Aspen Encroachment in Central Alberta: An Air Photo/GIS Derived Assessment

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Abstract

Two areas in the aspen parkland/northern fescue grassland natural subregion transition zone of Alberta were investigated for quantifying the magnitude and character of aspen encroachment. Aerial photography spanning almost 50 years was compiled, digitized and analysed for 3 sections of land in the Rumsey area and 1 section in the Hand Hills area. The analysis included the conversion of the aerial photographs to binary images that were combined to determine both quantitative and visual extent of the aspen encroachment. Further analysis included precipitation and topographic associations with aspen expansion to investigate these variables as controlling factors. Aspen clones showed a 3 to 9 times increase in area in the Rumsey and Hand Hills sections, with brush occupying between 14.6 % and 21.2% in the Rumsey sections, and 4.3% in the Hand Hills section. The Hand Hills aspen expansion rate and mean annual precipitation were highly correlated, with rates increasing during periods with mean precipitation of 450 mm or greater. A digital terrain model comparison was used to investigate brush expansion rate differences in two of the Rumsey sections. Favorable sites for aspen expansion were derived and added to the binary image maps. Favorable sites at the northern site with the lower expansion rate were found to be 76.5% occupied by brush while only 47.9% of the sites in the southern section with the higher expansion rate were occupied by brush. Observational evidence related to suppression of aspen expansion by grazing and to aspen clone senescence and succession is briefly discussed.

Introduction

The Aspen Parkland natural region of Alberta is an ecotonal zone between the boreal forest biome to the north and the grassland biome to the south. The southern area of this zone is characterized by a dynamic spatial tension between the native climax vegetation types of aspen woodlands (*populus tremuloides* Michx.) and fescue grasslands (*festuca hallii* (Vasey) Piper) (Bird 1961). Although the majority of the fescue grassland is now under cultivation (Strong 1977), there are some small areas that have been preserved whereby some rendition of the pre-settlement ecology can be observed. The Rumsey natural area/ecological reserve and the Hand Hills ecological reserve provide one of the few places in the parkland-grassland transition zone to observe the dynamics of native vegetational change .

Aspen encroachment on the Canadian prairies has been noted by a number of authors (Maini 1960, Nelson and England 1971, Bailey and Wroe 1974, Strong 1977, Bailey *et al.* 1980, Fitzgerald and Bailey 1984, Bailey and Anderson 1990). In most of these studies, the encroachment phenomena is treated as a adverse effect resulting from the suppression of fire and impinging on the productivity of grazing lands. Some reports, however, recognize the biodiversity inherent with the aspen woodlands (Legris and Cornish 1997, Alberta Environmental Protection 1997) and is observed in Hand Hills by Wallis (1990) as productive habitat for the variety of nesting birds; an example of the so-called edge effect phenomena (Odum 1983).

The purpose of this study is to investigate the extent of aspen expansion in the Rumsey and Hand Hills areas. The work is essentially an update of the original investigation done by Bailey and Wroe (1974) in Rumsey; however, the methodology presented here is based on image/GIS data sources and differs significantly from the previous approach.

Study Area

The Rumsey natural area and ecological reserve is located at about 51° 59'N, 112° 50'W straddling the Aspen Central Parkland and Northern Fescue Grassland Natural Subregions of Alberta (Achuff 1994, Fig. 1). The area is characterized by post-glacial hummocky morainal deposits giving a moderate-to-strongly rolling topographic impression. The vegetational patterns are closely associated with the topographic character of the landscape, with brush and wetland communities generally occupying the morainal troughs and north facing slopes, while the grass communities generally occupying the morainal crests and south facing slopes. Three sections (2.59 km^2 each) generally representative of the approximately 2 townships covering the area were investigated. One of the three sections analysed is situated just outside the natural area and reserve boundaries and is privately owned.

