LAND COVER

CHANGES AND ELK HABITAT IN WESTERN MONTANA

by

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DEDICATION & ACKNOWLEDGEMENTS

First, I would like to thank my husband, Christian, for his continued support and words of encouragement. You always push me to believe I can accomplish big things. I would also like to thank all the staff in the LRES department. I have learned so much and am excited to begin exercising this knowledge. Additionally, I thank Scott Powell for his insight and for leading me in the right direction with this project.

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ABSTRACT

Conifer encroachment in forested and grassland areas is a crucial issue in forest and wildlife management in the Western United States. Factors such as climate change, fire suppression, and changes in logging practices have driven encroachment, resulting in changes in forest structure and wildlife habitat. My study presents a time-series land cover analysis of tree and perennial grass cover changes from 1985 to 2022 in Montana's hunting districts in Regions 1 and 2. My research aims to identify the changes occurring in forest canopy and perennial grass cover in western Montana and to evaluate whether elk populations are correlated to changes in forest structure. I used data from the Rangeland Condition Monitoring Assessment and Projection, and the Rangeland Analysis Platform. Although analysis of the two datasets yielded different results, similar overall trends were observed. Tree cover has been increasing in Region 1, and perennial grass cover has been decreasing. There were only slight changes in Region 2, but the land covers have remained relatively consistent. A consistent negative correlation was found between tree canopy cover and perennial grass cover, indicating that when tree cover increases, grass cover decreases, lowering habitat diversity. The correlation between land covers and elk population counts was weak, making it difficult to determine their relationship. I emphasize the significance of diverse elk habitats and shed light on the negative impact of conifer encroachment. The results are significant as they address the current forest structure trends in western Montana and highlight the ongoing need to monitor these trends to effectively manage elk populations and their habitats.

INTRODUCTION

Background

The alteration of forest structure due to factors such as climate change, fire suppression, and changes in logging practices has led to changes in habitat conditions for wildlife. These changes include the colonization of open stands and forest floors by conifers, which affect many natural processes, such as the availability of food sources and canopy cover that provide secure habitat for wildlife. As a result, managing wildlife habitat is an increasingly challenging issue that requires a multifaceted approach to address the complex impacts of human and ecological factors (Lydersen et al., 2013; White et al., 2013).

Western Montana, which is heavily forested, has not been immune to these changes. Historically, fire regimes in parts of Montana were characterized by frequent and low-intensity fires, often burning fuel resources and naturally thinning saplings in open canopy forests, which created open stands with fire-resistant, mature conifer forests. Under current management and increasing human residency, fire suppression has resulted in longer fire intervals of 40 to 80 years, creating higher intensity, stand-replacing fires. Under this treatment, conifers have begun to colonize, encroaching on open stands, increasing canopy cover, and decreasing shade-intolerant shrub and grass species (Heyerdahl et al., 2006; Woods et al., 2013; Vance et al., 2017).

Elk in Montana

Elk (*Cervus canadensis*) are just one of the many wildlife species affected by forest habitat changes throughout Montana. As a keystone species, elk help maintain plant biodiversity, are a food source for carnivores, create healthier soils through grazing and trampling, and provide human cultural resources (Stewart et al., 2009). Elk are habitat generalists, both grazers of herbaceous vegetation and browsers on shrubs and bark. The use of their home ranges changes throughout the seasons in conjunction with their nutritional needs, so diversity in habitats is an essential factor in creating healthy ecosystems. Throughout the summer, elk choose open grassland areas with high-quality forage for weight gain before winter (Holland et al., 2005). During the winter and hunting season, dense forests away from roads are preferred for security, food sources, and thermal cover (Proffitt et al., 2013). In general, elk tend to prefer areas with high levels of canopy cover. This preference holds true across different seasons and sexes, with most elk choosing areas with canopy cover values greater than 53% (Lowry et al., 2019). High-quality elk habitat requires sufficient canopy cover, but excessive amounts can reduce available foraging areas (Young et al., 1967; McConnell & Smith, 1970).

Elk management has a turbulent history in Montana. Historically, elk had an extensive range and population throughout Montana, but in the 1800s and into the early 1900s, elk hunter harvests were unregulated, and population levels dropped to dangerously low levels. By 1940, the estimated elk population declined to approximately 22,000, and management steps were initiated to increase herd numbers. These management strategies aimed to increase canopy cover security zones, limiting hunter-harvest potential.

Montana is divided into 140 hunting districts (HDs) across seven regions, and each district is managed according to its unique land cover characteristics. Montana is diverse, and the percentage of forested and grassland areas in each HD varies based on landscape factors. Some HDs have more mountainous regions supporting forested habitats, whereas others have more non-forested valleys, resulting in larger grassland percentages. In 2022, Montana Fish, Wildlife and Parks (MFWP) estimated that the Montana elk population was approximately 141,000, over 1.5-times the planned objective based on carrying capacity (MFWP, 2022). However, these objectives were specific to regions, and not all areas exceeded their objective. Although much of eastern Montana's counts are above the objective range, western Montana contains HDs within or below their objective range (Figure 1). Understanding what happens in individual HDs and regions is crucial to managing elk and forest structure effectively.

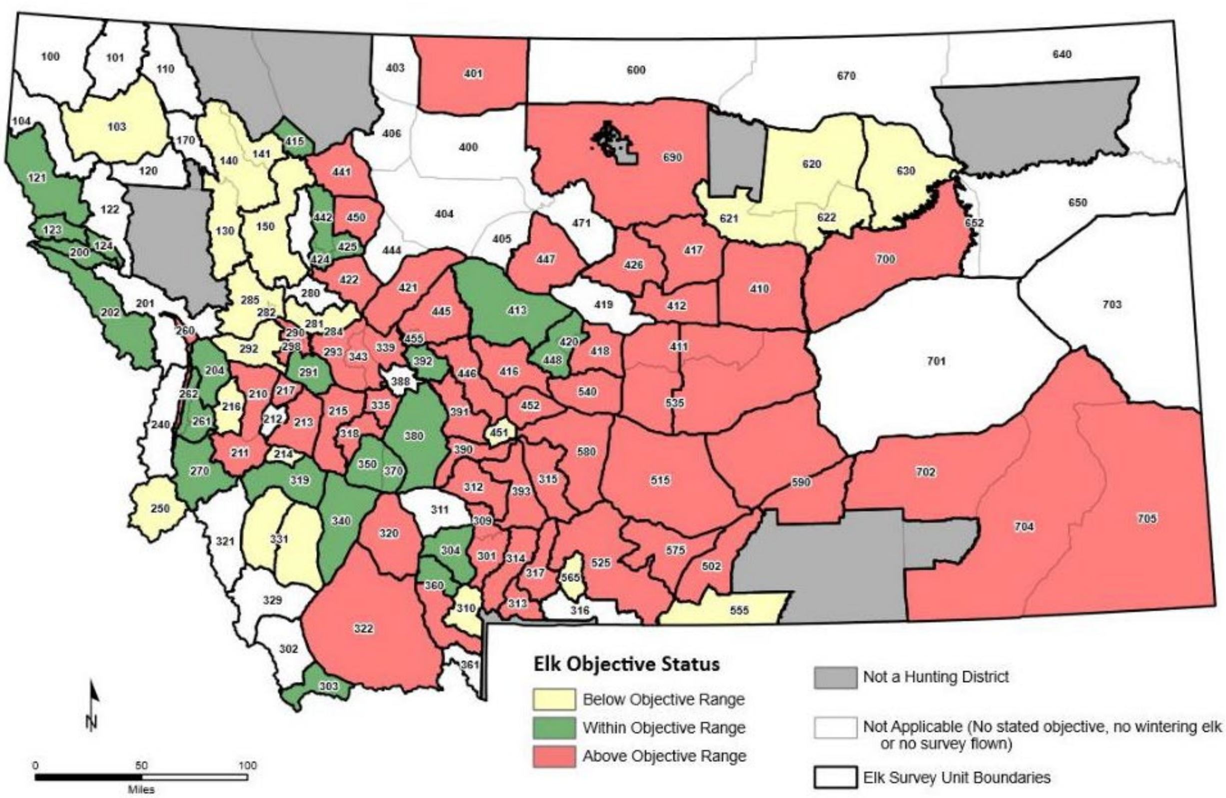

Figure 1. Montana's elk objectives map (MFWP, 2022)

Montana Habitat Management

In recent years, a focus on food production and diversity in habitats has shown that habitat quality may be a significant factor affecting the health of elk herds (Melis et al., 2009; Brodie et al., 2013). Dense forests create areas with low food production and decrease hunters' ability to locate elk as they provide more cover for elk security (Proffitt et al., 2013). Effectiveness of elk habitat varies by land cover type, with grassland, shrub, and open sapling pole serving as forage areas; open sapling, closed sapling/pole/sawtimber, and large sawtimber as hiding and thermal cover; and large sawtimber and old-growth as optimal cover (Figure 2). Open sapling pole and closed sapling/pole/sawtimber provide habitat for some hiding and thermal cover, but they do not offer optimal foraging nor what is considered optimal cover. Forested habitats that include diverse stand conditions provide a healthier ecosystem for elk. However, when one condition dominates, it reduces the others.

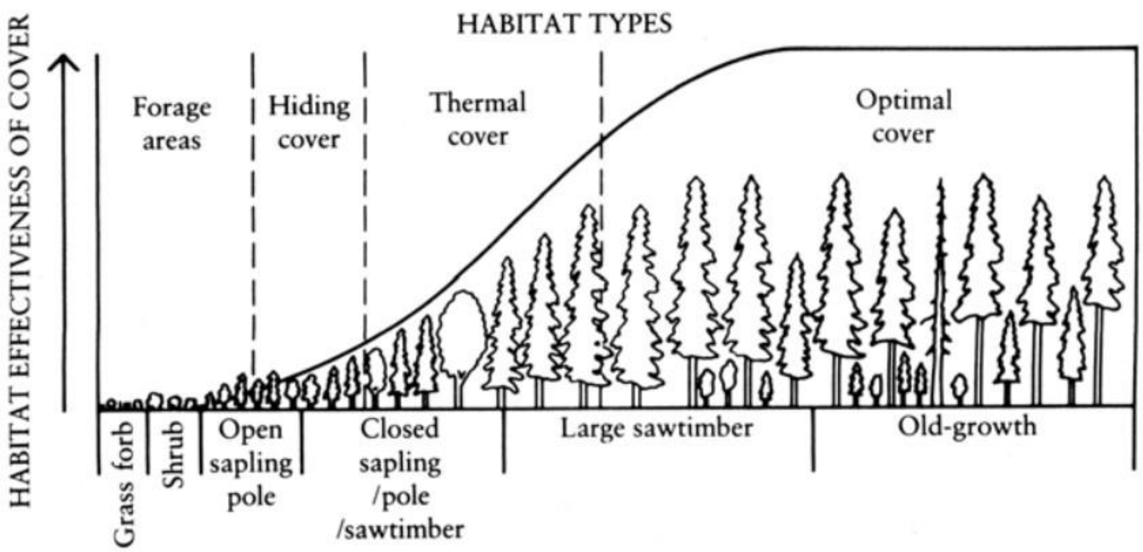

Figure 2. Stand conditions and effectiveness of habitat cover type (Morrison et al., 1998).

