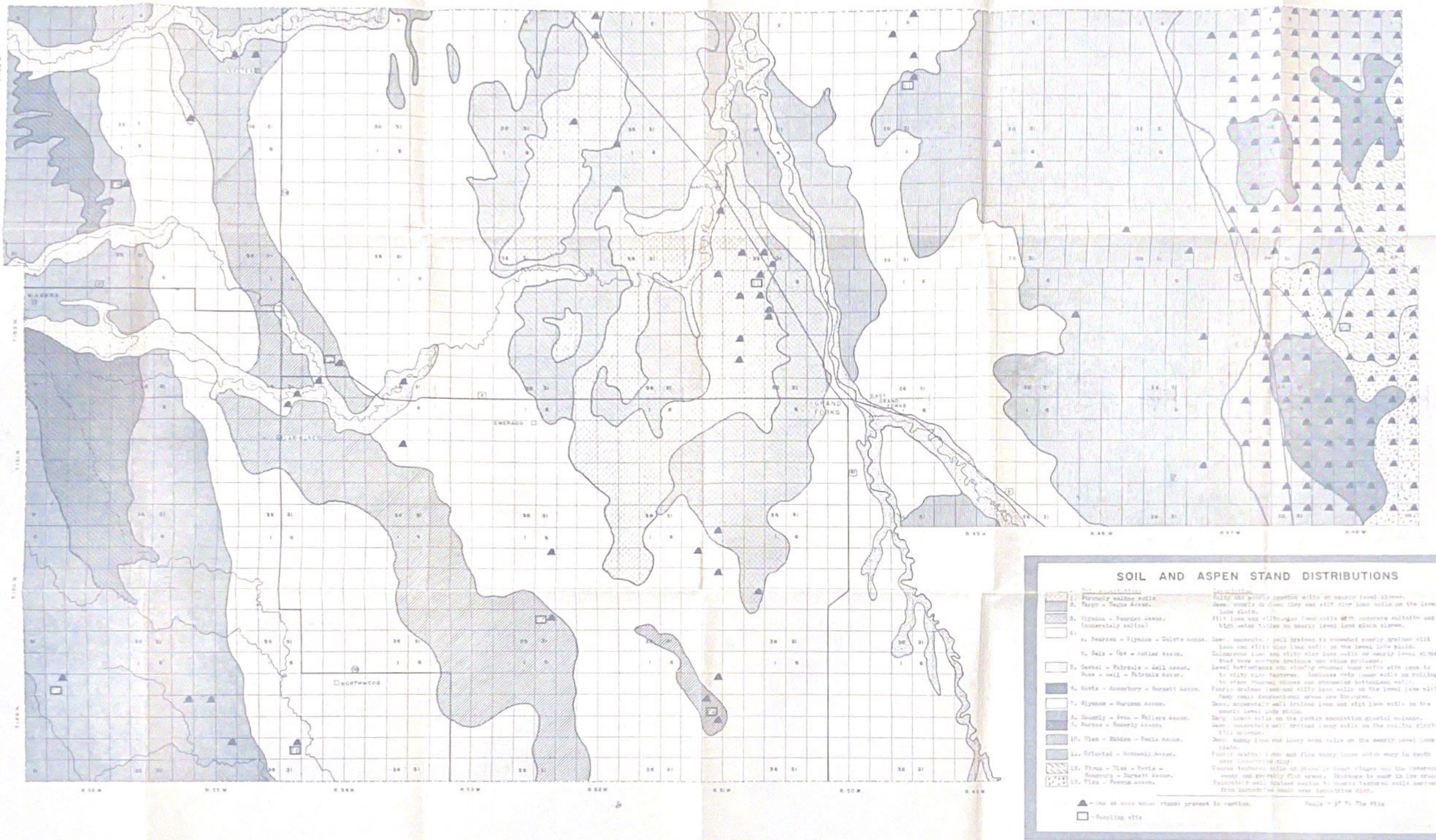
The Edinburg - Holt moraine runs along the east edge of the Elk Valley Delta. The most prominent part of this

Fig. 1



SURFACE GEOLOGY

Data from Allison (1932) and Colton, et al. (1963).


SOIL AND ASPEN STAND DISTRIBUTIONS
GRAND FORKS
EAST GRAND FORKS
EMERADO
- Sampling site

moraine is a ridge which runs through the study area at an elevation fluctuating around 1150 feet. This ridge was an island in Lake Agassiz (Upham, 1895).

Soils

Introduction

The study area was situated along the eastern edge of the Chernozem soil belt (Strahler, 1962). Six great soil groups are found within the study area according to the Soil Conservation Service, United States Department of Agriculture. These are, in order of decreasing drainage; the Regosol, Chernozem, Alluvial, Humic Gley, Solonchak, and Planosol. Descriptions of these groups were adapted from Larsen (1964) and the bulletin of the Experiment Station of the North Central Region (1960). The soil associations on the soil and aspen stand distributions map (in pocket) were taken from the general soil maps of Grand Forks County and Polk County which were obtained trhough the offices of the U.S. Soil Conservation Service at Grand Forks, North Dakota and Crookston, Minnesota. The western half of the map incorporates the modifications suggested by Kalin (1964).

Regosols:

The Regosols in the study area are in the Buse, Zell, Hecla, and Sioux series. These soils have developed on rolling topography where drainage is excessive and moisture conditions are very poor. According to Larsen (1964) the only morphologic changes in the parent material are: some removal of the more soluble salts; accumulation of a very small amount of organic matter in the A horizon; and a weak horizon of accumulated lime in some places. The Buse and Zell soils developed in glacial till and lacustrine silt respectively. The Hecla soils developed in sandy deposits from glacial melt water. The Sioux soils consist of a thin mantle of loam over gravel.

Chernozem:

The soil series in this great soil group are the Barnes, Gardena, Ops, Svea, and Embden. The soils in these series were formed under a dense vegetation of tall grass. In all the soils the A horizon is very dark and high in organic matter. Barnes soils developed in calcareous glacial till and are deep, dark, and well drained. Svea soils are similar to the Barnes soils except that they are not as well drained. The Gardena series consists of deep, dark soils that developed in silt and fine sand deposits from glacial melt water.

Alluvial Soils:

The Alluvial soils are represented by the Fairdale and Cashel series in the study area. They are found on recent deposits along streams and in the river bottoms. Generally, the soils in alluvium have only a thick, dark-colored A horizon, for other genetic horizons have not had sufficient time to develop. The Fairdale series consists of moderately well drained stratified silt loams and fine sands. The Cashel soils are silty clays that are calcareous at the surface and are found along the Red River.

Humic Gleys:

The Fargo series is the major representative of the Humic Gley soil group. This series developed under sedges and grasses in areas of poor drainage from a parent material of deep lacustrine clay. Many of these soils have a thick, dark A horizon over a limy C horizon; others are uniform in general appearance.

Solonchak:

The soil series in the calcareous Solonchak great soil group are the Bearden, Colvin, Glyndon, Hamerly, Hegne, Ulen, Vallers, Fossum, Rockwell, Antler, and Strongly Saline soils. In most places, the dark-colored A horizon is calcareous and is separated from a distinct calcareous C horizon by a clear lower boundary. This group, however, includes soils that are noncalcareous at the surface. Natural drainage ranges from moderately well drained to poorly drained. All the soils in this group have developed in deposits from glacial melt water except the Hamerly series which developed in glacial till. The Bearden and Colvin series were formed in silt loam or silty clay loam lacustrine sediments. The Glyndon and Hamerly soils developed in medium and fine textured lacustrine deposits. The Rockwell soils are loams and fine sandy loams which are about four feet in depth over lacustrine clay.

Planosols:

The only Planosols in the study area are in the Tetonka series. The Tetonka soils have a thick A horizon underlain by a B horizon that is more strongly cemented or compacted than the B horizon of normal soils. They develop in depressions in glacial till or on the glacial lake plains. These silty clay loam soils contain a large amount of freshly decomposed organic matter.

Climate

The following information regarding climate was taken from the U.S. Department of Commerce Weather Bureau (1961). The three weather stations were: Larimore in the western part of the study area; Grand Forks near the center; and Crookston which is located near the southeast corner of the study area. The climate is relatively constant throughout the study area. For example, the mean annual temperature is 39.9°F. at both Larimore and Crookston. The mean annual precipitation is 18.05 inches at Larimore, 20.12 inches at Grand Forks, and 21.34 inches at Crookston. About 65 percent of this precipitation falls in the months of May through September. The mean annual snowfall is approximately 30 inches.

The following data are from the University of North Dakota weather station at Grand Forks. The average dates of the last and first killing frosts are May 16 and September 25. This gives an average length of 132 days for the growing season. The mean monthly temperatures during the growing season are: May, 54.1°F; June, 64.0°F; July, 70.7°F; August, 68.2°F; and September, 57.4°F. The highest and lowest temperatures ever recorded were 109°F. and minus 44°F.

METHODS

Field work was done during the summer and fall of 1964. Aerial photographs of the study area were obtained from the Soil Conservation Service, U.S. Department of Agriculture (Grand Forks, North Dakota and Crookston, Minnesota). Potential sites for aspen were located from these photographs. All of these sites were subsequently visited by car and observations made of the aspen stands and the surrounding vegetation. The use of the aerial photographs, combined with reconnaisance, resulted in locating all the aspen stands in the study area except for a few stands in heavily wooded areas along rivers and streams which might have been overlooked. Only sites that had not experienced disturbance by cattle, cutting, or fire were used for sampling. In choosing sampling sites, consideration was also given to their distribution throughout the study area. Nine discrete stands were used as sampling sites in this study. The locations of these stands are given in Appendix I and have also been plotted on the accompanying soil and aspen stand distribution map.

At each site, sketch maps were made of each stand to show size, shape, and profile. Notes were taken on the topography, nearby sloughs, and drainage ditches to estimate the height of the water table at each site. Slope was recorded with a Brunten compass. Notes were also taken on ecotonal areas where the aspen stands came into contact with native prairie or other grassland. Observations were recorded on the invasion of prairie by young aspen, other woody species present in the young aspen areas, and the effect on the young aspen of grazing and fire.

Information on the flora of aspen communities was obtained by running a transect consisting of a series of one meter square plots through the stand. The criteria used in determining the direction of the transect were that the transect run perpendicular to the age gradient of the aspen and that the transect include as many of the old trees in the center of the stand as possible. Numbers of herbs were estimated by the use of a one to five abundance scale throughout the total area of the one meter square plots in the stand (Oosting, 1956). The classes used were:

1 - very rare

2 - rare

3 - infrequent

4 - abundant

5 - very abundant

In each one meter square plot, the species present, the number of each species, and the diameters for each species were recorded for all woody plants. A shrub with a number of stems was counted as one plant as long as the stems appeared to be by inspection from the same root system. The following quantitative characters were calculated for all the woody species in each stand:

$$\text{Frequency \%} = \frac{\text{No. of plots in which a species is present} \times 100}{\text{Total number of plots in the stand}}$$

$$\text{Density} = \frac{\text{No. of individuals of a species in the sample plots}}{\text{Number of sample plots in the stand}}$$

$$\text{Basal area} = \frac{\text{Total basal area of a species in the sample plots}}{\text{Number of sample plots in the stand}}$$

$$\text{\% Relative frequency} = \frac{\text{No. of plots in which a species is present} \times 100}{\text{The sum of the number of plots for each species}}$$

$$\text{\% Relative density} = \frac{\text{No. of individuals of a species in the stand} \times 100}{\text{Total no. of individuals of all species in the stand}}$$

$$\text{\% Relative dominance} = \frac{\text{Total basal area of a species} \times 100}{\text{Total basal area of all species in the stand}}$$

Importance value = Relative frequency + relative density + relative dominance

Age of the oldest trees in the stand was determined from increment cores which were obtained by the use of a Swedish increment borer. Cores were taken as close to ground level as possible (within one foot). A number of various methods have been used in preparing increment cores to make the rings stand out for counting (Diller 1935, Ghent 1952, Kirby 1935, Rose 1957, and Maini 1960). Age determination presented problems because of the presence of decayed wood in many of the increment cores which made it very difficult to count accurately the annual rings. There was also the problem of differentiating the annual rings from frost rings. The method used by Maini (1960) in which a free-hand section was cut with a razor blade and then viewed under a microscope was found to give the best results. Sections were cut after being soaked in water for ten minutes or longer, put between two glass slides, and viewed under a stereoscopic microscope (magnification X 130).

