Agriculture Demonstration of Practices and Technologies (ADOPT)

Project Final Report

The final project report should be made available electronically (MS Word). Additional data tables and or graphs may be submitted in spreadsheet format. Due to formatting, printing and distribution requirements, final reports will not be accepted as PDF documents. Completed reports must be returned by email to Evaluation.Coordinator@gov.sk.ca.

Project Title: Methods for establishing saline-tolerant forage mixes

Project Number: 20211110

Producer Group Sponsoring the Project: Saskatchewan Forage Council

Project Location(s): *Provide the name or number of the rural municipality, nearest town or legal land location if possible. Provide the name of any cooperating landowner(s).* South East Research Farm, Redvers, SK. RM No. 61; Western Applied Research Corporation, Scott, SK. RM No. 380; Livestock & Forage Centre of Excellence, Clavet, SK. RM No. 343.

Project start date *(month & year):* 5/1/2022

Project end date *(month & year):* 8/1/2023

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Abstract *(maximum 200 words)*

Detail key elements from the project objectives, methodology, results and conclusions to provide a short concise summary of the project. List extension activities such as field days or workshops and include the number of people who visited the project.

Perennial forages offer environmental, agronomic, and economic benefits to saline areas; however, their slow establishment limits producer's adoption. The study's objectives were to evaluate forage establishment, yield, nutritive value, pollinator abundance, and net returns of a saline mixture, pollinator mixture, hybrid wheatgrass, and salt-tolerant alfalfa seeded with and without a barley companion crop over two years at saline sites in Redvers (2.2-3.8 dSm^{-1}), Clavet (0.4-5.2 dSm^{-1}), and Scott (0.6-0.9 dSm^{-1}) in Saskatchewan. Results of the study found that forage mixtures established successfully at saline sites (>80%), regardless of companion crop. Yields over a two-year period were not significantly different between companion crop treatments, and forage mixtures resulted in 53-96% higher yields than the annual grain crops. Forage nutritive value was sufficient for all forage mixtures and varied based on species composition. The pollinator mixture resulted in 42-82% greater inflorescence and 10-66% greater honey bee abundance compared to other forage mixtures. Companion crops improved net returns by approximately \$150 ha^{-1}, and forage mixtures improved net returns by \$500 - \$700 ha^{-1} compared to the annual grain crops. Ultimately, this study confirms that establishing perennial forages with a barley companion crop is more productive than annual grain crops in saline soils.

Project Objectives

Provide a short statement outlining the project objectives. Identify the key concept this project was designed to demonstrate. For example, you might use a statement such as *"This project was intended to demonstrate and compare the benefits of……" or "The objective of this project was to demonstrate the impact of…."*

The objectives of this study were to; 1) evaluate seeding perennial forages with a barley companion crop in saline soils for improved forage establishment, yield, nutritive value, and net returns, and 2) assess perennial forage mixtures for pollinator habitat in saline areas.

Project Rationale

Briefly describe why this project is of interest to local producers. Why is it important to have this project? What are the potential beneficial outcomes? What is the perceived need?

There are many acres within fields of grainland that are currently unproductive and ill-suited to annual grain production of canola and pulses. These areas are problematic for development of herbicide resistant weeds and soil-borne pathogens. Finding an efficient and effective way of converting those acres to a perennial forage or wetland swale will help with the implementation of the current "Best Management Practice" projects supported by the Government of Saskatchewan and the "Marginal Areas Program" by Ducks Unlimited, that provide financial incentives to establishing forages in saline areas.

Since farmers want to avoid a loss in productivity and revenue during the establishment year of their perennial forage, seeding the forage with a low-density annual forage like barley is an established method in the industry. This 'under-seeding' is often not recommended due to the risk of the barley out-competing the forage resulting in failure of establishment. Under-seeding forage with a barley could have potential advantages in protecting the seedling forage from wind erosion, protecting the soil, and suppressing weeds like foxtail barley. By harvesting the crop as an annual forage, the competition with perennial seedling forage plants is reduced.

Methodology

Fully describe how the project was set up and run. You should provide enough information so that any reader can understand what you did, and where and when you did it. From that they can determine if your report has any relevance to their own operation. For example, your description should include all relevant items such as 1) the number and size of any field plots, 2) what was seeded, 3) what treatments were applied to the plots, 4) the schedule or timing of any relevant activities such as seeding, treatment application or harvest, and 5) what was measured to evaluate the success of any treatment. If your project dealt with animals, you should be sure to include 1) the number of animals in each trial group, 2) the treatment or procedure applied to each group, and 3) what was measured to evaluate the success of each treatment.

Experimental Design

The field study was conducted at the Livestock and Forage Centre of Excellence (LFCE) near Clavet, Saskatchewan, the Western Applied Research Corporation (WARC) at Scott, Saskatchewan, and the South East Research Farm (SERF) near Redvers, Saskatchewan in 2022 and 2023. The Clavet site is located on Dark Brown soil with salinity levels between 0.4 to 6.4 dS m^{-1}. The Scott site is located on Dark Brown soil with salinity levels between 0.4 to 0.9 dS m^{-1}. The Redvers site is located on Grey-wooded soil with salinity ranging from 2.2 to 4.2 dS m^{-1}.

The trial was arranged as a split-block randomized complete block design (RCBD) at each site. Plot dimensions measured 2.5 x 6 m, 3 x 6 m, 3 x 7 m for Clavet, Scott, and Redvers, respectively. There were 10 treatments in this study containing two factors: (1) Establishment method [companion crop and no companion crop], and (2) forage mixture [annual grain crop, salt-tolerant mixture, pollinator mixture, salt-tolerant grass, salt-tolerant legume]. Each treatment was replicated four times for a total of 40 plots per site. The trial was planted on perennial forage cover at Clavet, and wheat stubble at Scott and Redvers in May of 2022. The annual grain crop was seeded to barley in 2022, and canola in 2023. Treatments are listed in Table 1.

Table 1. Main effect (establishment method), sub effect (forage mixture), and species for each treatment.

Establishment Method	Forage Mixture	Species
Companion crop	Annual grain crop	2022- barley; 2023- canola
Companion crop	Salt-tolerant mixture	45% tall wheatgrass, 15% tall fescue, 15% smooth bromegrass, 15% alfalfa, 10% slender wheatgrass
Companion crop	Pollinator mixture	20% birdsfoot trefoil, 20% alfalfa, 20% yellow sweet clover, 20% hybrid wheatgrass, plantain, milkweed
Companion crop	Salt-tolerant grass	hybrid wheatgrass
Companion crop	Salt-tolerant legume	alfalfa
No companion crop	Annual grain crop	2022- barley; 2023- canola
No companion crop	Salt-tolerant mixture	45% tall wheatgrass, 15% tall fescue, 15% smooth bromegrass, 15% alfalfa, 10% slender wheatgrass
No companion crop	Pollinator mixture	20% birdsfoot trefoil, 20% alfalfa, 20% yellow sweet clover, 20% hybrid wheatgrass, plantain, milkweed
No companion crop	Salt-tolerant grass	hybrid wheatgrass
No companion crop	Salt-tolerant legume	alfalfa