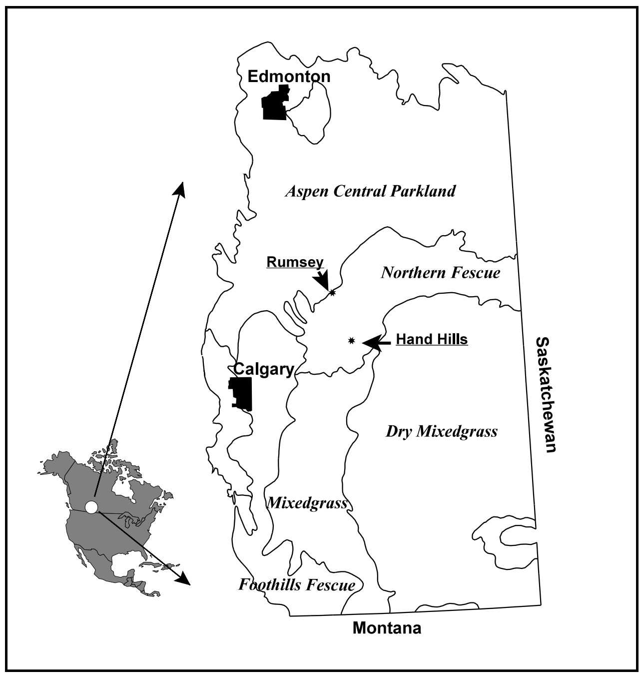


Figure1. The grasssland biome in Alberta depicted with natural subregions and study locations.

The Hand Hills ecological reserve is located at about 51° 28' N, 112° 30'W and is found wholly within the Northern Fescue Grassland Natural Subregion (Achuff 1994, figure 1). The ecological reserve is situated on a remnant plateau resulting from continental glaciation and rises approximately 200 m above the surrounding plain. The grassland communities dominate the landscape with shrublands occurring in shallow swales and ephemeral drainage channels (Legris and Cornish 1997). The encroaching aspen is found in the northeast section of the area (section 25) and is included in the area analysis. The Rumsey and Hand Hills areas are approximately 40-

50 km apart.

Materials and Methods

All historical aerial photography was identified and collected for the two study areas. The earliest air photos dated from 1950, the most current imagery was obtained in 1998. This provided a span of 48 years for investigating the spatial dynamics of brush encroachment in the two locales. Table 1 outlines the years and scales in which aerial photography was flown. The different years of photography provided a periodic indication of the extent of brush expansion from 1950 to 1998.

Table1. Air photo acquisition year, location and scale. All aerial photography was black and white.

Year of photo	Location	Scale
1950	Hand Hills	1:40 000
1963	Hand Hills	1:31 680
1967	Hand Hills	1:31 680
1974	Hand Hills	1:31 680
1986	Hand Hills	1:30 000
1993	Hand Hills	1:30 000
1996	Hand Hills	1:40 000
1950	Rumsey	1:40 000
1982	Rumsey	1:30 000
1998	Rumsey	1:30 000

The air photos were scanned to simulate a ground resolution of 1.7 m. The scanning resolution varied depending on the scale of the original aerial photography, generally 42 µm (600dpi) was used for 1:40 000 and 56 µm (450dpi) was used for1:30 000. The scanned images were then geo-referenced and rectified using ARCINFO software (Environmental Systems Research Institute 1997). Because all the images were black-and-white, a spectral classification of brush and grass pixels was not possible. A textural classification based on homogeneity using PCI software (PCI Geomatics 1997) was attempted to separate the two vegetation classes. A general aggregation of brush and grass areas was derived, however, there was some confusion by the classifier in recognizing these two types. The classification procedure was supplemented with a grey-level threshholding technique (Lillesand and Kiefer 1994) in combination with digital gamma enhancements of the aerial photographs using Corel Photopaint (Corel Corp. 1996). The final result was a binary image depicting the brush pixels as white (1) and the grass pixels as black (0). Area derivation and analyses from the pixel values was performed using ARCINFO's raster module, GRID.

The process was repeated for all the air photos and provided a measure and extent of the brush area for each of the years for the two study areas. Using map algebra techniques, the 1950 and the 1998 binary image masks produced from the image enhancement procedures were combined to produce composite change images (Fig. 2) depicting the brush extent in 1950 and 1998.