Conifer encroachment throughout the Rocky Mountains is a well-documented phenomenon and continues to be an issue for forest and wildlife management (Arno et al., 1979; Gallant et al., 2003; Kaye et al., 2005; Woods et al., 2013). Decades of forest fire suppression have changed the spatial dynamics of forest stand structures through a lack of disturbance. Sustainable timber harvesting attempts to mimic natural processes, but it has not been able to recreate the diverse effects of wildfires (Gallant et al., 2003). Without disturbance, conifer seedlings grow in forest understories, outcompeting shrub and grass species, and spread into adjacent open grassland areas. Left untreated, these trends continue to create elk hiding and thermal cover habitats but reduce foraging habitats and, therefore, hunter-harvest potential. The issue of conifer encroachment has long been recognized throughout western Montana, but the rates, and consequences of change on elk habitat need to be better characterized.

Data Resources

Over the years, freely available satellite imagery has greatly enhanced the ability to characterize forest conditions (Coops et al., 2020; Hermosilla et al., 2015; Shi et al., 2022). The Landsat satellite program, which offers earth imagery from early 1972, significantly contributes to these efforts. With the help of this resource, various programs have created tools that quantify patterns and changes in land cover. One such tool is the Rangeland Condition Monitoring Assessment and Projection (RCMAP), which is a joint project between the United States Geological Survey (USGS) through their Earth Resources Observation and Science Center and the Bureau of Land Management (BLM). It was created for land managers and scientists to evaluate land cover changes in management decisions (Rigge, 2023). Annual maps have been created using Landsat imagery from 1985 to 2021, showing the fractional cover of nine vegetation types, including annual herbaceous, perennial herbaceous, total herbaceous, sagebrush, non-sagebrush shrub, total shrub, litter, bare ground, and tree canopy cover. The validation of RCMAP has been extensively studied by comparing field data and high-resolution imagery (Shi et al., 2022)

Another tool is the Rangeland Analysis Platform (RAP) developed by the U.S. Department of Agriculture. It uses imagery from the Landsat program and field data from the Natural Resources Conservation Service's Natural Resources Inventory, the BLM's Assessment, Inventory, and Monitoring program, and the National Park Service Northern Colorado Plateau Network programs to predict landcover (Allred et al., 2021). The model learns and predicts the percentage cover of different vegetation types based on the relationships between satellite imagery and field data. The RAP western United States landcover dataset provides the average percentage cover of five vegetation types: annual forbs and grasses, perennial forbs and grasses, shrubs, trees, and bare ground. Multiple studies have used these resources for time series change detection in land cover analyses (Allred et al., 2019; Joubert et al., 2022; Rigge et al., 2021).

Study Objectives

To address the knowledge gaps regarding the changes in elk habitat in western Montana, my study aimed to answer two main questions: what changes are occurring in forest canopy and perennial grass cover, and how are forest structure changes correlated to elk populations? I hypothesized that western Montana is experiencing an increase in canopy cover and a decrease in perennial forage grasses due to a historical combination of fire suppression and reduced sustainable logging practices. These changes could result in a loss of diverse quality elk habitat and make hunter-harvest success more difficult.

Understanding the spatial dynamics of forest canopy cover and its potential impact on elk populations is crucial for ensuring the conservation of healthy elk populations across western Montana. To answer these questions, I analyzed changes in forest canopy cover by HD in Regions 1 and 2. I analyzed canopy cover changes based on remote sensing datasets derived from the RCMAP dataset from 1985 to 2020 and the RAP dataset from 1995 to 2022 to identify changes in forest and perennial grass cover. I compared these two datasets with elk population estimates conducted by FWP to determine if they are correlated.

I selected Regions 1 and 2 in Montana because of their unique habitat and general trends of being at or below their objective elk population numbers. As seen in Figure 1, much of western Montana has low to at-target population numbers, whereas much of eastern Montana has high population numbers. Regions 1 and 2 show different trends in elk population dynamics, possibly due to their habitat differences. Although both portions of the state are very diverse, eastern Montana generally consists of dry great plains mixed grass prairie, sand prairie, and wetlands and riparian areas. Western Montana generally consists of densely forested regions with low-elevation grasslands intermixed (Vance et al., 2017).

I also examined individual HDs to gain a more detailed understanding of what is happening in smaller areas. Some districts are more heavily managed or studied than others. For example, the elk population of HD 121 is undergoing extensive research to determine their spatial distribution and survival rates (Millspaugh, 2023). In 2016, comprehensive population studies were conducted on HD 250 and HD 270 due to their differing population trends despite being geographically close. The study found that HD 270 had a stable population and HD 250 had a declining population (Proffitt et al., 2016). Additionally, several hunting districts are located close to large human populations and are subject to higher hunting pressure. Among these districts are HD 140 and HD 103. However, compared to HDs 204 and 210, which are also near large human populations, HD 140 and 103 have lower elk populations and are below their objective range. By understanding the changes in forest structure in each HD, we can better comprehend the past and future changes in elk population numbers and manage them accordingly to cater to the specific needs of each elk herd.

METHODS

Study Area

The study area consisted of 43 HDs throughout western Montana, forming FWP Region 1 and Region 2 (Figure 3). These regions contain millions of hectares of land encompassing public and private lands, large and small communities, and numerous bodies of water. The study area follows the Montana-Idaho border to the west, the Canadian-U.S. border to the north, the Rocky Mountains to the east, and the Sapphire Mountain Range to the south.

Region 1 encompasses Glacier National Park and the Flathead Indian Reservation and spans 27,262 square kilometers. The region is known for its dense forest cover, estimated to be about 90% of the total land area, with moderate to heavy timber (Arno, 1979). It is often called the Crown of the Continent Ecosystem, with significant diversity in wildlife and habitat. Elk are particularly abundant in the region, with about 95% of the area populated by them (Sterling, 2020). As of 2022, Region 1 had an estimated elk population of 2,246 (MFWP, 2022).

Region 2 includes the Clark Fork River, the Bitterroot Range, and the Missoula Valley. The Bitterroot Range on the region's western border forms a moisture barrier; thus, much of Region 2 is characterized by a drier climate than Region 1 to the north. Trees are less abundant than in Region 1, with a past estimate of 80% of the land being forested and much of the rest being low-elevation valleys filled with grasslands (Arno, 1979). FWP conducts annual aerial surveys to determine the number of elk in each district and region throughout the winter and spring months. As of 2022, Region 2 had an estimated elk population of 20,871 (MFWP, 2022).

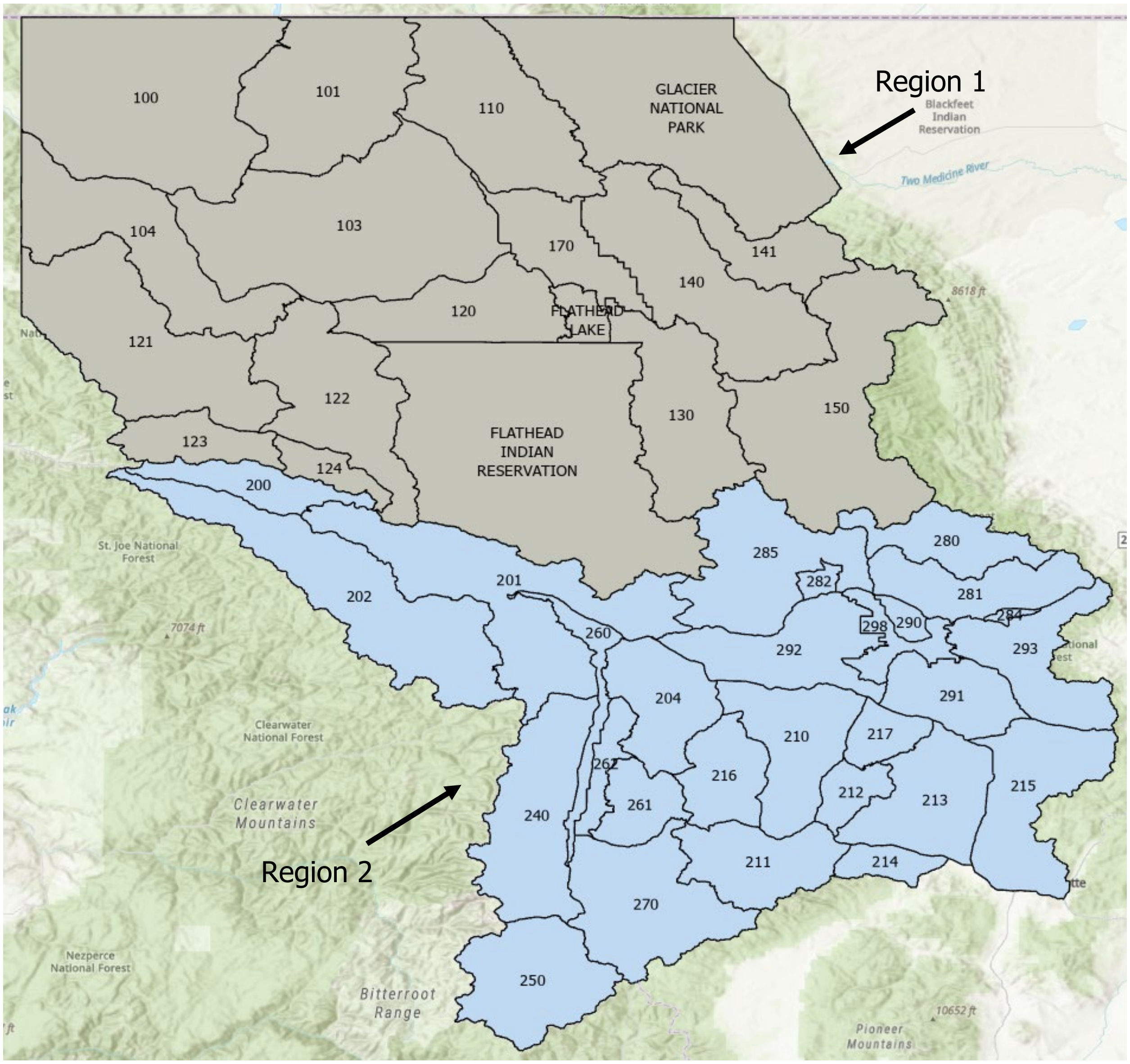

Figure 3. Western Montana study area Regions and Hunting Districts (MFWP GIS).

<u>Analysis of RCMAP</u>

First, I used the RCMAP dataset to analyze changes in tree canopy cover and perennial grass cover in western Montana. I obtained data on perennial herbaceous and tree canopy cover from RCMAP using the Multi-Resolution Land Characteristics (MRLC) Rangeland Viewer. This is a USGS application designed to allow users to view and download RCMAP time series data. I downloaded the imagery as TIFF image files for the western region of Montana. Next, I used

ArcGIS Pro to clip the imagery to the boundary of FWP management districts Regions 1 and 2. Due to the significant effort required for acquisition, I only downloaded the RCMAP data for HDs 121, 140, and 103, and the entirety of Region 1 and 2. The HDs chosen have unique characteristics, such as being currently studied for population numbers or being under their population objective. I used ArcGIS to extract the percent covers for perennial herbaceous and tree canopy from the attribute table for each area of interest. After analyzing the data, I found that most of the data consisted of areas with 100% tree canopy and 0% perennial herbaceous cover. Therefore, I focused on monitoring the changes in these categories.