Experimental Procedure

All treatments were fertilized based on spring soil test recommendations. In 2022, the Clavet site banded a blend of 31-28-0-0 prior to seeding at a rate of 80 kg ha^{-1}. The Scott site side-banded 11-52-0-0 at the time of seeding at a rate of 80 kg ha^{-1}. No fertilizer was applied at the Redvers site. In 2023, the Clavet site banded 165 kg ha^{-1} of 34-0-0-0, and 33 kg ha^{-1} of 11-52-0-0 to all forage treatments in the spring. Prior to seeding canola, 142 kg ha^{-1} of 34-0-0-0, and 68 kg ha^{-1} of 11-52-0-0 were banded on the annual grain crop treatments. At the Scott site, 2023 soil test results were variable between reps, so two different fertilizer blends were applied. In the spring, fertilizer was broadcast on forage treatments. For forages in reps 1 and 2, 46-0-0-0 was applied at 123.5 kg ha^{-1} and 11-52-0-0 at 33 kg ha^{-1}. In reps 3 and 4, 11-52-0-0 was applied at 33 kg ha^{-1}. For the canola, fertilizer blends were side-banded at time of seeding. For canola in reps 1 and 2, 46-0-0-0 was applied at 343.8 kg ha^{-1}, 11-52-0-0 was applied at 21.9 kg ha^{-1}, and 21-0-0-24 was applied at 47.4 kg ha^{-1}. For reps 3 and 4, 46-0-0-0 was applied at 192.2 kg ha^{-1}, 11-52-0-0 was applied at 87.4 kg ha^{-1}, and 21-0-0-24 was applied at 47.4 kg ha^{-1}. At Redvers, only canola plots were fertilized with a blend of 32-12-1-5 side-banded at the time of seeding at a rate of 224 kg ha^{-1}.

Prior to seeding in 2022, each site sprayed a non-residual herbicide for weed control. The plots in the Clavet site received an application of Glyphosate 540 at 2 L ha^{-1} and Heat LQ (saflufenacil) at 57.5 ml ha^{-1} on May 11, 2022. An application of Glyphosate 540 at 2.5 L ha^{-1} and AIM (carfentrazone) at 87.5 ml ha^{-1} on May 22, 2022 at the Scott site. An application of Glyphosate 360 at 2.5 L ha^{-1} was applied on May 25, 2022 at the Redvers site. In-crop weed control for all three sites consisted of hand weeding in 2022. In 2023, herbicides were only applied on canola plots. Herbicide application prior to seeding canola consisted of Glyphosate 540 at 2 L ha^{-1} and Heat LQ (saflufenacil) at 57.5 ml ha^{-1} at the Clavet site. An application of Glyphosate 360 at 2.5 L ha^{-1} was applied at the Redvers site. No pre-seed herbicide application was applied at Scott. In-crop herbicide application of Liberty 150 (glufosinate) at 4 L ha^{-1}, Centurion (clethodim) at 0.19 L ha^{-1}, and adjuvant (Amigo) at 0.5 L/100 L spray solution was applied to canola plots on June 7, 2023. No in-crop herbicide was applied at Clavet or Redvers.

All plots at the Clavet site were seeded on May 26, 2022 with a double disc opener and 30 cm row spacings, at a depth of 1.9 cm. Companion crop treatments were seeded as alternate rows with forages. Canola was seeded May 15, 2023 at a depth of 1.3 cm. Plots at the Scott site were seeded on May 25, 2022 with a 2.5 cm knife opener and 25 cm row spacings, at a depth of 1.6 cm. Companion crop treatments were seeded as mixed rows with forages. Canola was seeded at a depth of 1.3 cm on May 18, 2023. The Redvers site was seeded on June 9, 2022 with a 2.5 cm knife opener drill and 30 cm row spacings, at a depth of 1.3 cm. Companion crop treatments were seeded as mixed rows with forages. Canola was seeded at a depth of 1.3 cm on June 8, 2023. The monocrop barley was seeded at a rate to target 250 plants m^{-2}, and canola seeded to target 65 plants m^{-2}. Forage mixtures were seeded to target 400 plants m^{-2} for legume species and 300 plants m^{-2} for grass species. The barley in the companion crop treatments was seeded at half the monocrop barley seeding rate (125 plants m^{-2}).

Data Collection

Data collection consisted of soil sampling, forage establishment assessments, pollinator surveys, yield, forage nutritive value, and UAV-imagery for NDVI. Soil samples were taken early May in 2022 and 2023 at two soil depth increments (0-15 cm and 15-30 cm) and bulked for each replication of the study, to determine nutrient availability (N, P, K, S), electrical conductivity (EC), pH, and soil texture (Appendix A1). Two pollinator surveys were conducted in mid-June and early-July, 2023. At each survey, flower abundance was recorded by counting the number of open inflorescences per 0.5 m^2 quadrant. The number of pollinators was recorded by counting the number of bees found on flowering parts while walking along the plot. Plant species visited by bees were recorded, as well bees travelling through the plot but not on flowers were recorded as incidental observations. Whole plots were harvested by forage harvester at Scott and Clavet, and 0.5 m^2 quadrats at Redvers at the early hard dough stage of barley in 2022, and the anthesis stage of forages in 2023. Canola seeded in 2023 was harvested at maturity by plot combine at Scott. Due to low yields at Redvers and Clavet, plots were harvested by 0.5 m^2 quadrats. Sub-samples from the forage harvest were used for forage quality analysis to determine acid detergent fiber (ADF) and neutral detergent fiber (NDF) by use of an Ankom[2000] Fiber Analyzer and crude protein by use of a Leco CN628 Nitrogen/Protein Analyzer for each treatment. UAV imagery was collected in the spring of 2023 using a DJI Matrice 200 V2 drone mounted with a MicaSense RedEdge-MX sensor. Flights for each site were mapped using Pix4D Capture. Flight height was at a 15 m altitude, and flights were conducted at 0.7 m/s (1.75 mph). Drone images were processed using Pix4Dmapper Pro 3.0.18 and QGIS 3.28.2-Firenze software to determine average Normalized Difference Vegetation Index (NDVI) values per plot. Lastly, an economic analysis was conducted at the end of the study to determine average net returns across sites for the two-year period. Variable costs considered input costs (seed, fertilizer, and herbicide applications) and custom work costs (spraying, seeding, cutting, baling, combining) for each treatment. Price quotes for input costs were obtained from either place of purchase or Nutrien retail pricing (November 7, 2023). Custom work costs were obtained from the “2022-23 Farm Machinery Custom and Rental Rate Guide” (Government of Saskatchewan, 2022). Gross revenue was calculated using average yields (kg ha^{-1}) for each treatment in each growing season and market prices obtained from the “Fall Forage Market Price Discovery Report” (Sask Forage, 2022/23) for 2022 and 2023, respectively. A weighted average (\$ $tonne^{-1}$) was selected based on forage type. Canola market prices were obtained from Saskatchewan Crop Insurance Corporation “2023 Market Prices” for commercial crops. Net returns (\$ ha^{-1}) were calculated based on variable costs and gross revenue for each growing season. Total net returns were summed for the two-year period and averaged across sites for each treatment.

