Historic and Recent Vegetation Change at the Ann & Sandy Cross Conservation Area

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Introduction

The Ann & Sandy Cross Conservation Area (ASCCA) is located on the western edge of Alberta's Foothills Fescue Natural Subregion, along the eastern boundary of the Foothills Parkland Natural Subregion (Natural Regions Committee 2006). As such, the ASCCA is comprised of a mixture of open grasslands, trembling aspen woodlands, and smaller areas of conifer (white spruce) stands.

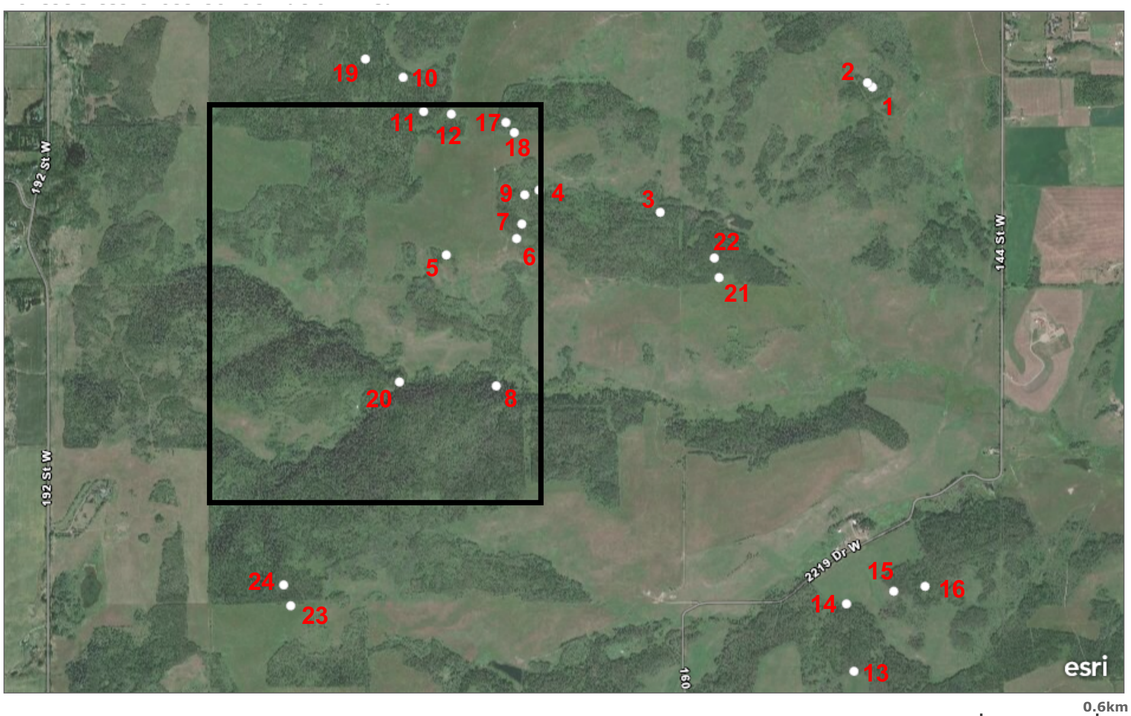
Prior to European settlement, the vegetation of southwestern Alberta (including the Foothills Fescue and Foothills Parkland Natural Subregions) was shaped by natural ecological processes, most importantly, disturbances (events that kill or damage existing members of the vegetation community) such as bison grazing and frequent wildfire – which combined to promote grassland vegetation in drier environments, and woodlands in the more mesic (moist) environments. However, European settlement in the region altered the natural disturbance regime, specifically the near extirpation of bison and significant suppression of wildfire – which were two important processes promoting grassland vegetation over woodland/forest plant communities. Further, in many places (including the ASCCA), there were systematic introductions of European forage plants following the mechanical removal of native grassland plant species (Romo and Girlz 1990, Mack and Erneberg 2002). Changes to the region's natural disturbance regime, coupled with the intentional introduction of European grassland species, has led to widespread dominance by European grass species across much of Canada's prairies. Further, the Foothills Parklands of southwestern Alberta are recognized to be highly sensitive to changes in disturbance regimes, and are experiencing encroachment of trees into grassland environments (Stockdale et al 2019).

