Alberta AgriSystems Living Lab: 2022 Baseline Adoption of Beneficial Management Practices

Survey Report

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1. Executive Summary

This report presents the findings from a comprehensive benchmarking survey conducted by the Alberta AgriSystems Living Lab (AALL) to assess the adoption of Beneficial Management Practices (BMPs) and their impact on sustainable agriculture. The voluntary survey focused on various BMPs related to land management, pasture, grazing, beef management, and crop management for producers in Alberta and the Peace region of British Columbia (BC).

The survey gathered data from 312 respondents, encompassing diverse producer demographics and regional characteristics. The respondents represented three regions in Alberta and BC: South (Alberta only), Central (Alberta only), and North and Peace (Alberta and BC) regions. The survey aimed to capture a holistic view of BMP adoption and its regional variability, providing valuable insights into current practices and areas for improvement. The total region represented by survey respondents was 683,067 acres and 24,533 beef cows (Table 1).

Table 1. Response summary for reported operational cattle and land characteristics in 2022.

Region	n % *	Respondents	Beef cows	Yearling grassers	Total operation area	Total grazed pastureland	Total cropland	Total non-workable land
South	n	72	5,650	570	265,695	128,195	67,945	17,696
	%	23.1%	23.0%	8.5%	38.9%	45.4%	33.4%	33.3%
Central	n	165	11,269	3,185	301,819	117,481	94,408	20,438
	%	52.9%	45.9%	47.8%	44.2%	41.6%	46.3%	38.5%
North and Peace	n	75	7,614	2,915	115,553	36,743	41,374	14,934
	%	24.0%	31.0%	43.7%	16.9%	13.0%	20.3%	28.1%
Total Region	n	312	24,533	6,670	683,067	282,419	203,727	53,068

*Where n = number of respondents, cattle, and acres; and % = proportion of the response relative to the total region.

The survey was organized into key sections:

- **Farm Summary and Land Management**: Included practices such as enhanced efficiency fertilizers (EEF), manure application on eroded knolls, cattle grazing for weed control, and wetland and riparian area management.
- **Pasture Management**: Covered practices such as legume integration, sod seeding, silvopasture, nutrient management, and tame versus native pastureland management.
- **Grazing Management**: Examined continuous and rotational grazing practices, extended season grazing, and land tenure.
- **Beef and Manure Management**: Focused on feed quality testing, breeding, calf efficiency, growth promotants, and overwintering strategies, including housing and diets in cattle classes of beef cattle, first calf heifers, backgrounding cattle, and finishing cattle. Manure management practices focused on storage.
- **Crop Management**: Included nutrient management, annual rotations, including perennial forages in rotation, land tenure, soil testing, crop residue management, and multi-cropping.

The survey respondents included a diverse group of producers with varying levels of education, financial stability, and operation sizes. Over 70% of respondents had some education beyond high school, with over half of these obtaining education with some focus in agriculture. Nearly 90% of respondents had a spouse and 85% had children. Of the respondents with children, 44% had children over the age of 18. Most producers prioritized profitability and did not anticipate changes in operation ownership within the next five years, but when they did anticipate changes, most indicated family would not be taking over the farm operations. Just under half of producers engaged in business planning for timeframes five-years and beyond.

Enhanced efficiency fertilizers were used by over 30% of producers, particularly in the North and Peace regions (Table 2). These fertilizers improve nutrient availability and reduce environmental impacts, demonstrating a commitment to sustainable nutrient management practices. Wetland management, including restoration and removal, was reported by respondents, highlighting efforts to maintain and improve water quality and biodiversity. Approximately 24% of respondents indicated wetland restoration activities (Table 2).

Cattle grazing practices, including weed control and rotational grazing, were widely adopted. Over 50% of producers used cattle for weed control, reducing reliance on chemical herbicides. Rotational grazing was practiced by 69.2% of respondents, improving pasture health and productivity (Table 2).

Precision-based BMPs, such as soil testing and the use of precision agriculture technologies, were employed to optimize input use and enhance productivity. Over 45% of respondents conducted annual soil testing, ensuring informed nutrient management decisions (Table 2). Practices aimed at improving soil health, including sod seeding and no-till methods, were noted. These practices contribute to soil conservation, reduced erosion, and improved water retention, supporting long-term agricultural sustainability.

Table 2. Adoption summary of selected BMPs.

	Producers		Acres		Beef cows**	
	n	%	n	%	n	%
Soil, erosion, wetlands						
Enhanced efficiency fertilizers	98	31.4%	99,113	20.4%	11,435	46.6%
Soil erosion: manure/compost on eroded knolls	136	43.6%	15,440	3.2%	8,115	33.1%
Cattle for weed control	170	54.5%	44,960	9.2%	19,373	79.0%
Wetland restoration	40	24.4%	1,619	3.1%	N/A	N/A
Cropland management						
Annual soil testing on cropland	48	46.6%	97,424	57.1%	N/A	N/A
Soil testing deeper than 12 inches	34	25.4%	87,658	36.2%	N/A	N/A
Perennial forage in rotation	39	25.5%	8,942	4.8%	N/A	N/A
Fertilizing cereal, oilseed or pulse crop	106	93.8%	101,466	52.2%	N/A	N/A
Multi-cropping	14	12.8%	1,954	1.0%	N/A	N/A
Pasture and grazing management						
Legumes on pasture	156	60.9%	40,279	14.2%	23,029	94.0%
Sod seeding as pasture rejuvenation	32	12.6%	3,496	1.2%	7,736	31.6%
Nutrient management (fertilizer applied)	62	28.3%	10,472	25.9%	12,751	52.0%
Rotational grazing	144	69.2%	128,542	57.1%	23,530	96.0%
Extended grazing: stockpiled / deferred	46	18.9%	19,811	8.8%	11,639	47.5%
Cattle management						
Concentrate in cow winter ration	87	67.2%	N/A	N/A	16,470	67.2%
Ionophores in cow winter diet ration	34	20.7%	N/A	N/A	11,205	45.7%
Cows overwintered in pastures	145	85.4%	N/A	N/A	21,052	85.9%

*Includes yearling grassers.
**As a total number of beef cows reported by producers affirming the practice (i.e., does not necessarily reflect the number of beef cows directly involved in the practice).

Overall, survey respondents exhibited a higher propensity for innovation compared to the general population. With 13.1% identified as innovators and 68.3% as early majority (Rogers, 2010), the producers demonstrated a proactive approach to adopting new practices and technologies, positioning them well for future advancements in sustainable agriculture.

The survey results underscore the importance of BMP adoption for sustainable agriculture production in Alberta and the Peace region of British Columbia. While significant progress has been made in adopting practices like enhanced efficiency fertilizers and rotational grazing, adoption challenges remain and may be influenced by factors such as producer financial stability. Many BMPs are inter-related as the implementation of one practice often enhances the effectiveness and benefits of others, creating a synergistic effect that promotes overall agricultural sustainability and productivity. Regional variability also highlights the need for tailored support and education to promote BMP adoption across different landscapes.

AALL endeavors to facilitate the widespread adoption of BMPs among producers through collaborative efforts and knowledge exchange. By promoting co-development and systems-based approaches that align with producers' operational realities, AALL aims to empower producers to embrace sustainable practices that not only benefit their bottom line but also contribute to the long-term viability of the agricultural sector. This report serves as a foundational step towards achieving these objectives, laying the groundwork for informed decision-making, based on these benchmark use and adoption rates, and targeted interventions to enhance BMP adoption rates across the regions.

2. Introduction

Agricultural practices result in varying impacts on the surrounding environment, often resonating at the societal level. Well-executed agricultural management yields food and promotes enhanced water quality, carbon sequestration, wildlife habitats, reduced soil erosion, and recreational amenities (CAPI, 2019). With escalating demands for land and water resources fueled by population growth and economic expansion, prudent utilization of these resources is critical. Efficient agricultural resource utilization safeguards against natural resource degradation while furnishing society with valuable natural capital which contributes to food production, manufacturing materials, and enhanced air and water quality. Agricultural production can substantially contribute to natural capital stocks through the adoption of on-farm Beneficial Management Practices (BMPs).

While various funding programs have encouraged the adoption of on-farm BMPs in Canada, adoption rates beyond those supported directly by programs lag expectations (Liu and Brouwer, 2022). Generally, Roger's Diffusion of Innovation Theory highlights various factors that shape potential adopters' evaluation of an innovation, including perceived relative advantage, compatibility, complexity, trialability, and observed effects (BCRC, 2019; Rogers, 2010). More specifically, adoption rates may vary due to regional disparities in climate, soil types, and environmental conditions, rendering some practices unsuitable for certain regions (Pruitt et al., 2012).

For producers to consider the adoption of BMPs they must perceive positive economic, environmental, or social benefits from a practice (Jelinski et al., 2018). To perceive these benefits, the producer's knowledge network and social capital play a significant role in the resulting on-farm BMP adoption rates (Micheels and Nolan, 2016), as knowledge networks, such as the Alberta AgriSystems Living Lab (AALL), can significantly affect the adoption pace of agricultural innovations.

Created in 2022, AALL is led by Alberta Beef Producers (ABP) with collaboration from numerous partners, including agriculture commissions, Indigenous communities, research institutions, non-governmental organizations, private industry, and various agricultural stakeholders. AALL was formed under Agriculture and Agri-Food Canada's Agricultural Climate Solutions Living Labs Program, a new approach to agricultural innovation in Canada, where farmers, scientists, and other stakeholders collaborate to develop and test innovative practices and technologies to address on-farm challenges effectively.

AALL endeavors to analyze barriers and incentives to Beneficial Management Practices (BMP) adoption, conduct cost-of-production analyses, develop extension materials and events, foster peer-to-peer networking and learning opportunities, and provide beef, forage, and crop producers with decision-making tools. Using a co-development approach, researchers and industry stakeholders identify, adapt if necessary, and implement various BMPs on-farm, while measuring their impacts. Defined as any production practice, management system, or technology offering environmental benefits while remaining practical and economically feasible, BMPs are at the center of AALL's efforts.

The focus areas for AALL include grazing management, livestock feeding, crop rotations and cropping systems, land use changes, nutrient management, and optimizing carbon storage on the whole farm. BMPs for each category are numerous, with some overlap between categories such as nutrient management on crop, hay, or pastureland, and optimizing carbon storage is variable and specific to landscapes.

AALL conducted a benchmarking survey aimed at assessing the current use of BMPs across Alberta and the Peace region of British Columbia. The primary objective of this survey and subsequent report is to establish a baseline understanding of BMP adoption rates, serving as a reference point for evaluating shifts in adoption due to AALL initiatives.

By gauging the current landscape of BMP adoption and identifying areas for improvement and intervention, and tracking the adoption of BMPs, AALL aims to gain insights into the effectiveness of a co-development approach for BMP adoption as it relates to potential contributions to environmental stewardship, climate change resilience, and overall farm productivity and profitability. Understanding the factors influencing BMP adoption is crucial for developing tailored strategies and practical, on-farm approaches that resonate with producers.

3. Methodology

Farmers and ranchers in Alberta and the Peace region of BC were invited to participate in a survey regarding their on-farm practices between March 10 and June 28, 2023. Survey questions were developed by Canfax Research Services in collaboration with AALL staff and the resulting survey was estimated to take 35 minutes to complete. The survey was designed to capture adoption rates (% of respondents, % of beef cattle, and % of land utilizing the practice) with the level of execution related to the practice to account for the variability in benefits related these variances.

Respondents were recruited to complete the online questionnaire using convenience sampling, a non-probability sampling technique which focuses on gaining information from participants who are convenient to access. As this sample method does not require a random selection of participants based on any set of criteria, caution should be used in extrapolating the results to larger populations. Word of mouth and advertising were used to encourage respondents to complete the survey, including collaboration with local 4-H groups with prize draws for fertilizer and other inputs for respondents from these local clubs.

Conditional branching, or skip logic, was used in the survey to guide respondents to questions that were relevant. This was done to ensure the best use of respondents' time as the entire survey included 294 questions. As such, the number of respondents between different sections is not consistent.

Survey respondents remained anonymous and refinements to the collected data and results (i.e., no summary of results is provided in cases where there are fewer than five respondents) were conducted to ensure anonymity was maintained. The survey responses were entered into an Access database to streamline data entry and ensure quality control. Subsequently, they were exported into an Excel spreadsheet for analysis.

Figure 1. Survey Area.

To account for regional diversity of on-farm BMPs survey responses were grouped into three geographic regions using respondent postal codes (Figure 1): South, Central, Peace. This regionalization will allow for more accurate future comparison of data and to assess regionally specific BMP adoption initiatives. South, Central, and Peace refer to respondents with postal codes below the bottom orange line in Figure 1, between the two orange lines, and above the top orange line, respectively.

3.1 Survey Design

BMP categories assessed in the benchmarking survey include cattle grazing management (i.e., rotational and extended season, stocking density, nutrient management), precision cattle management (i.e., cattle diet, additives, implants, shelter), manure management, pasture and hayland rejuvenation (i.e., re-seeding, forage diversification, nutrient management), optimization of soil inputs and management (i.e., fertilizer and manure application, reduced tillage, soil testing), multi cropping systems (i.e., polyculture and relay cropping), and current land use or conversion to perennial cover (i.e., wetlands, buffer zones, silvopasture, cropland conversion).

The survey was divided into seven main sections: producer demographics and business information, farm operation summary, pastureland management, beef cattle management, manure management, cropland management, and hayland management. Producers were asked about their practices for the 2022 season. The definitions for practices provided to the producers in the survey are provided in Appendix 7.1.

Results and analysis are organized as overall producer and operation characteristics; hayland, pasture and grazing management; cattle and manure management; and crop management. Where relevant, results pertaining to one section may be discussed in another.

Each section of the report provides a comprehensive analysis of the current adoption levels of these BMPs, supported by relevant literature, and offers insights into the factors influencing their implementation among beef producers in Alberta and the Peace region of British Columbia.