Statistical Analysis

The data was analyzed as a split-block in a randomized complete block design (RCBD) with four replications using R Studio (ver.2021.9.2.382) (RStudio Team, 2022) to determine the effects of site, companion crop, forage mixture, and their interaction on forage establishment, yield, forage nutritive value, and pollinator activity. The economic analysis was not statistically analyzed. Analysis of forage establishment, nutritive value, and pollinator activity only considered perennial forage treatments; whereas yield considered both perennial forage and annual crop treatments. For the response variables of forage establishment and yield, a random intercept mixed effects model was used with site, companion crop, and forage mixture as fixed effects, and replication and year as random effects. When site x treatment interaction was significant, data were analyzed by each site using a random intercept mixed effects model to further investigate the differences between companion crop, forage mixture, and their interaction within each site. A Pearson correlation coefficient was computed to assess linear relationship between in-field establishment assessments and UAV NDVI imagery. Forage nutritive value was analyzed using a random intercept mixed effects model with companion crop and forage mixture as fixed effects and site, replication, and year as random effects. To determine the effect of perennial forage establishment on pollinator abundance and habitat, a random intercept mixed effects model with site and forage mixture as fixed effects, and replication and survey timing as random effects. A Pearson correlation coefficient was computed to assess linear relationship between inflorescence and pollinator abundance. For all models, when analysis of variance (ANOVA) indicated significant differences ($p \leq 0.05$), means were separated using the estimated marginal means comparison (Lenth, 2017).

Results *(you must provide the following information)*

Present and discuss any project results, including any data or measurements taken to evaluate the demonstration. Include things that didn't appear to work. These results are just as important to share. List extension activities such as field days or workshops. List the activity, the date it occurred, and the number of people who attended.

Environmental Conditions

Average monthly temperature (°C) and precipitation (mm) were collected from in-field weather stations for the 2022 and 2023 growing season (May-August) at all three sites (Table 2). Monthly average temperatures were relatively similar among the sites in both years. Temperatures were slightly higher in 2023 than in 2022. In the establishment year, the precipitation varied greatly between the Redvers site and the Clavet and Scott sites. Redvers received 121 mm of precipitation in May; while Clavet and Scott received 54.2 mm and 11 mm, respectively. This delayed seeding in Redvers by one week as the field site was too wet. Redvers continued to receive higher amounts of precipitation throughout the entire growing season compared to the other two sites. The total precipitation between May and August for Redvers was 480.2 mm; while Clavet and Scott received 206.4 mm and 186.7 mm, respectively. The 2023 growing season experienced considerably less precipitation than the 2022 growing season at all three sites. Redvers received the highest amount of precipitation in May at 84.1 mm, while Clavet and Scott received less at 14.7 mm and 16.6 mm, respectively. In June, the Scott site received the greatest amount of precipitation at 81.1 mm, followed by Redvers at 33.0 mm and Clavet at 25.3 mm. The Clavet site finally experienced significant precipitation in August (60.1 mm). Despite the differences in timing of precipitation events across three sites, the total precipitation for the growing season was very comparable. Redvers received the highest amount of total precipitation at 165.5 mm, followed by Scott at 140.7 mm and Clavet at 120.7 mm. Overall, average monthly temperatures were comparable across sites and growing seasons; however, precipitation varied greatly between sites in 2022 and the timing of precipitation varied considerably in the 2023 growing season.

Table 2. Average monthly temperature (°C) and precipitation (mm) for the 2022 and 2023 growing seasons for three field sites (Clavet, Scott, and Redvers).

Year	Site	May	June	July	August	Sum/Average
		----------------------------Precipitation (mm)------------------------------				
2022	Clavet	54.2	44.5	67.3	40.4	206.4
	Scott	11.0	57.1	86.5	32.1	186.7
	Redvers	121.0	75.0	259.0	25.2	480.2
2023	Clavet	14.7	25.3	20.6	60.1	120.7
	Scott	16.6	81.1	11.3	31.7	140.7
	Redvers	84.1	33.0	10.8	37.6	165.5
		--------------------------Mean Temperature (°C)--------------------------				
2022	Clavet	11.5	15.8	19.0	19.9	16.5
	Scott	10.0	15.0	18.3	18.9	15.6
	Redvers	10.2	16.3	19.2	19.1	16.2
2023	Clavet	15.3	19.8	17.9	18.1	17.8
	Scott	14.9	17.2	17.1	17.4	16.7
	Redvers	14.5	19.7	17.6	17.9	17.4

Forage Establishment

The companion crop (p=0.545) and its interactions did not significantly affect forage establishment. Thus, indicating that companion crops had no effect on forage establishment in saline soils. However, significant differences were observed between forage mixtures (p=0.001), sites (p<0.001), and their interaction (p<0.001) (Table 3). Analysis of separate sites determined significant differences between establishment of forage mixtures at Clavet (p<0.001) (Figure 1). At this site the lowest establishment was observed by the alfalfa, with an establishment rate of 60%. The remaining mixtures experienced significantly higher establishment rates (>80%). There were no significant differences in establishment between forage mixtures at Redvers (p=0.346) or Scott (p=0.594). Salinity levels for study sites were classified as moderately saline at Clavet, slightly saline at Redvers, and non-saline at Scott. Mean establishment rates were highest for the non-saline site (Scott) at 97%, followed by the slightly saline site (Redvers) at 90%, and lowest at the moderately saline site (Clavet) at 83%. Altogether, forage establishment rates in non-saline (Scott) and slightly saline (Redvers) soils were adequate for all forage mixtures; whereas in moderately saline soils (Clavet), mixtures containing mostly grass species established better than mixtures with only legume species (the alfalfa mixture). Overall, these results suggest that selection of forage mixture is important in moderately saline soils to ensure adequate establishment of the stand.

Drone flights were conducted in the spring of 2023 at all three field sites to determine the normalized difference vegetation index (NDVI) values for forage treatments. NDVI measures the amount of vegetative biomass and can indicate levels of establishment in forages. Correlations between NDVI values collected by drone flights and in-field establishment assessments were done to determine accuracy of drone data. Analysis found a positive correlation between NDVI values and establishment assessments (r=0.22), although this correlation was not significant (p=0.080). Despite insignificance, NDVI values increased by 0.005 for each increase in forage establishment percentage, suggesting that forages with greater establishment also generate greater NDVI values. While the use of UAV imagery in this study was indicative of forage establishment, additional data points would be helpful to strengthen the analysis.

Table 3. P-values for the effects of companion crop, forage mixture, site, and their interactions on forage establishment.