Analysis of RAP

I then used the RAP dataset to continue my analysis using its data on canopy cover and perennial forage grasses to analyze trends. I downloaded the imagery from the RAP using their online application. I obtained the HD shapefiles from MFWP Maps and GIS resources and uploaded them individually to the RAP application to create areas of interest. I downloaded the available datasets from 1985 to 2022 for average annual tree cover and average annual perennial forb and grass cover for each HD and exported the data into Excel. From 1985 to 1999, only one Landsat satellite collected imagery, resulting in multiple data gaps and inconsistencies in the RAP products. The 1993 data displayed a sharp decline in all land covers across the state. However, in the subsequent year, there was an increase in the land covers, and they returned to their original state. This may indicate an error in the data for the year 1993. Due to this inconsistency, I used only the data from 1995 to 2022.

Statistical Analysis

I used RStudio for my analysis of both the RCMAP and RAP data. First, I used the Mann-Kendall (MK) Trend Test and Sen's Slope test using the R package "trend". The MK test analyzes for a consistent trend over time by comparing later measured values to earlier values. A significant p-value indicates that there is a statistically significant trend present. The Sen's Slope test analyzes a trend's linear rate of change. A positive value indicates an increasing trend, and a negative value indicates a decreasing trend. I calculated both analysis methods with a 95% confidence interval and a 0.05 alpha level for significance. My analysis of the MK and Sens Slope was performed on the tree and perennial grass cover and on the estimated elk counts.

I then used RStudio to calculate Pearson's correlation coefficient, which measures the statistical relationship of a linear association between two variables. Specifically, I analyzed the correlation between the amount of tree and perennial grass cover and the correlation between different cover types and elk counts. Values are given between -1 and 1, with a positive value describing a positive correlation, meaning that when one variable changes, the other changes in the same direction. A negative value indicates that when one variable changes, the other changes in the opposite direction. The strength of the correlation is relative to the discipline, but as a general rule, values between 0.0 and 0.1 mean there is no correlation between the variables, values between 0.2 and 0.4 indicate a weak correlation, values between 0.5 and 0.6 indicate a moderate correlation, values between 0.8 and 0.9 indicate a strong correlation, and a value of 1 indicates a perfect correlation.

RESULTS

Annual Trends

I observed similar overall trends between the RCMAP and the RAP analyses. According to the RAP results, the tree canopy cover in Region 1 increased by 0.33 % per year, and the perennial grass cover decreased by 0.22 % annually (Figure 4). However, the RCMAP results showed smaller trends, with Region 1 only experiencing an annual increase of 0.10 % in 100 % tree canopy cover and almost no change in 0 % perennial grass cover (Figure 5).

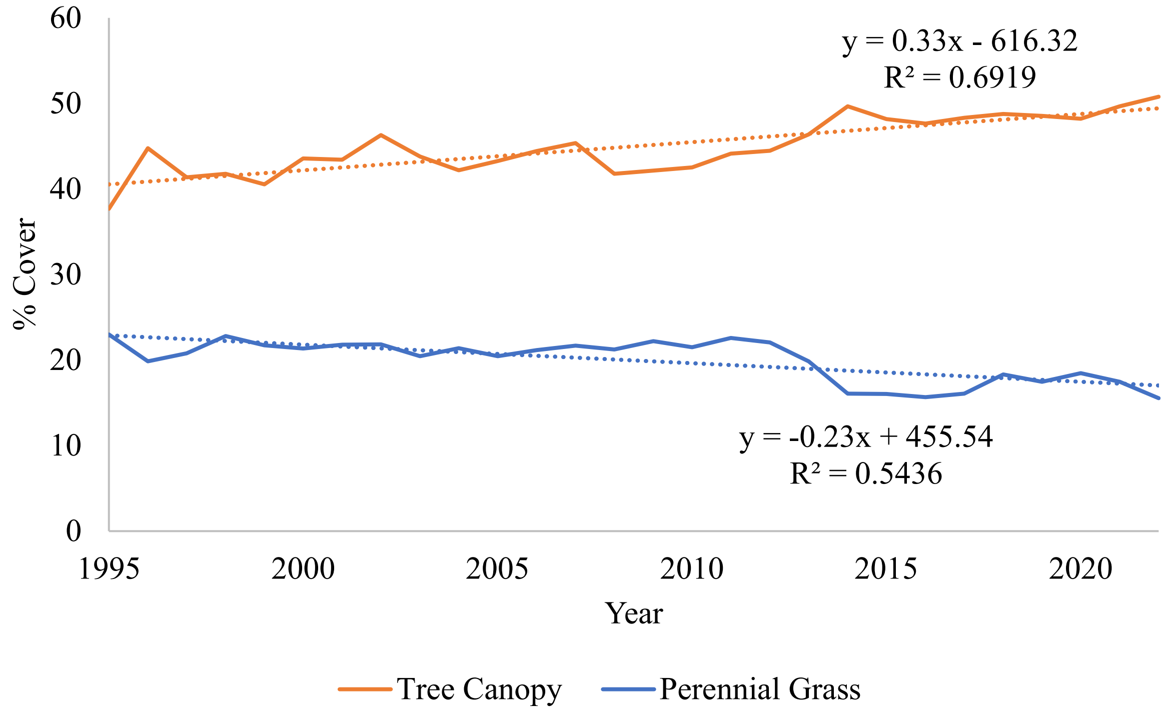

Figure 4. Rangeland Analysis Platform Region 1 trends.

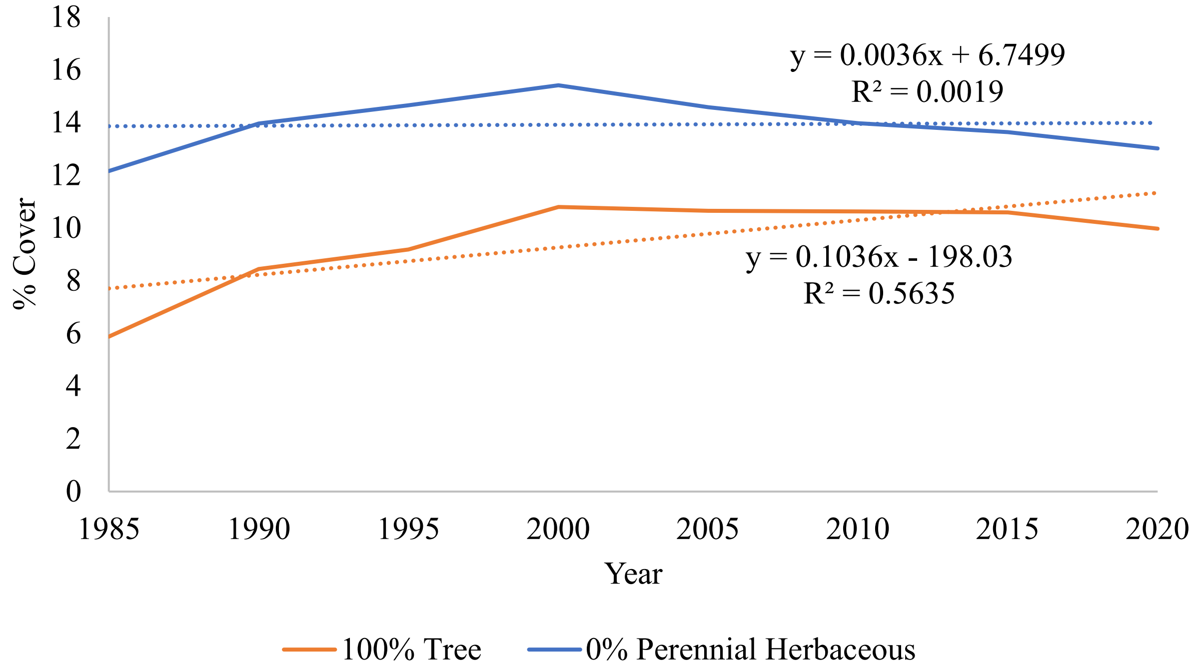

Figure 5. Rangeland Condition Monitoring Assessment and Projection Region 1 trends.

In Region 2, using the RAP data, I found that tree canopy coverage increased at a rate of less than 0.08 % per year, but perennial grass cover decreased by -0.17 % annually (Figure 6). Additionally, my RCMAP analysis shows a slight yearly increase of 0.010 % in 100 % tree canopy coverage. However, I was surprised to find a decrease of -0.11 % per year in 0 % perennial grass coverage, meaning perennial grass coverage is increasing (Figure 7). Overall, Region 1 showed the most significant increase in tree cover, as shown by both RCMAP and RAP.

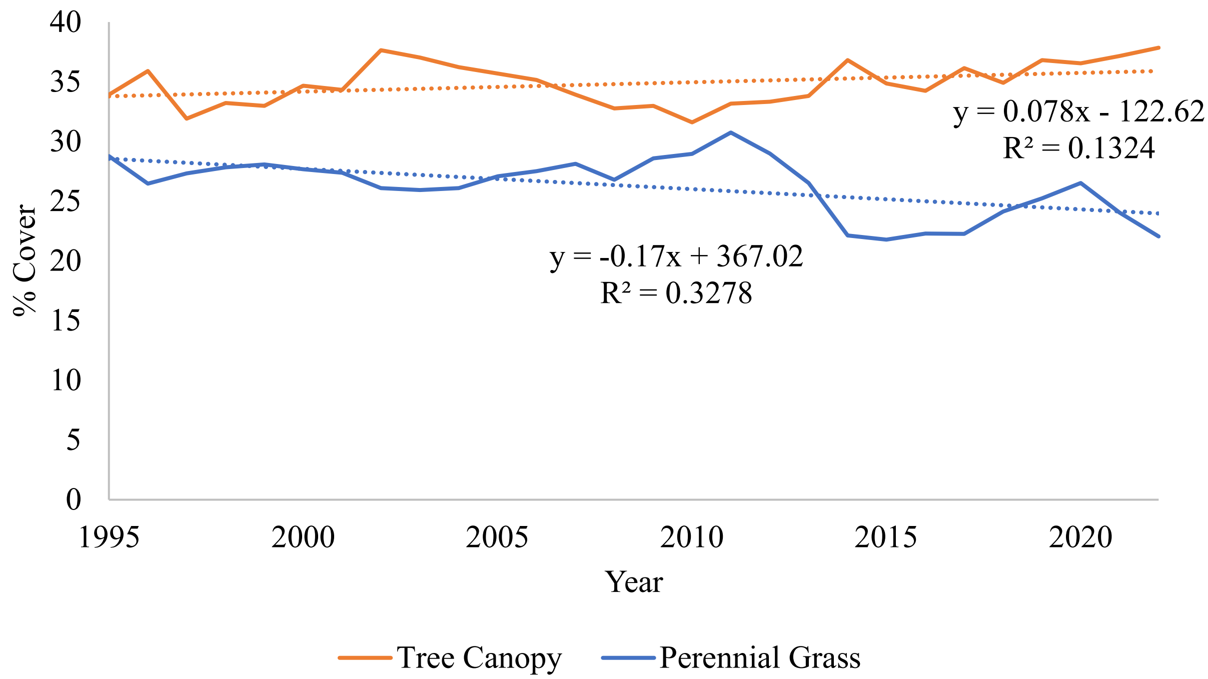

Figure 6. Rangeland Analysis Platform Region 2 trends.