3.2 Survey Response

Primary data were collected from 471 respondents. Data screening revealed 37 respondents who did not live in the qualifying geographic region, five duplicate entries, and 117 blank or substantially incomplete (i.e., no answers beyond the introductory sections) entries, resulting in 312 records for analysis. For each section, further data cleaning was conducted as necessary, including removing outliers and non-responses (i.e., sections irrelevant for specific producers). As the total number of individuals requested to complete the survey cannot be accurately estimated due to the sampling technique, an overall response rate is not calculated.

Of the 312 respondents, 261, 185, and 170 indicated ‘yes’ when asked if the operation managed pastureland, beef cattle, and crops grown for mechanical harvest in 2022, respectively. When evaluating producers who engaged in more than one practice, 125 indicated that they managed beef, pasture, and cropland in 2022.

Among the 185 respondents involved in beef cattle, the total number of cattle reported was 114,827 head, including beef cows, first calf heifers, backgrounded cattle, finishing cattle, and yearling grassers. Regarding cropland, the total area reported by the 227 respondents indicating cropland managed amounted to 199,667 acres. Of this, 44% (87,709 acres) was attributed to respondents solely focused on crop production, while the remaining 56% (111,958 acres) was reported by those involved in both beef cattle and cropping.

For grazed pastureland, the total area reported by surveyed producers was 222,681 acres from 203 producers. Among this total, 12,879 acres (5.8%) were managed by crop-only respondents, while the majority, 94.2% (208,706 acres), was reported by producers with beef cattle operations.

3.2.1 Limitations

The producer BMP survey and analysis is a critical component of measuring progress towards AALL's goals. To distinguish nuances in various BMP adoption rates, the survey included iterations of similar questions to capture seasonal variances and land use type (i.e., crop, hay, or pasture). This information is necessary for best measuring improvements and level of execution of practices; however, the result was a relatively lengthy and complex survey. The outcome in terms of respondents was mixed, with some non-valid responses recorded. While conditional branching enhanced the overall experience for respondents, it is possible that some participants simply stopped completing the survey instead of appropriately indicating if a practice was relevant to them or not.

Further, the operation size (i.e., acreage and/or number of cattle) was skewed to the lower end; while this is partially attributed to the actual operation sizes in Alberta and northern BC, it created challenges for assumptions made in removing outliers. As such and only when deemed necessary, an ad hoc methodology was employed for the removal of outliers to ensure legitimate data are reflected in the results. Where a methodological approach could be taken, the Interquartile Range (IQR) method was used to remove outliers.

As convenience sampling was used, these results can only be generalized to the producers who responded and not to the entire population. AALL aims to demonstrate management practices that improve production and profitability, while benefiting the environment; to effectively assess the desired changes, a starting point, or benchmark, of BMPs in the Alberta and Peace Region of BC is necessary, which the survey and report achieve.

3.3 Results Analysis and Presentation

Summary results are provided in the following section. Average and median values are calculated to provide a better understanding of the distribution of values in the dataset. Where the median is close to the average, it suggests a symmetric and normal distribution, while a significant difference between the two suggests the distribution is likely skewed. In instances of skewness, the median often provides a more accurate representation of the central tendency, as the average may not necessarily reflect the true center of the distribution.

To evaluate whether there are significant differences between certain practices among beef producers, a Kolmogorov-Smirnov (K-S) test was conducted. This non-parametric test was chosen due to the non-random and non-normally distributed nature of the sample. Specifically, three sets of practices were assessed: the grazing length in days for continuous versus rotational grazing systems, the stocking rates of cattle on pasture under continuous versus rotational grazing systems, and the acreage for crop management of operations categorized as mixed (beef and crop) versus crop-only. The K-S test was employed to determine if these sets of practices are drawn from the same distributions, providing a robust measure of the differences between the two groups for each practice. Results of the K-S tests failed to reject the null hypothesis for each case, indicating there is no significant difference between the distributions being compared (see Appendix 7.2 for results in tabular form).

Respondent numbers for each section differ, as not all sections were relevant for all participants. Each section reports on the total number of useable respondents for the section, and the sample of interest.

The management of outliers in the results required case-by-case analysis. As outlined in the previous section, some data may appear as an outlier but contain important detail. As such, outliers were removed in an ad hoc manner, based on sound judgment and industry knowledge, to maintain as much richness of the data as possible. Where removal of data outliers was necessary, they were identified using the IQR method, where data points outside the middle 50% of the data are removed.

In cases where there are fewer than five respondents the average and median are not calculated, and these are noted as insufficient response rate. In some cases, totals do not sum to 100% as not every respondent answered every question, for instance in cases where the question was not applicable or where a respondent did not fully complete the survey.

Adoption Rate Calculations

For each BMP and specific region, Formula 1 is used to calculate adoption rates, as a percentage of adopters, Formula 2 is used to calculate adoption rates, as a percentage of acres, and Formula 3 is used to calculate adoption rates, as a percentage of beef cows.

Formula 1:

$$Adoption\ Rate\ (BMP\ \&\ Region) = \frac{Number\ of\ Adopters\ in\ Specific\ Region}{Total\ Number\ of\ Respondents\ in\ Specific\ Region} \times 100$$

Formula 2:

$$Adoption\ Rate\ (BMP\ \&\ Region) = \frac{Number\ of\ Acres\ of\ Adopters\ in\ Specific\ Region}{Total\ Number\ of\ Eligible\ Acres\ of\ Respondents\ in\ Specific\ Region} \times 100$$

Formula 3:

$$Adoption\ Rate\ (BMP\ \&\ Region) = \frac{Number\ of\ Adopters'Beef\ Cows\ in\ Specific\ Region}{Total\ Number\ of\ Beef\ Cows\ of\ Respondents\ in\ Specific\ Region} \times 100$$

Stocking Rate Calculations

The calculation of cattle stocking rate is needed to assess forage availability for pasture BMPs. In section 4.2.3.1, stocking rates are calculated for continuous and rotational grazing. To calculate the stocking rate, four variables were used: number of head per livestock category, average weight of livestock by category, average grazing days continuous and rotational practices, and the size of grazing area.

First, the animal unit (AU) per head belonging to a specific operation is calculated using following the formula:

$$AU_{ij} = \frac{Average\ weight_{ij}}{1{,}000}$$

Where AU_{ij} is the AU per head for the livestock category *j* in the *i-th* operation. AU_{ij} is calculated by dividing the average weight of livestock category *j* in operation *i* by one thousand.

Second, the group AU is calculated using the following formula:

$$Group\ AU_{ij} = AU_{ij} \times Head\ number_{ij} \times Grazing\ days_i$$

The Group AU_{ij} if the AU for all livestock of category *j* in operation *i*. It is calculated by multiplying the AU_{ij} by the number of heads if livestock category *j* in operation *i*, by the total number of grazing days in operation *i*.

Third, the total herd AU is calculated using the following formula:

$$Herd\ AU_i = \sum_j Group\ AU_{ij}$$

Where, the Herd AU_{ij} is the AU for all livestock categories in operation i.

Finally, the stocking rate for operation *i* is calculated using the following formula:

$$Stocking\ Rate_i = \frac{Herd\ AU_i}{Total\ grazing\ days_i}$$

4. Results and Discussion

This section is organized into four main areas: Producer and Operation Characteristics, Pasture and Hayland Management, Cattle and Grazing Management, and Crop Management. Each section provides detailed insights into the practices currently being implemented by producers as indicated in survey responses, and a briefing on relevant literature to provide context and support for the findings.

4.1 Producer and Operation Characteristics

This section reports on the demographics and operational details of the survey respondents, including farm size, production scale, and producer experience. Understanding these characteristics is essential for interpreting the adoption rates of BMPs and identifying potential barriers to their implementation. The literature review will focus on factors influencing the adoption of BMPs, such as economic incentives, knowledge transfer, and access to resources.

4.1.1 Producer Characteristics

Understanding characteristics related to producers helps contextualize the adoption rates of BMPs and identify demographic factors influencing their implementation. For instance, key BMPs include succession planning, which ensures the continuity and sustainability of farming operations, collaborative relationships with neighbors, which facilitate knowledge sharing and resource optimization, and producer attitude towards innovation to assess comfort in investing in new practices.

4.1.1.1 Producer Demographics

Nearly all survey participants (90.1%; n = 281) reported being the **primary decision-maker** for their operation. Among respondents, there was an almost even split between women (51.6%; n = 161) and men (46.2%; n = 144), with one respondent (0.3%) identifying as "other" for gender and six respondents (1.9%) opting not to disclose their gender. Almost all respondents (99.0%; *n* = 309) reported speaking **English** most often and nearly all respondents reported having a **spouse** (88.1%; *n* = 275). Nearly half (48%; n = 149) of all respondents indicated they have children under the age of eighteen; a further 37% (n = 116) indicated that their children were over age eighteen, and 13% (n = 41) indicated no children in the family (6 respondents indicated 'none of these').

Regarding **education**, most respondents reported having received a certificate or diploma (45.2%; *n* = 141). Having completed high school (23.1%; *n* = 72) or a bachelor's degree or applied diploma (22.1%; *n* = 69) were also common responses (Figure 2). A small percentage of respondents reported having completed some high school (3.5%; *n* = 11), a master's degree (2.9%; *n* = 9), or a Doctoral degree (0.3%; *n* = 1), and nine respondents (2.9%) preferred not to provide information about their education.

There is generally mixed evidence on the role the level of **education** achieved plays in influencing BMP adoption on-farm, with some research finding a positive influence of education on adoption (Prokopy et al., 2019) and others finding no distinguishable difference (Shah et al., 2022). Of the respondents who have a post-secondary degree, certificate, or diploma, more than half of them obtained the post-secondary degree in an agricultural field (52.7%; *n* = 116; e.g., animal science, animal husbandry, veterinary science, agriculture business, forage management, environmental studies), which may be more relevant for associations with BMP adoption.

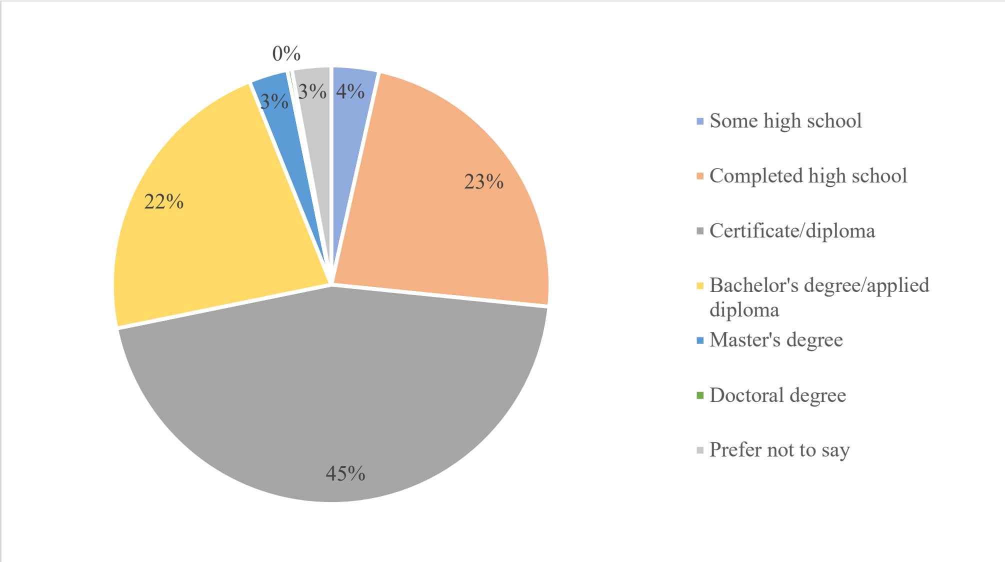


Figure 2. Stated education levels of respondents.

4.1.1.2 Farm Financials, Business Planning, Innovation, and Agricultural Knowledge

Socio-economic factors, such as farm income and financial stability, play a crucial role in BMP adoption. Producers with higher incomes and greater financial stability are more likely to invest in new technologies and practices that enhance sustainability. Additionally, access to financial incentives and support programs can significantly influence the adoption rates of BMPs.

Over one-third of producers (n = 116) indicated that the operation is facing **financial** constraints that will limit new, significant (i.e., more than $15,000) investments in the next 1 to 3 years. Fifty respondents were not sure (16.0%) and 23 (7.4%) preferred not to comment. The remaining 123 respondents (39%) indicated no significant financial constraints in the near future. Favourable personal financial conditions are often cited as influencing BMP adoption (Prokopy et al., 2019) and Smith et al. (2020) found that farmers make significant financial investments in agri-environmental projects, which would not be feasible for those under financial stress.

Related to financial consideration, producers engaged in off-farm **labor** may have additional financial resources that might support BMP adoption. Conversely, they may have limited time and resources to dedicate to the adoption of BMPs. Respondents were asked about hours worked off-farm themselves and hours of paid work for their spouse on- and off-farm in 2022. Approximately 40% (n = 119) of respondents and 40% (n = 106) of their spouses did not perform any paid work off-farm (Table 3); and 44% (n = 111) of spouses did not perform any paid work on-farm[1].

[1] Responses exceeding 3000 hours were removed as this would average to more than 8 hours for every day of the year.

Table 3. Hours of work performed on and off farm (respondent and spouse) in 2022.

	Count*	Total hours*	Count of 0 hours reported	Average hours	Median hours	Standard deviation (SD) hours
Hours per year respondent performed paid work off the operation	299	232,147	119	776	100	937
Hours per year respondent's spouse performed paid work on the operation	250	157,170	111	629	40	893
Hours per year respondent's spouse performed paid work off the operation	261	238,400	106	913	400	995

*A total of 312 respondents answered however, responses indicating more than 3000 hours per year were assumed outliers and removed from analysis.

As BMPs are often a long-term investment in the operation producers were asked about **general business planning** (Figure 3) and **profitability considerations** (Figure 4). Some respondents indicated multiple timeframes for planning with the highest response rate indicating a one-year business planning timeframe and the second highest with a five-year timeframe. This is likely related to the seasonal nature of farming in western Canada as producers often plan their business based on current and expected market prices and climate predictions. Profitability considerations varied, but with many respondents indicating cost-savings, long-term profitability, whole operation profitability, and enterprise specific profitability resonating most with respondents.