Effect	p-value
Companion Crop (C)	0.545
Forage Mixture (F)	0.001
Site (S)	<0.001
C x F	0.307
C x S	0.231
F x S	<0.001
C x F x S	0.634

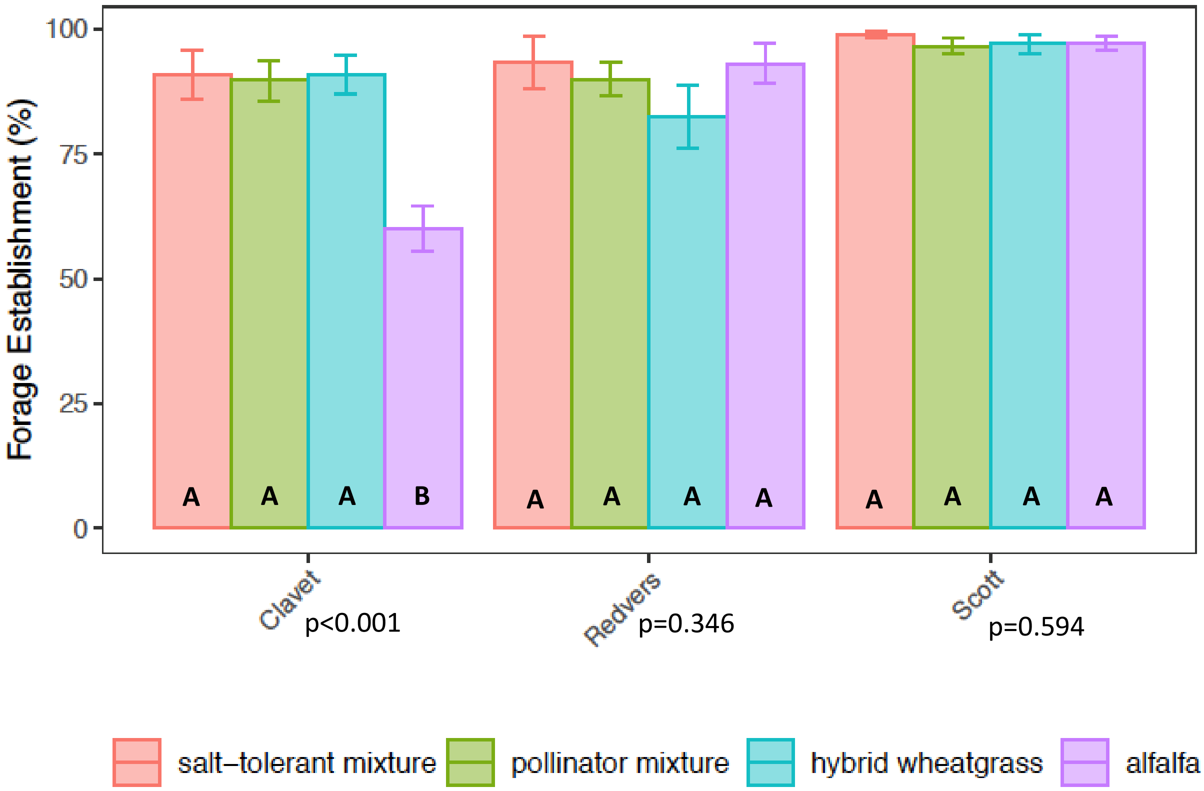

Figure 1. Mean forage establishment (%) of four forage mixtures at three saline sites (Clavet, Redvers, Scott) across two years (2022, 2023). Different letters within each site indicate significance at p<0.05 using estimated marginal means comparison.

Yield

Yields were not significantly affected by companion crop treatments (p=0.129). Barley does not have tolerance to salinity and grew poorly at saline sites, in particular the moderately saline site Clavet. Reduced barley growth in saline soils allowed the companion crop to provide additional vegetative cover without out-competing the forages. Therefore, a barley companion crop may be a suitable practice to establish perennial forages, particularly in moderately saline soils. Alternately, significant yield differences were observed between forage mixtures (p=0.003) and sites (p<0.001) (Table 4). The Scott site experienced significantly higher yields (10,665 kg ha^{-1}), compared to Redvers (2427 kg ha^{-1}) and Clavet (1397 kg ha^{-1}). This trend in mean yields is similar to the level of electrical conductivity (EC) at each site, with the non-saline site (Scott) experiencing the highest yields and the moderately saline site (Clavet) experiencing the lowest yields. Comparison of yields between forage mixtures and annual grain crops revealed that yields were lower for the annual grain crop treatment compared to four forage mixtures (Figure 2). Thus, perennial forage mixtures may provide a more profitable option in saline areas compared to an annual grain crop rotation. Forage mixtures yielded highest for the pollinator mixture (5935 kg ha^{-1}), followed by alfalfa (5530 kg ha^{-1}), salt-tolerant mixture (5045 kg ha^{-1}), and hybrid wheatgrass (4617 kg ha^{-1}). In this study, mixtures containing legume species outyielded predominately grass mixtures.

Legume species are generally quicker to establish and produce greater yields in establishment years compared to grass species, although many legume species have lower inherent salinity tolerance than grass species. Therefore, a grass-legume mixture may be the most productive and risk-adverse option for saline soils.

Table 4. P-values for establishment method, forage mixture, site and their interaction on yield (kg ha^{-1}) at three sites in Saskatchewan (Scott, Redvers, Clavet) over a two-year period (2022, 2023).

Effect	p-value
Companion Crop (C)	0.129
Forage Mixture (F)	0.003
Site (S)	<0.001
C x F	0.915
C x S	0.958
F x S	0.111
C x F x S	0.100