With the objective of better understanding and quantifying the spatial and temporal vegetation dynamics of the ASCCA, we 1) analyzed vegetation change using both local historical aerial images from the 1920s through the present day and historical Dominion Land Survey records and 2) determined ages of trees across the ASCCA landscape. Information from these ecological and historical sources provides context for better understanding recent trends and trajectories in the ASCCA vegetation communities.

Methods

Data was collected from several sources. For Objective 1, historical aerial images and Dominion Land Survey maps were obtained from the Spatial and Numeric Data Services (SANDS) branch of the University of Calgary library. Aerial photos that covered the entire ASCCA property were available for: 1926, 1966, 1980, 1999, 2004, and 2014. Photos were digitally scanned, georeferenced (aligned), and orthorectified within ESRI ArcMap to the 2014 orthophoto. Vegetation type (forest or grassland) was identified for the entirety of each image, and the vegetation polygons were manually digitized. Total coverage (in hectares) of forest and grassland vegetation was tallied for each photo year. Shifting locations of forest-grassland edges were analyzed with 100 randomly placed "virtual" transects that spanned forest-grassland edges across the ASCCA. A change in edge position was only recorded if the measured shift in grassland/forest edge exceeded 10 m (to account for minor georeferencing errors). To evaluate ages of forest and woodland trees, for Objective 2, a total of 24 tree plots were placed throughout the ASCCA (Figure 1). Within rectangular plots (ranging in size from 100 – 400 m^2) all trees (>5 cm diameter at breast height [dbh]) were cored with an increment borer (at 30 cm height), identified to species, and their dbh was recorded. In the University of Calgary tree-ring lab, tree cores were air dried, sanded, and annual tree rings were counted under a stereo-zoom microscope. Given that tree cores are collected at 30 cm height, all tree ages reported below are age at coring height, not true tree ages. Thus, ages presented necessarily underestimate the actual age of the trees as core age does not include the years it took the tree to reach coring height. While it varies widely, young trembling aspen (originating from either sexual or asexual reproduction) tend to grow fairly rapidly, and likely take 3-5 years to reach coring height (Perala 1990). White spruce are generally slower to reach coring height (Lieffers et al. 1996), thus core age counts likely underestimate actual tree age by 7-10 years.

Figure 1. Forest and woodland plots across the ASCCA (n=24) sampled for estimation of tree ages. Black-framed area shows the approximate area covered by the 1926 aerial image in Figure 5.



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Findings

Early maps

The township (Township 22; Range 2 West of the 5th Meridian) which includes the ASCCA was first surveyed in 1881, with a follow up two years later in 1883 (Figure 2), and a "corrected" survey based on these surveys was produced in 1895 (Figure 3). A rudimentary survey was conducted in 1919 (Figure 4). From the late-19th Century surveys, the landscape of the ASCCA is depicted as being "very hilly", comprised of "rolling" valleys, and is marked as being a mixture of wooded and open (prairie) terrain. The earliest aerial image of the ASCCA region dates to 1926 (Figure 5), with images available sporadically throughout the following 90 years. A visual comparison of the contemporary landscape (Figure 1) with the 19th Century Survey (Figure 3) and earliest aerial image (Figure 5) shows general similarities in the mixture of vegetation types.

Figure 2. Dominion Lands Office Survey of Section 22, Range 2 West of the Fifth Meridian from the fall of 1883 (approved in 1884). Green shaded area generally corresponds with the area of the ASCCA. Source: SANDS, University of Calgary.

Figure 3. The Dominion Land Survey published in 1895 based on the 1881 and 1883 field surveys. Green shaded area generally corresponds with the area of the ASCCA. Source: SANDS, University of Calgary.