Digital terrain models (DTM) for the three Rumsey sections were also compiled to investigate topographic influences on brush expansion. Using ARCINFO GRID, the DTMs were queried for specific conditions of slope, aspect, and elevation to produce classified areas depicting 'favorable' sites for brush propagation. The classified DTMs were then combined with the brush area image masks to investigate topographically related effects.

Climatic data was obtained from the Atmospheric Environment Service's Craigmyle and Hanna weather stations to obtain a climatic perspective on the trends observed.

Results

The Hand Hills and Rumsey areas continue to show a progressive expansion of the brush vegetation on a magnitude greater than that reported by earlier workers. Bailey and Wroe (1974) noted a brush increase of 3.2% (from 4.8% to 8.0%) in the Rumsey area between the years 1907 and 1966. In the three sections investigated in this study, the brush cover increased by an average of 15.5% (from 3.4% to 18.9%) between the years 1950 and 1998. In the Hand Hills area, the brush increase for the section with the aspen clones was 3.8% (from 0.5% to 4.3%). Figure 2 provides a visual impression of the degree of the expansion occurring in both Rumsey and Hand Hills.

A review of the descriptive statistics of the brush areas for the two endpoint years provides more information regarding the character of the expansion. The sections represented by Rumsey N (north) and Rumsey S (south) contain about the same total area of brush in 1998 (Table 2), with no significant difference ($P>0.05$) in the mean area of the brush stands; however, the 1950 brush coverage conditions for these two sections are different suggesting site related controlling factors are responsible for the greater rate of expansion observed in Rumsey S. As noted the total area of brush cover in 1950 is much higher in Rumsey N than in Rumsey S but the total number of stands is lower (394 vs. 1128); there is also a significant difference ($P<0.05$) in the mean area of the stands in this period, with the average size of the stand significantly larger in Rumsey N. The third section in the Rumsey area, Rumsey C, is privately owned, and although the total area of brush cover is less than the other two, this section has also experienced a substantial expansion of brush cover. This area shows an expansion of 13.0% (from 1.6% to 14.6%) of total brush cover during the 1950 to 1998 period while Rumsey N shows an increase of 15.3% (from 6.5% to 21.2%) and Rumsey S shows an increase of 17.2% (from 3.6% to 20.8%). All three sections also show an increase in standard deviation of the mean brush areas indicating more numerous larger and smaller brush islands.

Table 2. Comparison of the 1950 and 1998 brush area descriptive statistics for the two study areas and four sites.

Year	Location	Total Brush Area (m^2)	Number of Brush Stands	Mean Area of Stands (m^2)	Standard deviation
1950	Hand Hills (sec)	12 794	79	73.4	115.8
1996	Hand Hills (sec)	110 263	121	1579.0	2610.4
1950	Rumsey N sec.	166 387	394	731.7	1313.6
1998	Rumsey N sec.	543 683	1231	775.3	3634.6
1950	Rumsey S sec.	91 680	1128	137.5	373.3
1998	Rumsey S sec.	532 332	739	947.2	2531.4
1950	Rumsey (private)	39 581	469	133.4	271.8
1998	Rumsey (private)	374 725	589	837.9	1726.6

The Hand Hills data follow the same pattern as in Rumsey. The total brush area, number of stands, mean area of the stands and the standard deviation of the mean stand area all show an increase (Table 2). The Hand Hills change data, however, does show that 9840m^2 of brush existed in1950 but disappeared in 1998. This vegetative loss occurred mostly within the clonal centers of some of the older stands due to aspen senescence.

Figure 3. An aspen clone expanding onto fescue grassland via root suckers.

Discussion

Biotic and climatic factors

Aspen is well adapted for regeneration in moderately dry sites because of its root suckering capability. Stress to saplings induced from periodic lack of moisture can be tolerated because of the saplings' reliance on the main root for their moisture and nutrients which can extend to depths of 3 m (Peterson and Peterson 1992). In the Aspen Parkland-Fescue Grassland transition zone found at the study sites, the processes involving aspen suckering regeneration and consequent expansion are plainly visible (Fig. 3).