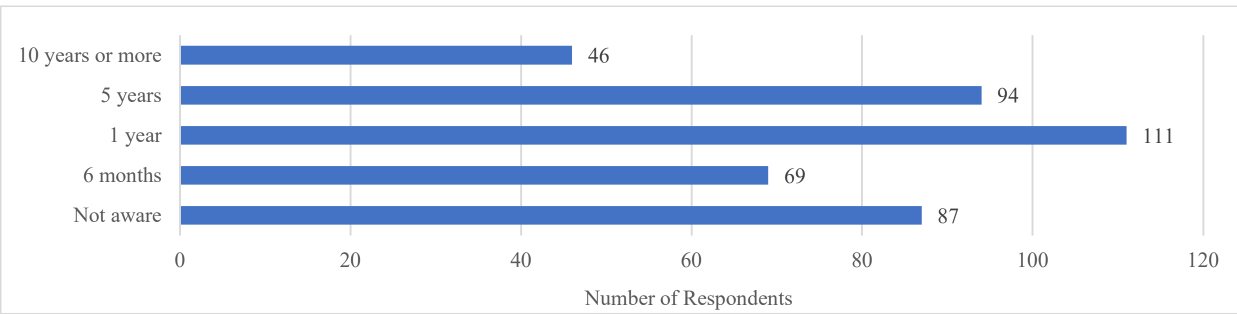


Figure 3. Respondent business planning timeframe.

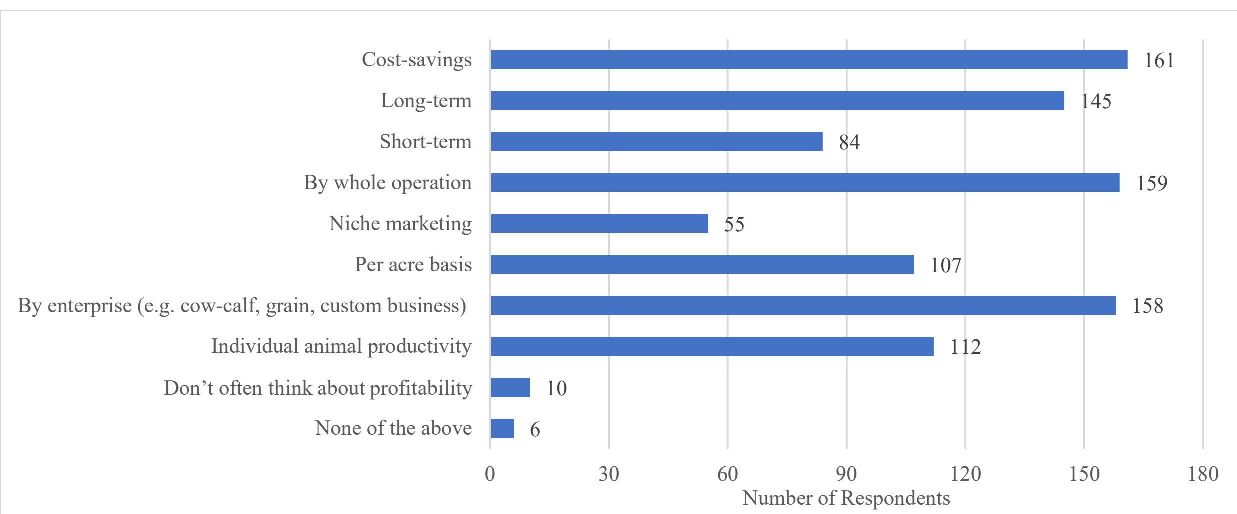


Figure 4. Respondent profitability considerations.

Related to **long-term planning**, the majority of producers (n = 275; 88.1%) did not anticipate a change in **ownership** in the next five years. When asked if someone from the family or inner circle would continue operations, over two-thirds indicated this was unlikely or would 'definitely not occur' (Figure 5). Producers with a clear succession plan may be more inclined to adopt BMPs as this may indicate a long-term commitment to the farm's sustainability and profitability. Since most respondents were not anticipating a change in ownership, conclusions here cannot be drawn as succession planning may not yet be a factor for many respondents.

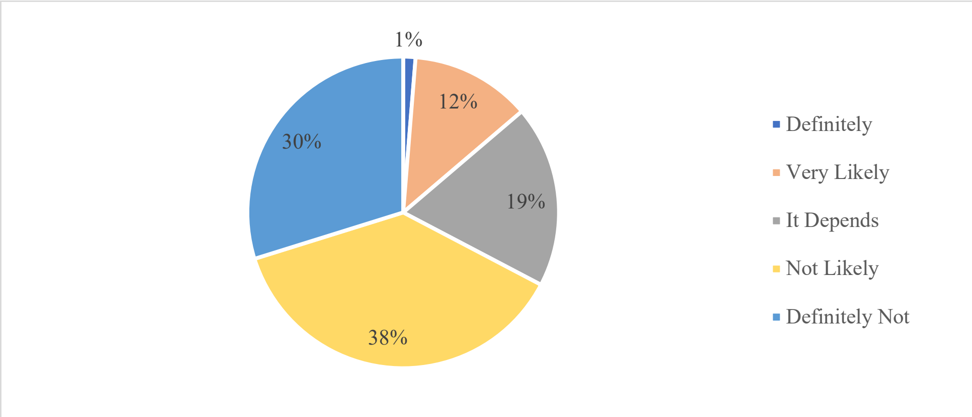


Figure 5. Expectation that family or inner circle to take over the operation when it's time for succession.

Collaborative relationships facilitate the sharing of knowledge and resources, and producers can learn from each other's experiences and successes. This community approach can enhance the overall adoption of BMPs within a region. When asked about the likelihood of **collaboration** with neighboring operations on practices that may have shared benefit, 50% (n = 156) indicated this would be unlikely or extremely unlikely. Only 11% (n = 35) responded that this type of collaboration would be likely to occur, with 39% (n = 121) indicating that it depends on the situation (Figure 6).

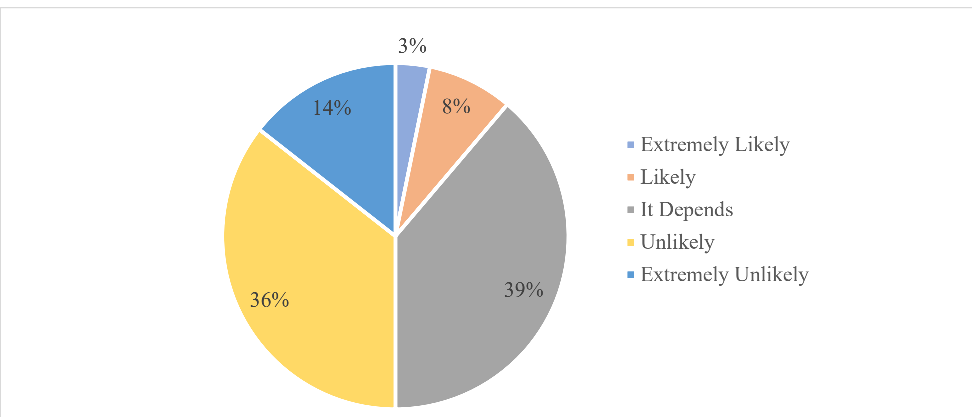


Figure 6. Likelihood of collaboration with neighbouring operations on practices with potential shared benefits.

The sources from which producers obtain their farm information significantly influence BMP adoption. Research has shown that producers who access information from extension services, agricultural consultants, and industry organizations are more likely to adopt BMPs (Prokopy et al., 2019). More than two-thirds of respondents indicated that they spent 1-10 hours per month seeking new information on the agricultural industry (Figure 7). Popular stated sources of information included producer organizations, service providers, veterinarians, other producers, and through personal experience (Figure 8) with the access to information generally from print or online magazines, tradeshows, and Facebook (Figure 9). In general, there was no difference between how straight crop and mixed operations source their information, with the exception that mixed operations utilize their vets more than straight crop operations.

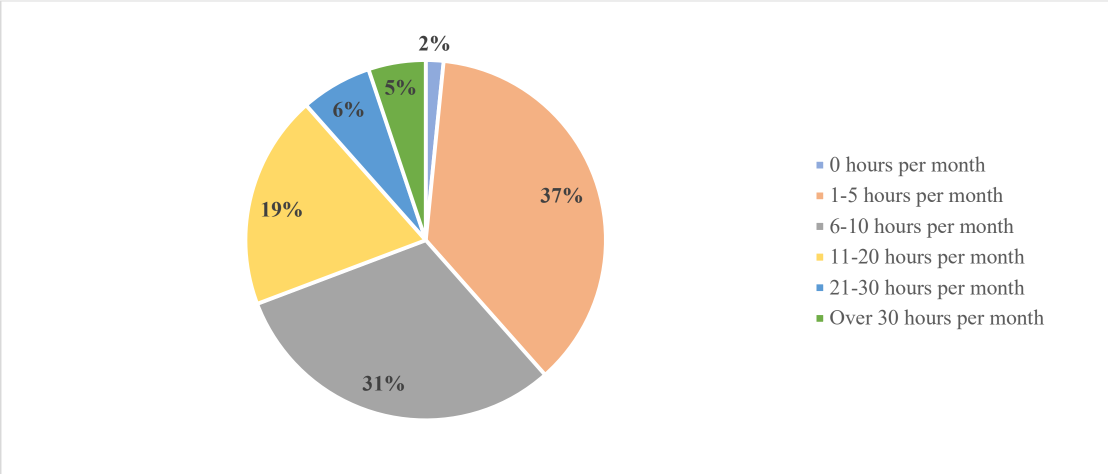


Figure 7. Hours per month respondents seek new information on the agricultural industry.

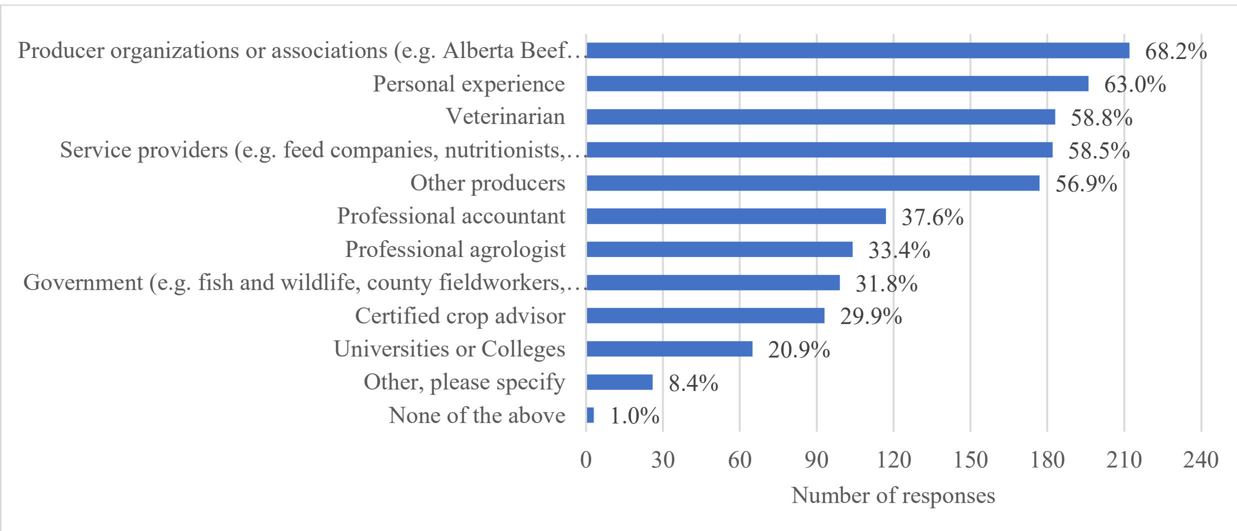


Figure 8. Respondent sources for information about the agricultural industry.

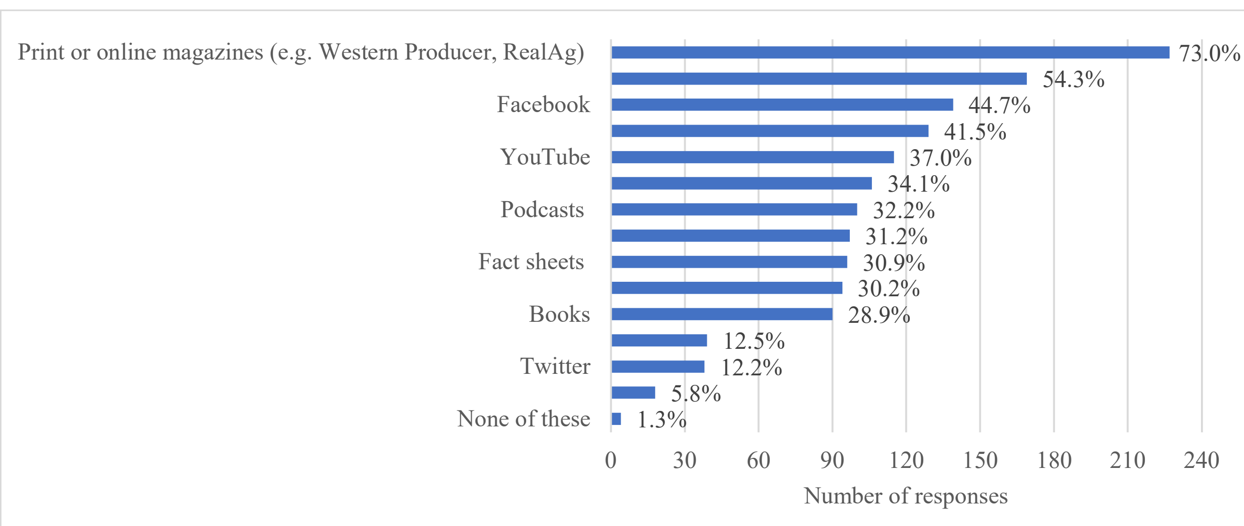


Figure 9. Respondent access of information about the agricultural industry.