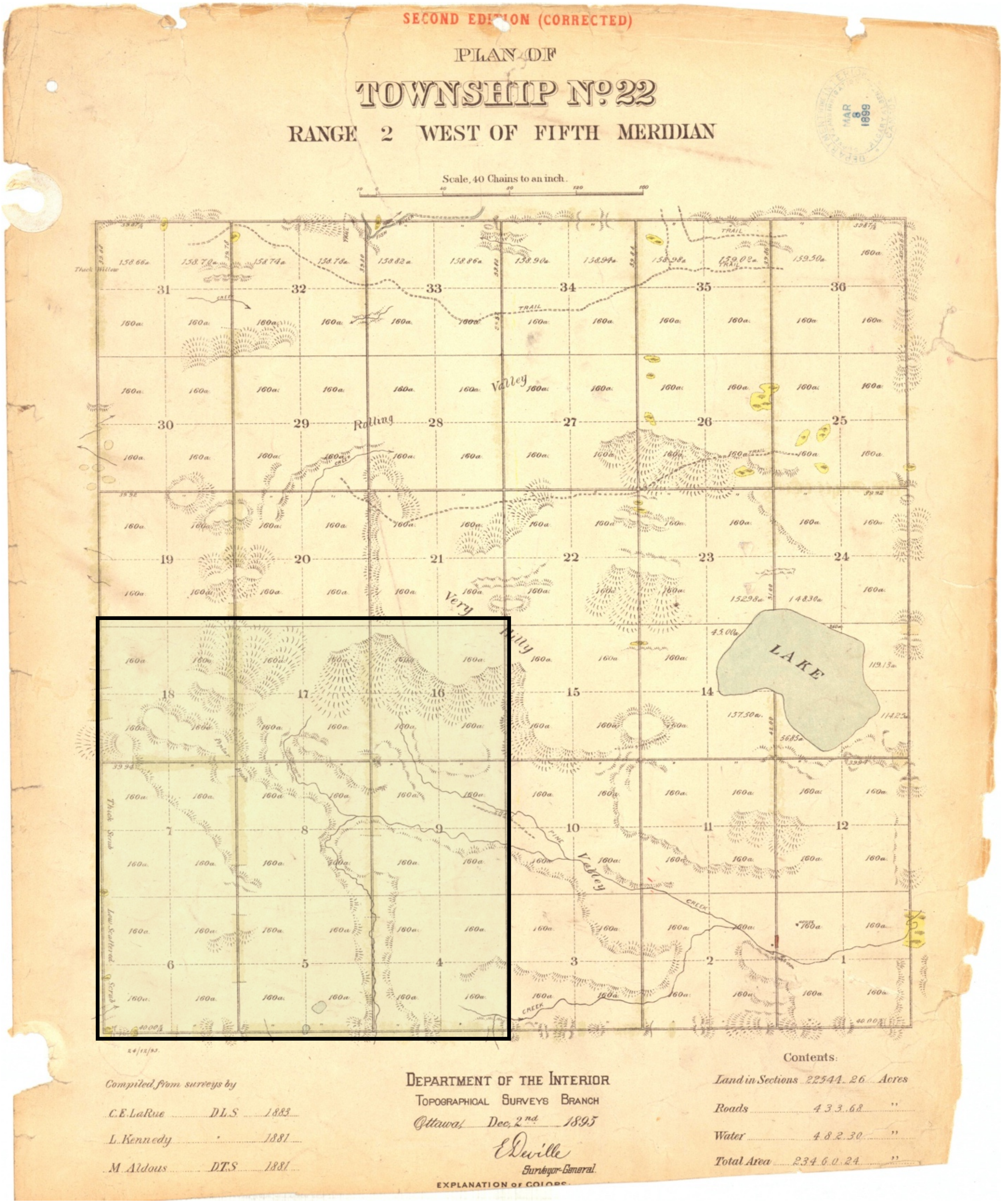


Figure 4 The Dominion Land Survey published in 1919 based on the original 1881 and 1883 field surveys, and a 1918 field survey. Green shaded area generally corresponds with the area of the ASCCA. Source: SANDS, University of Calgary.