Once established, an aspen stand will regenerate primarily by root suckers, but initial establishment must be seed induced. A cursory look at Figure 2 does suggest that many of the current islands of aspen in the Hand Hills area were not present in 1950. A stereo-photo analysis of the location of the aspen islands indicates that these islands are establishing themselves along ephemeral drainages that are almost imperceptible on the ground. It is apparent that these sites maintain enough moisture allowing aspen seedlings to germinate and establish themselves during wetter periods. The situation in the Rumsey area is more indicative of an expansion of the pre-existing aspen via the root sucker mode. Because the topography of Rumsey is more extreme, ideal sites would have been colonized by aspen prior to the initial photo acquisition in 1950. The aspen stands in Rumsey may likely be expanding on to more dryer sites.

Table 3. Brush area increase in the Hand Hills (section 25) derived from the periodic air photos

Year	Total Brush Area (m^2)	Number of years between aerial photo	Brush area change between aerial photo years (m^2)
1950	12 794	-	-
1963	47 532	13	34 738
1967	53 047	4	5 515
1974	71 078	7	18 031
1986	71 991	8	913
1993	98 635	7	26 644
1996	110 263	3	11 628

An important aspect of the aspen regeneration process is the rate at which the clonal expansion is occurring. The Hand Hills site is a good area to investigate this issue with the air photo/GIS techniques presented because of the periodic acquisition of aerial photography and the minimal grazing activity that has occurred in the northern section of the study area. The total brush area was calculated for each of the years that aerial photography was flown including the change between each air photo period (Table 3). It is evident from the tabular data that the encroachment is not a constant between the 1950 and 1998 period, with more extensive expansion occurring at the beginning and end of the period and relatively slow growth during the latter 1970s and early 1980s.

The minor disturbance of this section provided a good case for relating the expansion rate with climatic conditions. The expansion rate (total brush area change /number of years in period) and the average precipitation, were determined and ranked for each of the periods (Table 4). The Spearman's correlation result (Mosteller and Rourke 1973) indicates a significant correlation between increased rates of expansion and higher precipitation ($r_s = 0.89$, $P<0.05$). The average temperature change, however, was minor for each of the periods (± 0.28°C) and was not a factor. A closer look at the rate change data (Table 4) provides more insight on how the precipitation quantity is affecting brush change. Two of the periods (‘67-‘74 and ‘86-‘93) have equal time intervals and have the almost the same average precipitation, yet the rate of change is much higher in the later period. Assuming insignificant temperature differences

Table 4. Brush change rate (m^2/yr^{-1}), associated with precipitation mean and standard deviation.

Period	Brush Change Rate	Mean Precip.[1]	Precip. std. dev.	Rank Brush Change Rate	Rank Mean Precip.
1950-63	2672	358	98.9	3	4
1963-67	1386	348	41.0	5	6
1967-74	2572	421	40.7	4	3
1974-86	114	349	39.6	6	5
1986-93	3806	426	57.8	2	2
1993-96	3876	464	76.7	1	1

[1] Source: Atmospheric Environment Service, Environment Canada, station data for Craigmyle AB and Hanna AB.

between the two periods and, as previously noted, minimal rangeland disturbance, the year-to-year change rates may be more sensitive to the annual precipitation amounts. The standard deviation data for precipitation (Table 4) does in fact show that the annual precipitation during the '86-'93 period was more variable. If an annual precipitation value of 450 mm is used as a dividing level, it is apparent that at least this amount occurred in 4 of the 7 years in later period and only in 2 of the 7 years of the earlier period (Fig. 4). The choice of 450 mm is not arbitrary, this precipitation value is acknowledged as representing the mean yearly precipitation for the Aspen Parkland ecoregion in Alberta (Strong and Leggat 1992).The implication that brush expansion was more vigorous during in the '86-'93