The influence of information and information sources on decisions and behaviors is well established in the study of adoption of agricultural practices. Awareness and forming a positive attitude about a practice are crucial steps in Rogers (2010) diffusion of innovation framework. Producers were asked about their preferences related to investing in new practices following the stages of Rogers (2010) with the categories of adopters being innovators, early adopters, early majority, late majority, and laggards (see Figure 10 for the wording provided in the survey). Survey respondents represented 13.1%, 5.4%, 68.3%, 11.2%, and 1.9% of these respective categories. These producers were skewed as more innovative when compared with Rogers' (2010) theoretical framework, which proposes the averages at 2.5%, 13.5%, 34%, 34%, and 16% for innovators, early adopters, early majority, late majority, and laggards, respectively.

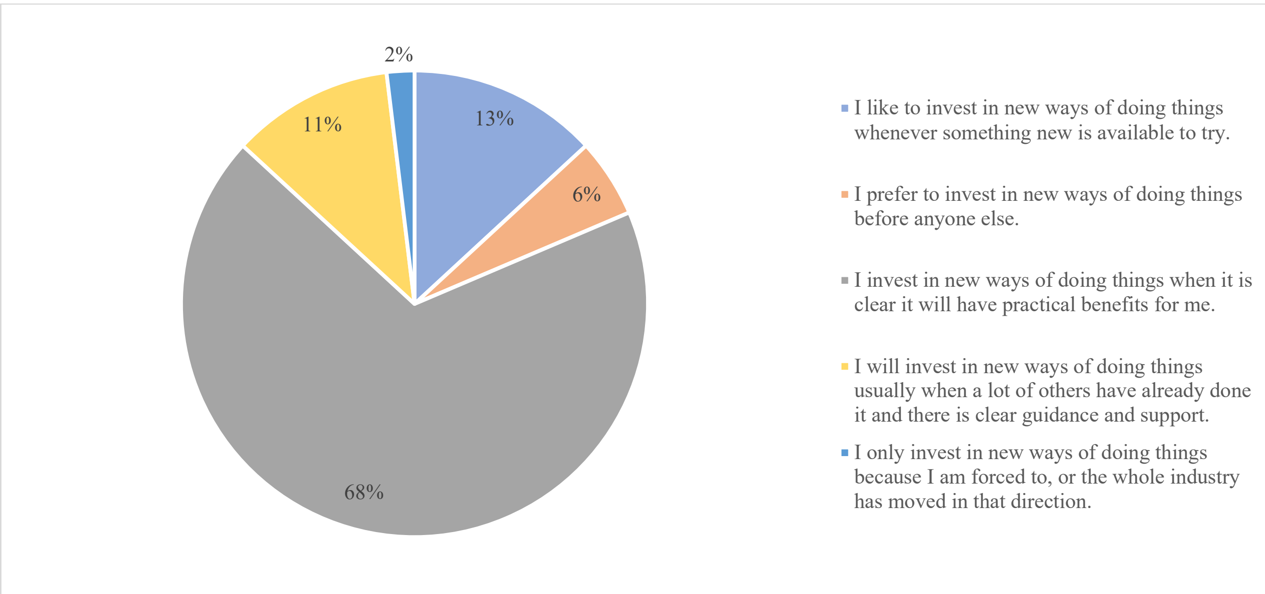


Figure 10. Respondent stated preferences in innovation.

4.1.2 Land and Operation Characteristics and Management Overview

Agricultural BMPs are crucial for enhancing farmland sustainability. They improve soil health, reduce erosion, and retain valuable nutrients, leading to increased average yields and better on-farm productivity, and promote overall environmental well-being.

There were 312 survey respondents reporting 683,067 acres of total operational land. Respondents were asked to report on non-workable land, which was defined as land that is idle and limited for use in agricultural production (e.g., areas with unsuitable soil texture, dense bush/forest, ponds, bogs, marshes, sloughs, coulees, riverbanks, saline areas, eroded areas, buffer strips, riparian areas, or rocky areas); it was further specified that non-workable land excludes grazing lands. Workable land was defined as including all cropland, grazing land/pasture, and summer fallow. Sections 4.2, 4.3, and 4.4 report on management and enterprise specific BMPs, but producers were also asked about whole farm practices, which are reported below as management of workable and non-workable land.

4.1.2.1 Management of Workable Land

When asked about general management practices on workable land, five respondents indicated that 100% of their land was 'non-workable', and these were removed from analysis. Whole farm practices for workable land included use of **enhanced efficiency fertilizers (EEFs)**, **erosion control on eroded knolls**, and **cattle grazing for weed control** (Table 4).

EEFs are designed to optimize nitrogen use efficiency; in doing so they reduce nitrogen emissions and promote consistent plant growth, leading to reduced disease and higher quality crops (Hall, 2005). EEFs enable the synchronization of nutrient release with plant needs and allow for adjustments based on environmental conditions, such as water and temperature; as such they can be precisely blended to match local crop, soil, and growing conditions, optimizing nutrient use and enhancing overall agricultural productivity (Hall, 2005). Of all respondents, 98 used EEFs on a total of 99,113 acres, representing a respondent adoption rate of 31.4% and an acreage adoption rate of 20.4% (as a proportion of all pasture and cropland). Fertilizer Canada recently reported on survey results, estimating that current EEF use in the Prairie Provinces to be 10-15% of total nitrogen fertilizer volume (Gamble and Heaney, 2022).

Organic matter provides essential nutrients to plants and binds soil particles to prevent erosion, enhancing the soil's aggregation and suitability for agriculture. It also improves water infiltration and water-holding capacity. The state of soil organic matter is influenced by biological processes, such as plant growth, and human activities, including tillage (Manitoba Agriculture, Food and Rural Initiatives, 2008). Cultivation can lead to soil erosion when the soils are left uncovered. Upper slope landscapes and knolls are more prone to water and wind erosion due to the slope gradient. With tillage and cultivation, slopes and knolls lose soil organic matter, and as such often further lose soil binding properties, making the lands even more prone to erosion. Applying heavier rates of manure to eroded knolls replenishes some of the soil organic matter (OMAFRA, 2005), with the aim of this practice to reduce overall erosion. Over 40% of survey respondents with workable land indicated the application of manure on eroded knolls occurred in 2022, representing approximately 3.2% of all pasture and cropland acreage.

Targeted grazing involves using livestock species to control unwanted vegetation, such as noxious weeds or shrub encroachment. This non-herbicide practice is beneficial when herbicide use is environmentally infeasible, too costly, or in inaccessible areas. When implementing this practice, grazing plans should include detail on the vegetation and control stocking rates. As cattle can be selective and will often avoid browsing weeds if given the option (i.e., large pasture with low stocking density), optimal weed control requires detailed information on the vegetation, timing of grazing as some weeds are more readily grazing when immature, and stocking density (OMAFRA, 2012). Over half of the survey respondents (54.5%; n = 170) indicated the use of cattle grazing for weed control on nearly 45,000 acres, representing just over 9% of the total pasture and cropland reported in 2022. Cattle grazing as weed control is often part of a rotational grazing strategy; when asked about this practice specifically (see section 4.2.3.2), nearly 70% of all beef producers indicated the use of rotational grazing in 2022.

Table 4. Respondent adoption of EEFs, manure or compost on eroded knolls, and cattle grazing for weed control in 2022.

Region		Area EEF applied	Adoption rate (%) of EEF	Manure or compost applied on eroded knolls	Adoption rate (%) of manure or compost on eroded knolls	Cattle grazing for weed control	Adoption rate (%) of cattle grazing for weed control
South	acres	34,255	17.5%*	4,668	2.4%*	16,861	8.6%*
	respondents	24	33.3%	30	41.7%	36	50.0%
Central	acres	34,226	16.2%*	6,977	3.3%*	17,211	8.1%*
	respondents	51	30.9%	78	47.3%	95	57.6%
North and Peace	acres	30,632	39.2%*	3,795	4.9%*	10,888	13.9%*
	respondents	23	30.7%	28	37.3%	39	52.0%
Total Region	acres	99,113	20.4%*	15,440	3.2%*	44,960	9.2%*
	respondents	98	31.4%	136	43.6%	170	54.5%

*As a proportion of the sum of all pasture and cropland reported.

In terms of regional results, in the North and Peace region of BC, there was a higher proportion of acreage with the practices of EEF, manure or compost applied to eroded knolls, and cattle grazing for weeds, as compared to the South and Central regions. This was particularly evident for the use of EEFs with a lower overall respondent reported use at approximately 31%, but with nearly 40% of the acreage reported with this practice.

4.1.2.2 Management of Non-Workable Land

It's estimated that 60-70% of the slough/marsh wetlands in the settled areas of Alberta no longer exist (AEP, 2014). **Wetlands** are among the most diverse ecosystems, providing crucial ecological functions for plants and animals and serving as biodiversity hotspots. These ecosystems benefit agriculture by supporting crop pollination, supplying nutrients from organic matter breakdown, degrading contaminants, and controlling agricultural pests (Benalcazar, 2019). They also conserve water quality and quantity by filtering nutrients and pesticides, holding water during droughts, and reducing greenhouse gases through soil carbon storage (Benalcazar, 2019). Despite the stated benefits of wetlands, in agricultural regions, they may be viewed as a nuisance as it means less workable land, possibly disrupting the optimal machinery path for land under cultivation. Related to this, is the management of **riparian and buffer areas**, the vegetated zones next to streams and wetlands, which are essential for effective wetland management as the loss or degradation of riparian areas surrounding wetlands impairs their ability to function healthily. Research shows that these buffers, regardless of vegetation type, effectively reduce nitrogen levels in groundwater and streams (Mayer, 2005).

More recently, government and non-governmental initiatives have focused efforts on the restoration of wetlands (Bruneau, 2017) in an effort to reverse the land use change. In agriculture much of the focus is on the financial implications of wetland restoration, primarily evaluating the trade-offs of cultivation or other agricultural use, wetland restoration costs, and quantifying the ecological benefits related to agricultural productivity (Lloyd-Smith et al., 2020).

Approximately two-thirds of survey respondents (n = 202) indicated the presence of non-workable land on their operation in 2022, representing 53,068 acres or 7.8% of total operational area; after the removal of responses with data errors, the useable responses were 160 representing 35,412 acres (Table 5). Regarding wetland areas on farm, more than 80% (n = 132) affirmed the presence of wetlands on their operations in 2022, representing nearly 30% of non-workable land (10,444 acres). Fewer producers reported on the presence of riparian or buffer areas, meaning some proportion of producers did not use a protected area around their wetland areas. Just over 70% of producers with non-workable land had riparian areas in place, representing 20.1% (7,113 acres) of the reported non-workable land. Over half of the respondents (57.5%) with non-workable land reporting having buffer strips, representing 19.6% (6,938 acres) of the total non-workable land reported in 2022. A significant amount of non-workable land was reported as 'other' by 62 respondents, amounting to over 10,000 acres.

When independently asked about wetland areas managed since 2018, as a proportion of all producers reporting wetland areas (n = 164), 15.2% (n = 25) and 24.4% (n = 40) respondents indicated they removed and restored wetland areas, respectively. Total acres removed and restored amounted to 1,450 and 1,619 acres, respectively.

When asked about management goals for non-workable lands, producers indicated several prominent goals (Figure 11), with wildlife habitat improvement being the most common. When asked about 'other' uses respondents indicated the area was native grassland, the land is used as a woodlot and used as a riparian buffer.

Table 5. Details of respondents reporting wetlands, riparian areas, and buffer areas on their operation in 2022.

Non-workable land	Count	Respondent occurrence rate (%)	Total acreage	Average acreage	Median acreage	SD acreage	Acreage occurrence rate (%)**
Non-workable land	160*	64.7*	35,412	221	100	683	***
Wetlands							
South	21	72.4%	1,349	64	20	88	23.4%
Central	78	83.9%	6,014	77	25	150	35.5%
North and Peace	33	86.8%	3,082	93	40	173	24.3%
Total Region	132	82.5%	10,444	79	29	148	29.5%
Riparian Areas							
South	17	58.6%	820	48	15	78	14.2%
Central	69	74.2%	3,949	57	20	181	23.3%
North and Peace	28	73.7%	2,343	84	38	108	18.5%
Total Region	114	71.3%	7,113	62	21	154	20.1%
Buffer Areas							
South	14	48.3%	2,022	144	47	205	35.0%
Central	53	57.0%	2,529	48	20	81	14.9%
North and Peace	25	65.8%	2,388	96	30	149	18.8%
Total Region	92	57.5%	6,938	75	27	130	19.6%
Other							
South	11	37.9%	1,584	144	60	163	27.4%
Central	34	36.6%	4,459	131	36	355	26.3%
North and Peace	17	44.7%	4,875	287	80	642	38.4%
Total Region	62	38.8%	10,917	176	43	430	30.8%

*202 respondents indicated non-workable land; when asked about the proportions 42 respondents were removed due to a failure to sum to 100%. The official count is 160, but the respondent occurrence rate is calculated using the 202 respondents.
**As a proportion of non-workable land.
****Not calculated due to discrepancy in acres initially reported as non-workable land (53,068 acres) and total non-workable land used for calculations after the removal of responses that failed to sum to 100% (35,412 acres).*

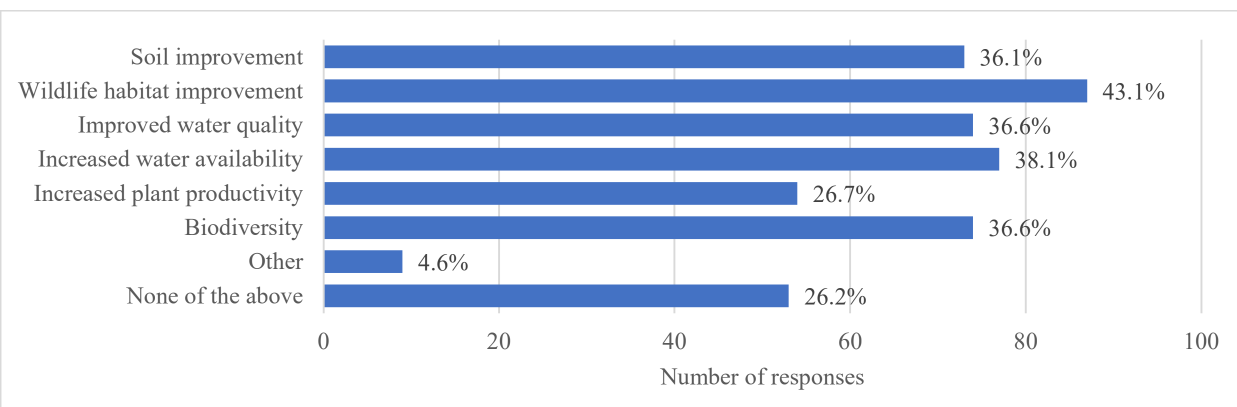


Figure 11. Management goals for non-workable land, by responses*
*Data label percentages are based on the 202 respondents.