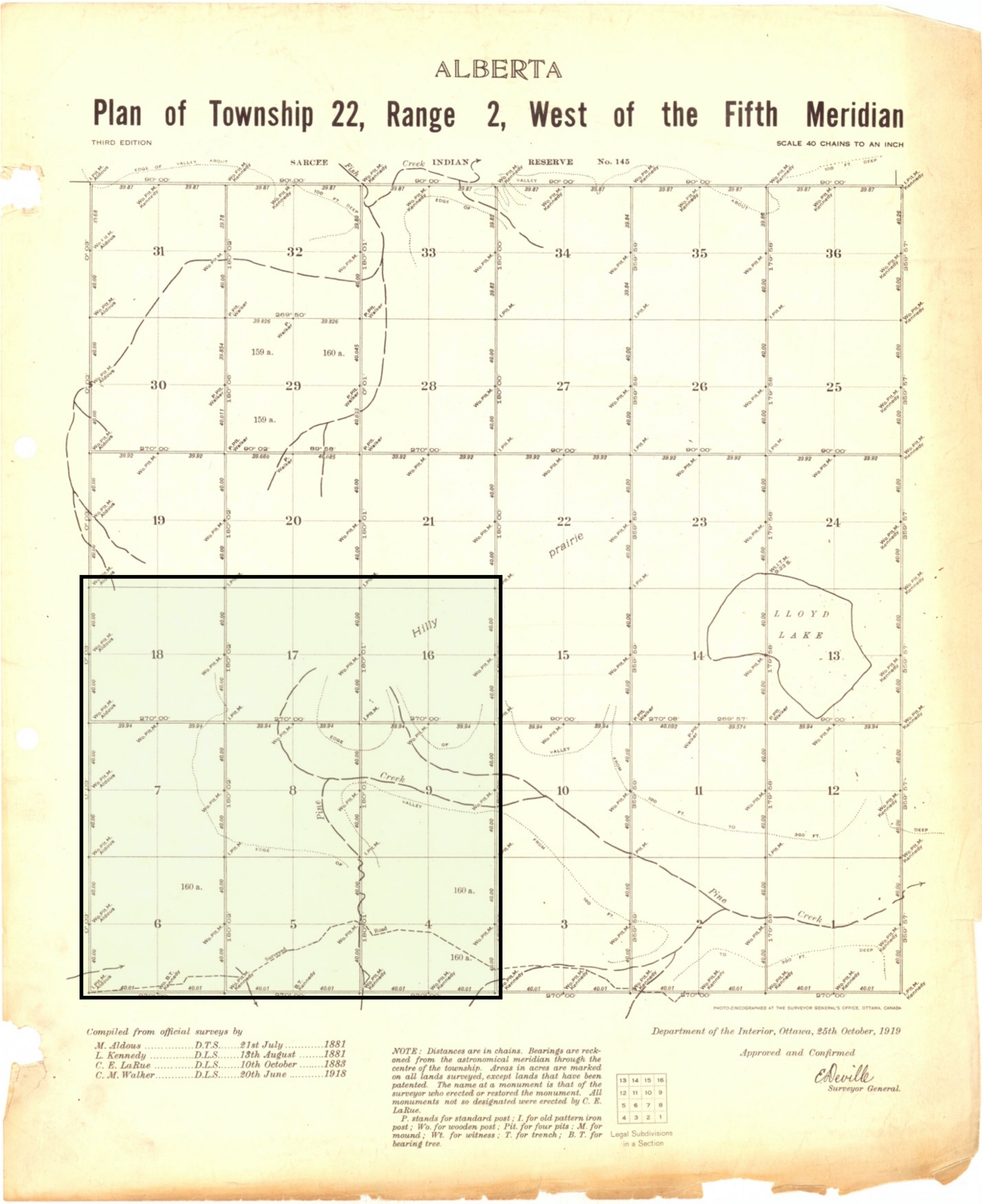


Figure 5. Aerial image for a portion of ASCCA dating to 1926. Source: SANDS, University of Calgary. Area covered by this image is highlighted in Figure 1.