Diameter at breast height (d.b.h.) and height were determined for the apparent oldest trees in the stand. This was done for three to five trees in each stand. Diameter at breast height was measured with a diameter tape. Tree height was measured with a Brunten compass. The age and height of these dominant trees were used to estimate the site index which is the average annual increment in height. Other investigators used the site index of aspen as an indicator of the sum of all the environmental factors acting on a stand (Kittredge and Gevorkiantz 1929, Kittredge 1938, Maini 1960, Graham et al. 1963). Since site index can be a means of evaluating the productivity of a site, it was used in this study to compare the site quality of the different stands. Growth curves for aspen at different site indices have been prepared by Kittredge and Gevorkiantz (1929). The site index of each tree was determined by plotting the age and height on these growth curves.

Soil samples were taken from each stand at depths of one and two feet and the color and general texture of these samples were noted. Soil surveys (U.S. Soil Conservation Service) provided additional information on the soils of these stands. Soil samples were analyzed for water-retaining capacity following a modification used by Curtis (1956). The soil samples were pulverized with a mortar and pestel, the soil cups were filled with air-dried soil to a depth of one centimeter, and placed for 30 minutes in a tray containing a small amount of distilled water. The cup and soil were weighed on a triple-beam balance, then dried in a soil oven (105° centigrade for 72 hours). The cups were then weighed again. The formula used to calculate the per cent water-retaining capacity is:

$$\text{WRC} = \frac{\text{Total wet weight} - \text{total dry weight} \times 100}{\text{Total dry weight} - \text{weight of cup plus filter paper}}$$

Soil salinity was measured with a model TRB-A26G Soil Tester consisting of a Wheatstone Bridge circuit. Soil samples were prepared for testing by mixing them with water to the point of saturation. The water was then filtered from the soil by using a hand operated vacuum pump. Electrical conductivity of the soil filtrates was measured (millimhos per centimeter at 25 degrees centigrade) on the Wheatstone Bridge circuit.

Similarity coefficients were used to indicate the degree of similarity between the different stands on the basis of the quantitative characters obtained from the vegetative sampling of the woody species. This formula as given by Oosting (1956), Greig-Smith (1964), and Phillips (1959) is:

$$\text{Similarity coefficient between stands A and B} = \frac{\sum 2w_n}{\sum a_n + \sum b_n}$$

The symbols are defined as follows:

a_1 = Quantitative value of species 1 in stand A.

b_2 = Quantitative value of species 1 in stand B.

w_1 = Smallest value of species 1 in either stand.

Similarity coefficients were calculated among all stands on the basis of all seven of the different quantitative characters used in this investigation (frequency, relative frequency, density, relative density, basal area, relative dominance, and importance value). A total of 22 woody species were used in these calculations.

Coefficients of correlation were calculated between the quantitative characters of the seven most important woody species, stand characteristics, the growth rate of aspen, and environmental factors. Non-numerical characteristics were assigned numerical scores in the following manner.

Geology.--Silt, clay and washed till, 1; Drift Prairie, 2; alluvium, 3; and Elk Valley Delta and sand plains, 4.

Water table.--Less than five feet below the surface, 3; between five and ten feet below the surface, 2; and more than ten feet below the surface, 1.

Soil texture.--The particle size composition of the soil at each stand was taken from the U.S. Soil Conservation Service soil mapping units. The mean particle size for each stand was then calculated for each stand by using standard particle sizes as given in Oosting (1956).

Fig. 2. Typical "dome-shaped" aspen stand in the eastern part of the study area (Sec. 16, T. 152 N., R. 46 W.). Salix spp. bordering aspen; sedge-grass association in foreground. September, 1964.

Fig. 3. "Dome-shaped" aspen stand on low-lying prairie in the western part of the study area (Sec. 8, T. 149 N., R. 56 W.). Salix spp. bordering aspen stand. August, 1964.

Fig. 4. "Flat-topped" aspen stand on east-facing slope along edge of coulee. (Sec. 30, T. 150 N., R. 52 W.). Prairie in foreground. August, 1964.

Fig. 5. Invasion of grassland by aspen suckers. (Sec. 16, T. 149 N., R. 51 W.). Native prairie in foreground. July, 1964.

RESULTS

Stand Profiles and Invasion of Grassland by Aspen

The profiles or silhouette features of the aspen stands in the study area were of two general types: "dome-shaped" stands and "flat-topped" stands (Appendix I). All "flat-topped" aspen stands were even-aged stands which originated vegetatively after the destruction of the previous stand. "Dome-shaped" stands consisted of a small number of old trees in the middle, and the curvature represented an age gradient in the stand. This curvature indicated a rather constant increase in the area covered by the stand.

Stands GF 2, GF 4, GF 5, and GF 6 all had "dome-shaped" profiles. The invasion of grassland by aspen took place at GF 1 at a greater rate than at any of the other "dome-shaped" stands. Within the past five years, as determined by ring counts of saplings, young aspen suckers have appeared in the grassland around the stand. Their maximum distance from the old stand was 21 feet on the south, 35 feet on the east, and relatively a few feet on the west.

Stand GF 4 was located on the edge of a slough which prevented the movement of the stand on the north and east sides. Southward, invasion was prevented by mowing except for one indentation of prairie into the stand which a number of young aspen have invaded successfully.

Stand GF 5 was somewhat similar in that extension of its boundary was prohibited to the north and east by a slough. The aspen had extended to the west and south, giving the stand a one-sided "dome" effect. Stand GF 6 which had comparatively straight sides below the dome is probably typical of those stands surrounded by cultivated land.

All the "flat-topped" stands had one factor in common: the dominant trees within the stand were all of one age group, thus presenting a flat-topped silhouette. These stands had either slanted or straight sides depending on the state of the surrounding terrain: whether native or under cultivation. In the latter category were GF 2, GF 8, and P 1 with the surrounding land cultivated up to the edge of the stand on all sides. Stand GF 7 had some, although little, recent invasion of the grassland by aspen which was sufficient to give the stand a sloping-sided silhouette. Stand P 2 was surrounded by native grassland, with relatively little movement of aspen into the native prairie.

Vegetational Analysis

The results of the vegetational analysis of each of the nine stands is incorporated in Appendix II. Of the quantitative characters used in this analysis, the character of importance value is probably the most meaningful in terms of the importance of a species in a community. The mean importance value of each woody species in the nine sampling sites has been calculated (Table 1). The mean value of aspen (156) is over one half the sum of all the mean importance values (300). Mean importance values for other important species are: *Symphoricarpos occidentalis*, 30; *Cornus stolonifera*, 19; *Prunus virginiana*, 17; and *Rhus radicans*, 15.

When each of the nine stands was considered individually (Appendix II), aspen had the highest importance value in all cases. Of the species of shrubs, *Cornus stolonifera* had the highest value in three of the stands (GF 1, GF 4, and P 2) and *Symphoricarpos occidentalis* had the highest value in two of the stands (GF 5 and GF 7). *Prunus virginiana*, *Rhus radicans*, and *Parthenocissus inserta* each had the highest value in one of the stands (GF 2, P 1, and GF 6 respectively).

The frequency of each species also shows the relative importance of the various woody species (Table 2). Aspen was the only species which was found in all of the stands, while *Symphoricarpos occidentalis* was present in eight of the nine stands, and *Cornus stolonifera*, *Ribes americanum* and *Acer Negundo* in seven. *Prunus virginiana* and *Rosa blanda* were present in six of the nine stands.

A species list of the herbs present in each stand and an estimate of abundance of each species are presented in Appendix III. *Anemone canadensis*, *Fragaria* sp., *Galium boreale*, and *Smilacina stellata* were present in five of the nine stands. *Anemone canadensis* had a mean abundance value of 3.2 for the five stands in which it was found as compared to 2.8 for *Fragaria* sp., 2.0 for *Galium boreale*, and 1.2 for *Smilacina stellata*. *Poa palustris* and *Bromus inermis* were found in four of the stands while *Solidago gigantea*, *Viola*

Table 1. Mean Importance Values of Woody Species

Species	Mean Importance Value
Populus tremuloides Michx.	156
Symphoricarpos occidentalis Hook.	30
Cornus stolonifera Michx.	19
Prunus virginiana L.	17
Rhus radicans L.	15
Ribes americanum Mill.	9
Parthenocissus inserta (Derner) K. Fritsch	9
Rosa blanda Ait.	8
Acer Negundo L.	7
Rosa arkansana Porter	6
Salix petiolaris J. E. Smith	5
Salix cordata Michx.	4
Spiraea alba Du Roi	4
Populus deltoides Marsh.	3
Celastrus scandens L.	3
Symphoricarpos albus (L). Blake	3
Amelanchier alnifolia Nutt.	2
Salix discolor Muhl.	2
Viburnum trilobum Marsh.	2
Vitis vulpina L.	2
Populus balsamifera L.	1
Fraxinus pennsylvanica var. subintegerrima (Vahl.) Fern.	1

Table 2. Presence table of woody species

Species	P2	P1	GF1	GF4	GF7	GF2	GF6	GF8	GF5
Populus tremuloides	P	P	P	P	P	P	P	P	P
Symphoricarpos occidentalis	P	P	P	P	P	P	P		P
Cornus stolonifera	P	P	P	P	P	P	P		
Ribes americanum	P	P	P	P	P		P		P
Acer Negundo	P	P	P	P	P	P	P		
Prunus virginiana	P	P			P	P	P		P
Rosa blanda		P		P	P	P	P		P
Rhus radicans	P	P				P	P		
Populus balsamifera	P	P		P					P
Parthenocissus inserta	P	P					P		
Rosa arkansana			P	P					P
Salix cordata			P			P			
Salix discolor			P	P		P			
Salix petiolaris			P	P		P			
Amelanchier alnifolia	P	P					P		
Fraxinus pennsylvanica var. *subintegerrima*			P	P			P		
Celastrus scandens	P	P							
Populus deltoides	P					P			
Symphoricarpos albus					P		P		
Vitis vulpina		P					P		
Viburnum trilobum	P								
Spiraea alba				P					

papilionacea, Viola sororia, Thalictrum dasycarpus and Asclepias incarnata occurred in three of the stands.

Soil Water Retaining Capacity and Soil Salinity

The percent water retaining capacity of the soil and soil salinity for each of the nine sampling sites are presented in Table 3. Water retaining capacity at the one foot level ranged from 27.9 per cent at GF 7, to 57.9 per cent recorded at GF 1, and were all greater than 41 per cent except at GF 7 and GF 4. The two foot soil samples had slightly lower water retaining capacities and were less variable than the one foot samples. These samples ranged from 22.7 per cent at GF 4 to 44.5 per cent at GF 6, and were all greater than 34 per cent except for GF 4 and P 2.

One foot soil samples from each of the stands were tested for soil salinity. The conductivity of the samples from eight of the nine stands was below 2.7 millimhos per centimeter. Stand GF 4 had a somewhat higher value of 5.2 millimhos per centimeter.