4.2 Hayland, Pasture, and Grazing Management

Grassland ecosystems comprise a significant portion of the earth's surface and store substantial soil organic carbon. These stocks are sensitive to various factors including grazing, forage species composition, and mineral nutrient availability, which can result in either carbon losses or gains (Conant et al., 2017). Given the substantial carbon sink capacity in grasslands, there is increasing interest in management changes to enhance soil carbon stocks through carbon sequestration efforts.

Soils, forages, and waterways are influenced by management practices and land use change, including forage utilization method (i.e., grazing or haying) and timing, species composition, frequency and type of rejuvenation, and nutrient management. Implementing BMPs in hayland, pasture, and grazing management are essential for maintaining the long-term productivity and ecological integrity of agricultural landscapes while supporting the economic viability of livestock operations. These practices contribute to improved forage quality, increased livestock carrying capacity, and enhanced ecosystem resilience, ultimately benefiting both producers and the environment.

4.2.1 Hayland Management

BMPs in hayland management may include soil conservation practices to prevent erosion, maintain soil fertility, and improve soil carbon sequestration. Management of forage blend for seeding, type of seeding and rejuvenation, fertilizer application (timing, rate, type), and harvest contribute to optimizing forage yield and quality while minimizing negative environmental impacts such as nutrient runoff and improving beneficial ecosystem outcomes such as soil fertility. Surveyed producers were asked if **crops, including hay, oilseeds, cereals, and pulses, were grown for mechanical harvest** in 2022; of the 225 useable responses in this section, 72.7% (n=165) indicated yes.

Hayland was subsequently defined as a perennial species grown for mechanical harvest. Approximately 71% of respondents managing crops or 52% of all respondents (n=117) indicated that hayland was managed in 2022, representing approximately 15.3% or 29,861 acres of all mechanically harvested cropland (195,257 acres). Of respondents who grew perennial forage (i.e., hay) for mechanical harvest, 85.6% also owned beef cattle. Regional results and adoption rates are provided in Table 6. The average acreage of managed hayland across all regions in 2022 was 255 acres, with the South region having the highest and the North and Peace region having the lowest average acreages at 633 and 143 acres, respectively.

Table 6. Respondent adoption/use of perennial hayland for mechanical harvest, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)
South	22	62.9%	13,919	633	288	1310	21.9%
Central	62	73.8%	11,236	181	112	187	11.9%
North and Peace	33	75.0%	4,706	143	105	137	12.6%
Total	117	71.8%	29,861	255	130	606	15.3%

4.2.1.1 Land Use and Land Use Change on Managed Haylands

Soil carbon stocks are significantly influenced by management practices and land use changes, such as forage species composition, rejuvenation, harvest timing, and nutrient availability, resulting in either carbon losses or gains, with improved practices (Conant et al., 2017). Land conversion to permanent or semi-permanent vegetation, such as hayland, has been also found to be more effective for reducing nutrient and sediment runoff when compared to no-till cropland practices (Rousseau et al., 2013).

Hayland Continuous Production

To establish a benchmark of land use change in hayland areas, producers were asked if they had any portion of the reported **hayland in continuous production** for five years or less[2]. Nearly two-thirds of respondents (62.4%; n = 73) indicated this to be true on their operations, providing an estimated area of 16,162 acres, or 54.1% of total respondents harvested hayland area (Table 7). Producers reported hayland acreage ranging from 16 to 5,000 acres (average = 207, median = 100, and standard deviation; SD = 572). These producers managed 49.1% (n = 15,069) of all respondents' beef cows and yearling grassers on their operation and 37.6% (73,387 acres) of all respondents' cropland in 2022. Twenty-nine percent (n = 34) of respondents indicated they did not have any portion of hayland in continuous production for five years or less, and 2.5% were unsure.

Table 7. Respondent adoption/use of continuous hayland production for five years or less, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number of beef cows & yearling grassers
South	13	59.1%	7,403	529	110	1,300	53.2%	2,026
Central	41	66.1%	6,051	144	100	167	53.9%	5,937
North and Peace	19	57.6%	2,708	123	90	117	57.5%	7,106
Total region	73	62.4%	16,162	207	100	572	54.1%	15,069

Low forage yield is often cited as a factor when terminating a forage stand, with stands maintained on average for 3-5 years in high moisture regions of western Canada and 6-9 years in semi-arid regions (BCRC, 2023c). Respondents were asked if the hayland reported was in production during any of the years between 2015-2022 (Table 8). A diminishing number of respondents and acreage were reported for each previous year. Respondents located in the South region had proportionally more land under continuous production with a reduction of 12.8% in 2015 from 2022, while Central and North and Peace regions saw the acreage change with a reduction of 75.5% and 58.5% over the same period. This is consistent with previous observations, which noted the average forage stands being maintained for 3-5 years in higher moisture regions and 6-9 years in semi-arid regions (BCRC, 2023c).

Table 8. Respondent hayland acreage by region, 2015-2022.

Region	Year	2022	2021	2020	2019	2018	2017	2016	2015
South	Respondents	14	13	13	10	7	6	6	6
	Estimated Acres	7,403	7,103	7,103	6,933	6,575	6,455	6,455	6,455
Central	Respondents	43	40	38	34	26	18	13	11
	Estimated Acres	6,051	5,861	5,721	5,216	3,006	2,316	1,990	1,480
North and Peace	Respondents	21	20	17	15	10	7	7	7
	Estimated Acres	2,408	2,008	1,578	1,848	1,200	1,000	1,000	1,000
Total region	Respondents	78	73	68	59	43	31	26	24
	Estimated Acres	15,862	14,972	14,402	13,997	10,781	9,771	9,445	8,935

Land Use Change

[2] If more than one area of hayland was in continuous production for five years or less, participants were instructed to consider the questions for the largest applicable hayland area.

Prior to the current use as hayland, producers reported that these acreages were most often used for annual crop production (77.2%; n = 61) and pastureland (11.4%; n = 9) (Figure 12). Among producers who indicated that the land area was used for annual crop production, 63.6% (n = 42) knew the crop species grown immediately prior to the **conversion to hayland**, with barley (33.3%; n = 14) and oats (26.2%; n = 11) being the most common (Figure 13). For 40.5% (n = 32) of respondents the previous land use was in place for more than seven years (Figure 14). Additional results on reported practices in annual crop rotations are provided in section 4.4.5.

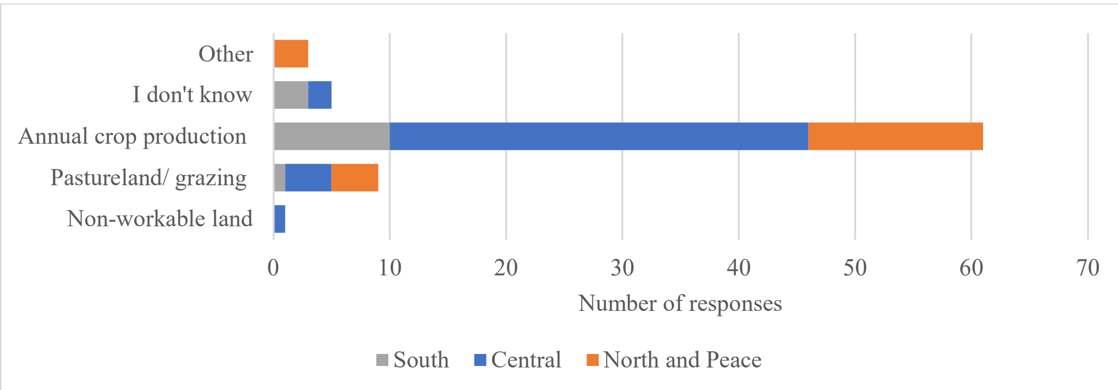


Figure 12. Reported land use prior to current area managed as hayland.

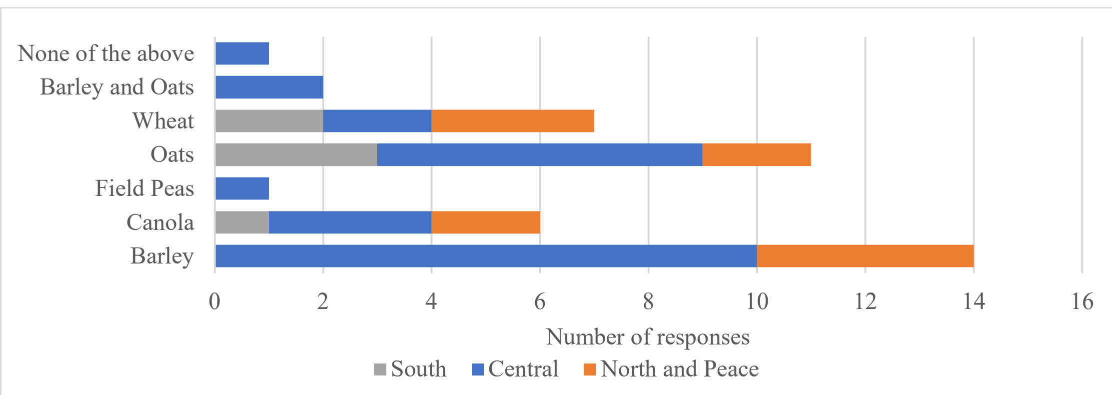


Figure 13. Reported crops grown prior to conversion to hayland.

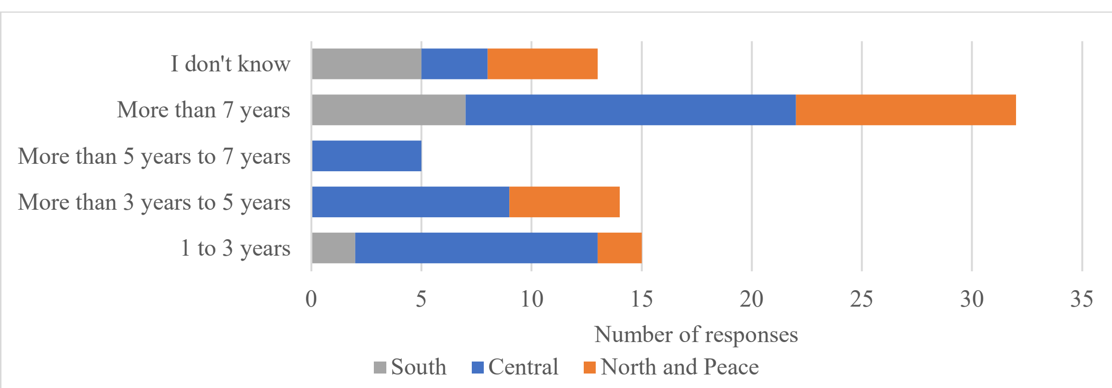


Figure 14. Length of time in land use prior to hayland conversion.

Crop rotations in western Canada often integrate multiple annual crops, with the addition of short-term perennial forages offering various agronomic and environmental advantages. These benefits include moisture conservation, reduced pest infestation, weed suppression, improved soil quality, increased soil organic matter, and wildlife habitat (Entz et al., 2002). Even short term (i.e., 2 years) inclusion of perennial forages has been shown to have beneficial soil carbon sink properties, primarily due to increased soil organic matter content, reduced nitrous oxide emissions, and a longer growing season with forages for improved net carbon dioxide uptake when compared to annual crops (Maas et al., 2013).

Conversion to perennial forage from annual cropland may have occurred on lands operated by producers who did not specifically grow perennial forage for hay in 2022. Respondents who **grew oilseeds, cereals, or pulses** on operational lands in 2022 were also asked about perennial forages in rotation. More than a quarter of respondents in this section of the survey (27.5%; n = 42; N = 152) reported that a perennial forage was included in the crop rotation since 2018, accounting for approximately 4.8% (8,942 acres) of total respondents' cropland. For further results on cropland management practices, see section 4.4.

When asked about **perennial forages in annual rotations** in 2022, 39 producers responded that they managed 23.7% (44,570 acres) of the total cropland represented in the survey; these producers also managed 38.3% (n = 11,146) of total respondents' beef cows and yearling grassers (Table 9). In terms of acreage, this practice was more common in the Central and South regions, when compared to the North and Peace region. Perennial forages were present as part of a crop rotation operated by these survey participants on areas ranging from 2 to 2000 acres (average = 213 acres; median = 200 acres; SD = 973). Respondents reported including perennial forages in crop rotations for a variety of reasons, including for hay, greenfeed, and silage (71.8%; n = 28), to improve soil quality (56.4%; n = 22), and to provide grazing (48.7%; n = 19)[3].

Table 9. Respondent adoption/use of perennial forages in annual rotations, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total cropland acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number of cows and yearling grassers
South	5	15.2%	3,580	597	550	1,501	6.0%	635
Central	25	32.1%	3,937	151	155	391	4.3%	4,727
North and Peace	9	21.4%	1,425	143	200	148	3.9%	5,784
Total	39	25.5%	8,942	213	200	973	4.8%	11,146

4.2.1.2 Hayland Forage Species Composition

Utilizing a combination of grass and legume species optimizes hayland productivity, forage quality, and environmental stewardship. Grass species offer high biomass production and persistence, while legumes provide valuable livestock nutrition and improve soil fertility. Plant genetics influence digestibility, important for livestock feed energy and feed efficiency; having a mixed forage stand allows producers to take advantage of the difference in maturity between and within species to optimize forage quality at harvest. Additionally, mixed grass-legume stands are more likely to provide higher quality forage than pure grass stands (Nelson et al., 2012).