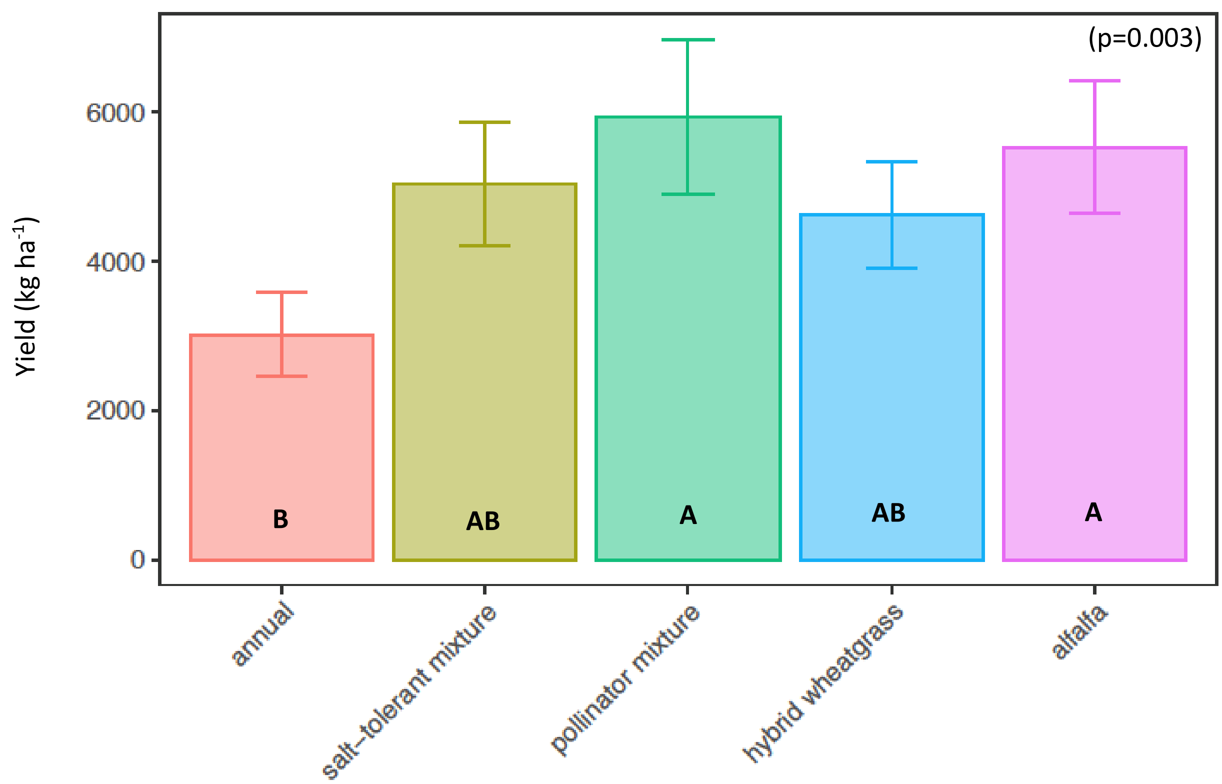

Figure 2. Mean yield (kg ha^{-1}) of forage mixtures and annual grain crop rotation at three sites (Clavet, Redvers, Scott) in Saskatchewan across a two-year period (2022, 2023). Different letters indicate significance at p<0.05 using estimated marginal means comparison.

Forage Nutritive Value

Forage samples were analyzed for acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude protein (CP) to assess forage nutritive value. Forages seeded with a companion crop resulted in significantly different NDF (p<0.001) and CP (<0.001) values, but only small differences in ADF content (p=0.675). The CP of forages was 23% lower when seeded with a companion crop. Alternately, forages seeded with a companion crop resulted in 8% higher NDF content (Table 6). These differences are likely a result of the barley companion crop in the establishment year, causing forage samples to be higher in NDF and lower in CP compared to forages seeded alone. Forage mixtures varied significantly for ADF (p=0.028), NDF (p<0.001), and CP (p=0.003) (Table 5). Mixtures that were predominately legume species (alfalfa and pollinator mixture) tended to have higher CP and lower fiber content (ADF and NDF) compared to mixtures that were predominately grass species (hybrid wheatgrass and salt-tolerant mixture) (Table 6). These results suggest that nutritive value of forage mixtures was largely influenced by species composition.

Table 5. Effects of companion crop, forage mixture, site, and their interaction on acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude protein (CP) at three sites (Scott, Redvers, Clavet) over two years (2022, 2023).

Effects	ADF	NDF	CP
Companion Crop (C)	0.675	<0.001	<0.001
Forage Mixture (F)	0.028	<0.001	0.003
C x F	0.941	0.063	0.292

Table 6. Effect of companion crop and forage mixtures on acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude protein (CP) at three sites (Scott, Redvers, Clavet) over two years (2022, 2023).

	ADF		NDF		CP	
--------------------Companion Crop--------------------						
no companion crop	29.5	*a*[y]	49.1	*b*	16.0	*a*
companion crop	29.3	*a*	53.1	*a*	12.4	*b*
p-value	0.675		<0.001		<0.001	
SEM[z]	2.8		1.7		1.9	
--------------------Forage Mixture--------------------						
hybrid wheatgrass	30.2	*a*	56.3	*a*	12.8	*b*
salt-tolerant mixture	29.7	*ab*	52.2	*b*	14.3	*ab*
alfalfa	29.6	*ab*	48.9	*bc*	15.4	*a*
pollinator mixture	28.1	*b*	46.5	*c*	14.3	*ab*
p-value	0.028		<0.001		0.003	
SEM	2.8		1.8		2.0	

[y]Means within a column with different letters *(a-c)* are significantly different (p≤0.05) for companion crop and forage mixture effects

[z]SEM, standard error of the mean

Pollinator & Inflorescence Abundance

Pollinator surveys were conducted in the second year of forage growth to determine the potential of different perennial forage mixtures as pollinator habitat in saline areas. In total, there was 78 honey bee and 100 native bee individuals recorded across three sites and two surveys. Significant differences were found between honey bee, native bee, and inflorescence abundance of forage mixtures and sites (Table 7). However, the interaction of forage mixture and site was only significant for honey bee and inflorescence abundance (Table 7).

Table 7. Effects of forage mixture, site, and the interaction on honey bee, native bee, and inflorescence abundance (number observed per plot) at three sites (Scott, Redvers, Clavet), 2023.

Effects	Honey Bee Abundance	Native Bee Abundance	Inflorescence Abundance
	----------------------------p-value----------------------------		
Forage Mixture (F)	<0.001	0.043	<0.001
Site (S)	<0.001	<0.001	0.001
F x S	<0.001	0.342	<0.001

When analyzing the differences in inflorescences, abundance was significantly higher for the pollinator mixture at all three sites (Figure 3). Different trends emerged between honey bee and native bee abundance across sites. However, abundance of both groups of bees was highest in the pollinator mixture (Figure 4). At Clavet, honey bee and native bee abundance followed the order of pollinator mixture>salt-tolerant mixture>alfalfa>hybrid wheatgrass. Alfalfa performance at the Clavet site was poor, and is reflected in the inflorescence abundance (Figure 3). At Redvers, honey bee abundance was greatest for the pollinator mixture, followed by the salt-tolerant mixture, hybrid wheatgrass, and alfalfa. Comparatively, native bee abundance was greatest for the pollinator mixture, followed by alfalfa, salt-tolerant mixture, and hybrid wheatgrass. Similar trends were observed at Scott, with honey bee abundance following the order of pollinator mixture>alfalfa>salt-tolerant mixture>hybrid wheatgrass. And native bee abundance in the order of pollinator mixture>alfalfa>hybrid wheatgrass>salt-tolerant mixture. Overall, the pollinator mixture proved to be most suitable for bee populations as the mixture observed the highest inflorescence and bee abundance across all three sites compared to other forage mixtures.

Correlations between honey and native bee abundance and inflorescence abundance revealed that bees were most attracted to forage mixtures with the greatest number of inflorescences. Abundance was significantly positively correlated to the number of inflorescences per plot for honey bees ($r = 0.42$, $p<0.001$) and native bees ($r = 0.25$, $p=0.001$). Thus, indicating that forage mixtures with the greatest inflorescence abundance resulted in a greater abundance of bee activity, with a stronger correlation for honey bees than native bees. These correlations explain the trends observed across sites, with the greatest bee activity observed in plots with the greatest number of inflorescences, which was the pollinator mixture. Observational notes taken during surveys also indicated that bees tended to land on yellow sweet clover inflorescences the most, which was a species included in the pollinator mixture only. Yellow sweet clover is a biennial species; therefore, the persistence of this species in the mixture may influence pollinator activity in the long-term. Additional studies assessing pollinator mixtures may be needed to determine appropriate forage mixtures for long-term pollinator habitat.