One aspen stand was located on the edge of a highly saline zone (Sec. 33, T. 154 N., R. 52 W.). The boundary of the stand on the side facing the saline zone had been stable for approximately 20 years. A transect consisting of a number of one foot soil samples was run from the center of this stand into the saline zone. These samples were then tested for soil salinity and the results plotted on a graph (Fig. 6). A value of 1.60 millimhos per centimeter was obtained at the edge of the stand. The roots of the trees on the periphery

Table 3. Soil water retaining capacity and salinity

Stand	Soil Water Retaining Capacity (per cent)		Soil Salinity (millimhos per cent.)
	1 Foot	2 Feet	
GF 1	41.4	38.7	.92
GF 2	57.9	35.4	2.21
GF 4	33.9	22.7	5.20
GF 5	51.8	39.6	1.96
GF 6	49.6	44.6	2.67
GF 7	27.9	34.6	1.62
GF 8	41.7	36.4	1.36
P 1	41.5	40.3	1.18
P 2	47.3	26.1	2.02

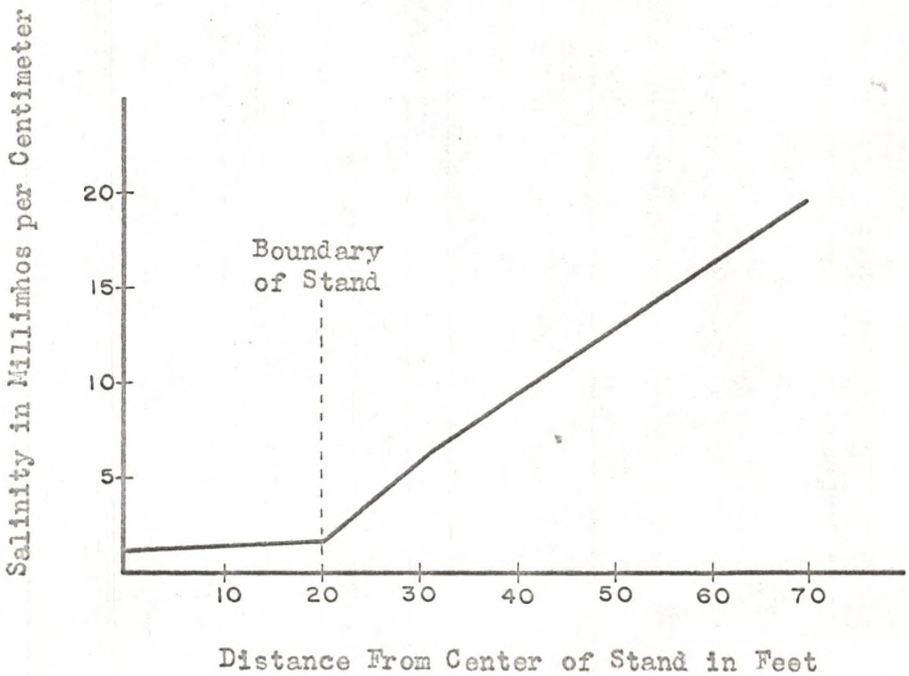


Fig. 6. Results of a soil salinity transect from an aspen stand which was located next to a highly saline zone (Sec. 33, T. 154 N., R. 52 W.).

of the stand probably extend some distance out into the surrounding grassland, exposing them to a higher salinity than was recorded at the edge of the stand.

Topography and Water Table

A brief description of the topography and water table at each site is given in Appendix I. Five of the nine stands (GF 2, GF 4, GF 5, GF 7, and P 2) were situated in areas of slightly rolling terrain. Stands located on almost flat topography were GF 1, GF 6, and P 1. The only stand located on rolling terrain was GF 8. The remaining eight stands were situated on the slopes or bottoms of depressions. Stands GF 4, GF 5, GF 6, GF 7, and GF 8 were located on the slopes of depressions, with the degree of slope varying from five to 15 degrees. Two of these stands were on north-facing slopes, two on south-facing slopes, and one on an east-facing slope. The water table was above the surface in four of these five depressions. The other four stands (GF 1, GF 2, P 1, and P 2) were situated in the bottoms of very slight depressions. At GF 1, and P 1 the water table was within ten feet of the surface throughout the summer, while in the other two stands it was not possible to measure the depth of the water table. At P 2 the soil was very moist at a depth of one foot even towards the end of the summer, which could be indicative of a permanently high water table.

The greatest concentration of stands in Grand Forks County occurred in the following three sections: Sec. 36, T. 153 N., R. 51 W.; Sec. 2, T. 152 N., R. 51 W.; and Sec. 11,

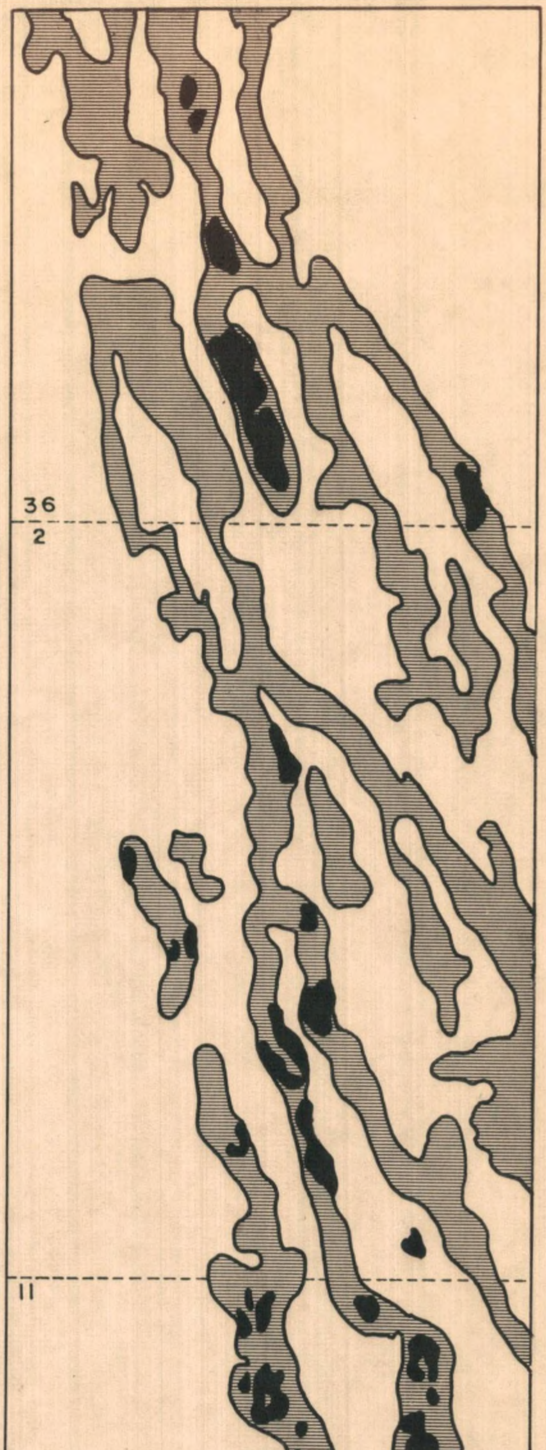
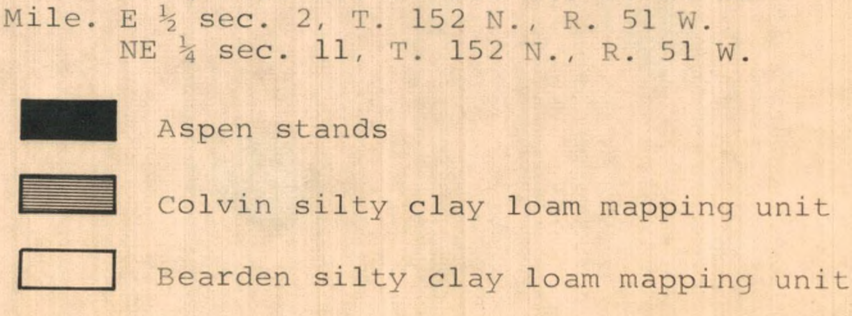


Fig. 7. SOIL AND ASPEN STAND DISTRIBUTIONS

Scale=4" to the Mile. SE ¼ sec. 36, T. 153 N., R. 51 W.
E ½ sec. 2, T. 152 N., R. 51 W.
NE ¼ sec. 11, T. 152 N., R. 51 W.



T. 152 N., R. 51 W. This area included GF 1 and approximately 20 other stands. A study of soil maps from the U.S. Conservation Service revealed that all of the stands in this area, with one exception, were located in long shallow depressions (Fig. 7). The soil in these depressions has been classified as Colvin silty clay loam, while the soil outside the depressions has been classified as Bearden silty clay loam. According to the U.S. Soil Conservation Service, there is no difference in texture between these two soil mapping units. These soils differ only in the amount of water present, being greater in the Colvin silty clay loam.

Growth Characteristics of Aspen

Height, diameter, age and site index of aspen

The mean values of height, diameter and age for three to five of the dominant trees in each stand are presented in Table 4. The stands are arranged according to their distance from the aspen parkland. The mean height of aspen varied from 49.5 feet at P 2 to 22.7 feet at GF 2. Six of the stands had means between 35.0 feet and 49.5 feet, while the other three stands had means between 22.7 feet and 28.0 feet. The latter three stands were 44 miles or more from the parkland and were situated on the Drift Prairie.

The mean age of the dominant trees varied from 19.0 years at GF 4 to 44.4 years at GF 6. Six of the stands had means between 33.8 and 44.4 years. Oldest trees recorded in this study were 51 years old at P 2 and 50 years at GF 6.

The mean site index of the dominant trees in each stand was obtained from the site index curves for aspen which were constructed by Kittredge and Gevorkiantz (1929) and based on an age of 50 years. The means varied from 30 at GF 2 to 67 at GF 4 (Table 4). The stands fell into two groups according to their site indices: four of the stands had means between 54 and 67; the other five stands had means between 30 and 39.