Grasses exhibit sod forming or bunch grass growth patterns, with each formation being favourable under differing conditions. Sod forming grasses spread via rhizomes and stolons, creating dense stands, while bunch grasses remain as individual plants with clustered tillers (BCRC, 2024). In Canada, most cultivated grass species are classified as cool-season varieties, exhibiting early growth in spring under cool and moist conditions. During this peak growth phase (before mid-July) they typically yield higher protein content compared to warm-season counterparts. Bromegrass species are favored for hay production due to their high biomass production, palatability, and adaptability to different soil types. Wheatgrasses are often

[3] Regional results are not reported due to limited sample size.

incorporated due to their resilience under drought conditions, ability to thrive in diverse soil environments, and early growth in the spring. Ryegrasses offer versatility in forage production with its rapid establishment and high yield potential. Fescues are sought after for their drought tolerance and ability to improve soil stability. Orchard grasses are prized for their ability to yield high quantities of palatable forage and exhibit robust regrowth after harvest. And, timothy is renowned for its superior forage quality, palatability, and persistence, making it a cornerstone in hay production systems.

Legumes, characterized by having seeds in pods and robust root systems, enhance soil biological activity, structure, aeration, water retention, and reduce erosion while increasing organic matter (BCRC, 2024). Like tame grasses, most Canadian legumes are cool-season forages, initiating growth in early spring. Nitrogen-fixing capabilities enable legumes to produce much of the nitrogen required, reducing the need for additional nitrogen application, when compared to non-leguminous row crops. Alfalfa enriches soil fertility and supports livestock nutrition with its high protein content. Clovers play a vital role in boosting soil nitrogen levels, providing high-quality forage, and creating habitat for pollinators, promoting sustainable agricultural practices. Sainfoin, valued for its high protein content, palatability, and nitrogen-fixing capacity, thrives in hay production, particularly in regions with alkaline soils, further augmenting soil health. Trefoil, with its resilience to acidic soils, contributes to soil fertility. Vetches play a crucial role in improving soil health, diversifying forage options within hayland management systems.

Producers were asked to rank the **tame pasture species growing on their largest hayland** area. Common grasses and legumes included bromegrasses, wheatgrasses, ryegrasses, fescues, orchard grasses, timothy, alfalfa, clover, sainfoin, trefoil, and vetches, with 'other' included to capture any additional pasture species grown. The most abundant species was alfalfa, with 45.6% (n = 36) of respondents ranking it as first in abundance. Brome grasses and timothy were ranked as most abundant by 17.7% and 13.9% of producers, respectively (Figure 15).

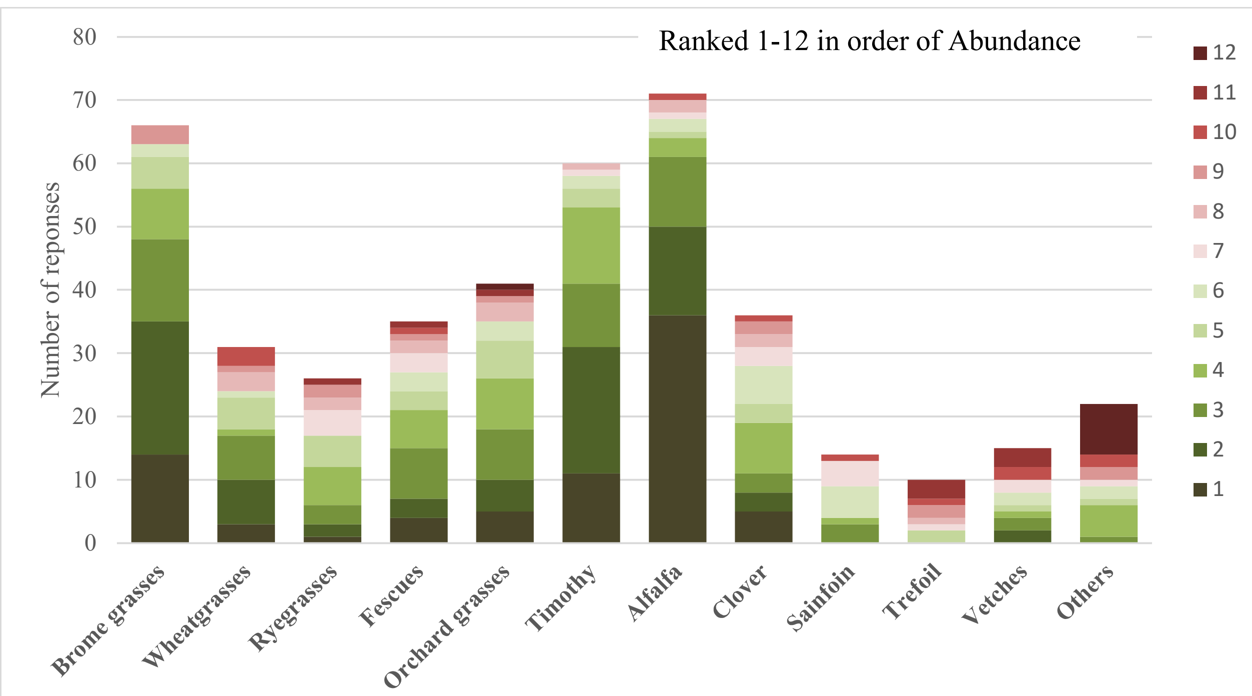


Figure 15. Tame hay species composition reported on producers' largest hayland areas in 2022, ranked 1-12 in order of abundance.

4.2.1.3 Hayland Rejuvenation

Without active management, many cultivated forage species have a productive lifespan of around four to five years before productivity declines due to aging stands and encroachment of undesirable or less productive forage species, as well as potential proliferation of weedy or woody vegetation. Rejuvenation refers to treatment aimed at enhancing the productivity of an existing forage stand and may include reseeding, sod seeding or overseeding, and fertilization of haylands.

Newly established forage stands initially exhibit high production and low maintenance requirements, but productivity may decline over time due to soil quality, moisture availability, species suitability, and management practices (BCRC, 2023b). Assessing the status of the pasture or hayfield and evaluating past management decisions and soil conditions inform producers on the rejuvenation strategy. The presence of unwanted species could warrant the use of mowing, herbicide, or fertilizer, while a too low density of desired species might warrant sod seeding, overseeding with a legume, improved grazing management, or even a complete reseeding of the stand (BCRC, 2023b).

When asked about **seeding hayland** areas, approximately a quarter of respondents utilized this practice in 2022. These producers managed 18.9% (336,712 acres) of the total respondents' cropland area and 30.3% (n = 9,219) of total respondents' beef cows and yearling grassers (Table 10). The hayland area seeded ranged from 13 to 1,700 acres (average = 159.4, median = 85, SD = 308.1).

Table 10. Respondent adoption/use of seeding on existing hayland, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number of beef cows and yearling grassers
South	NR	13.6%	2,105	702	300	870	15.1%	200
Central	17	28.8%	1,513	89	72	78	13.8%	3,103
North and Peace	9	26.5%	1,005	112	80	86	21.4%	5,916
Total region	NR	25.2%	4,623	159	85	308	15.6%	9,219

NR = not reported due to insufficient sample size and to maintain respondent confidentiality.

Using reseeding methods that minimize soil disturbance is an important consideration for optimizing the carbon sequestration benefits of haylands. **Sod seeding** was defined to survey participants as the direct drilling of seed into land where little or no seedbed preparation has been made. Most producers used direct/sod seeding (44.8%; n = 13) and broadcasting (41.4%; n = 12) to re-seed hayland areas (Figure 16). Additional context on sod seeding, and the related BMP implications, are provided in section 4.2.2, as it pertains to sod seeding on pasturelands.

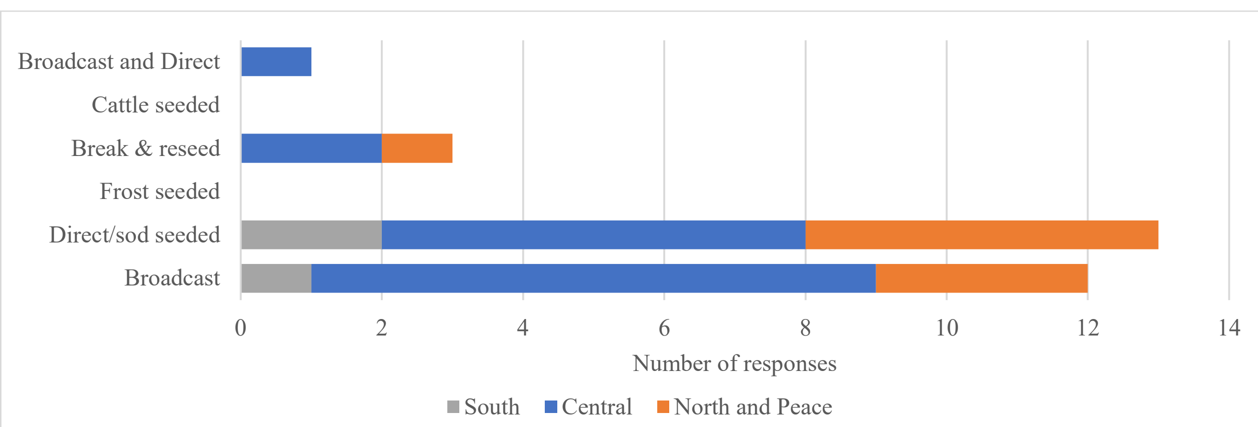


Figure 16. Method of seeding on largest established hayland area, by region, in 2022.

4.2.1.4 Hayland Harvest Management

Hayland **harvest timing** significantly impacts hay nutritional quality, with most forage crops experiencing a decline in nutritive value as they mature through the season (Nelson et al., 2012). Farmers aiming to enhance forage quality may be advised to harvest grasses at the late vegetative stage and legumes at late bud formation (Rathgeber, 2022).

However, early harvesting may lead to reduced yields and shorten stand longevity over time as early harvest is associated with reduced storage of carbohydrates and nitrogen in legumes and grasses, reducing regrowth vigor and persistence of forages (MacAdam and Nelson, 2003). Additionally, stand persistence depends on natural reseeding, with earlier harvest occurring before natural re-seeding can take place. This impacts the ability of the forage to regrow and outcompete weeds, potentially further reducing the optimal lifespan of the forage stand (Nelson et al., 2012).

There is a direct impact of forage quality and yield on greenhouse gas production and sequestration. The more productive a forage stand, the greater its root biomass and potential for carbon sequestration. Productive perennial forage stands boast extensive root systems capable of storing up to 2.7 times more carbon than annual crops, sequestering it deeper in the soil for longer-term storage (Rathgeber, 2022).

Overall, a more robust forage stand has greater ability for carbon sequestration, but this may come with trade-offs for optimal nutritional content of harvested forages. More than half (51.3%; n = 59) of producers surveyed harvested hay when 10-50% of the stand was in bloom/headed out (Figure 17). This indicates a slight preference among producers for nutritional quality of harvested forage, meaning rejuvenation methods such as re-seeding and nutrient management are important considerations for overall land productivity and profitability.

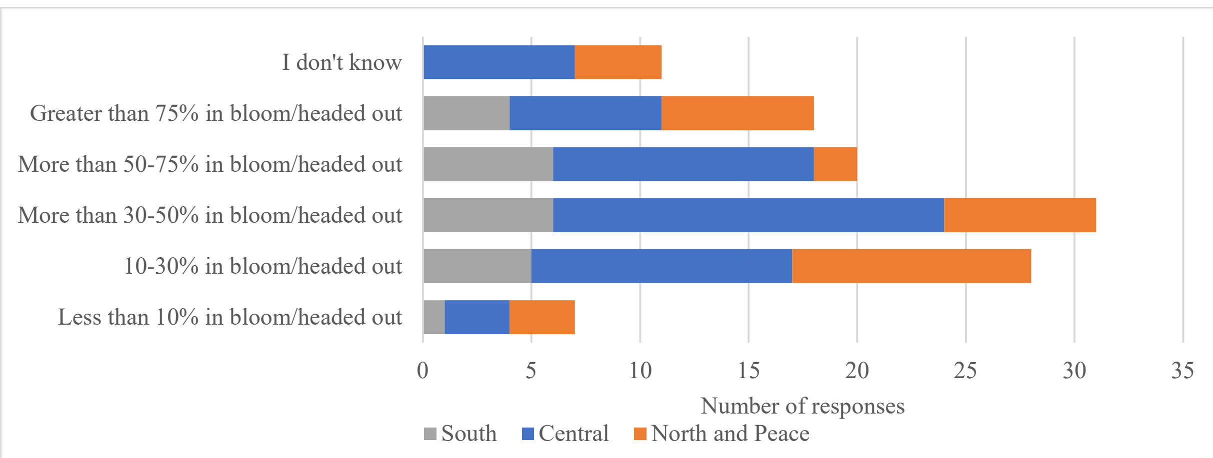


Figure 17. Reported timing of hayland harvest by forage stage and region in 2022.

4.1.2.5 Hayland Nutrient Management

The goal of nitrogen fertilizer application is to boost crop yield and enrich soil nitrogen levels. However, the effectiveness of nutrient uptake by plants depends on the availability and accessibility of nitrogen in the soil over time, potentially leading to increased emissions of nitrous oxide (Asgedom and Kebreab, 2011). Soil organic carbon levels can increase or decrease with nitrogen fertilizer application, depending on soil, management, and climate variables, and as such, BMPs for fertilizer application in forage stands focus on improved nitrogen use efficiency and optimal biomass production. The 4Rs, "Right rate, Right source, Right place, and Right time" nutrient stewardship approach is a guiding principle for enhancing nitrogen use efficiency in forage grasses and ensuring a comprehensive system is followed to make informed decisions about fertilizer application (Edvan and Bezerra, 2018). Each aspect of the 4R's is interconnected, impacting both fertilizer outcomes and dry matter production. Fertilizer application and timing is an adaptive management practices that can revitalize the forage stands by reducing weed problems, altering insect cycles, reducing disease pressures, and restoring a better balance of legumes and grasses in the mixture (Nelson et al., 2012).