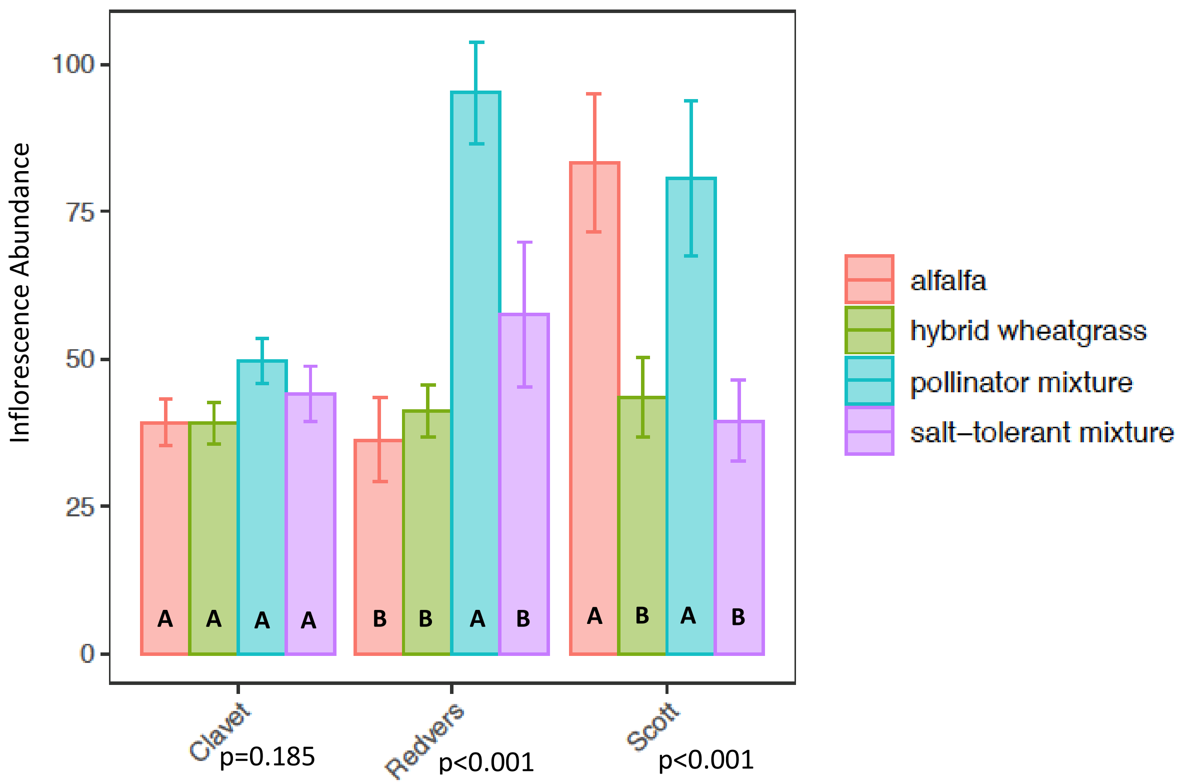

Figure 3. Abundance of inflorescences in four forage mixtures (salt-tolerant mixture, pollinator mixture, hybrid wheatgrass, alfalfa) at three sites (Clavet, Redvers, Scott), 2023. Different letters within each site indicate significance at p<0.05 using estimated marginal means comparison.

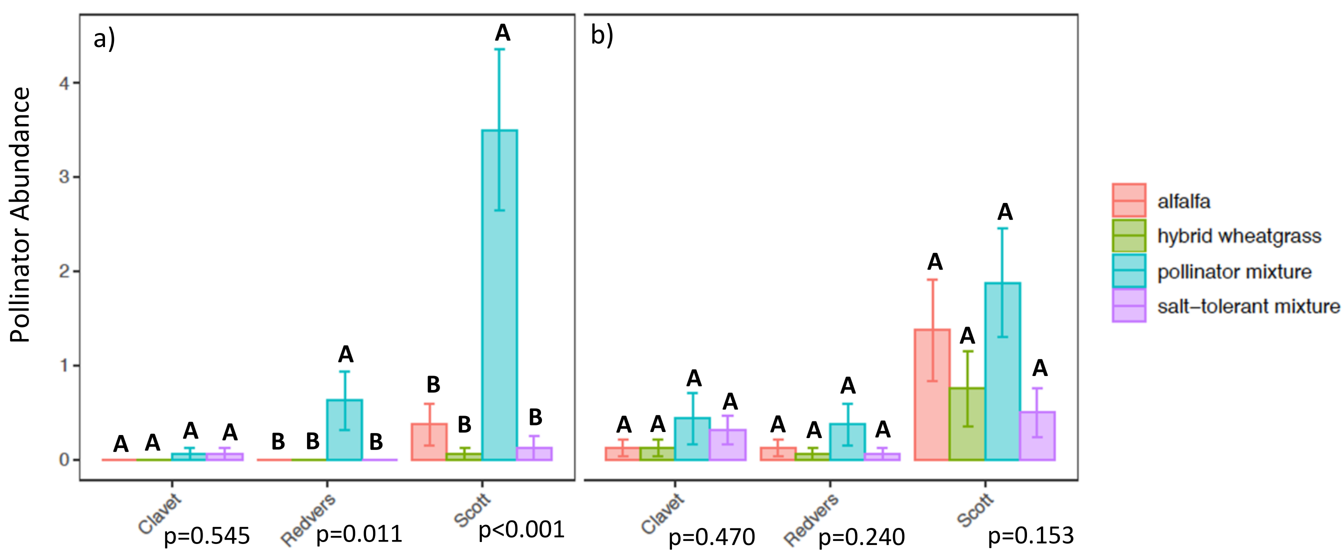

Figure 4. Abundance of honey bees (a) and abundance of native bees (b) in four forage mixtures (salt-tolerant mixture, pollinator mixture, hybrid wheatgrass, alfalfa) at three sites (Clavet, Redvers, Scott), 2023. Different letters within each site indicate significance at p≤0.05 using estimated marginal means comparison.

Economic Analysis

Variable costs, gross revenue, and net return was calculated for each treatment considering the input costs and yields from each site over the two-year period. Overall net returns for forages seeded with a companion crop were $1.19, while forages seeded alone recorded a negative net return of -$146.13 (Figure 5). Variable costs were higher for companion crop treatments as the cost of barley seed was included. However, the companion crop treatment also resulted in higher gross revenue from the increased yields experienced in the establishment year. These results show net returns over a two-year period, so it is important to consider the high input costs and low yields associated with establishing perennial forages. Over a longer time-frame, input costs generally decrease and forage yields increase, so net returns should also increase. Despite low net returns, this two-year study confirms that establishing forages with a companion crop in saline soils can improve net returns compared to establishing forages alone.