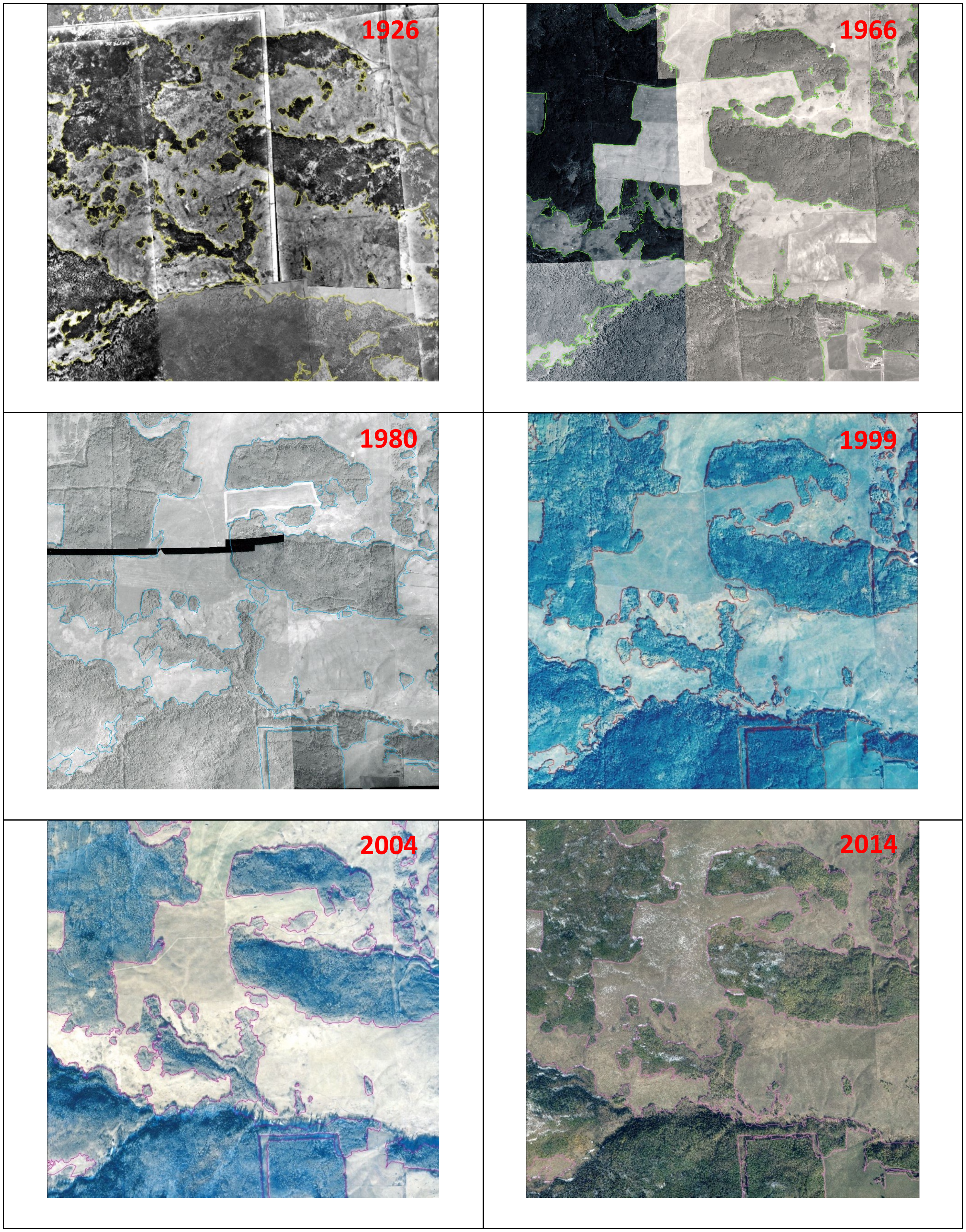
Forest-grassland dynamics

Moving beyond visual comparisons, and quantifying historical change to the landscape, six historic aerial images covering the full extent of the ASCCA from 1926 to 2014 were analyzed to determine the total area covered by forest/woodland vs grassland (Table 1; Figure 6). Overall, the total land area of the ASCCA is approximately 1967 hectares (ha). From the 1926 aerial images, 66.4% of the ASCCA was grassland at that time, and the remaining 33.6% was forest or woodland. While as of 2014, grassland coverage was 58.3%, with the remaining 41.8% covered by forest and woodland. The overall decrease of 8.1% of the ASCCA's grassland cover between 1926 and 2014 has been slow (0.09%/yr or 0.9%/decade) during this nearly 90 years (Figure 7; Table 1). However, the rate of grassland loss has varied considerably, with the greatest relative decreases in the periods from 1966-1980 (0.16%/yr or 1.6%/decade) and 2004-2014 (0.19%/yr or 1.9%/decade), 2-10 times faster than during the historic periods with the slowest losses (e.g. 1980-1991 – 0.18%/decade; 1999-2004 – 0.4%/decade) (Table 1).

Table 1. Land cover type for ASCCA based on aerial images since 1926. Total area of ASCCA is 1967 hectares (ha).

Year	Grassland (ha)	Forest (ha)	Percent Grassland (%)
1926	1306	660	66.4
1966	1247	719	63.4
1980	1203	764	61.2
1991	1200	767	61.0
1999	1188	778	60.4
2004	1183	783	60.2
2014	1146	821	58.3

Figure 6. Historic aerial images from the same portion of the ASCCA with manually digitized outlines of wooded plant communities. Area covered by each image is 2.2 x 2.2 km.