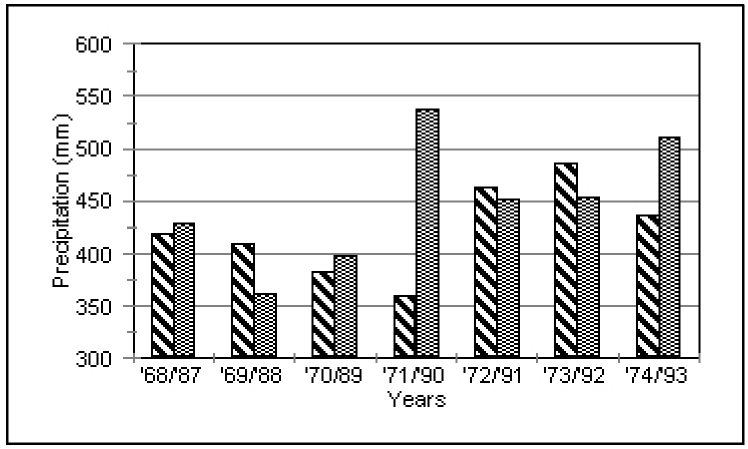
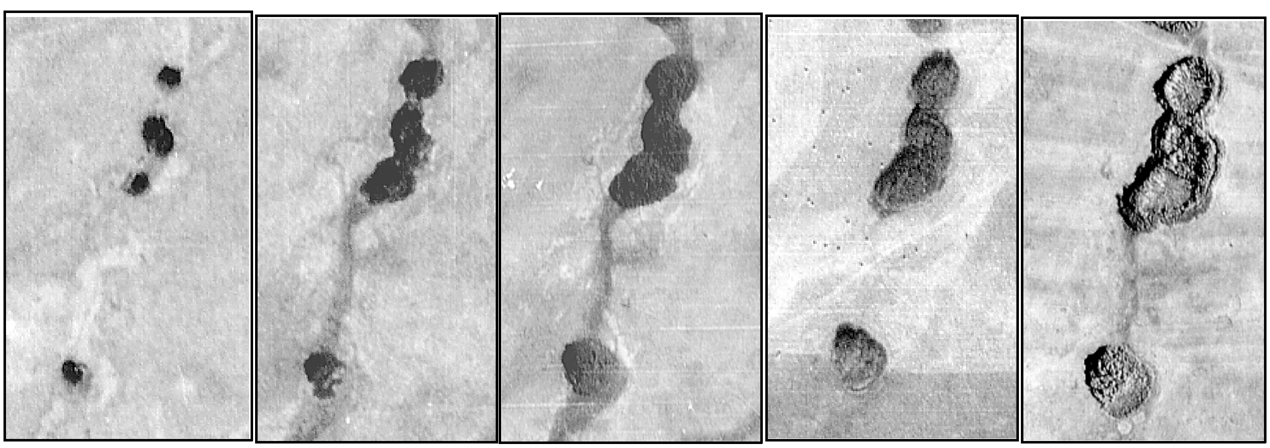


Figure 4. A comparison of the average precipitation in the study area for the periods '68-'74 and '87-'93. Although the mean precipitation of the two periods is similar the '87-'93 period exhibits more yearly events with precipitation greater than or equal to 450 mm and is associated with more vigorous aspen expansion during this period.



1950 1963 1974 1986 1998

Figure 5. Time-series air photos of an expanding aspen clone in Hand Hills. Note the relative stagnation in growth between the '74 and '86 sequence (associated with a period of relatively low precipitation) and doughnut shaped stand structure in the 1998 image.

period during the more numerous years of precipitation amounts conducive to aspen growth would seem to justify the expansion rate difference between the two periods. The high variation in precipitation during the ‘50-‘63 period could also account for the relatively high rates of expansion during this period but is associated with the relatively low average precipitation (Table 4).