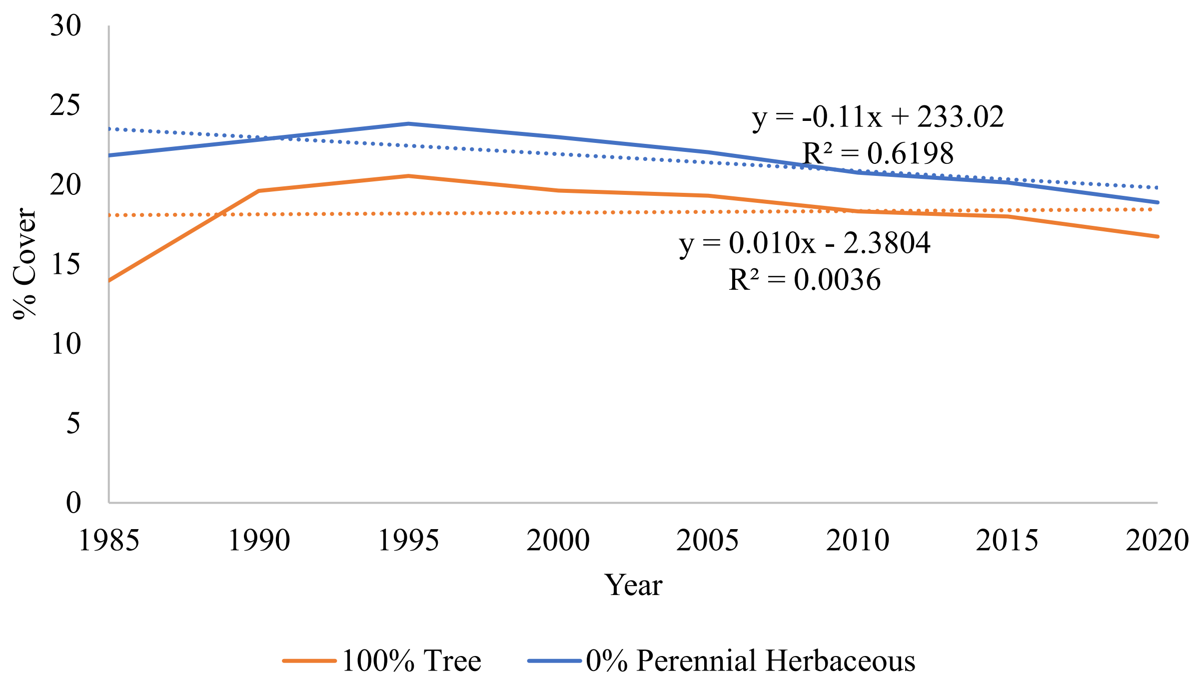

Figure 7. Rangeland Condition Monitoring Assessment and Projection Region 2 Trends.

<u>RCMAP Changes Between 1985 to 2020</u>

RCMAP assesses the distribution of land cover in terms of their percentages. According to their data, most areas have complete tree canopy cover (100 %) and no perennial grass cover (0 %). Due to this, it is important to note that when the results show an increase in tree canopy cover, the tree canopy cover increases. However, when the results show an increase in 0% perennial grass cover, this means that the areas with 0% perennial grass cover are increasing. Put simply, the perennial grass cover is decreasing. An increase in perennial grass cover percentage for RCMAP does not mean an increase in the actual grass cover but rather an increase in the areas where grass cover is absent.

Using the RCMAP data, I observed an increase in 100% tree cover in all areas of interest. Region 1 had the highest percent increase at 70% (Table 1). However, the results for areas with 0% perennial grass cover were less consistent. In Region 1, HD 103, and HD 121, I found a gain in areas with 0% grass cover, indicating a loss of overall grass coverage. Conversely, I observed that Region 2 and HD 140 experienced a loss in area with 0% grass coverage, which means there was a gain in the overall grass coverage. I only found statistical significance in a change in tree and perennial grass cover in HD 121. Except for Region 2, I observed a positive trend in the percent tree coverage for all areas of interest. However, as indicated by Sen's slope, I also observed a positive trend in the percent grass coverage in all areas of interest except HD 121. In general, I observed a moderate to strong correlation between tree and perennial grass coverage, besides HD 103 (Table 1).

Table 1. Rangeland Condition Monitoring Assessment and Projection statistical analysis.

Area of Interest	**100% Tree Cover**			**0% Perennial Grass Cover**			**Tree vs. Perennial Grass Correlation Coefficient**
	Mann Kendall P-value	Sen's Slope	% Change	Mann Kendall P-value	Sen's Slope	% Change	
Region 1	0.39	0.46	70	0.71	-0.11	7.1	0.68
Region 2	0.27	-0.41	20	0.063	-0.76	-14	0.52
HD 103	0.063	0.21	0.21	0.17	-0.095	28	0.04
HD 121	0.019	0.55	0.55	0.035	0.28	9.5	0.93
HD 140	0.063	0.53	0.53	0.71	-0.19	-3.3	0.64

I observed a moderately positive trend between the percent tree coverage and perennial grass coverage in Region 1 and Region 2 and a strongly positive trend in HD 121 (Figures 8 through 10). These trends may indicate that as tree cover increases, the areas with 0% perennial grass cover also increase, showing a loss in overall grass coverage.

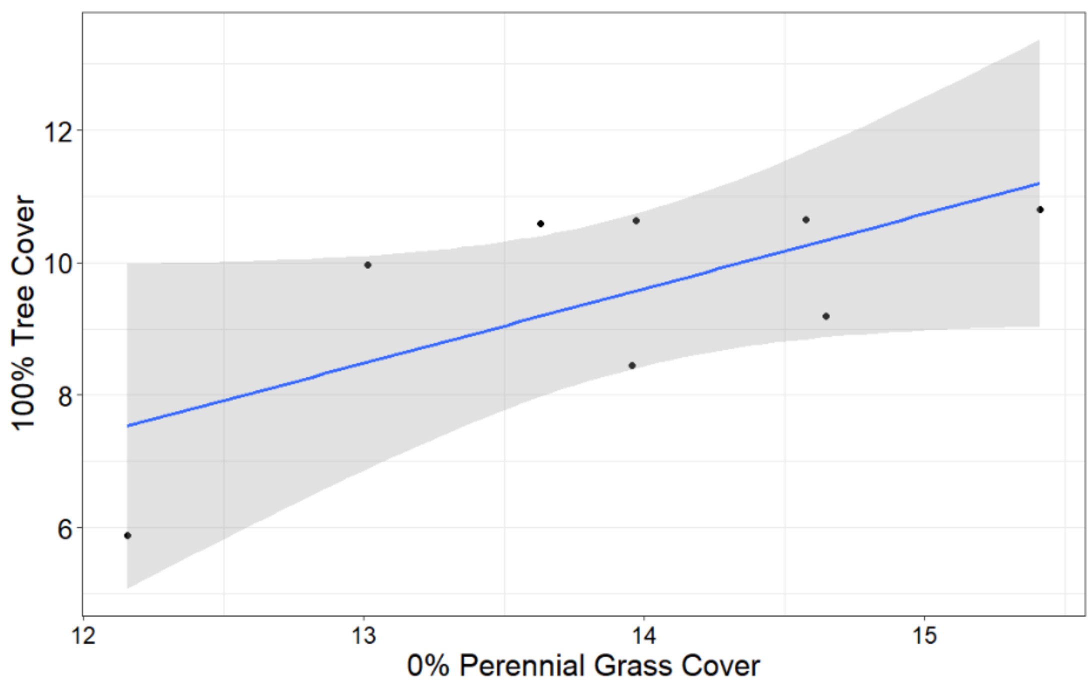

Figure 8. Region 1 percentage tree cover and perennial grass cover correlation.

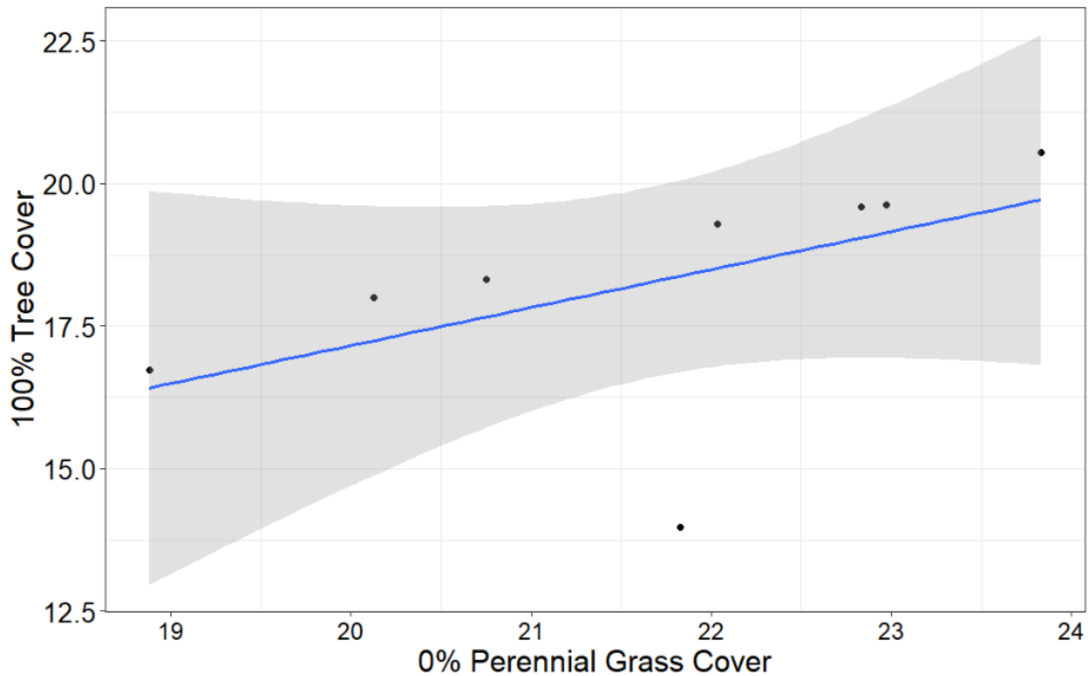

Figure 9. Region 2 percentage tree cover and perennial grass cover correlation.

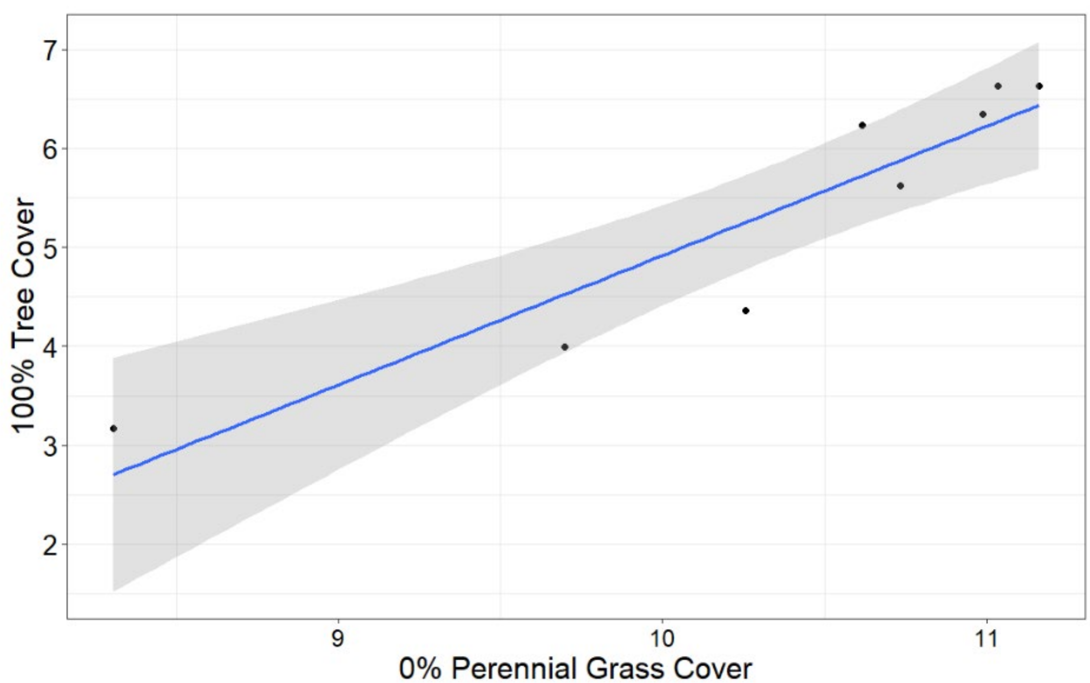

Figure 10. Hunting District 121 tree cover and perennial grass cover correlation.