About 36% of respondents (n = 41) indicated that they applied **fertilizer (synthetic, manure, or compost)** to any of their managed haylands (Table 11). The total hayland area fertilized in 2022 by producers completing the survey represented 26.6% (or 7,878 acres) of total respondents' hayland area. Respondents fertilized between 10 and 4000 acres (average = 192.1, median = 80, SD = 613.8). Respondents who said they applied fertilizer to any of the hayland in their operation in 2022, reported managing 25.28% of total of cropland (n = 49,206 acres) and 51.9% of the total hayland (n = 15,359 acres) reported in the survey. These operators also reported managing 33.73% of all respondents' beef cows and yearling grassers (n = 10,253).

Table 11. Respondent adoption/use of fertilizer application on the largest reported hayland area, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acreage	SD acres	Acreage adoption rate (%)	Number of beef cows and yearling grassers
South	5	22.7%	4,468	894	158	1738	32.1%	210
Central	24	40.7%	2,370	99	78	73	21.6%	3,880
North and Peace	12	36.4%	1,040	87	45	76	22.2%	6,163
Total Region	41	36.0%	7,878	192	80	614	26.6%	10,253

BMPs for **nutrient management** on managed haylands involve strategic seasonal application, precise methods of application, and careful selection of nitrogen products. Seasonal application should be timed to coincide with periods of active plant growth, maximizing uptake efficiency and minimizing losses due to leaching or runoff. For haylands, this often means applying fertilizer in the spring before the peak growth period, as well as possibly during other periods of rapid growth throughout the growing season. If soil tests indicate nitrogen levels to be particularly low, it would be better to split the application into multiple phases to avoid runoff or leaching (BCRC, 2023b).

Producers were asked for details regarding nutrient management across the four different **seasons**. Respondents did not respond to all sections, presumably because the question did not apply to them (i.e., no responses if they did not answer yes to fertilizer application in winter); this resulted in different number of total respondents in each season. The share of respondents that answered yes to the question if they applied fertilizer to their largest hayland area in the spring, summer, fall, and winter 2022 was 85.4% (n = 35), 15% (n = 6), 15.4% (n = 6), and 5.1% (n = 2), respectively. Figure 18 shows the breakdown related to the season producers applied fertilizer to their largest hayland area, with most respondents applying fertilizer in spring.

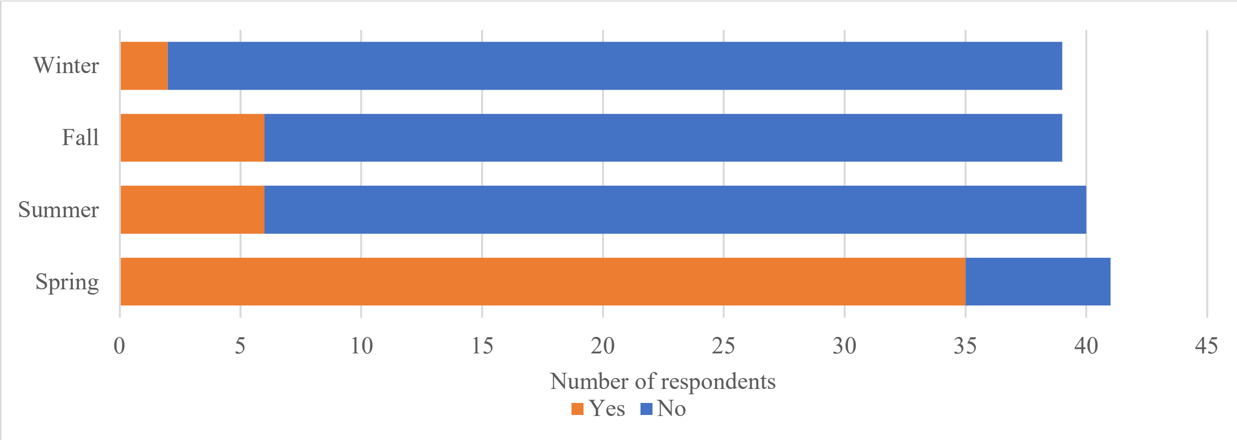


Figure 18. Reported seasonal application timing for hayland fertilizer in 2022.

The **method of fertilizer application** plays a role in nutrient distribution, soil contact, and potential losses. Broadcast spreading is a common method that evenly distributes fertilizer over the soil surface, promoting uniform nutrient availability to plants and is commonly used in dry fertilizers. However, it can also increase the risk of nutrient runoff or volatilization, especially on sloped terrain or in windy conditions. Precision application techniques such as dribble or injection allow for more targeted placement of fertilizer, reducing potential losses and improving nutrient uptake efficiency (BCRC, 2023b). These methods minimize soil disturbance which helps preserve soil structure and reduce erosion.

Producers most commonly applied urea (46-0-0) as their main source of nitrogen, regardless of season (Figure 19). Fertilizer application rate was highest in the spring and fall with averages of 119 and 129 lbs/acre respectively (Table 12). Regardless of season, most producers used surface broadcast for fertilizer application on managed haylands (Figure 20).

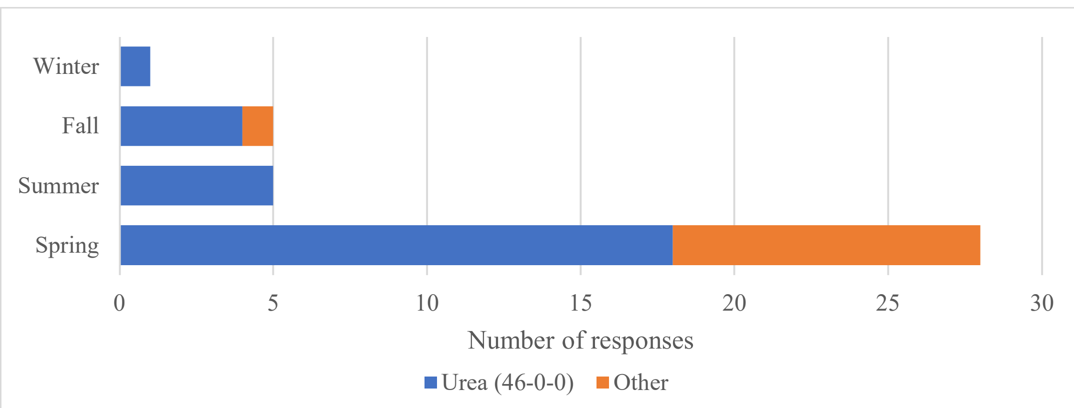


Figure 19. Reported seasonal hayland nitrogen fertilizer sources for largest area of hayland in 2022.

Table 12. Reported urea fertilizer application rates on hayland, by season in 2022.

Season	Count	Average (lbs/acre)	Median (lbs/acre)	SD (lbs/acre)
Spring	16	119	103	67
Summer	4	88	75	48
Fall	4	129	100	75
Winter	1	-	-	-

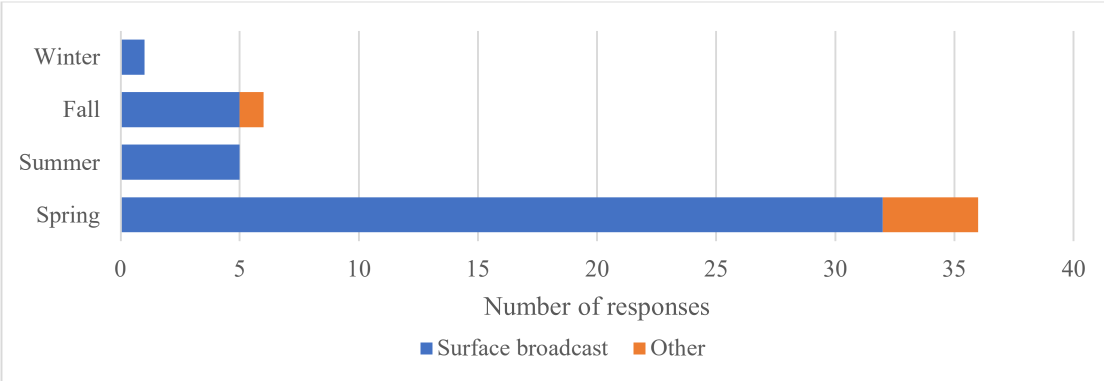


Figure 20. Most common hayland fertilizer application method, by season 2022.

4.2.2 Pastureland Management

Pasture management BMPs focus on rotational grazing systems, pasture rejuvenation with over-seeding, incorporation of legume species within the forage stand, integration of silvopasture, and nutrient management. Grazing management is discussed in the following section (4.2.3) and this section focuses on non-rotational BMPs. Rejuvenating pastures by integrating new or higher yielding forage species, silvopasture, and nutrient management enhances forage productivity and nutritive value. This contributes to improved livestock management, increased farm profitability, and enhanced environmental stewardship by optimizing the use of available land resources while minimizing negative impacts on soil, water, and biodiversity.

For the survey, **pasturelands were defined as grazing lands** managed by the operation with either native or introduced (i.e., tame) forage species, which may or may not receive periodic management such as tillage, fertilization, mowing, weed control, and irrigation. There were 297 respondents associated with this section of the survey, with 85.9% (n = 255) reporting managed pasturelands in 2022. From these 259 respondents, 255 provided acreage data. The total acreage of reported grazed pasturelands managed in 2022 was 283,435 acres, which represented 54.1% of workable land from respondents who answered yes to managing pasturelands in 2022 (Table 13).

From the 297 respondents, 94.6% who reported managing beef cattle in their operation also reported managing pastureland. And in a similar trend, operators who provided acreage of managed pastureland managed 94.1% (n = 29,332) of all respondents' beef cows and yearling grassers[4]. Producers reported managing pasturelands of 2 to 25,000 acres, with an average of 1,112 acres and a median of 400 acres (SD = 2,406.4). Pastureland as a proportion of total land managed ranged from 0.13% and 100% (average = 48.1%, median = 44.4%, SD = 30.4%).

Table 13. Respondent adoption/use of grazed pastureland management, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number of beef cows and yearling grassers
South	61	85.9%	128,195	2,102	940	2,967	55.0%	5,962
Central	138	88.5%	117,026	848	330	2,317	44.0%	12,841
North and Peace	56	80.0%	38,214	682	200	1,524	35.9%	10,529
Total Region	255	85.9%	283,435	1,112	400	2,406	46.8%	29,332

[4] Ten respondents reported pastureland area exceeding the total land they reported on their operation and were removed from the analysis for this question.

4.2.2.1 Land Use and Land Use Change on Pasture

Managing pasturelands directly benefits producers with higher forage yield, decreased soil erosion, and enhanced herd health. Increasing forage production on pasturelands can lead to higher stocking rates and improved animal performance, ultimately reducing feed costs per cow. Pressure from competing land uses underscores the need for the forage industry to boost margins or risk conversion into more lucrative ventures (BCRC, 2023c).

Among respondents with pastureland, 22.8% (n = 58) indicated that at least some **land had been converted into tame pasture** since 2018, with most acres (acres = 13,496) being converted from low productivity cropland, followed by land conversion from native grass converted into tame pasture (acres = 1,467).Tame pasture was also converted from low productivity cropland (acres = 13,496), eroded lands (acres = 382), and saline lands (acres = 237).

Table 14. Land conversion into tame pasture from different types of land.

Previous land use	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)
Low productivity cropland	53	21.5%	13,496	255	80	635	4.78%
Native grass	15	6.1%	1,467	98	100	82	0.52%
Eroded/bare lands	7	2.8%	382	55	40	48	0.14%
Saline lands	5	2.0%	237	47	25	59	0.08%

Among producers who converted land into tame pasture over the last five years, 51.7% (n = 30) reported an **annual crop** has been included in this rotation. Producers reported the tame pasture in annual crop rotation acreage to be between 10 and 750 acres, with an average of 171 acres, a median of 160 acres, and a SD of 155.9 (Table 15). Crops were established in the tame pasture/annual crop rotation throughout the past ten years, with establishment years occurring more commonly from 2020 to 2022 (Figure 21). When asked about the year an annual crop was introduced into a tame pasture rotation, the general trend (Table 16) indicates this practice has become more common in recent years.

Table 15. Respondent adoption/use of tame pasture included within an annual crop rotation since 2018, by region.

Region	Count	Respondent adoption rate (%)	Total acreage	Average acreage	Median of acreage	SD acreage	Acreage adoption rate (%)
South	6	46.2%	1,080	180	180	108	0.84%
Central	18	54.5%	3,091	172	90	186	2.66%
North and Peace	6	46.2%	960	160	160	106	2.51%
Total Region	30	50.8%	5,131	171	160	156	1.82%

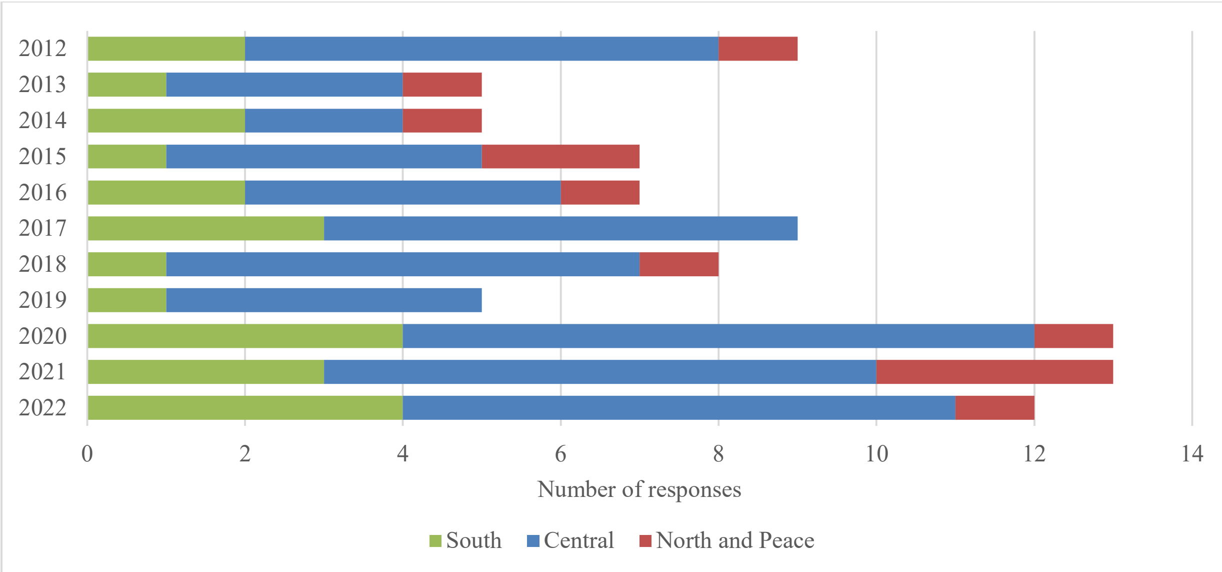


Figure 21. Reported years tame pasture was established within an annual crop rotation among respondents with pastureland, 2012-2022.