It was noted earlier that some tree loss is occurring in the centers of old aspen clones. An air photo sequence of an aspen clone in Hand Hills showing periodic expansion and terminating with a ring like stand structure with old dead aspen at its center is depicted in Figure 5. Field investigations provide very little evidence of the aspen root suckering regeneration directed towards these clonal centers. As the aspen senece, the original smooth brome (*Bromus inermis* Leyss.) understory of the aspen clone eventually dominates the ground cover along with Canada thistle (*Cirsium arvense* (L.) Scop.) and fireweed (*Epilobium angustifolium* L.) - plants typically associated with disturbed landscapes (Fig 6).

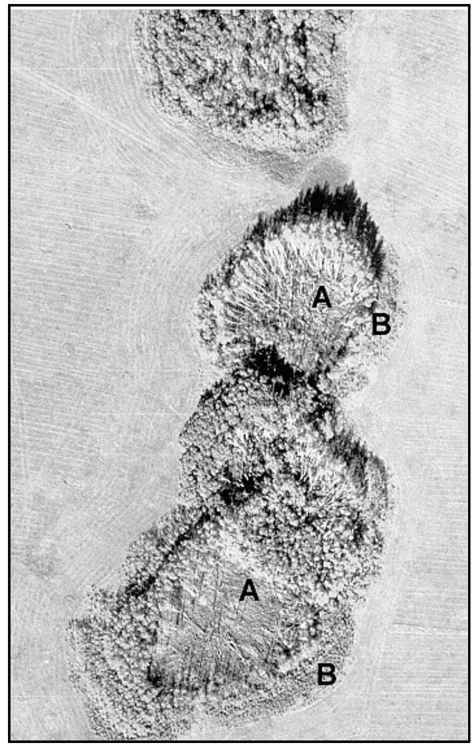


Figure 6. The 1998 aspen clone from figure 5 photographed at a larger scale (1:5 000 vs 1:30 000) showing the expanding aspen periphery (B) and the seneced aspen clone nucleus.

Grazing and terrain factors

Grazing is generally known to be an effective method for controlling brush growth (Fitzgerald *et al.* 1986*,* Bailey *et al.* 1990). The areas in this study range from zones that show evidence of substantial grazing activity to areas in which haying only is allowed. These two extremes, and their effect on brush activity, exist adjacent to one another in two sections in the Hand Hills area. The aspen clones along the southern fenced boundary of study section 25 (the hayed section) are showing active expansion in all directions except southwards into section 23. This southern section (section 23) contains ample range condition evidence to suggest that intensive grazing is occurring in close proximity to the northern fenced boundary and preventing the aspen clones from propagating southward. The cattle not only find the tender sucker shoots palatable but are also ingesting overhanging leaves and tender twigs along the fence line leaving a distinct horizontal demarcation level associated with their overhead browsing (Fig. 7). The high grazing


Figure 7. Fence line demarcation of active aspen growth and expansion (right) and obstructed growth on the left due to heavy cattle grazing.

intensity in this area is also likely related to the animals' desire for shade on hot sunny days.

The Rumsey study areas, unfortunately, did not have the same period image coverage as in Hand Hills and a similar type of periodic analysis of brush expansion was not possible. Comparative differences in brush area between the 1950 and 1998 period for the three sections were noted earlier, in particular, the expansion rates between Rumsey N and Rumsey S. These sections are being grazed with distinctive techniques: Rumsey S follows a two field summer rotational system from late May to early October, Rumsey N is a hayed section with no summer grazing and minimal winter grazing (F. Gebbink Alberta Agriculture, Food and Rural Development 1998). Historical data associated with these grazing practices and intensity is difficult to quantify and exists mostly as anecdotal information from the areas' ranchers. If climate differences are assumed to be negligible between the sections (separated by 20 km) and other variables such as parent material and soil type are known to be similar (Karpuk 1995) then grazing practices would be expected to the primary determinant for controlling brush extent. The Rumsey N section would be expected to have the highest rates of brush expansion since the grazing factor is minimal, but as noted earlier, the data indicates otherwise (Table 2). The lower rate of expansion in Rumsey N

Table 5. Map algebra results from a query of the digital terrain model and the 1998 binary masks depicting brush occurrence.