As HD 121 is undergoing extensive research on elk population and distribution and the area showed significant trends in land cover, I visually analyzed the changes in land cover from 1985 to 2020. Areas 1 and 2 experienced the most change with an increase in tree density, indicated by the darker shades of red in Figure 11 in 2020. Additionally, I observed increased perennial grass cover in HD 121 over multiple areas during the same period. The darker shades of green in Figure 12 indicate increased perennial grass density.

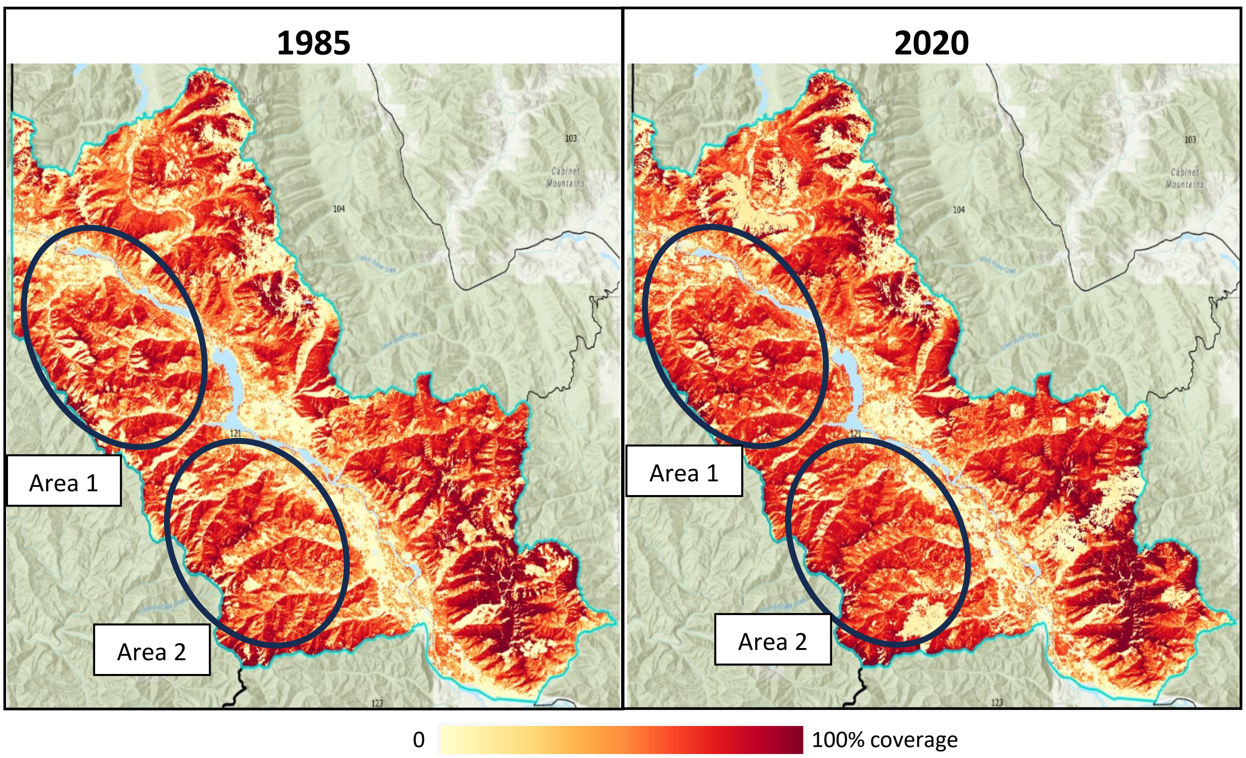

Figure 11. Hunting District 121 Rangeland Condition Monitoring Assessment and Projection tree canopy cover.

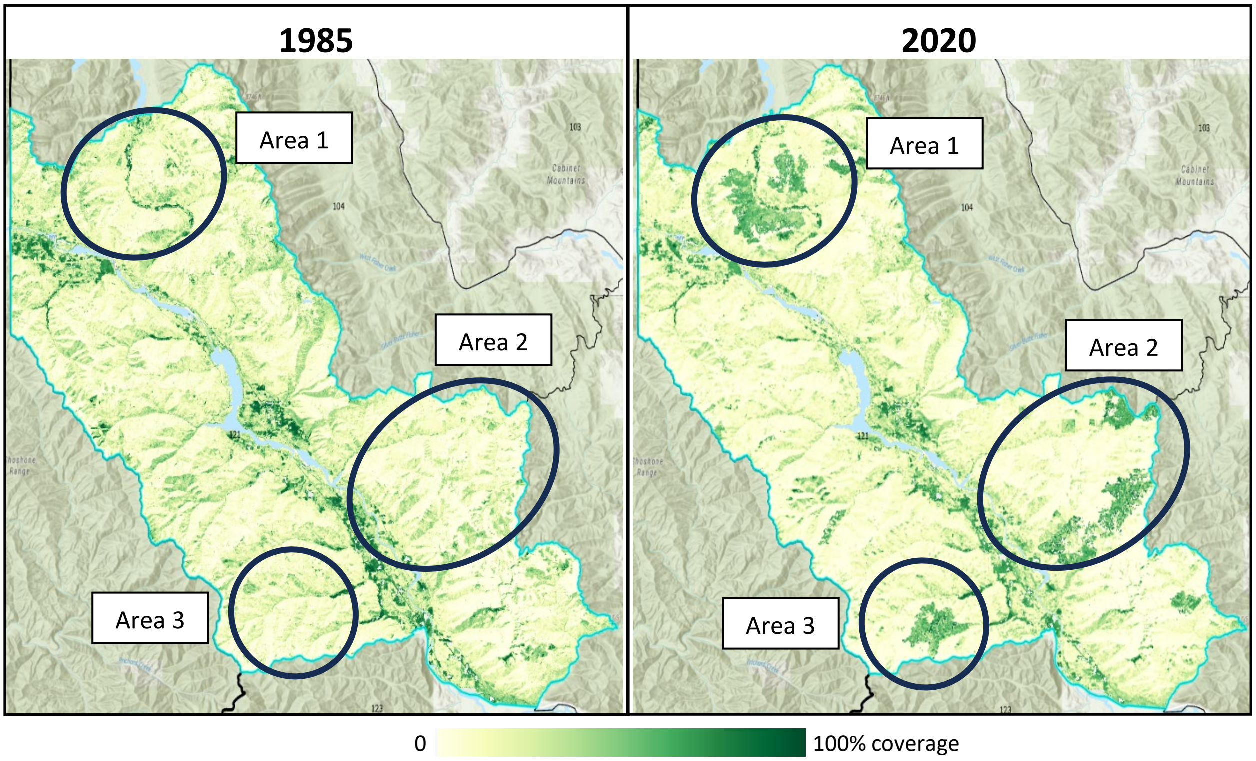

Figure 12. Hunting District 121 Rangeland Condition Monitoring Assessment and Projection perennial grass cover.

<u>RAP Changes Between 1995 to 2022</u>

I found the results more reliable using the RAP data as there are more areas of interest with statistically significant trends. In Region 1, I found that all areas of interest, except for one, have experienced an increase in tree coverage. Perennial grass cover has also decreased in all areas of interest. On average, the tree cover in Region 1 has increased by 27%, whereas the average perennial grass cover has decreased by 52%. Using Sen's Slope, I found that most trends showed increasing tree cover and decreasing perennial grass cover. Over half of the areas of interest demonstrated a strong correlation between tree and perennial grass cover, and also evident in Region 1 with a correlation coefficient of 0.86 (Table 2).

Table 2. Rangeland Condition Monitoring Assessment and Projection statistical analysis of Region 1.

Area of Interest	% Tree Cover			% Perennial Grass Cover			Tree vs. Perennial Grass Correlation Coefficient
	Mann Kendall P-value	Sen's Slope	% Change	Mann Kendall P-value	Sen's Slope	% Change	
Region 1	8.68E-07	0.37	27	4.36E-04	-0.23	-52	-0.86
HD 100	8.97E-09	0.70	33	0.15	-0.38	-86	-0.88
HD 101	6.15E-08	0.57	43	0.70	-0.41	-89	-0.85
HD 103	6.37E-07	0.74	40	0.26	-0.54	-121	-0.90
HD 104	3.44E-06	0.38	25	0.96	-0.26	-61	-0.80
HD 110	2.16E-05	0.56	29	0.44	-0.21	-90	-0.89
HD 120	0.0047	0.45	31	0.81	-0.51	-85	-0.82
HD 121	0.14	0.13	14	0.48	-0.12	-35	-0.56
HD 122	0.92	0.01	9.0	0.13	-0.28	-71	-0.19
HD 123	0.59	0.05	16	0.23	-0.07	-58	-0.46
HD 124	0.035	-0.26	-16	0.30	-0.08	-20	-0.31
HD 130	5.12E-05	0.39	22	0.48	-0.21	-90	-0.67
HD 140	0.0081	0.26	22	0.43	-0.03	-54	-0.53
HD 141	3.64E-05	0.42	26	0.32	-0.16	-72	-0.61
HD 150	0.24	-0.10	4.3	0.72	0.11	-12	-0.41
HD 170	0.020	0.21	24	0.19	-0.23	-17	-0.71

For Region 2, there were significant changes in tree cover observed in multiple HDs and Region 2 overall. However, only Region 2 displayed a significant change in perennial grass coverage. Sen’s slope indicated an increase in tree coverage in all HDs except for four and a decrease in perennial grass coverage in all areas of interest except for HDs 216 and 270. Furthermore, a moderate to strongly negative correlation existed between tree and perennial grass cover in half of the areas of interest and Region 2 (Table 3).

Table 3. Rangeland Condition Monitoring Assessment and Projection statistical analysis of Region 2.