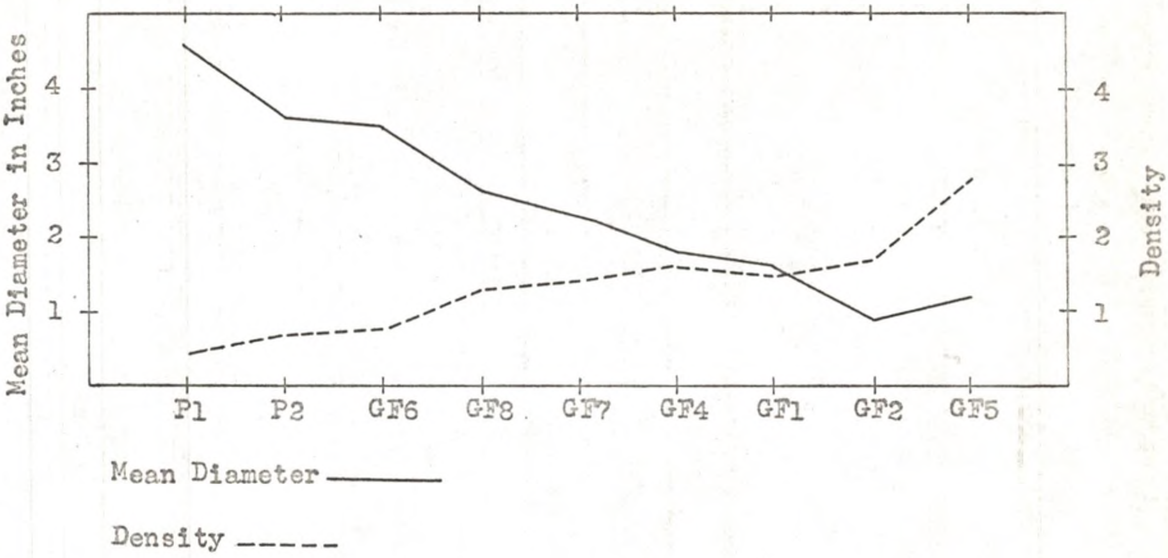
Frequency, density, and mean diameter of aspen

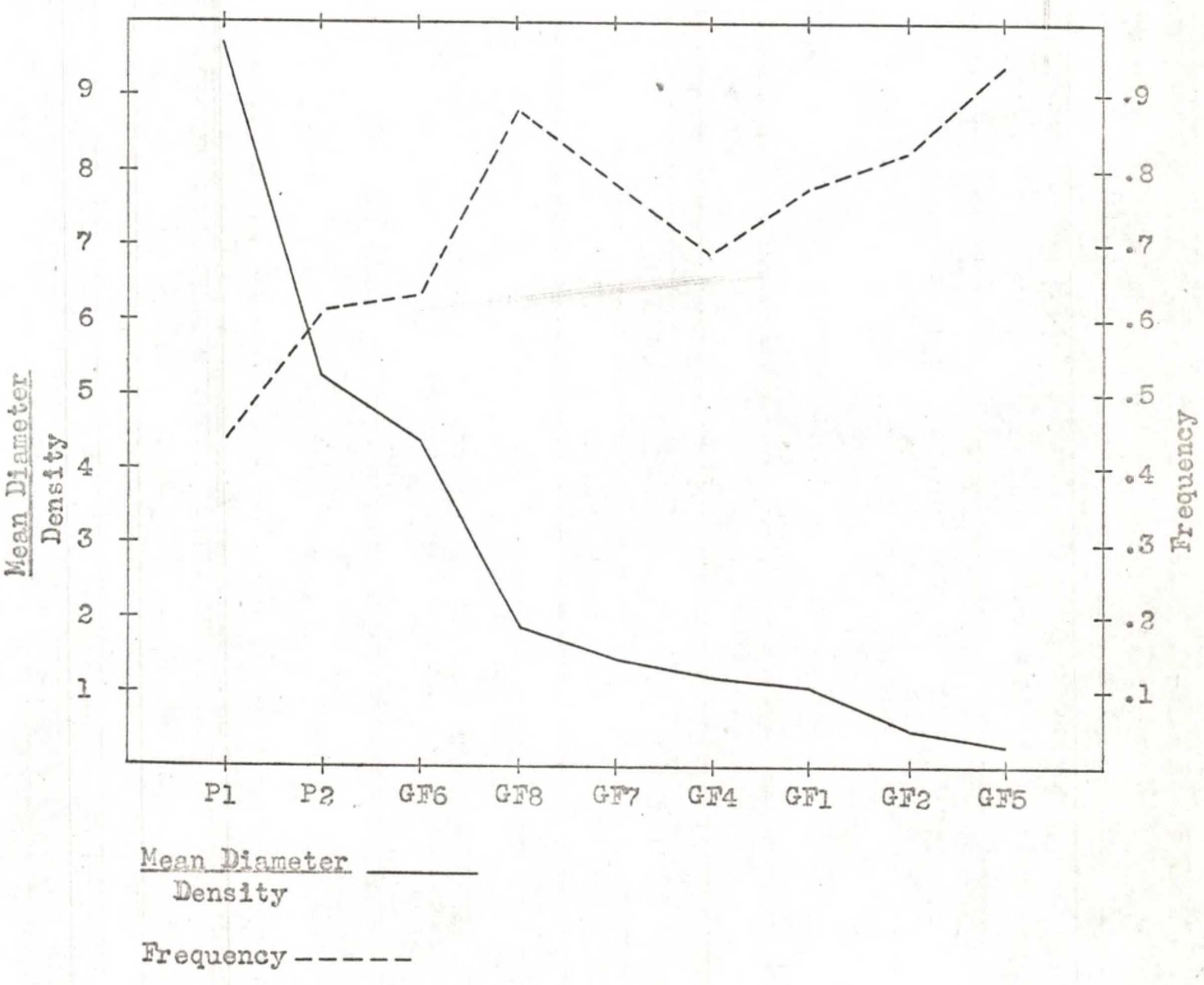
The frequency, density, and mean diameter of aspen were also used as indicators of site quality. These characteristics for the nine different stands are illustrated in Figure 8. In the upper graph, the stands are arranged in decreasing order of mean diameter of aspen, with P 1 having the highest value and GF 5 having the lowest value. As the mean diameter decreases, the density increases in all stands. Under normal conditions, it would be expected that a decrease in the size of the trees would be accompanied by an increase in number. A similar pattern is shown in the frequency curve of the lower graph, if one assumes that the aspen are randomly distributed throughout the area of the stand. The two curves in the upper graph have been combined by dividing the density of aspen in each stand into the mean diameter. This results in a steep curve (lower graph) with the stands being arranged in the same order as in the top graph. The stand with the highest value has the largest mean diameter and the smallest density of aspen while the stand with the lowest value has the smallest mean diameter and the largest density. The

Table 4. Mean height, diameter, age, and site index of dominant aspen

Stand	Height	Diameter	Age	Site Index
P 2	49.5 feet	9.0 inches	37.5 years	57
P 1	45.0 feet	10.1 inches	36.5 years	55
GF 1	43.4 feet	8.1 inches	33.8 years	54
GF 4	37.5 feet	7.2 inches	19.0 years	67
GF 7	35.0 feet	8.0 inches	42.0 years	39
GF 2	22.7 feet	6.1 inches	28.4 years	30
GF 6	35.0 feet	8.5 inches	44.4 years	37
GF 8	23.7 feet	5.6 inches	23.0 years	37
GF 5	28.0 feet	7.8 inches	37.7 years	33

Fig. 8. Frequency, density, and mean diameter relationships of aspen.





order of the stands according to their mean diameters and densities is quite different from the order of the stands arranged according to site index.

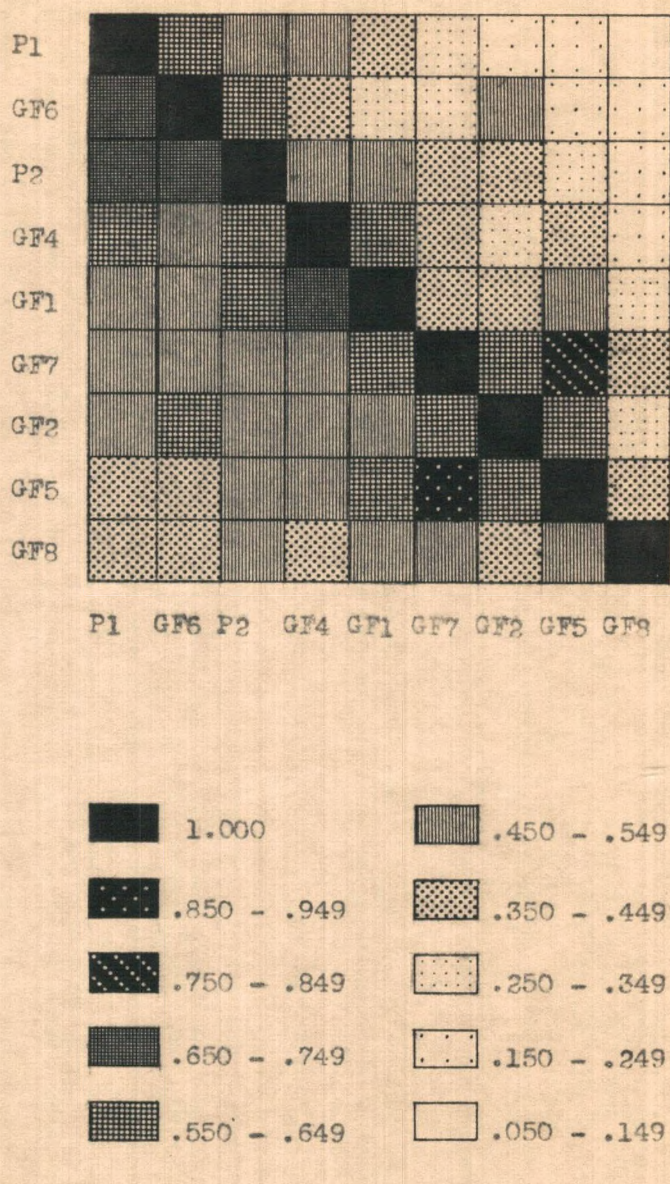
Statistical Analysis

Similarity coefficients were calculated among all stands on the basis of frequency, relative frequency, density, relative density, basal area, relative dominance, and importance value (Appendix 4). The coefficients based on frequency range from .703 between GF 5 and GF 7 to .177 between GF 8 and P 1. Most of the coefficients were between .300 and .600. Coefficients based on relative frequency, density, and relative density were slightly lower than the frequency coefficients while those based on importance value were slightly higher. Coefficients based on basal area and relative dominance were much higher than the coefficients based on any of the other quantitative characters.

Matrices of similarity coefficients based on frequency and importance values are illustrated in Figure 9. The stands have been arranged in the order of greatest similarity by considering all the similarity coefficients in the matrix. This was done by changing the order of the stands until the highest coefficients were next to the diagonal and the lowest were in the right angle corner of the matrix. The order of the stands is the same in both the frequency and the importance value matrices.

Fig. 9. MATRICES OF SIMILARITY COEFFICIENTS

Similarity coefficients above the diagonal calculated on the basis of species' frequencies; those below, on the basis of species' importance values.



The seven sets of similarity coefficients were compared to each other by means of correlation coefficients (Table 5). The correlation coefficients between the similarity coefficients based on frequency, relative frequency, density, relative density, and importance value were all significant at the 1% level. The similarity coefficients based on basal area and relative dominance did not correlate significantly with the similarity coefficients based on the other five quantitative characters, although they did correlate significantly with each other.

A total of 40 different measurements were used in the calculation of correlation coefficients between specific characters, stand characteristics, the growth rate of aspen, and environmental factors. This gives a total of 780 comparisons. A list of these measurements and the significant correlations between them are given in Appendix 5. The one per cent level of significance is .798 and the five per cent level is .666 for the coefficients.

Some of the more important significant correlations will be mentioned here. One of the growth characteristics of aspen, mean diameter, correlates with the following environmental factors: water table, soil texture, and soil salinity. Another growth characteristic of aspen, mean diameter divided by density, correlates with the same environmental factors as mean diameter and also with percent water retaining capacity at two feet (negative correlation).

A number of the environmental factors correlate with each other. Water table correlates with soil texture, soil

Table 5. Total Correlation Matrix

A comparison of similarity coefficients which were calculated on the basis of seven different quantitative characters.

Importance Value	1.000						
Relative Density	.947	1.000					
Relative Frequency	.938	.909	1.000				
Frequency	.870	.860	.933	1.000			
Density	.834	.862	.827	.898	1.000		
Relative Dominance	.198	.013	-.041	.026	.007	1.000	
Basal Area	.146	-.032	-.068	-.040	.017	.938	1.000
	Importance Value	Relative Density	Relative Frequency	Frequency	Density	Relative Dominance	Basal Area

salinity, and per cent water retaining capacity at two feet (negative correlation). Soil texture correlates with soil salinity and per cent water retaining capacity at two feet (negative correlation).

Quantitative characters of certain woody species correlate with each other. These correlations are: frequency of *P. tremuloides* with frequency of *Acer Negundo*; relative frequency of *Prunus virginiana* with relative frequency of *Acer Negundo*; relative frequency of *Prunus virginiana* with relative frequency *Rosa blanda*; and relative frequency of *Acer Negundo* with relative frequency of *Rosa blanda*.