Nearly all the conversion of habitat from grassland to woodland has taken place on existing woodland edges, rather than in the middle of existing grassland habitat. Woodland expansion into grasslands along existing woodland edges is commonly characterized as "woodland encroachment". Woodland encroachment, based on the 100 virtual transects across the ASCCA for the entire 88-year period of record, averaged 0.34 m/yr – in other words, the average woodland edge in the ASCCA has been shifting into grassland at the rate of 3.4 meters per decade. However, as described above, this varies by historic period. From the mid-1960s to 1980 trembling aspen woodlands encroached into grasslands at the rate of 6-7 m/yr, slightly faster on north-facing slopes. However, this varies considerably by decade over the past 90 years (Figure 8).

Figure 7. Percentage of the ASCCA land area in grassland ecosystem.

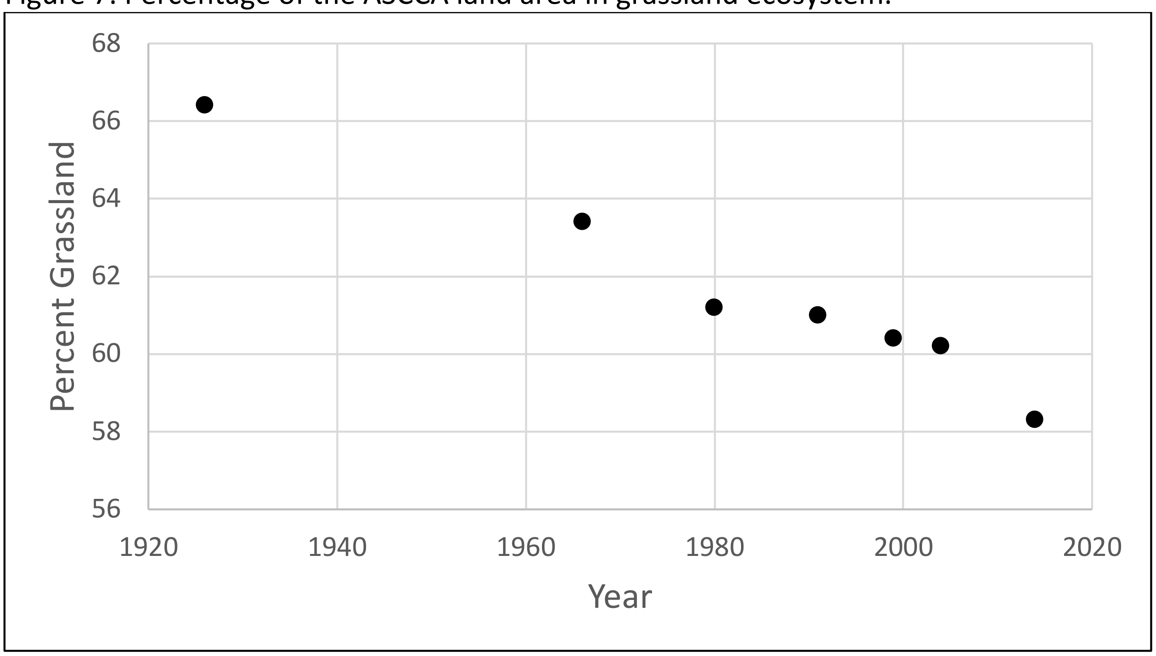
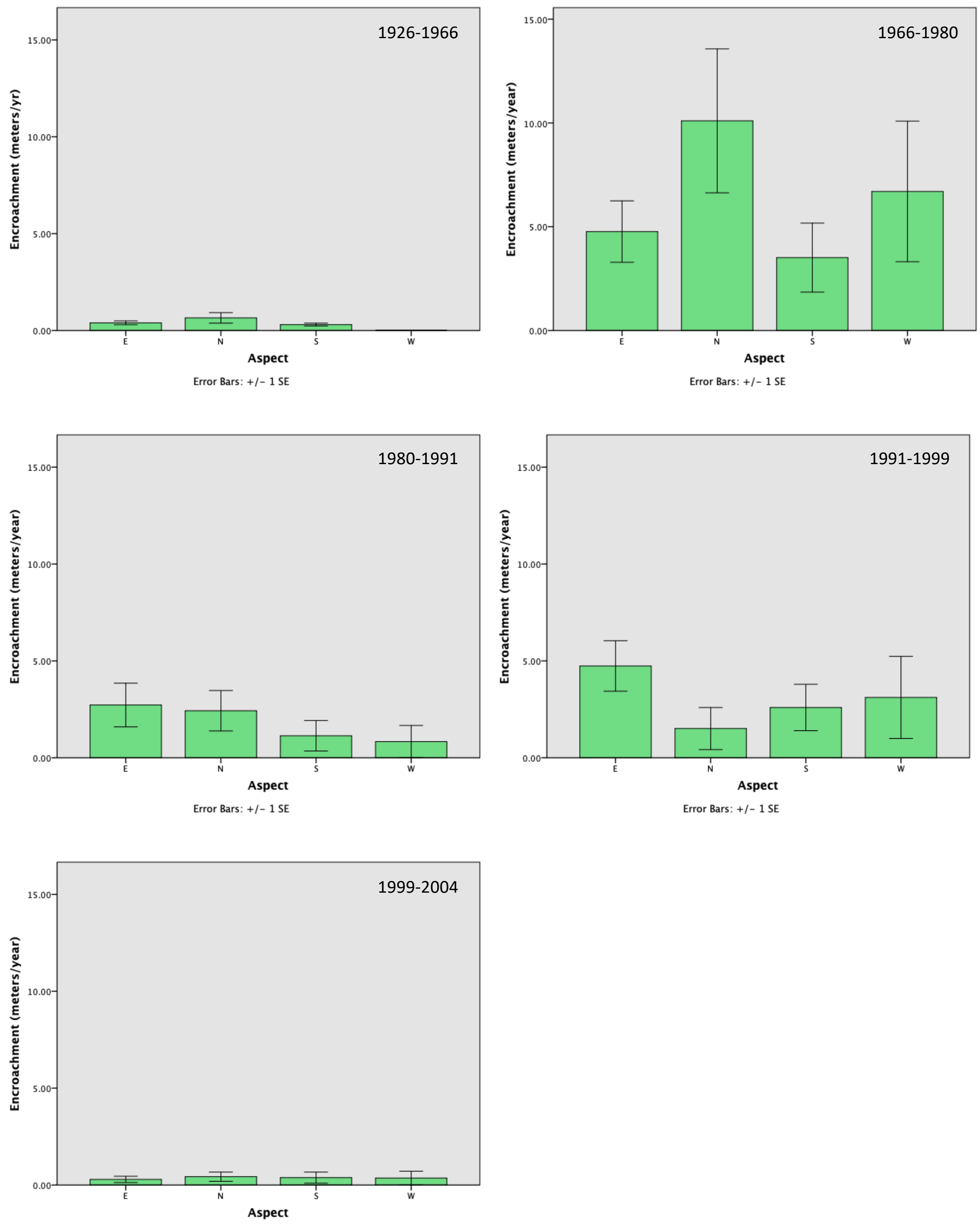