Area of Interest	**% Tree Cover**			**% Perennial Grass Cover**			**Tree vs. Perennial Grass Correlation Coefficient**
	Mann Kendall P-value	Sen's Slope	% Change	Mann Kendall P-value	Sen's Slope	% Change	
Region 2	0.048	0.095	10	0.022	-0.14	-31	-0.61
HD 200	3.06E-05	0.29	13	0.51	-0.22	-91	-0.66
HD 201	0.00078	0.21	19	0.42	-0.18	-45	-0.41
HD 202	0.00097	0.21	16	0.46	-0.17	-82	-0.54
HD 204	0.038	0.09	13	0.63	-0.21	-37	-0.40
HD 210	0.011	0.15	17	0.19	-0.34	-32	-0.64
HD 211	0.77	0.02	-6.0	0.67	-0.09	-32	-0.20
HD 212	0.40	0.12	-3.1	0.55	-0.13	-57	-0.37
HD 213	0.014	0.21	16	0.55	-0.10	-14	-0.67
HD 214	5.55E-05	0.40	27	0.15	-0.14	-33	-0.76
HD 215	0.59	0.03	6.7	0.24	-0.15	-18	-0.64
HD 216	9.94E-05	-0.46	-32	0.28	0.14	-5.1	-0.71
HD 217	0.017	0.14	6.5	0.91	-0.24	-17	-0.61
HD 240	0.16	0.05	13	0.22	-0.10	-23	-0.36
HD 250	0.42	-0.07	6.0	1.00	-0.00048	-47	-0.37
HD 260	1.50E-05	0.11	21	0.12	-0.26	1.1	-0.43
HD 261	0.023	0.09	12	0.52	-0.13	-21	-0.31
HD 262	0.028	0.06	-19	0.29	-0.31	0.9	-0.24
HD 270	0.83	0.06	-2.4	0.57	0.042	-16	-0.77
HD 280	0.046	0.15	13	0.42	-0.10	-30	-0.52
HD 281	0.14	-0.11	-5.3	0.20	-0.11	-21	-0.59
HD 282	8.97E-09	0.43	41	0.53	-0.51	-39	-0.87
HD 284	0.41	0.03	3.5	0.72	-0.28	-15	-0.46
HD 285	0.00051	0.21	18	0.84	-0.32	-55	-0.80
HD 290	0.038	0.04	-15	0.53	-0.25	-2.6	-0.29
HD 291	0.050	0.14	21	0.27	-0.28	-27	-0.72
HD 292	0.046	0.18	14	0.27	-0.28	-50	-0.76
HD 293	0.46	-0.06	3.2	0.20	-0.15	-26	-0.71
HD 298	0.00055	0.24	30	0.99	-0.38	-25	-0.75

I found a strong negative correlation between tree cover and perennial grass cover in Region 1 (Fig. 13) and in HD 103 (Figures 15), with only a moderately negative correlation in Region 2 (Figure 14). These negative trends in all areas of interest imply that perennial grass cover tends to decrease as tree cover increases.

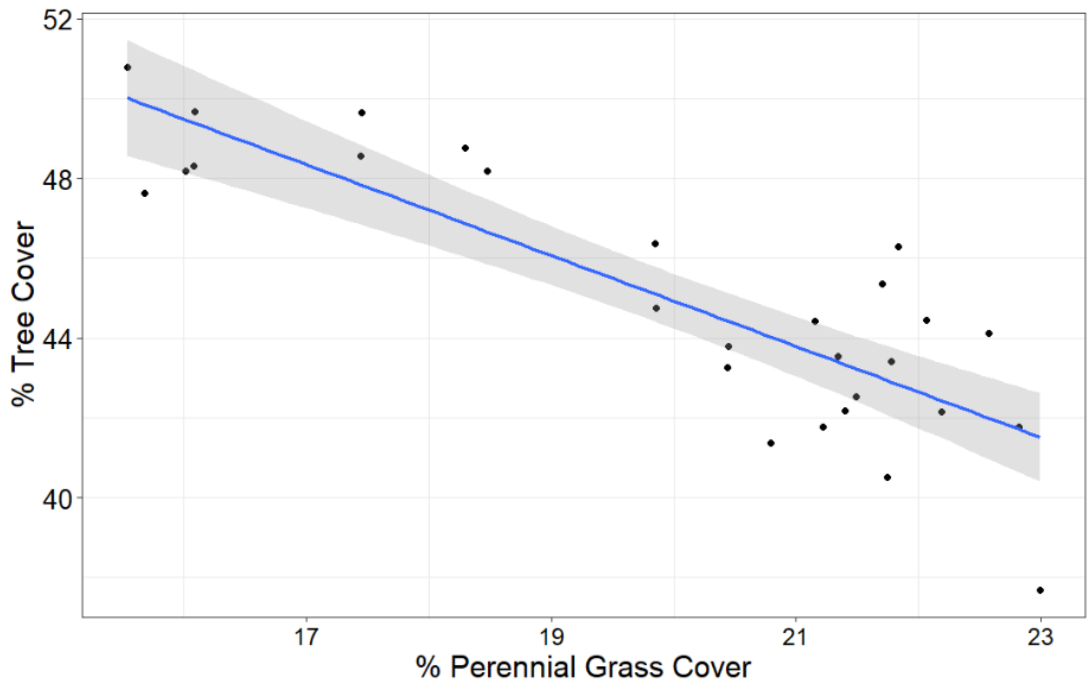

Figure 13. Region 1 tree cover and perennial grass cover correlation.

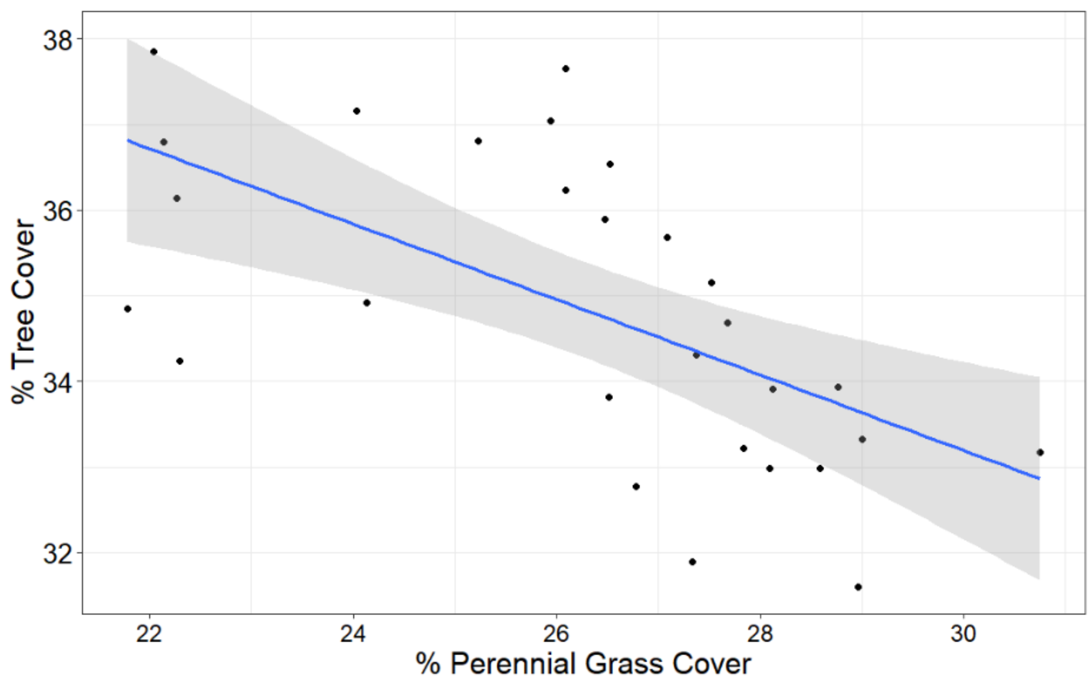

Figure 14. Region 2 tree cover and perennial grass cover correlation.

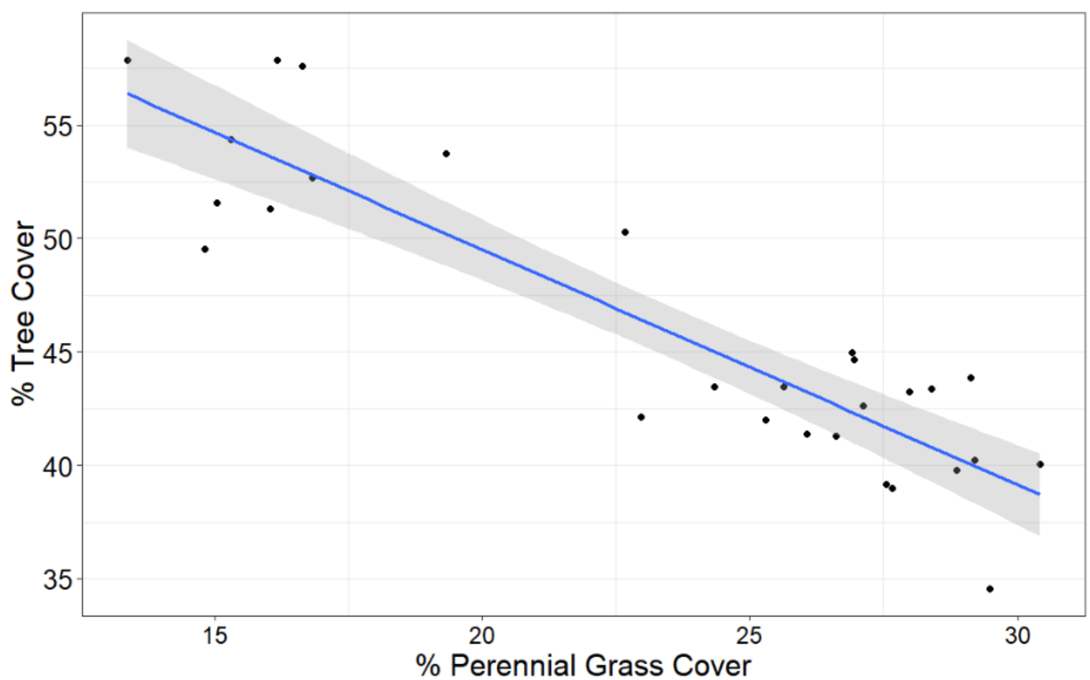

Figure 15. Hunting District 103 average tree cover and perennial grass cover correlation.

I used RAP data to create comparison maps from 1995 to 2022 to observe western Montana's land cover changes. After analyzing the tree canopy cover, I found that areas 1 through 3 had denser tree coverage, as indicated by the visually darker shades of red in Figure 16. Additionally, I observed a loss in perennial grass cover in areas 1 and 2, which were shown to have lighter shades of green, indicating a lower density of perennial grass coverage in Figure 17.