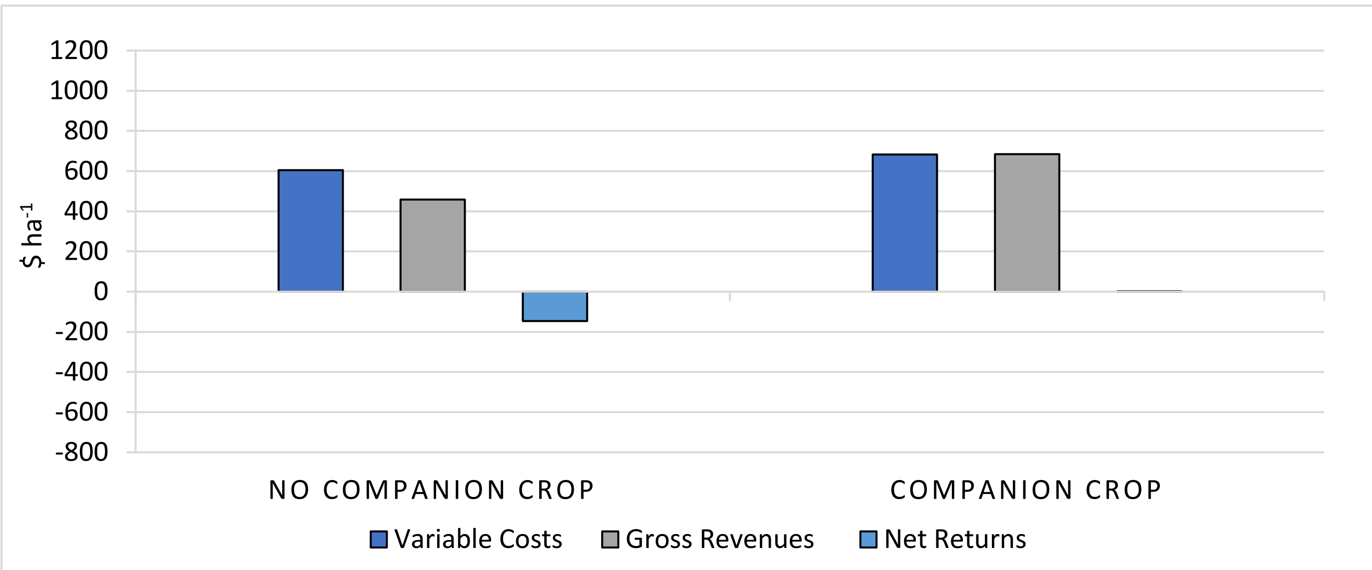

Figure 5. Variable costs, gross revenues, and net returns ($ ha^{-1}) for no companion crop and companion crop treatments averaged across three sites (Clavet, Scott, Redvers) and two growing seasons (2022, 2023).

When comparing perennial forage mixtures to an annual grain crop rotation, each forage mixture resulted in greater net returns than the annual grain crop rotation (Figure 6). The annual crop treatment resulted in a net return of -$660.57, compared to net returns of -$124.78 to $52.51 for forage treatments. While forage treatments also experienced negative net returns, the extent was much lower. Net returns were lowest for the pollinator mixture (-$124.78), followed by the salt-tolerant mixture (-$116.63), hybrid wheatgrass (-100.98), and alfalfa ($52.51). These results can be explained by the differences in variable costs and gross revenues. The variable costs were highest for the annual crop treatment, as there were input costs (seed, herbicide, fertilizer) for both years; whereas forage treatments only incurred input costs in the establishment year. Furthermore, yields were higher for the forage treatments compared to the annual crop. While market prices are generally higher for grain crops, the barley and canola did not perform as well as the perennial forage mixtures. These plant species generally have very low salt-tolerance compared to forage species, and were affected by the salinity level of each site to a greater degree, resulting in lower yields. While this study only covers forage growth over a two-year period, once forages are established, they can continue to produce yields for 5-10 years with little to no additional inputs. Over the span of 5-10 years, a forage mixture should produce greater positive returns compared to an annual grain crop, which requires input costs each year and may not produce adequate yields in saline areas. This economic analysis would suggest that it is more profitable to grow perennial forages in saline areas than an annual grain crop rotation.

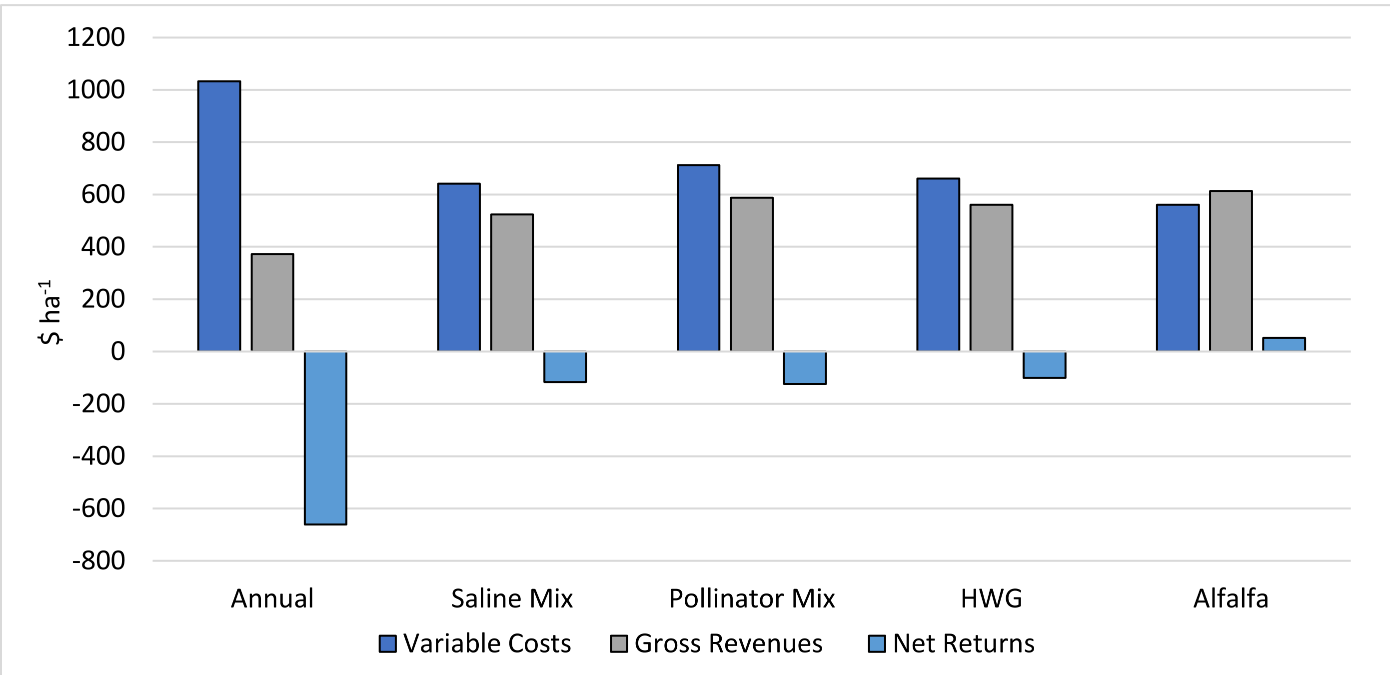

Figure 6. Variable costs, gross revenues, and net returns ($ ha^{-1}) for annual grain crop (barley, canola), salt-tolerant mixture, pollinator mixture, hybrid wheatgrass (HWG), and alfalfa treatments averaged across three sites (Clavet, Scott, Redvers) and two growing seasons (2022, 2023).

Extension

This study was part of an M.Sc. project by University of Saskatchewan student, Alex Waldner. Throughout her M.Sc. studies, Alex promoted this project through various extension activities. In particular, a QR code developed by Sask Forage Council and Saskatchewan Cattlemen's Association was used to provide easy access to information about the project and highlight various aspects of the study through a video series.