Figure 8. Rates (m/yr) of trembling aspen woodland edge encroachment into grassland habitat by slope aspect, during historic periods. Error bars represent 1 standard error.



Tree ages

Based on historical aerial imagery and field visual assessment, the 24 tree plots were characterized as: established aspen woodland (trembling aspen present from the 1926 aerial image to present day; n=16), woodland edge (grass-dominated in the 1926 aerial image, but partially wooded in present day; n=5), or conifer forest (evergreen trees from the 1926 aerial image to present day; n=3) (Table 2, Figure 1).

Table 2. Sampled tree core plot locations and details in the ASCCA, see Figure 1 for locations.

Plot	UTM Easting	UTM Northing	Aspect (°)	Slope (°)	Vegetation category
1	695653	5639308	190	4.5	Established aspen woodland
2	695627	5639329	220	4	Established aspen woodland
3	694594	5638630	18	7	Established aspen woodland
4	693971	5638720	28	30	Conifer forest
5	693510	5638372	155	8	Established aspen woodland
6	693866	5638469	55	4	Woodland edge
7	693890	5638544	10	8.5	Established aspen woodland
8	693790	5637715	5	13	Conifer forest
9	693899	5638693	10	13	Established aspen woodland
10	693256	5639268	250	6	Established aspen woodland
11	693386	5639066	250	21	Established aspen woodland
12	693367	5639098	265	7	Woodland edge
13	695671	5636331	15	0	Established aspen woodland
14	695620	5636673	350	0.5	Established aspen woodland
15	695859	5636746	310	9.5	Woodland edge
16	696018	5636777	350	11.5	Established aspen woodland
17	693789	5639058	10	9	Established aspen woodland
18	693834	5639008	10	2.5	Woodland edge
19	693060	5639354	40	6	Established aspen woodland
20	693295	5637717	340	21	Conifer forest
21	694907	5638309	355	8	Woodland edge
22	694879	5638408	0	7	Established aspen woodland
23	692782	5636557	295	11	Woodland edge
24	692742	5636662	295	11	Established aspen woodland