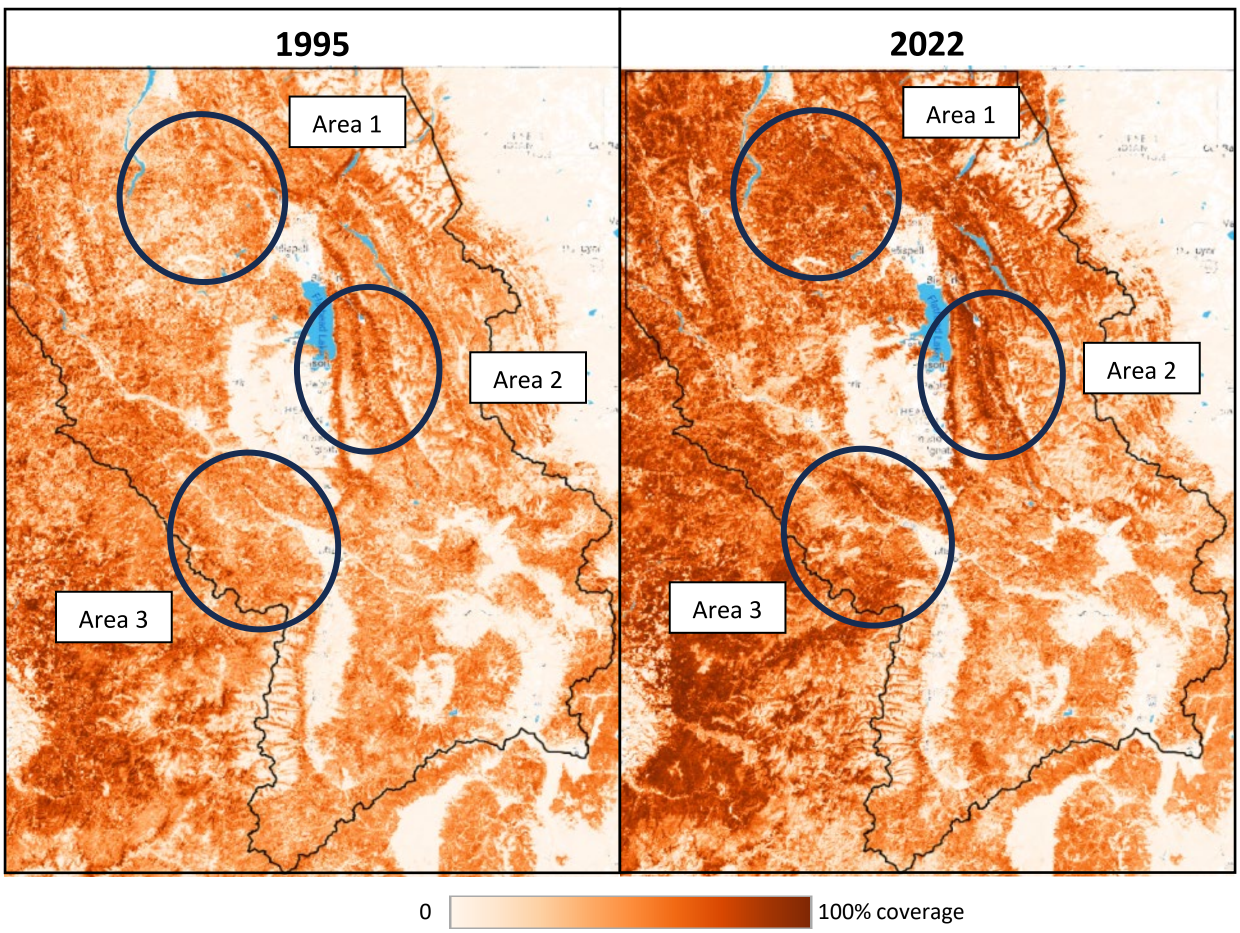

Figure 16. Rangeland Analysis Platform tree canopy cover.

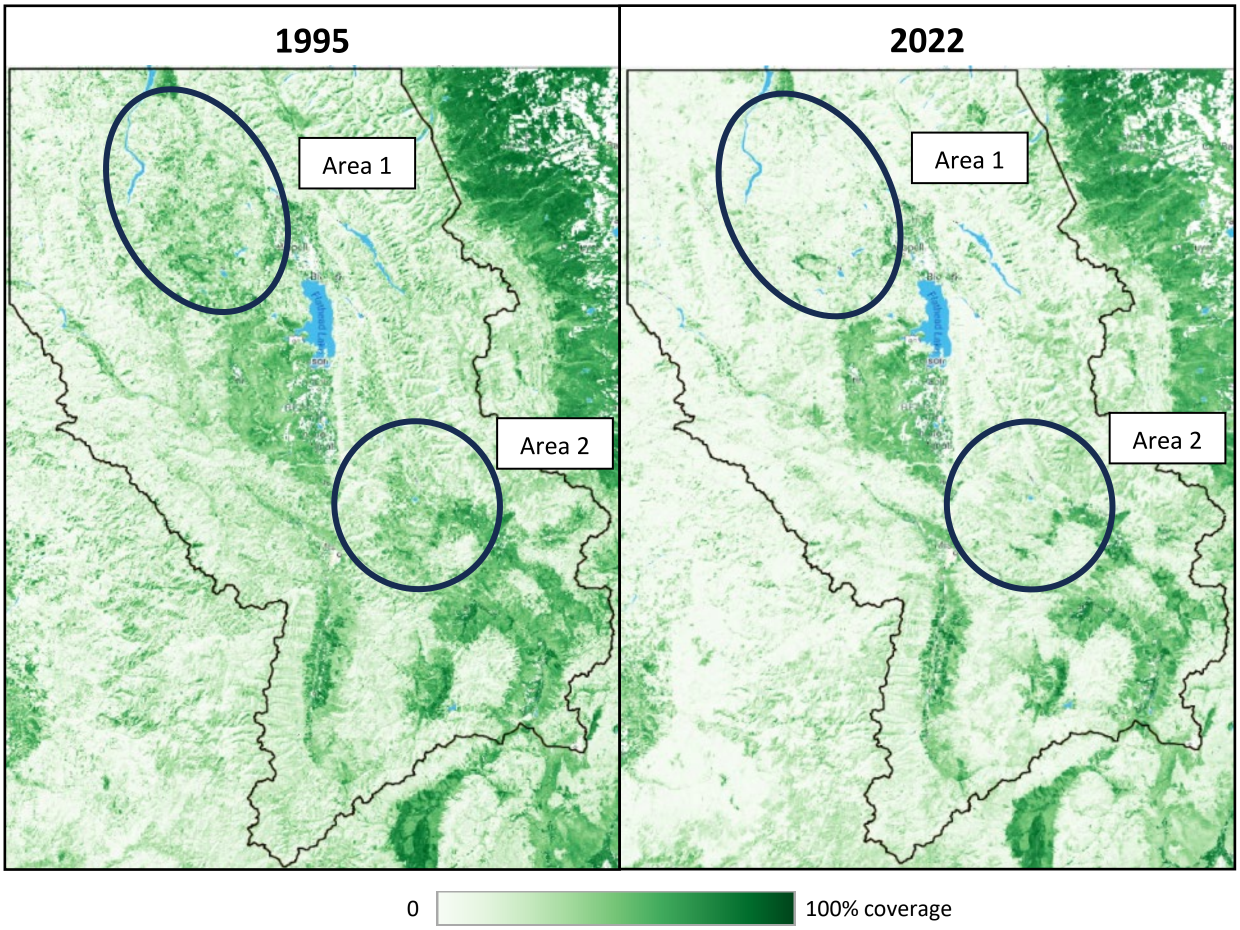

Figure 17. Rangeland Analysis Platform perennial grass cover.

Elk Population Counts

Based on the available data, I found that the estimated elk population counts were not very predictable. There were large gaps in the data due to the unavailability of elk surveys and large fluctuations in the data within short periods. I observed a negative trend in Region 1 and HD 140's elk counts (Figures 18 and 19, respectively). Only HD 140 displayed a statistically significant decline in the elk population.

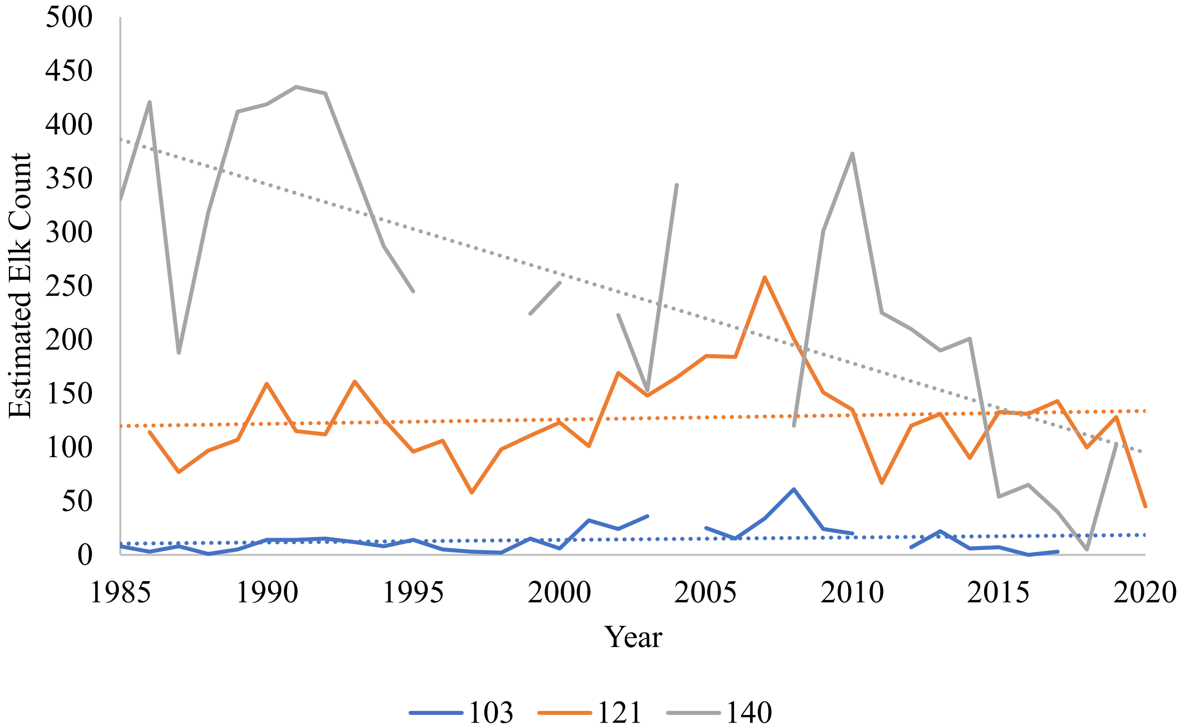

Figure 18. Elk population count estimates for Hunting District 103, 121, and 140 from 1985-2020.

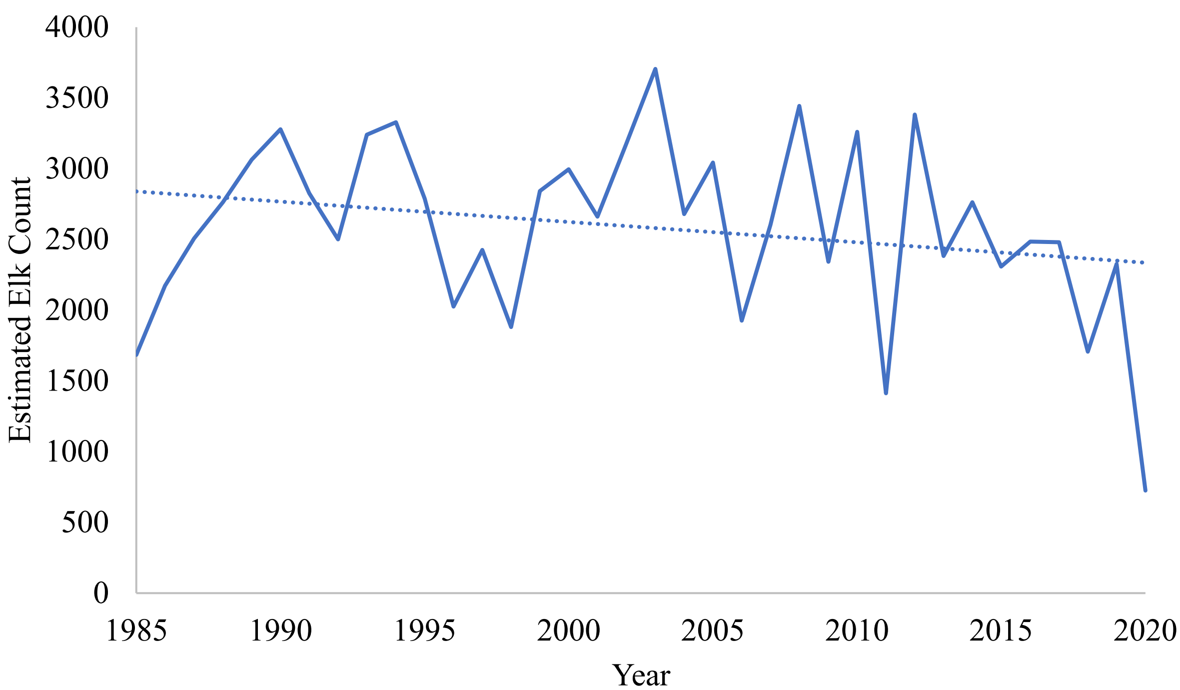

Figure 19. Elk population count estimates for Region 1 from 1985-2020.