Conclusions and Recommendations

Describe what was learned from the demonstration. Highlight any significant conclusions and provide recommendations for the application and adoption of the project results. Be sure that you have presented the relevant data to support your conclusions. Identify any further research, development and communication needs, if applicable.

This study evaluated a barley companion crop to establish perennial forage mixtures in saline soils. Overall, the results of this study determined that seeding perennial forages with a barley companion crop is a viable management strategy for saline soils. All forage mixtures were established successfully at saline sites (>80%), regardless of companion crop. At Clavet, forage mixtures with grass species resulted in greater establishment than alfalfa, suggesting that grass-legume mixtures may be more suitable in moderately saline soils. The UAV imagery determined that NDVI values were positively correlated to in-field establishment assessments, but were not significant. Yields over a two-year period were not significantly different between companion crop treatments, indicating that a barley companion crop could be a suitable practice in saline soils to provide additional cover without hindering forage growth. Forage mixtures resulted in higher yields than the annual grain crop rotation. Additionally, mixtures containing legume species yielded higher than mixtures without legumes, indicating the importance of using grass-legume mixtures for saline areas. Based on these results, producers would benefit from establishing perennial forages in saline soils and should consider grass-legume mixtures seeded with a barley companion crop. Forage nutritive value was sufficient for all forage mixtures and varied based on species composition. Pollinator surveys determined that forage mixtures with high floral abundance can improve bee activity in saline soils, particularly, with the inclusion of yellow sweet clover. However, since yellow sweet clover is a biennial species, additional research on long-term pollinator mixtures in saline soils may be required. An economic analysis of three sites over a two-year period confirmed the benefits of establishing perennial forages in saline areas. While a barley companion crop only marginally increased yields, it improved net returns by approximately \$150 ha^{-1}. Additionally, forage mixtures improved net returns by \$500 - \$700 ha^{-1} compared to the annual grain crop rotation. While most treatments experienced negative net returns, it is important to consider that this study only covers a two-year period, and once forages are established, they can continue to produce yields for 5-10 years with little to no additional inputs. Over the span of 5-10 years, it is expected that a forage mixture would produce greater positive returns than annual grain crops, which require yearly input costs and may not produce adequate yields in saline areas. Therefore, this study would suggest that it is more profitable to grow perennial forages in saline areas compared to an annual grain crop rotation. Based on the results of this study, producers would benefit agronomically and economically from seeding their saline areas to perennial forages and can improve their net returns with a barley companion crop.

Sustainable Canadian Agricultural Partnership (Sustainable CAP) Performance Indicators

a) List of performance indicators

Sustainable CAP Indicator	Total Number
Scientific publications from this project (List the publications under section b)	
• Published	0
• Accepted for publication	0

HQPs trained during this project	
• Master's students	1
• PhD students	0
• Post docs	0
Knowledge transfer products developed based on this project (presentations, brochures, factsheets, flyers, guides, extension articles, podcasts, videos). List the knowledge transfer products under section (c)	9

[1] Please only include the number of unique knowledge transfer products.

b) List of scientific journal articles published/accepted for publication from this project.

Title	Author(s)	Journal	Date Published or Accepted for Publication	Link (if available)

c) List of knowledge transfer products/activities developed from this project.

Knowledge Transfer Product or Activity	Event/Location Where Knowledge Transfer Was Conducted	Estimated Number of Producers Participated In Knowledge Transfer	Link (if available)
University of Saskatchewan: 3 Minute Thesis Competition	March 17, 2022; Saskatoon, SK.	30	
Ducks Unlimited Internal Meeting	November 7, 2022; Saskatoon, SK.	15	
Canadian Society of Agronomy Annual Conference	November 15, 2022; Halifax, NS.	200	
Saskatchewan Forage Advisory Meeting	November 24, 2022; Saskatoon, SK.	75	
WARC Crop Opportunity	March 2, 2023; North Battleford, SK.	100	
Soils & Crops	March 7, 2023; Saskatoon, SK.	50	
LFCE Field Day	June 20, 2023	150	
Saskatchewan Forage Seed Development Commission Annual General Meeting	December 11, 2023; White Fox, SK.	100	

Acknowledgements

Include actions taken to acknowledge support by the Ministry of Agriculture, the Canadian Agriculture Partnership (for projects approved between 2017 and 2023) and the Sustainable Canadian Agriculture Partnership (for projects approved between 2023 and 2028).

Sustainable Canadian Agricultural Partnership   Saskatchewan   Canada

This project was funded under the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canadian Agricultural Partnership bi-lateral agreement between the federal government and the Saskatchewan Ministry of Agriculture. Thank you to collaborators of this project, including the Western Applied Research Corporation (Jessica Enns, Kayla Slind), South East Research Farm (Lana Shaw), Saskatchewan Forage Council (Shannon McArton), and the Livestock and Forage Centre of Excellence (Alex Waldner). Additional guidance was provided by Dr. Bill Biligetu from the University of Saskatchewan.

Appendices

Identify any changes expected to industry contributions, in-kind support, collaborations or other resources.

Soil analysis and M.Sc. stipend were provided by funding from Mitacs.

Table A1. Soil Characteristics for three sites in Saskatchewan (Clavet, Redvers, Scott) over two years (2022, 2023). Electrical conductivity (EC) sampled at two soil depths (0-15 and 15-30 cm); all other characteristics sampled at one soil depth (0-15 cm).

		Clavet	Redvers	Scott
			--------------------2022------------------	
Soil Zone		dark brown	grey	dark brown
Soil Texture		loam	--	--
EC (0-15 cm)	dS m^{-1}	3.42*	2.71	0.83
EC (15-30 cm)	dS m^{-1}	5.04	2.84	2.16
pH		7.8	8.1	5.8
Organic Matter	%	4.3	4.3	3.9
Nitrogen	ppm	4.2	19.0	24.1
Phosphorus	ppm	9.8	16.0	29.0
Potassium	ppm	99.3	495.0	375.8
Sulphur	ppm	823.6	>60.0	>60.0
			--------------------2023------------------	
EC (0-15 cm)	dS m^{-1}	4.04	4.18	0.46
EC (15-30 cm)	dS m^{-1}	5.76	--	1.73
pH		8.0	8.2	5.7
Organic Matter	%	3.8	4.0	3.7
Nitrogen	ppm	4.4	30.3	8.3
Phosphorus	ppm	10.5	9.0	22.5
Potassium	ppm	414.0	447.0	317.5
Sulphur	ppm	1580.0	>60.0	>58.5

*all values based on averages sampled across replications

Expenditure Statement

Sustainable Canadian Agricultural Partnership   Saskatchewan   Canada

You must provide an expenditure statement showing how ADOPT funds were used. Expenditures must be reported using the budget categories shown in Appendix B of your contract. We recommend that you report your expenditures using the Excel spreadsheet we have developed for this purpose (ADOPT Expenditure Statement.xls). That spreadsheet is available from the research branch project manager or the evaluation coordinator.

Note that the ADOPT contract requires you to retain all receipts and financial records relating to the project for at least six years after the project is completed.

See attached budget spreadsheet from all three collaborating sites.