DISCUSSION AND CONCLUSIONS

Vegetation

One of the objectives of this study was to describe the vegetation of the aspen stands in the Red River Valley by sampling nine individual stands throughout the study area. These stands were quite different in both species composition and numbers as can be ascertained by inspecting the sampling data (Appendix II). The number of species of woody plants present in each stand varied from one at GF 8 to 13 at stands GF 6, P 1, and P 2. Only one species, Populus tremuloides, was common to all the stands. Despite this variation, the stands were placed in the same abstract community because aspen, the one dominant species, was present in every stand. Aspen, the only species in the canopy, was responsible for 70 to 100 percent of the basal area in the different stands.

One possible explanation for the variation in species composition between the stands is that the stands were in different stages of development. According to Ewing (1924), who worked on the Minnesota parkland, many of the shrubs cannot invade areas which are covered with a thick mat of grass. These species could not move into the stand until aspen had formed a closed canopy and shaded out the grasses. Even after this had occurred, a long time may be required for the seeds of these shrubs to reach the stand, for the closest source may be a number of miles away.

If these stands were, in fact, in different stages of development, they should fall into some logical order according to the similarity coefficients between stands. This can best be shown by the matrices of similarity coefficients which were calculated on the basis of frequencies and importance values (Fig. 9). According to the matrices, the order of the stands is: GF 8, GF 5, GF 2, GF 7, GF 1, GF 4, P 2, GF 6, and P 1. The first stand, GF 8, had aspen as the only woody species present and the tree canopy was not dense enough to prohibit the growth of a thick mat of grass. Therefore, invasion of the shrub species had been restricted. The last three stands in the order (P 2, GF 6, and P 1) had a well developed shrub stratum consisting of *Symporicarpos occidentalis*, *Cornus stolonifera*, *Ribes americanum*, *Prunus virginiana*, *Rhus radicans*, *Rosa blanda*, and *Amelanchier alnifolia*. These three stands represent the most mature stage of development of the aspen community as it is found in the Red River Valley.

Balance Between Aspen and Grassland

The origin and persistence of grasslands and the causes of treelessness of the prairies have been controversial subjects for the past 60 years. Many factors have been suggested as being responsible for checking the invasion of grasslands by forests. These factors will now be considered in relation to the present investigation.

Variation in the precipitation pattern has been suggested as a factor responsible for the perpetuation of grasslands. The climate of grasslands is characterized by a limited precipitation and an annual period of drought. Drought, usually occurring in the summer, is sufficient to kill tree seedlings from the previous spring. Where trees have become established in moist habitats during wet years, they are usually killed during periods of drought. A series of dry years in grasslands may result in the death of already established stands of trees.

Many workers have recognized fire as an important factor in maintaining grassland. However, according to some, grassland climates favor fire, just as they favor grassland in the presence or absence of fires.

Various soil factors have been proposed as being responsible for checking the invasion of grasslands by forests. Deficient drainage and poor aeration tend to favor grassland over forests in areas of fine textured soil. In coarse textured soils, insufficient soil moisture is thought to limit the growth of tree species. Upland forest species have been considered to be less tolerant of carbon dioxide than are grasses. Decomposition of organic matter and respiration from the roots of grasses result in a relatively high concentration of carbon dioxide in most prairie soils. High concentrations of soluble salts has also been mentioned as a factor favoring prairie.

There is undoubtfully a complex of factors which determine the distribution of aspen stands on the prairie. The presence of a relatively small number of aspen stands in a prairie region such as the Red River Valley provides an ideal situation in which to evaluate the importance of these factors.

Under natural conditions the boundary of each stand is actually a small ecotone between the forest and prairie formations. Along these ecotones there is extreme competition between the two types of vegetation for occupancy of the land. According to the results of this study, the aspen stands which are in contact with grassland have been able not only to maintain their boundaries, but in most cases, to extend them at a slow rate, into the surrounding grassland. Since these stands apparently have been able to meet the competition from the surrounding prairie, the environment at these sites must be somewhat different from that of the adjacent land. Environmental differences between the aspen and prairie sites must be edaphic, since the area under study has a relatively uniform climate.

The problem of determining which edaphic factor or factors limit aspen to certain sites was attacked by attempting to relate the various edaphic factors to certain growth characteristics of aspen. If variation in growth characteristics of aspen is related to corresponding variations in certain edaphic factors, then these edaphic factors must restrict the growth of aspen over a certain part of their range.

One of the growth characteristics of aspen which was studied was site index (Table 4). An attempt to relate site index to any of the edaphic factors by standard statistical correlations failed possibly due to:

1. Some of the trees have grown under the protection of a canopy while others have not. This factor would be expected to have a marked effect on the heights of the various trees.

2. Some of the trees were much older than others and extremes in the precipitation pattern of the last 50 years could have affected some trees more than others.

3. Trees which follow the destruction of a stand by fire grow upon already established root systems and therefore, regardless of site, increase in height at a rapid rate.

Other growth characteristics of aspen studied were frequency, density, and mean diameter (Fig. 8). A combination of mean diameter and density (mean diameter divided by density) correlated significantly with four of the edaphic factors (Appendix V). These correlations indicate that the mean diameter divided by density increases in linear proportion to an increase in the height of the water table, soil particle size, and soil salinity. Also, as the water retaining capacity of the soil at two feet decreases, the mean diameter divided by density increases. According to these correlations, the best sites for aspen in the Red River Valley are apparently on the coarser sandy and loamy soils with a high water table, while the poorer sites are on the finer silt and clay soils with a somewhat lower water table. To make this conclusion, one must assume that the stands with the largest mean diameters and the highest densities are growing on the poorer sites. According to Graham et al.

(1963) aspen deteriorate at a younger age on poor sites than they do on the good sites. Deterioration is brought about by a loss of vigor followed by disease and attack by insects. Death of these dominant trees opens holes in the canopy which makes room for a number of young trees within the stand. The overall effect is that the stands on the poorer sites are composed of a large number of small trees, while on the better sites, the trees are larger and, therefore, less dense.

High soil salinity is an obvious limiting factor to aspen stands in some sectors of the Red River Valley. According to Richards et al. (1956), soil salinity values below four millimhos per centimeter affect only very sensitive plants, while values between four and eight millimhos per centimeter affect many plants. Most of the stands were growing in soils of low salinity (below 2.7 millimhos per centimeter) indicating a preference for sites of low to moderate salinity. Only one site was located where an aspen stand was growing next to a highly saline zone (Sec. 33, T. 154 N., R. 52 W.). At this site the high salinity had apparently limited the movement of aspen in the direction of the saline zone (Fig. 6).

An attempt has been made to evaluate the interactions of edaphic factors. Significant correlations were obtained between the following three factors: the height of the water table; the soil particle size; and the per cent water retaining capacity of the soil at two feet (Appendix V). According to these correlations, soil texture and soil moisture, as indicated by the height of the water table, must be in proper proportions for the growth of aspen in the Red River Valley. On the sandy and loamy soils, soil moisture is insufficient to support aspen in most cases. On the finer silt and clay soils, the soil moisture may be either too high or too low for the growth of aspen. The distribution of the aspen stands in the vicinity of GF 1 is an example of the factors of soil moisture and soil texture interacting to limit the stands to certain sites (Fig. 7). In this particular area the soil texture is constant and the distribution of the stands is apparently controlled by soil moisture.

The information obtained from this investigation helps to explain the present position of the western boundary of the aspen parkland in the study area. This boundary, which stands out very distinctly on the accompanying soil and aspen stand distributions map, lies just inside the western boundary of the Grimstad - Rockwell soil association. The soils in this association are moist loams and fine sandy loams, with the water table held near the surface by underlying deposits of lacustrine clay. According to the results of this study, these conditions would provide a large number of good sites for aspen stands. The soils just to the west of the aspen parkland are fine textured silts and clays which are poorly drained. These conditions are apparently better suited for prairie and, therefore, aspen cannot compete successfully in this area except in a very few sites.

There are probably a number of potential aspen sites in the Red River Valley which do not support aspen because invasion has been unsuccessful. According to Ewing (1924) aspen cannot successfully invade prairie on the heavier soils because they cannot compete with the dense mat of grasses which would be present on these soils under natural conditions. Even after young aspens have been able to gain a foothold at one of these potential sites, they could very easily be killed by prairie fires or drought while in the seedling or sapling stages.

SUMMARY

Nine aspen stands, isolated from the transitional aspen parkland by prairie, were studied in the North Dakota and Minnesota Red River Valley. The objectives were to describe their vegetation and to investigate the aspen-grassland interrelationships.

The results of this study indicate that the aspen stands are in various stages of succession. There is a gradual change from prairie species to forest species as the aspen develop a closed canopy. Important shrubs in the most mature stands include *Symphoricarpos occidentalis*, *Cornus stolonifera*, *Ribes americanum*, *Prunus virginiana*, *Rhus radicans*, *Rosa blanda*, and *Amelanchier alnifolia*. The most important herbaceous species are *Anemone canadensis*, *Fragaria* sp., *Galium boreale*, and *Smilacina stellata*.

Statistical analysis of the growth characteristics of aspen and selected edaphic factors reveal that the growth characteristic of mean diameter divided by density correlates with the edaphic factors of soil particle size and the height of the water table. Hence, soil texture and soil moisture, as indicated by the height of the water table, must be in proper proportions for the growth of aspen in the Red River Valley. The most favorable sites for aspen in the Valley would seem to be on the sandy and loamy soils which have a

high water table. In most cases, aspen is unable to compete with the native grasses on the finer silt and clay soils.

Thus, it appears as if the western boundary of the aspen parkland in the study area is controlled by the height of the water table and soil texture. This boundary lies just inside the western boundary of a moist loam and sandy loam soil association which provides a large number of good sites for aspen. The soils to the west of the parkland are fine textured silts and clays which are apparently better suited for prairie.

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APPENDIX I

Descriptions of Individual Stands

The following criteria were used to describe all aspen stands used as sampling sites.

Stand identification.--Sampling sites in Grand Forks County were designated by the letters GF and followed by a number. Those in Polk County were designated by the letter P. The location of all sampling sites can be found on the accompanying soil and aspen stand distributions map.

Outline map of stand.--The outline map shows the shape and size of each stand.

Distance from aspen parkland.--This measurement is the distance west of the western boundary of the aspen parkland.

Direction of transect.--This is the direction of the transect used in sampling the vegetation.

Length of transect.--This measurement is equivalent to the number of square meters which were sampled in the stand since the transects were one meter wide.

Height of tallest tree in stand.--This measurement is only an approximation for the two stands in Polk County because both of these stands cover a large area and it is possible that the tallest tree was not measured.

Age of oldest tree in stand.--This measurement is also an approximation for the two stands in Polk County because age was not determined for all of the large trees.

Profile.--The profiles or silhouette features of the aspen stands in the study area are of two general types: "dome-shaped" stands and "flat-topped" stands.

Surface geology.--The distribution of drift types in the study area are shown in Figure L.

Soil.--Information about the soil at each stand was obtained from the U.S. Soil Conservation Service's soil survey maps. The following soil mapping units were encountered at one or more of the sampling sites.