Location	% of area with favorable[1] sites	% of brush area	% of area with favorable sites and no brush
Rumsey N	42.9	21.2	28.5
Rumsey S	76.9	20.8	52.1

[1] Favorable site conditions were determined by stratifying the digital terrain model for the following conditions: north facing slopes and elevations < 865 m, and slopes < 5°.

may due to the area approaching a maximum site capacity for supporting brush vegetation. As the moister troughs and north-facing slopes become fully forested, the rate of brush expansion onto dry south-facing slopes and subxeric/mesic plateaus slows down considerably. In Rumsey S, the expansion in favorable areas such as north-facing slopes and moister troughs may be less advanced thus presenting the opportunity for more expansion. The hypothesis is supported by the results obtained from the map algebra techniques combining the brush area coverage with the digital terrain model 'favorable site' classification for the Rumsey sections. Favorable sites for brush expansion in Rumsey S are noticeably higher and, more importantly, over half have yet to be occupied by brush (Table 5).

Conclusions

The pattern of aspen and brush expansion in the northern fescue grassland/aspen parkland zone has been quantified now for over 90 years. Although the Rumsey and Hand Hills study areas have been appropriate in studying the nature of this expansion because of their relatively low disturbance, their small area do not make them the norm in characterizing the land use pattern of this ecological transition area. The historical conversion of both fescue grassland and aspen groveland to cropland define the main determinants for the actual amount of fescue grassland or aspen parkland remaining in this area.

Is aspen encroachment onto fescue grasslands, therefore, a concern? The question relates to scale, magnitude, and perspective. On the ecoregion and subregion level, not only is the remaining northern fescue grassland threatened, but aspen itself may also be a declining species; the 'encroachment' at this scale being not aspen but cropland conversion. It is an area where further historical change investigations may be warranted. From the ecodistrict and ecosite perspective, the present day occurrences of northern fescue rangeland being infringed upon by aspen have been established, but there is also observational evidence to show that aspen may not be the stable vegetation community replacing the fescue and that aspen succession is leading to possibly undesirable grammaniods; the ecological dynamics in this area should be pursued.

With image data now spanning almost 50 years, it is certain that future changes using satellite/airphoto/GIS techniques will provide the opportunity to continue to monitor the changes in these two unique areas and provide land managers important information for implementing land use strategies.

Acknowledgement

Authors would like to thank Mr. Alan Violette for his assistance in formatting the digital terrain elevation data.

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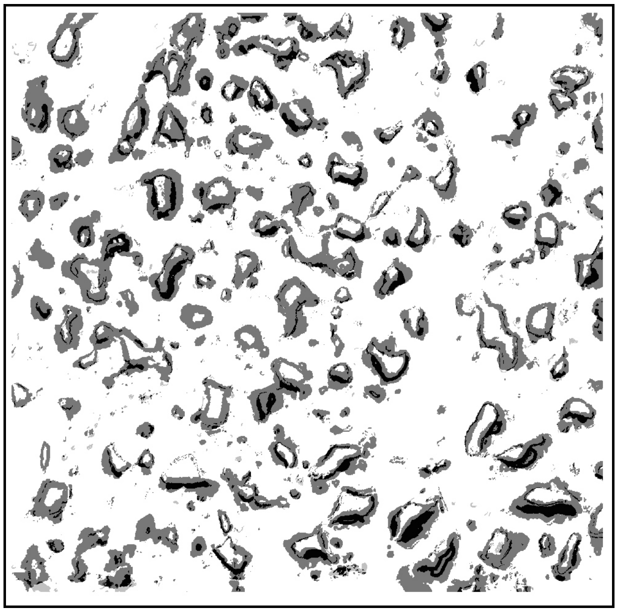
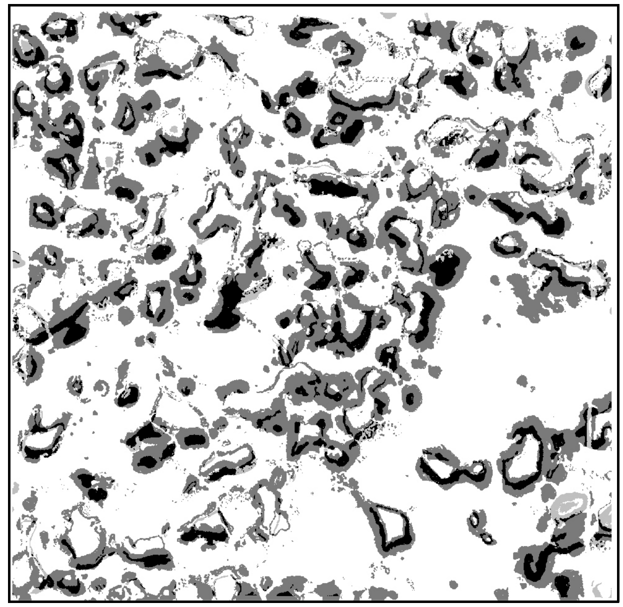