Table 4. Elk population count estimates from Montana Fish Wildlife and Parks.

Area of Interest	Mann Kendall P-value	Sen's Slope
Region 1	0.22	-12
HD 140	< 0.0001	-11
HD 121	0.39	0.64
HD 103	0.55	11

I did not find a strong correlation between the elk population count estimates and the land covers using either RCMAP or RAP. The lack of statistical correlation may be due to the large data fluctuations in the elk count estimates. I found the strongest correlation to be 0.70 between perennial grass cover and elk counts using the RCMAP data (Table 5). Surprisingly, this positive correlation indicates that elk population counts may increase as perennial grass cover decreases (Figure 20).

Table 5. Estimated elk count correlation between land covers.

Area of Interest	RCMAP		RAP	
	Tree vs. Elk Correlation Coefficient	Perennial Grass vs. Elk Correlation Coefficient	Tree vs. Elk Correlation Coefficient	Perennial Grass vs. Elk Correlation Coefficient
Region 1	0.29	0.70	-0.33	0.20
HD 121	0.047	0.12	0.34	0.0032
HD 140	-0.34	0.18	-0.41	0.43
HD 103	0.27	0.42	-0.44	0.40

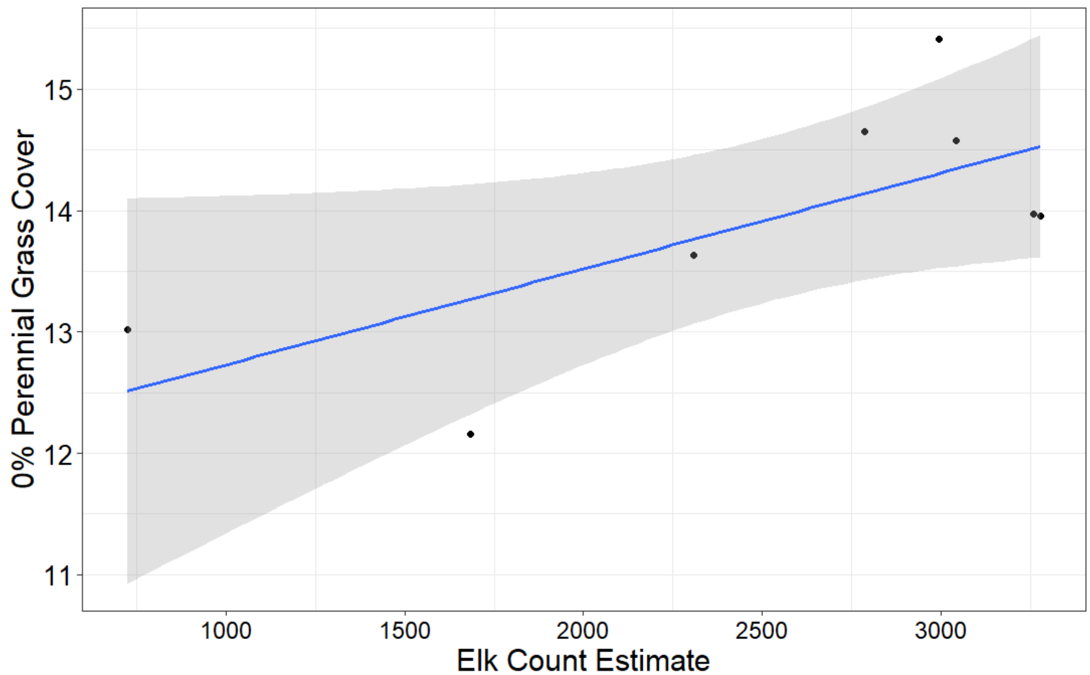

Figure 20. Region 1 Rangeland Condition Monitoring Assessment and Projection 0% perennial grass cover/elk count estimate correlation.

DISCUSSION

Change In Cover

Western Montana has diverse elk habitat and faces similar disturbances as other western regions, such as a lack of natural fire cycles and high-intensity fires. These disturbances can lead to increased tree coverage through conifer encroachment (Heyerdahl et al., 2006; Woods et al., 2013), which could be driving the trends observed in my analysis. After analyzing the RCMAP and the RAP data, I discovered that the trends for tree canopy and perennial grass coverage were overall similar, despite displaying some different outcomes in individual areas of interest. In Region 1, both datasets indicated an increasing annual trend of tree coverage, although tree coverage showed only slightly increasing to static trends in Region 2. The perennial grass cover varied, with the RCMAP results revealing overall slightly increasing to static trends and the RAP results indicating slightly decreasing trends. Despite the differences, these results provide insight into the structure of the forest in Montana and suggest further areas of study. Both datasets show an increase in tree coverage in Region 1, indicating conifer encroachment, which negatively impacts hunter-harvest success and elk habitat quality. Region 2, on the other hand, is either experiencing slower changes or less change overall. The differences in landscape factors between the two regions most likely play a role in this, and potential differences in forest management.

The analysis of HD 121, which is currently within its elk population objective and is of interest to MFWP research on population dynamics, revealed that tree coverage has increased and perennial grass cover has decreased. The RAP analysis suggests that there has been a 14% increase in tree coverage and a 35% decrease in perennial grass cover. These changes in spatial dynamics may help to understand how the elk in this area use their environment through additional research. Additionally, HD 250 and HD 270 showed little to no trends in tree or perennial grass cover. As recent elk population studies were conducted in both hunting districts, it may be possible to rule out large land cover changes as a factor in why HD 250 was experiencing a decrease in population while HD 270 remained consistent. Managing each hunting district individually is important due to varying land cover changes and their impact on elk herds.

My analysis also raises the question of how much habitat diversity is changing in western Montana due to a shift in forest dynamics. The majority of correlations between tree and grass cover in both datasets were moderate or stronger, all pointing to the same result: as tree cover increases, grass cover decreases. Since elk use different habitats throughout the seasons (Holland et al., 2005; Proffitt et al., 2013), their habitat diversity is critical. The significant and consistent correlations within the data between tree and grass cover mean that when one land cover dominates, the other suffers, decreasing western Montana's diversity. This loss in diversity reduces optimal cover in old-growth forests, reduces foraging areas in grasslands, and creates more thermal and hiding cover. These changes lead to a loss of elk food sources and decreased hunter-harvest success.

Elk Estimates

Determining the impact of land cover change on elk herds in western Montana was challenging due to the unpredictable nature of elk surveys. Analyzing the correlation between land cover and elk population count estimates revealed weak correlations, which made it difficult to distinguish the relationship between elk counts and land cover types. In addition, I observed large population fluctuations between years in each HD, as indicated by the large MK test for all areas of interest except HD 140. However, even within the raw data, HD 140 also displayed large fluctuations, which made the statistical analysis results unpredictable.

I was, however, able to visually observe changes in elk population numbers through MFWP surveys. For example, in HD 140, elk population counts remained at around 140 elk in the late 1980s, but since 2015, counts have fluctuated from 50 to 100 elk. Moreover, Region 1 is exhibiting a slight decline in elk population. MFWP's reports indicate that many of the HD elk population objectives in Region 1 are either at or below their target range, whereas in Region 2, they are generally at or above their target range. Although statistical correlations could not be established, my analysis did find that Region 1 has increasing tree coverage and decreasing perennial grass, while Region 2 is primarily static. These types of habitats may be indicative of the elk count results. The loss of optimal elk habitat in Region 1 may contribute to the decline in elk populations. In contrast, a more diverse habitat in Region 2 could provide land for elk herds to grow, even beyond their ideal numbers.

To determine any correlations between land cover and elk count estimates in the future, it is necessary to have a more accurate count on elk. Many factors can affect elk populations, but elk habitat is essential for herd health (Lydersen et al., 2013; White et al., 2013). Therefore, I suggest continued monitoring of elk population numbers and habitat to help us understand how one may be affecting the other.

Data Differences in RCMAP & RAP

The RCMAP and the RAP datasets were created to assist in land cover assessments for land use management decisions. However, they differ in the type of data they produce and how it is collected. I found the RCMAP data useful for conducting a detailed analysis as it provided me with the density percentages of each land cover type. I focused my analysis on areas that had 100% tree coverage and 0% grass coverage, which leaves out the intermediate zones with intermixed grass and tree cover. Due to the process of acquiring data from the RCMAP database, I had limited data available for this project. Although analyzing the extremes of land cover is important, it resulted in a narrower understanding of how it is changing in western Montana.

I found that the RAP was more useful for my project because it depicted the average amount of each land cover within the chosen area of interest yearly, giving me a comprehensive view of land cover changes. Additionally, I noticed a difference between the two methods regarding their statistically significant results. Although only one of the areas of interest had a significant trend using the RCMAP data, a large majority of the RAP trends were significant. This gave me more confidence in the results generated by the RAP. I believe the discrepancies between the two datasets were due to differences in how the data was presented. Using the RAP data averages offered a better insight into land cover changes, as I was able to understand the underlying trends better. In contrast, extremes failed to consider overall changes in land cover types.

Study Limitations

My analysis was over a vast area of Montana, and the data collection methods in the RCMAP and the RAP datasets differ. The accuracy of the land cover datasets raises concerns because both heavily rely on Landsat imagery. Even though both databases were designed to assist in land management decisions, independent studies suggest that the claimed accuracy for both is often overestimated (Applestein et al., 2023). Therefore, the results of this study should be considered estimates rather than precise measurements.

Additionally, the method used by FWP to estimate elk populations generates inconsistent results. Counting is done from aircraft during winter or spring, and only the elk spotted during the count are reported (MFWP, 2022). Furthermore, consistent yearly counts have only been performed in Region 1 and its associated HDs, so counts for Region 2 could not be used. Factors such as weather conditions, personnel constraints, and the unpredictable movements of elk can all contribute to the elk counts being, at best, rough estimates. A more accurate method of estimating elk populations and historical counts throughout more HDs would enable a more precise correlation between land cover types and elk counts.

Implications

My study aims to fill the knowledge gaps regarding a topic important to forest and elk herd management. Although conifer encroachment has been documented in regions of the Rocky Mountains (Heyerdahl et al., 2006; Woods et al., 2013), more large-scale research in western Montana needs to be done. Based on my analysis of two datasets, the results suggest that conifer encroachment is likely occurring in areas of western Montana, particularly in Region 1. Additionally, I found there is a loss of grasslands in some areas of the state, and a consistent correlation that suggests an increase in tree coverage results in a loss in grassland. This could threaten elk herd populations and reduce habitat quality in western Montana. The changes may affect hunter-harvest success and reduce forest diversity as grasslands and old-growth forests are encroached upon, creating hiding cover for elk. A comprehensive approach to wildlife management is essential for land managers in western Montana, as conifer encroachment is just one factor affecting elk herds. Further, continued analysis of forest structure is crucial for elk herd and habitat management throughout Montana.

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