1. Tetonka silt loam mapping unit.--This unit comprises somewhat poorly drained to poorly drained soils of the northern Chernozem zone. They have developed in glacial till of alluvium and occupy flat bottomed, shallow depressions in the glacial upland and also have been noted in very shallow depressions on the Lake Agassiz Plain where the lacustrine sediments are shallow over glacial till.
2. Tegner silty clay mapping unit.--This unit comprises the poorly and very poorly drained, fine textured soils of the northern Chernozem zone. They have developed on the bottoms of quite deep depressions on the Lake Agassiz Plain. Unless drainage has been established the land is wet until late in the summer.
3. Colvin silty clay loam mapping unit.--This unit comprises poorly drained calcium carbonate solonchak

soils developed in medium and moderately fine textured glacio-lacustrine sediments on the Lake Agassiz Plain. They occur on the bottom of shallow depressions and also on the slopes rising out of these depressions. Many times the mapping unit is located on the bottoms of long depressions in a low ridge-depression type of topography.

4. Gardena loam, silt loam, or very fine sandy loam, nearly level mapping unit.--This unit comprises moderately well drained Chernozem soils developed in medium textured glacio-fluvial materials deposited in old glacial Lake Agassiz. This very productive soil covers much of the Elk Valley Delta.

5. Fargo silty clay loam mapping unit.--This unit comprises poorly drained Chernozem soils developed in stone free calcareous lacustrine clays deposited in old glacial Lake Agassiz. They occur on the flat lake plain and, unless drainage has been established, the land is wet until late in the summer.

6. Rockwell fine sandy loam mapping unit.--This unit comprises poorly drained Solonchak soils developed in sandy and gravelly sediments deposited in old glacial Lake Agassiz. They occur in flat or depressed areas between the gravelly beach ridges.

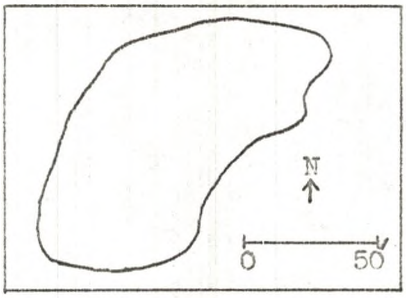
<u>Perimeter of stand</u>.--Under this criterion, the vegetation around the stand and the recent movement of aspen outside the old boundary of the stand have been described.

Other stands in area.--The distance to the closest stand or stands is given here.

Topography and water table.--The measurement of the depth of the water table is only an estimate because the proper equipment for making an accurate measurement was not available. Estimates for most of the stands were made from the water lines in nearby sloughs or drainage ditches.

Stand identification . . . . .GF 1

Outline map of stand.



Location . . . . .Sec. 2, T. 152 N., R. 51 W.

Distance from aspen parkland . . . .22 miles

Direction of transect. . . . . . . .N. 37°E.

Length of transect . . . . .41 meters

Height of tallest tree . . . . . . .45 feet

Age of oldest tree . . . . .40 years

Profile. . . . ."Dome-shaped"

Surface geology. . . . . .Silt, clay and washed till

Soil . . . . .Colvin silty clay loam

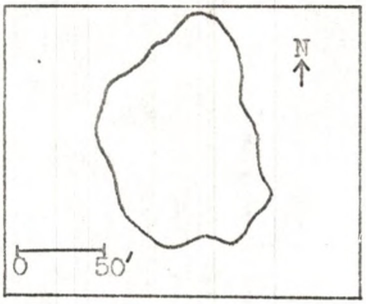
Perimeter of stand.--The land around this stand has been in domestic grassland for the last five years. In this time, young aspen have moved out into the grassland 21 feet on the south side of the stand and 35 feet on the east side. There has been no movement of aspen outside of the old boundary of the stand on the north side and relatively few feet on the west side were occupied by invading aspen.

Other stands in area.--There are approximately 20 stands within a 1 mile radius.

Topography and water table.--This stand is located in a slight depression on the very flat lake plain. Drainage ditches indicate that the water table is within ten feet of the surface.

Stand identification . . . . .GF 2

Outline map of stand.



Location . . . . .Sec. 28, T. 152 N., R. 54 W.

Distance from aspen parkland . . .44 miles

Direction of transect. . . . . . . $N. 69^{o}E.$

Length of transect . . . . .29 meters

Height of tallest tree . . . . . . .26 feet

Age of oldest tree . . . . .31 years

Profile. . . . ."Flat-topped"

Surface geology. . . . . .Alluvium

Soil . . . . .Gardena Loam, silt loam and very fine sandy loam.

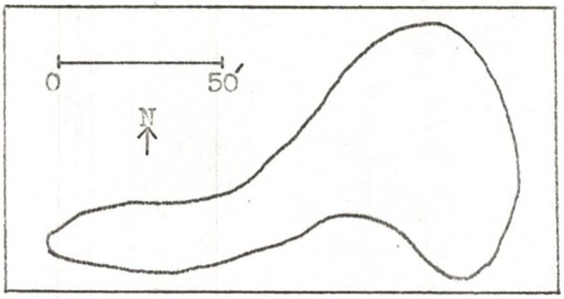
Perimeter of stand.--The surrounding land has been cultivated up to the edge of the stand.

Other stands in area.--The closest stand is located 1½ miles to the southwest.

Topography and water table.--This stand is located in a shallow depression on slightly rolling topography. There were no nearby sloughs or drainage ditches to use in estimating the water table.

Stand identification . . . . .GF 4

Outline map of stand.



Location . . . . .Sec. 16, T. 149 N., R. 51 W.

Distance from aspen parkland . . .27 miles

Direction of transect. . . . . . . .N. 29°W.

Length of transect . . . . .26 meters

Height of tallest tree . . . . . . .41 feet

Age of oldest tree . . . . .19 years

Profile. . . . ."Dome-shaped"

Surface geology. . . . . .Silt, clay and washed till

Soil . . . . .Tetonka silt loam

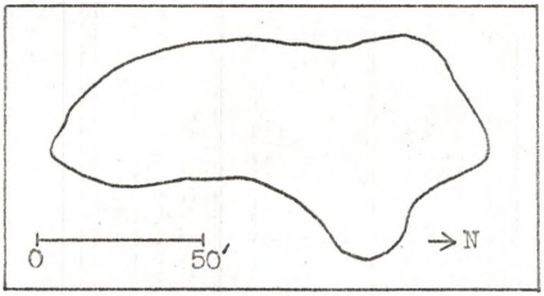
Perimeter of stand.--The grass on the south side of the stand has been cut each year except for a small indentation which has a number of young aspen on it. The north and east side of this stand is bounded by a slough.

Other stands in area.--There are ten stands within a mile radius, all of which are located around wet depressions.

Topography and water table.--This stand is located on a five degree north-facing slope. The topography around the stand is slightly rolling with a number of long, shallow depressions. The water table is about three feet below the surface in the lowest part of the stand.

Stand identification . . . . .GF 5

Outline map of stand.



Location . . . . .Sec. 8, T. 149 N., R. 56 W.

Distance from aspen parkland . . . .57 miles

Direction of transect. . . . . . . .N. 35°E.

Length of transect . . . . .34 meters

Height of tallest tree . . . . . . .29 feet

Age of oldest tree . . . . .43 years

Profile. . . . ."Dome-shaped"

Surface geology. . . . . .Drift prairie

Soil . . . . .Tetonka silt loam

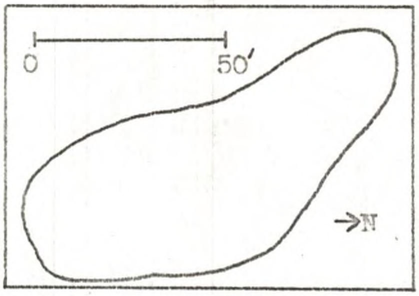
Perimeter of stand.--This stand is limited on the north and east sides by a slough. There has been continuous movement to the west and south, resulting in a "dome-shaped" profile in these direction.

Other stands in area.--There is a small stand approximately 400 feet to the southeast which is located on the other side of the slough. The next nearest stand is located six miles to the east.

Topography and water table.--This stand is located on a five degree east-facing slope. The topography of this area is slightly rolling. The east edge of the stand is within seven feet of the water line of the slough.

Stand designation. . . . . .GF 6

Outline map of stand.



Location . . . . .Sec. 30, T. 149 N., R. 54 W.

Distance from aspen parkland . . .46 miles

Direction of transect. . . . . . . .N. 70°E.

Length of transect . . . . .28 meters

Height of tallest tree . . . . . . .37 feet

Age of oldest tree . . . . .50 years

Profile. . . . ."Dome-shaped" top with straight sides.

Surface geology. . . . . .Elk Valley Delta

Soil . . . . .Gardena loam, silt loam, or very fine sandy loam.

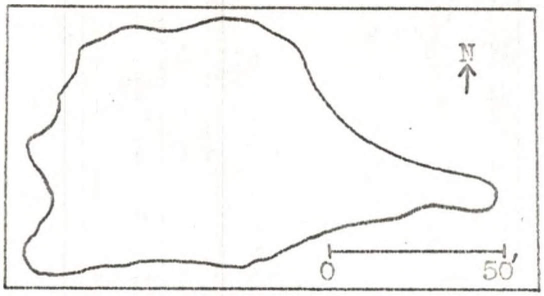
Perimeter of stand.--The land to the north and west of the stand is cultivated, while that to the south and east is domestic grassland. There are no young aspen outside the boundary of the old trees.

Other stands in area.--The closest stand is located three miles to the west.

Topography and water table.--This stand is located on the south-facing bank of a gully with a slope of ten degrees. The topography of this area is almost flat except for the Goose River valley which is about one half mile to the east of the stand.

Stand identification . . . . .GF 7

Outline map of stand.



Location . . . . .Sec. 30, T. 150 N., R. 52 W.

Distance from aspen parkland . . .35 miles

Direction of transect. . . . . . . .N. 30°W.

Length of transect . . . . .28 meters

Height of tallest tree . . . . . . .38 feet

Age of oldest tree . . . . .42 years

Profile. . . . ."Flat-topped" with sloping margins.

Surface geology. . . . . .Silt, clay and washed till

Soil . . . . .Tegner silty clay

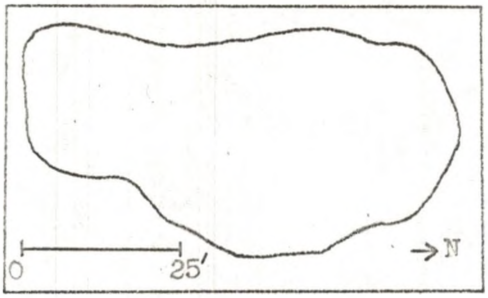
Perimeter of stand.--This stand is surrounded by native grassland on the north and west, cultivated land on the south, and a coulee on the east. There has been very little recent invasion of the grassland by young aspen.

Other stands in area.--The nearest stand is located three miles to the north.

Topography and water table--This stand is located on 15 degree slope which faces north 35 degrees east. The east edge of the stand is within a foot of the normal water line of the coulee, while the west edge is approximately 20 feet above the water line. The topography of this area is slightly rolling.

Stand identification . . . . .GF 8

Outline map of stand.



Location . . . . .Sec. 13, T. 153 N., R. 56 W.

Distance from aspen parkland . . .52 miles

Direction of transect. . . . . . . .N. 25°E.

Length of transect . . . . .28 meters

Height of tallest tree . . . . . . .26 feet

Age of oldest tree . . . . .24 years

Profile. . . . ."Flat-topped"

Surface geology. . . . . .Drift prairie

Soil . . . . .Tetonka silt loam

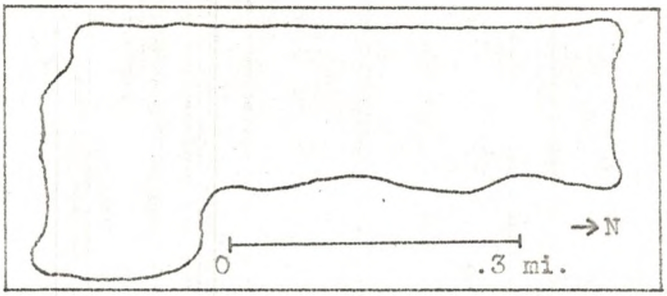
Perimeter of stand.--The land is cultivated up to the edge of the stand.