Tree ages (plot average and maximum age) are summarized and grouped by vegetation category (Table 3). Most of the trembling aspen trees located in established aspen woodlands throughout the ASCCA are no more than 120 years old, with the average tree ages in the 15 trembling aspen plots ranging from 30-70 years old. However, given that trembling aspen's primary mode of regeneration is through vegetative suckering, the trembling aspen clones at the ASCCA are likely 100s to 1000s of years old. The reproductive habit of trembling aspen, combined with the sampled tree ages (Table 3), suggests that the ASCCA trembling aspen woodlands are in an equilibrium state undergoing continuous regeneration, with dying trees being replaced by new trembling aspen suckers. Thus, most of the trembling aspen stands visible in the aerial image from 1926 (Figure 5) and sketched as "Poplar Bush" in the 1895 Dominion Land Survey (Figure 3), are likely a stable vegetation formation in the ASCCA landscape.

By contrast, the habitat on the periphery of the established aspen woodlands (woodland edge) that was grassland in the 1926 aerial images is quite dynamic, and shows evidence of transitioning from grassland to trembling aspen woodland. Most of the trembling aspen trees growing along the woodland edges are young (average ages range from 20-35 years old; Table 3), with the oldest trees being no older than 45 years old, suggesting a period of pronounced trembling aspen establishment in the late 1960s to early 1970s, which generally corresponds with the rapid trembling aspen encroachment into grasslands noted above between the 1966 and 1980 aerial images (Figures 6 and 7).

Only covering a small portion of the ASCCA, the stands of white spruce trees are largely restricted to north-facing slopes adjacent to riparian habitat. The maximum ages of these trees

(70-90 years old; Table 3) is likely an underestimation given that some of the largest trees were rotten in the centre, which limits total age determination. The abundance of young white spruce (20-30 years old), coupled with numerous trees between 30 and 70 years old, clearly indicates active regeneration in these stands.

Table 3. Summary of tree ages for the forest and woodland plots. See Figure 1 for plot locations.

Plot number	**Average age**	**Oldest tree**
Established aspen woodland		
1	40.0	48
2	41.9	50
3	70.5	78
5	32.8	43
7	49.9	76
9	72.2	87
10	59.6	87
11	58.6	73
12	60.1	74
13	37.0	46
14	61.6	83
16	60.4	76
17	71.1	91
19	47.2	108
22	28.4	35
24	65.8	117
Average	***53.6***	
Woodland edge		
6	19.3	38
15	25.3	32
18	37.6	45
21	29.5	35
23	26.2	31
Average	***27.6***	
Conifer forest		
4	42.1	77
8	50.2	71
20	53.7	93
Average	**48.7**	

Change in overall vegetation cover

Given that numerous studies (e.g. Elliott and Baker 2004, Grant et al. 2004, Halpern et al. 2010) from western North America document forest and shrubs expanding at the expense of grasslands and meadows, the ecological changes underway at the ASCCA are not surprising. Common factors across the region, such as fire suppression, decreased (bison) grazing pressure, and climatic changes have been suggested as potential drivers. In the Cypress Hills of southeastern Alberta and southwestern Saskatchewan, Widenmaier and Strong (2010) documented a 51% increase (0.9%/year) in tree cover from 1950-2007. Similarly, in the Loess Hills of South Dakota, Spencer et al. (2009) found a 37.5% increase in forest cover (at the expense of grasslands) from 1941-2000. The loss of grassland at the ASCCA is considerably slower than many other studies, partly due to active management (targeted mowing and cattle grazing) of woodland edges, which has limited what otherwise might have been more rapid expansion of trembling aspen into grassland communities. However, should these practices be abandoned (without a return to the natural disturbance agents of fire and bison grazing) there would likely be an acceleration of woodland expansion into grassland. This would ultimately pose a threat to what should be the long term ecological goal of the ASCCA, namely the reintroduction of the native Foothills Fescue grassland species.

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