Rumsey S (twp. 33 rge. 19 sec. 3 W4)



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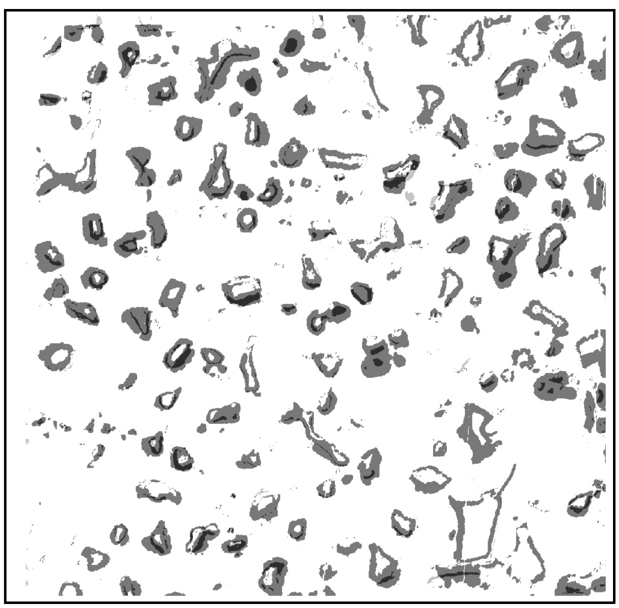
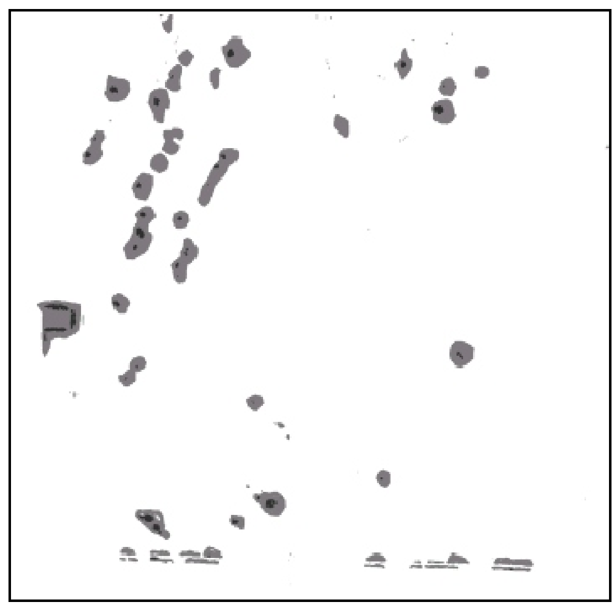


Rumsey C (twp. 33 rge. 20 sec. 24 W4)



Hand Hills (twp. 28 rge. 14 sec 25 W4)

Figure 2. Combined 1950 and 1998 (Rumsey), 1996 (Hand Hills) binary image masks of the four study sites. The black areas show the aspen/brush extent in 1950, the dark grey areas outline the aspen/brush encroachment in 1998/96.