Other stands in area.--The nearest stand is located four miles to the northeast.

Topography and water table.--This stand is located in a shallow depression next to a slough. The stand is approximately six feet above the water line of the slough. The topography of this area is made up of a number of ridges and depressions.

Stand identification . . . . .P 1

Outline map of stand.



Location . . . . .Sec. 19, T. 154 N., R. 49 W.

Distance from aspen parkland . . .14 miles

Direction of transect. . . . . . .N. 52°E.

Length of transect . . . . .46 meters

Height of tallest tree . . . . . .46 feet

Age of oldest tree . . . . .49 years

Profile. . . . ."Flat-topped"

Surface geology. . . . . .Silt, clay and washed till

Soil . . . . .Fargo silty clay loam

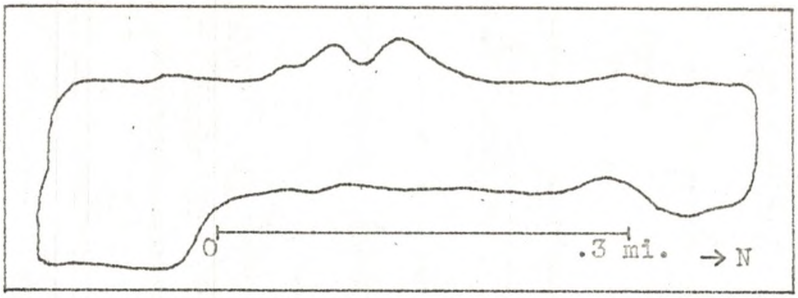
Perimeter of stand.--This stand is completely surrounded by cultivated land.

Other stands in area.--There is another large stand located one half mile to the north.

Topography and water table.--This stand is located in a slight depression on the very flat lake plain. Drainage ditches around the section indicate that the water table is approximately 7 feet below the surface.

Stand identification . . . . .P 2

Outline map of stand.



Location . . . . .Sec. 16, T. 152 N., R. 46 W.

Distance from aspen parkland . . .This stand is within the parkland

Direction of transect. . . . . . . .N. 5°W.

Length of transect . . . . .41 meters

Height of tallest tree . . . . . . .56 feet

Age of oldest tree . . . . .51 years

Profile. . . . ."Flat-topped"

Surface geology. . . . . .Sand plains

Soil . . . . .Rockwell fine sandy loam

Perimeter of stand.--This stand is surrounded by native grassland. There has been some movement of young aspen outside the boundary of the old trees.

Other stands in area.--Approximately one fifth of the land in this area is covered with aspen.

Topography and water table.--The water table under the stand is probably quite high. Many of the other shallow depressions in this area have small sloughs in them.

APPENDIX II

Vegetational Analysis of Woody Species

The absolute values of density, frequency, and basal area were used in the characterization of the woody species in these stands. The preceding quantitative characters are dependent on the size of the quadrat, but are completely independent of the other species in the community. All three of these values must be used to give an adequate characterization of a particular species in the community. Density is an expression of actual numbers of a species in a community. Since it is an average value, it tells nothing about the distribution of the species in the stand. The value used to express distribution is frequency which is the percentage of sample plots in which a species occurs. Although density and frequency indicate numbers and distribution, they do not indicate the area covered by a species. In this study, basal area was used as an expression of the space occupied by a species.

The values of relative density, relative frequency, and relative dominance have been calculated from the absolute values. The relative values for a species are dependent on the absolute values of that species as well as on the absolute values of all the other species in the stand. For this reason, the relative values were used in comparing the stands with each other. Since these values are expressed as percentages, they can be added to give a total value which is called the importance value. The quantitative characters which have been discussed here have been calculated for all woody species in the sampled stands and are presented in this appendix. The nomenclature used in naming the plants in this study follows Fernald (1950).

	Frequency Per Cent	Density	Basal Area	Relative Frequency	Relative Density	Relative Dominance	Importance Value
Stand GF 1							
Populus tremuloides	76	1.54	8.90	32.3	33.1	91.8	157.2
Cornus stolonifera	51	1.07	.34	21.9	23.2	3.4	48.5
Ribes americanum	32	.81	.05	13.5	17.4	.5	31.4
Rosa arkansana	27	.61	.03	11.5	13.2	.3	25.0
Salix cordata	20	.20	.11	8.3	4.2	1.2	13.7
Salix petiolaris	9	.20	.14	4.1	4.2	1.5	9.8
Salix discolor	7	.07	.13	3.1	1.6	1.3	6.0
Acer Negundo	7	.09	.01	3.1	2.1	.0	5.2
Symphoricarpos occidentalis	2	.02	.00	1.0	.5	.0	1.5
Fraxinus pennsylvanica var. *subintegerrima*	2	.02	.00	1.0	.5	.0	1.5
Total	233	4.63	9.70				
Stand GF 2							
Populus tremuloides	82	1.68	3.71	28.0	19.9	70.1	118.0
Prunus virginiana	68	3.54	.72	23.2	41.9	13.2	78.3
Symphoricarpos occidentalis	82	1.93	.13	28.0	22.9	2.4	53.3
Rosa blanda	25	.72	.14	8.5	8.5	2.6	19.6
Salix cordata	18	.21	.42	6.1	2.5	7.8	16.4
Acer Negundo	7	.07	.04	2.4	.8	.7	3.9
Salix discolor	4	.03	.12	1.2	.4	2.2	3.8
Salix petiolaris	4	.03	.04	1.2	.4	.7	2.3
Rhus radicans	4	.21	.01	1.2	.4	.0	1.6
Total	294	8.44	5.34				

Cornus stolonifera - present in stand

	Frequency Per Cent	Density	Basal Area	Relative Frequency	Relative Density	Relative Dominance	Importance Value
Stand GF 4							
Populus tremuloides	69	1.69	10.38	19.4	24.7	89.4	133.5
Cornus stolonifera	69	1.08	.55	19.4	15.7	4.8	39.9
Salix petiolaris	46	.96	.37	12.9	14.1	3.2	30.2
Rosa blanda	42	1.12	.12	11.8	16.3	1.0	29.1
Spiraea alba	42	.89	.06	11.8	12.9	.5	25.2
Ribes americanum	23	.34	.03	6.5	4.5	.3	11.3
Rosa arkansana	19	.25	.02	5.4	3.9	.1	9.4
Salix discolor	15	.19	.06	4.3	2.9	.5	7.7
Acer Negundo	15	.12	.01	4.3	1.7	.0	6.0
Symphoricarpos occidentalis	8	.18	.00	2.2	1.1	.0	3.3
Populus balsamifera	4	.12	.00	1.1	1.7	.0	2.8
Fraxinus pennsylvanica var. subintegerrima	4	.04	.02	1.1	.6	.1	1.8
Total	356	6.86	11.61				

	Frequency Per Cent	Density	Basal Area	Relative Frequency	Relative Density	Relative Dominance	Importance Value
Stand GF 5							
Populus tremuloides	94	2.94	8.65	35.9	28.1	95.9	159.9
Symphoricarpos occidentalis	94	6.69	.30	35.9	62.2	3.5	101.6
Rosa arkansana	35	.53	.03	13.5	5.1	.3	18.9
Ribes americanum	15	.26	.02	5.6	2.3	.2	8.1
Salix cordata	9	.09	.01	3.4	.7	.0	4.1
Rosa blanda	6	.06	.00	2.2	.5	.0	2.7
Prunus virginiana	3	.03	.00	1.1	.3	.0	1.4
Populus balsamifera	3	.03	.00	1.1	.3	.0	1.4
Populus deltoides	3	.03	.00	1.1	.3	.0	1.4
Total	262	10.66	9.01				
Stand GF 7							
Populus tremuloides	78	1.47	12.68	39.1	28.7	98.5	166.3
Symphoricarpos occidentalis	69	2.97	.14	34.4	57.8	1.2	93.4
Acer Negundo	28	.38	.03	14.1	7.3	.3	21.7
Ribes americanum	9	.09	.01	4.7	1.8	.0	6.5
Rosa blanda	6	.06	.00	3.2	1.2	.0	4.4
Prunus virginiana	3	.09	.00	1.6	1.8	.0	3.4
Cornus stolonifera	3	.03	.00	1.6	.8	.0	2.2
Symphoricarpos albus	3	.03	.00	1.6	.6	.0	2.2
Total	199	5.12	12.86				

	Frequency Per Cent	Density	Basal Area	Relative Frequency	Relative Density	Relative Dominance	Importance Value
Stand GF 6							
Populus tremuloides	64	.79	12.21	17.3	10.1	95.8	123.2
Parthenocissus inserta	86	1.96	.11	23.1	25.2	.9	49.2
Prunus virginiana	72	1.86	.18	20.2	24.8	1.4	46.4
Rhus radicans	36	1.29	.06	9.6	16.5	.5	26.6
Cornus stolonifera	43	.75	.11	11.5	9.6	.9	22.0
Amelanchier alnifolia	25	.54	.05	6.7	6.9	.4	14.0
Symphoricarpos occidentalis	14	.64	.02	3.9	3.7	.1	7.7
Acer Negundo	11	.11	.00	2.9	1.4	.0	4.3
Rosa blanda	4	.04	.00	1.0	.4	.0	1.4
Ribes americanum	4	.04	.00	1.0	.4	.0	1.4
Symphoricarpos albus	4	.04	.00	1.0	.4	.0	1.4
Vitis vulpina	4	.04	.00	1.0	.4	.0	1.4
Fraxinus pennsylvanica var. *subintegerrima*	4	.04	.00	1.0	.4	.0	1.4
Total	371	8.11	12.74				

	Frequency Per Cent	Density	Basal Area	Relative Frequency	Relative Density	Relative Dominance	Importance Value
Stand GF 8							
Populus tremuloides	89	1.43	12.60	100.0	100.0	100.0	300.0
Stand P 1							
Populus tremuloides	44	.48	13.73	10.7	6.6	94.0	111.3
Rhus radicans	100	2.90	.43	24.6	40.3	2.9	67.8
Parthenocissus inserta	72	1.17	.05	17.7	16.2	.4	34.3
Cornus stolonifera	50	.67	.17	12.3	9.6	1.2	23.1
Vitis vulpina	41	.50	.02	10.2	6.9	.2	17.3
Ribes americanum	33	.56	.06	8.0	7.8	.4	16.2
Rosa blanda	24	.33	.02	5.9	4.5	.1	10.5
Acer Negundo	17	.22	.08	4.3	3.0	.5	7.8
Prunus virginiana	13	.20	.02	3.2	3.0	.2	6.1
Symphoricarpos occidentalis	4	.06	.01	1.1	.9	.0	2.0
Populus balsamifera	4	.04	.02	1.1	.6	.1	1.8
Celastrus scandens	2	.04	.00	.5	.6	.0	1.1
Amelanchier alnifolia	2	.02	.00	.5	.3	.0	.8
Total	407	7.22	14.62				

	Frequency Per Cent	Density	Basal Area	Relative Frequency	Relative Density	Relative Dominance	Importance Value
Stand P 2							
Populus tremuloides	61	.71	11.86	21.0	19.3	94.2	134.5
Cornus stolonifera	51	.68	.15	17.7	18.7	1.2	37.6
Rhus radicans	51	.71	.03	17.7	19.3	.3	37.6
Celastrus scandens	29	.39	.02	10.1	16.7	.2	27.0
Prunus virginiana	29	.36	.19	10.1	10.0	1.5	21.6
Viburnum trilobum	17	.22	.29	5.9	6.2	2.2	14.4
Acer Negundo	15	.20	.02	5.0	5.3	.2	10.5
Ribes americanum	10	.10	.01	3.4	2.7	.1	6.2
Amelanchier alnifolia	10	.10	.02	3.4	2.7	.1	6.2
Symphoricarpos occidentalis	7	.10	.01	2.5	2.7	.0	5.2
Populus balsamifera	5	.05	.00	1.7	1.3	.0	3.0
Crataegus sp.	2	.02	.00	.8	.7	.0	1.5
Populus deltoides	2	.02	.00	.8	.7	.0	1.5
Total	289	3.66	12.60				

Rubus strigosa - present in stand
Parthenocissus inserta present in stand

APPENDIX III

Vegetational Analysis of Herbs

Numbers of herbs were estimated by the use of a one to five abundance scale throughout the total area of the one meter square plots in each stand. The herbs present in each transect and their relative abundance are presented in this appendix. The nomenclature used in naming the plants follows Fernald (1950).

	Abundance
Stand GF 1	
Anemone canadensis L.	5
Solidago gigantea Ait.	4
Stachys palustris L.	2
Fragaria sp.	1
Poa compressa L.	1
Lathyrus palustris L.	1
Galium boreale L.	1
Stand GF 2	
Urtica procera Muhl.	4
Anemone canadensis L.	2
Smilacina stellata (L.) Desf.	2
Convolvulus sepium L.	2
Oxalis stricta L.	1
Convolvulus arvensis L.	1
Stand GF 4	
Anemone canadensis L.	3
Galium boreale L.	3
Stachys palustris L.	3
Solidago altissima L.	2
Poa palustris L.	2
Viola papilionacea Pursh.	2
Lycopus americanus Muhl.	1
Andropogon furcatus Muhl.	1
Smilacina stellata (L.) Desf.	1
Lathyrus palustris L.	1
Stand GF 5	
Anemone canadensis L.	4
Fragaria sp.	4
Bromus inermis Leyss.	4
Spartina pectinata Link.	4
Poa palustris L.	3
Viola papilionacea Pursh.	3
Galium boreale L.	3
Thalictrum dasycarpum Fisch. & Lall.	2
Teucrium occidentale Gray.	2
Mentha arvensis L.	1
Asclepias incarnata L.	1
Monarda fistulosa L.	1
Solidago mollis Bartl.	1

	Abundance
Stand GF 6	
Bromus inermis Leyss.	3
Setaria viridis L.	2
Thalictrum dasycarpum Fisch. & Lall.	1
Melilotus officinalis (L.) Lam.	1
Poa palustris L.	1
Urtica procera Muhl.	1
Fragaria sp.	1
Stand GF 7	
Thalictrum dasycarpum Fisch. & Lall.	4
Bromus inermis Leyss.	3
Anemone canadensis L.	2
Setaria viridis L.	2
Berteroa incana (L). DC.	2
Viola sororia Willd.	1
Viola papilionacea Pursh.	1
Galium boreale L.	1
Smilacina stellata (L.) Desf.	1
Asclepias incarnata L.	1
Aralia nudicaulis L.	1
Stand GF 8	
Andropogon furcatus Muhl.	5
Bromus inermis Leyss.	4
Spartina pectinata Link.	4
Stand P 1	
Fragaria sp.	4
Galium triflorum Michx.	3
Physostegia parviflora Nutt.	2
Poa palustris L.	2
Asclepias incarnata L.	1
Teucrium occidentale Gray	1
Solidago gigantea Ait.	1
Bidens frondosa L.	1
Smilacina stellata (L.) Desf.	1
Viola sororia Willd.	1

	Abundance
Stand P 2	
Fragaria sp.	4
Galium boreale L.	3
Elymus villosus Muhl.	1
Cicuta maculata L.	1
Smilax herbacea L.	1
Smilacina stellata (L.) Desf.	1
Viola papilionacea Pursh.	1
Solidago gigantea Ait.	1

APPENDIX IV

Similarity coefficients calculated among all sampled stands on the basis of frequency, relative frequency, density, relative density, basal area, relative dominance, and importance value.

Key to the table.

1.--Frequency.

2.--Relative frequency.

3.--Density.

4.--Relative density.

5.--Basal area.

6.--Relative dominance.

7.--Importance value.

Stands	1	2	3	4	5	6	7
F 1, F 2	.421	.399	.291	.245	.534	.733	.477
F 1, F 4	.642	.630	.645	.573	.891	.947	.726
F 1, F 5	.521	.538	.354	.316	.927	.923	.633
F 1, F 6	.404	.347	.270	.224	.803	.927	.509
F 1, F 7	.449	.427	.352	.337	.790	.923	.575
F 1, F 8	.472	.323	.472	.331	.798	.918	.524
F 1, P 1	.422	.351	.314	.250	.750	.934	.524
F 1, P 2	.502	.462	.388	.433	.813	.931	.617
F 2, F 4	.360	.349	.342	.389	.465	.723	.503
F 2, F 5	.655	.627	.397	.443	.537	.725	.598
F 2, F 6	.484	.460	.436	.402	.433	.716	.594
F 2, F 7	.661	.632	.535	.466	.427	.716	.610
F 2, F 8	.428	.280	.290	.199	.414	.701	.393
F 2, P 1	.274	.245	.172	.159	.382	.709	.451
F 2, P 2	.370	.372	.241	.338	.441	.718	.501
F 4, F 5	.388	.359	.271	.328	.843	.897	.528
F 4, F 6	.380	.369	.244	.234	.862	.903	.523
F 4, F 7	.382	.354	.308	.311	.850	.894	.520
F 4, F 8	.310	.194	.345	.247	.857	.894	.445
F 4, P 1	.430	.467	2.93	.284	.807	.910	.553
F 4, P 2	.459	.481	.329	.418	.868	.907	.631
F 5, F 6	.281	.243	.163	.149	.797	.959	.450
F 5, F 7	.703	.783	.586	.885	.805	.971	.880
F 5, F 8	.507	.359	.237	.281	.801	.959	.533
F 5, P 1	.224	.242	.103	.109	.734	.942	.423
F 5, P 2	.305	.299	.138	.256	.802	.943	.500

	1	2	3	4	5	6	7
F 6, F 7	.372	.303	.265	.188	.963	.959	.483
F 6, F 8	.278	.173	.141	.101	.964	.958	.411
F 6, P 1	.614	.616	.539	.554	.913	.960	.705
F 6, P 2	.609	.583	.575	.536	.966	.969	.702
F 7, F 8	.542	.391	.436	.287	.990	.985	.554
F 7, P 1	.284	.272	.169	.159	.927	.943	.459
F 7, P 2	.402	.351	.276	.309	.935	.944	.540
F 8, P 1	.177	.107	.111	.066	.926	.940	.371
F 8, P 2	.323	.210	.278	.193	.941	.942	.448
P 1, P 2	.555	.543	.457	.457	.891	.969	.655

APPENDIX V

Measurements of species characters, stand characteristics, the growth rate of aspen, and environmental factors which were used in the calculation of correlation coefficients.

1. Frequency of P. tremuloides.
2. Relative frequency of P. tremuloides.
3. Importance value of P. tremuloides.
4. Frequency of Cornus stolonifera.
5. Relative frequency of Cornus stolonifera.
6. Importance value of Cornus stolonifera.
7. Frequency of Ribes americanum.
8. Relative frequency of Ribes americanum.
9. Importance value of Ribes americanum.
10. Frequency of Prunus virginiana.
11. Relative frequency of Prunus virginiana.
12. Importance value of Prunus virginiana.
13. Frequency of Acer Negundo.
14. Relative frequency of Acer Negundo.
15. Importance value of Acer Negundo.
16. Frequency of Symphoricarpos occidentalis.
17. Relative frequency of Symphoricarpos occidentalis.
18. Importance value of Symphoricarpos occidentalis.
19. Frequency of Rosa blanda.
20. Relative frequency of Rosa blanda.

21. Importance value of *Rosa blanda*.

22. Density of *P. tremuloides*.

23. Basal area of *P. tremuloides*.

24. Mean diameter of *P. tremuloides*.

25. Mean diameter of *P. tremuloides* divided by density of *P. tremuloides*.

26. Oldest tree in stand in years.

27. Site index of *P. tremuloides*.

28. Number of woody species in stand.

29. Tallest tree in stand in feet.

30. Total density of shrubs in stand.

31. Total basal area of shrubs in stand.

32. Total density of stand.

33. Total basal area of stand.

34. Geology.

35. Distance from parkland in miles.

36. Water table.

37. Soil texture.

38. Salinity.

39. Per cent water retaining capacity of the soil at a depth of one foot.

40. Per cent water retaining capacity of the soil at a depth of two feet.

CORRELATIONS BETWEEN ASPEN AND ENVIRONMENTAL FACTORS

	Correlation Coefficient
Frequency of aspen with water table.	-.782
Frequency of aspen with soil texture	-.776
Frequency of aspen with soil salinity.	-.781
Frequency of aspen with WRC[1] of soil at 2 feet	.744
Mean diameter of aspen with water table.	.742
Mean diameter of aspen with soil texture	.744
Mean diameter of aspen with soil salinity.	.719
Mean diameter of aspen with WRC of soil at 2 feet. . .	-.631
$\frac{\text{Mean diameter of aspen}}{\text{Density of aspen}}$ with water table.	.840
$\frac{\text{Mean diameter of aspen}}{\text{Density of aspen}}$ with soil texture	.845
$\frac{\text{Mean diameter of aspen}}{\text{Density of aspen}}$ with soil salinity.	.814
$\frac{\text{Mean diameter of aspen}}{\text{Density of aspen}}$ with WRC of soil at 2 feet. . .	-.729
$\frac{\text{Mean diameter of aspen}}{\text{Density of aspen}}$ with frequency of aspen	-.809
$\frac{\text{Mean diameter of aspen}}{\text{Density of aspen}}$ with mean diameter of aspen . . .	.848

[1]Water retaining capacity.

CORRELATIONS BETWEEN ENVIRONMENTAL FACTORS

	Correlation Coefficient
Water table with soil texture	.883
Water table with soil salinity	.856
Soil texture with soil salinity	.858
Percent water retaining capacity at 2 feet with water table	-.823
Percent water retaining capacity at 2 feet with soil texture	-.811
Percent water retaining capacity at 2 feet with soil salinity	-.853

SPECIES CORRELATIONS

	Correlation Coefficient
Frequency of *Populus tremuloides* with frequency of *Acer Negundo*	-.796
Relative frequency of *Prunus virginiana* with relative frequency of *Acer Negundo*	.756
Relative frequency of *Prunus virginiana* with relative frequency of *Rosa blanda*	.742
Relative frequency of *Acer Negundo* with relative frequency of *Rosa blanda*	.786

ADDITIONAL CORRELATIONS

	Correlation Coefficient
Relative frequency of *Prunus virginiana* with density of *P. tremuloides*	.782
Relative frequency of *Prunus virginiana* with site index of *P. tremuloides*.	-.730
Frequency of *Acer Negundo* with density of *P. tremuloides*.	.856
Relative frequency of *Acer Negundo* with density of *P. tremuloides*.	.849
Relative frequency of *Rosa blanda* with density of *P. tremuloides*.	.796
Density of *P. tremuloides* with tallest tree in stand.	-.771
Basal area of *P. tremuloides* with total basal area of stand.	.825
Site index of *P. tremuloides* with tallest tree in stand.	.811
Number of woody species in stand with total density of shrubs.	.710
Distance from parkland with water table. . . .	-.719