Table 16. Reported years tame pasture was established within an annual crop rotation among respondents with pastureland, 2012-2022.

Year	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
Total region	12	13	13	5	8	9	7	7	5	5	9

4.2.2.2 Pasture Rejuvenation

Soil disturbances (e.g., including an annual crop in rotation with tame pasture) or degradation (e.g., from over-grazing) can occur with agricultural production and this can lead to significant losses of soil carbon. Even within pasture management, methods of rejuvenation are important considerations for producers to improve forage productivity. Similarly to hayland rejuvenation, pasture rejuvenation can lead to increases in ecosystem carbon stocks via the increased sequestration of atmospheric carbon dioxide in grazed pastures (Conant et al., 2017).

Many of the BMPs of interest for pastureland are complementary in their applications. In general, sod seeding involves overseeding existing pastures with desirable forage species to increase productivity and improve species composition, improving grazing quality. However, establishing new tame grasses in existing stands may prove difficult, but sod-seeding with a legume-grass mix may be more effective, particularly in thin grass stands.

Legumes such as clover and alfalfa are often incorporated into pasture and hayland rejuvenation strategies due to their ability to fix nitrogen from the atmosphere, improving soil fertility and forage quality, and reducing the need for synthetic fertilizers. In addition, legumes such as alfalfa are often recommended due to their ease of establishment, adaptability to various conditions, and rapid growth. Red clover, birdsfoot trefoil, sainfoin, and cicer milkvetch are other legume options, and while slower to establish, offer grazing tolerance and non-bloating properties (BCRC, 2023b). Pasture carrying capacity can be significantly improved with the incorporation of legumes, with a Manitoba study citing an improvement of 28% when compared to rejuvenation with bromegrass alone (Kopp et al., 2003).

Among respondents who had pastureland in operation in 2022, more than half (60.6%; n = 157) reported including **legumes** in the **perennial forage** blend (e.g., alfalfa, sainfoin, cicer milkvetch, birdsfoot trefoil, perennial clovers). Respondents who reported including legumes in their operation managed 69% (n = 195,588 acres) of grazed pasturelands, but legumes were only grown in 20.6% of that area (n = 40,279 acres). The acreage of legumes in the forage blend reported ranged between under one acreage up to 3,000 acres. The average area size of legumes crops was 258 acres, with a median of 88 acres and a SD of 447 (Table 17). Respondents who reported incorporating legumes on grazed pasturelands and managing beef cattle in their operation managed 74.3% (n = 156,059 acres) of all grazing pastureland where beef cattle were managed (n = 210,022 acres) and held 73.9% of all beef cows and yearling grassers.

Table 17. Respondent adoption/use of legumes in grazing pasturelands, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acreage	Average acreage	Median acreage	SD acreage	Acreage adoption rate (%)	Number of beef cows and yearling grassers
South	37	60.7%	14,968	405	300	452	11.7%	4,198
Central	85	61.2%	17,799	209	64	394	15.2%	9,380
North and Peace	34	60.7%	7,512	221	57	539	19.7%	9,451
Total Region	156	60.9%	40,279	258	88	447	14.2%	23,029

There were 292 respondents represented for this portion of the survey, with 254 reported managing pastureland on their operation in 2022. Of those managing pastureland in 2022, 12.6% (n = 32) reported that they **direct seeded** 3,496 acres, representing approximately 1.24% of the total grazed pastureland area managed in 2022 (Table 18). These producers managed 24.8% (n = 7,736) of total beef cows and yearling grassers and managed 11.8% (33,502 acres) of total **grazed** pastureland of survey respondents in 2022.

Table 18. Respondent adoption/use of sod seeding on perennial pastureland, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acreage	Average acreage	Median acreage	SD acreage	Acreage adoption rate (%)	Number beef cows and yearling grassers
South	6	9.8%	760	127	130.00	69	0.6%	245
Central	22	16.1%	2,294	104	27.50	216	2.0%	2,072
North and Peace	4	7.1%	442	111	93.50	115	1.2%	5,419
Total Region	32	12.6%	3,496	109	60.00	184	1.2%	7,736

The area of reported perennial pastureland directly sod seeded in 2022 ranged from 2 to 1,000 acres, with an average of 109 acres, a median of 60 acres, and a SD of 183.6. After correcting for respondent entry errors[5], the **pastureland area sod seeded** among producers managing pastureland ranged from 1.7% to 100% of their total pastureland area (average = 21.6%, median = 9.8%, SD = 24.9%). Brome grasses (54.8%; n = 17) and alfalfa (51.6%; n = 16) were the most common **forage varieties** sod-seeded among producers in 2022 (Figure 22). Producers specified "other" to include oats, wheat, oats and triticale, and oats and wheat. As these are annual grain crops it's likely that producers included these varieties as companion crops to ensure some additional feed, provide additional cover of the soil, or reduce the incidence of weeds during the establishment year. Sod-seeding was reported to be most often used to improve forage productivity with 80.6% (n = 25) of producers indicating this reason for use. This was followed by improving soil quality with 67.7% (n = 21), avoiding breaking land with 54.84% (n = 17), and increasing the number of desirable species in the stand with 51.61% (n = 16) (Figure 23).

[5] After one respondent was removed from the analysis for reporting, the results on the data were more pastureland being sod seeded than total pastureland reported.

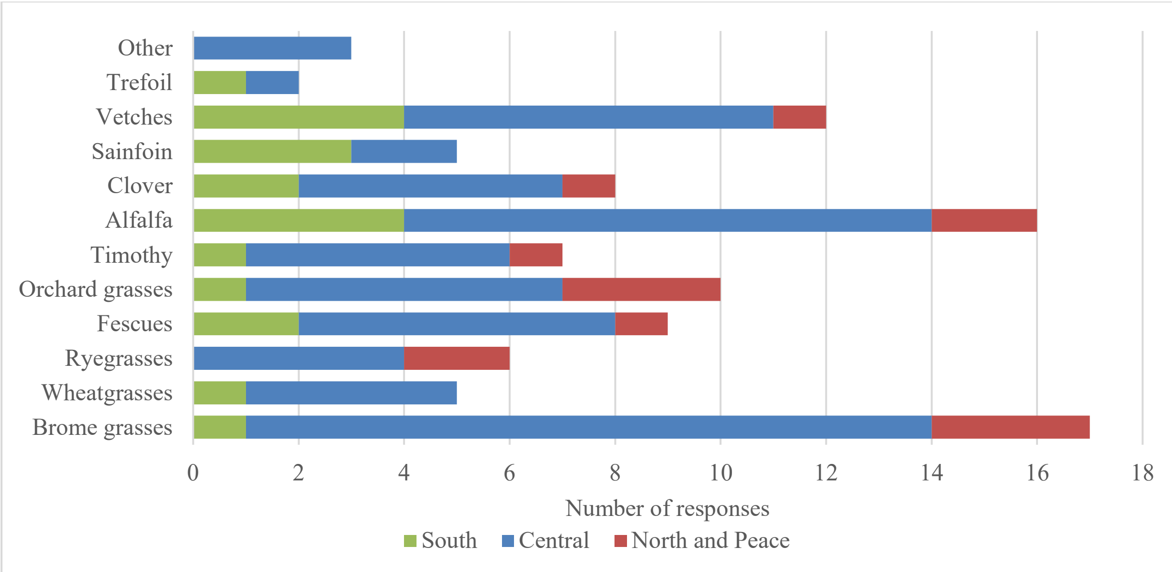


Figure 22. Forage species sod-seeded on pastureland.

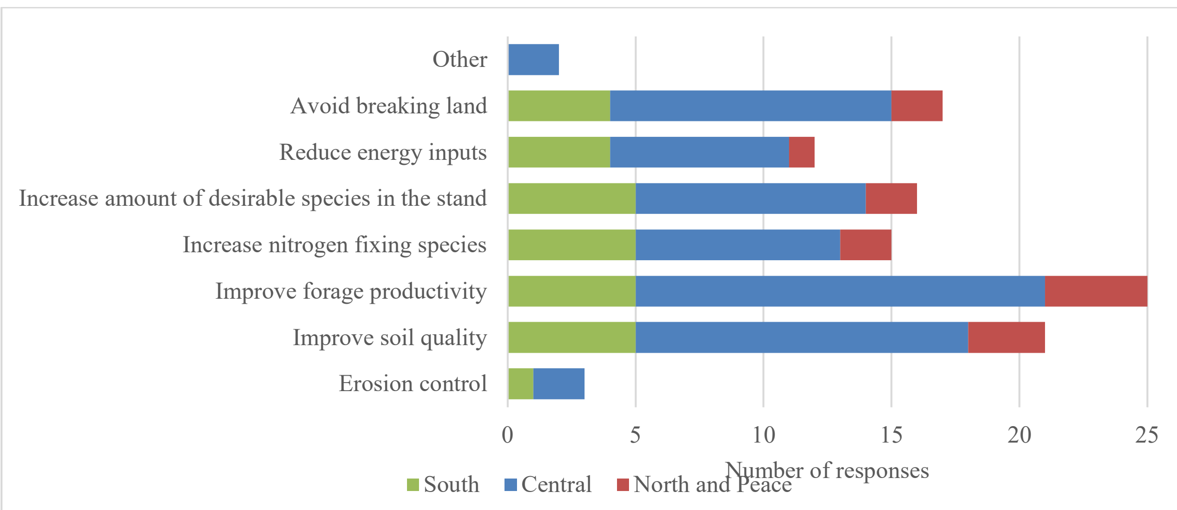


Figure 23. Producer management goals related to the use of sod-seeding on pastureland.

Producers were asked about their decision to not incorporate sod-seeding on pastureland, with the most common reason being that they found the pasture productivity to be acceptable (30.8%; n = 68). Additional reasons (Figure 24) included lack of equipment (14.9%; n = 33), the up-front investment (13.1%; n = 29), and drought (11.3%; n = 25). Producers could also specify the reason for not sod-seeding pasturelands in 2022, with responses including the ground being too rough, they have native grass (i.e., where the *de facto* BMP is to not disturb native forage stands), or they plan to do it in the future.

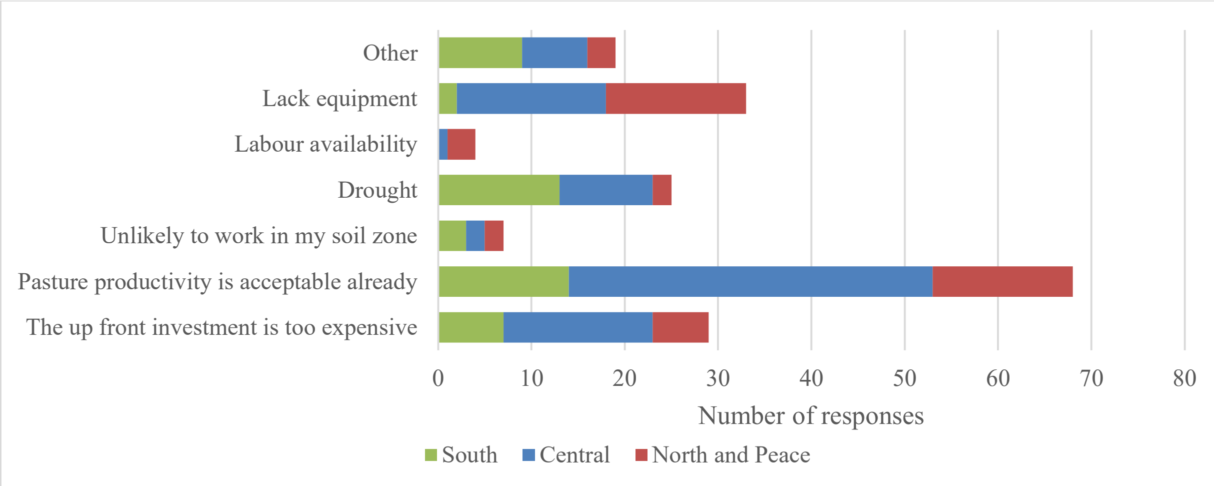


Figure 24. Recorded reasons producers did not sod-seed pastureland in 2022.

Silvopasture integrates trees, forage, and livestock production in a mutually beneficial system, enhancing biodiversity, improving soil health, and providing additional sources of forage or shade for livestock. Silvopasture require significantly less land area to achieve equivalent net productivity in cattle weight gain, forage production, and harvested yields from the trees, while also enhancing ecosystem services, such as improved soil quality, landscape diversity, carbon sequestration, and resilience to climate variability (Amorim et al., 2023).

Survey participants were informed that silvopasture is a farm system that combines cultivated trees with grazed pastureland for livestock where both the trees and the livestock provide income to the operation (e.g., orchards, personal timber sales). In total, 8.3% of respondents with pastureland reported silvopasture on 0.7% (2076.5 acres) of total respondents grazed pastureland, with an average area size of 104 acres, a median of 27.8 and a SD of 180. Respondents who reported using silvopasture owned 3.9% (n = 954) of total respondents' beef cows and yearling grassers. These producers indicated that 1% to 60% of their grazed pastureland could be called silvopasture in 2022 (Table 19), with an average of 18.1%, a median of 15%, and a SD of 15.3.

Table 19. Respondent adoption/use of grazed pastureland used for silvopasture, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number beef cows and yearling grassers
South	NR	NR	NR	NR	NR	NR	NR	NR
Central	11	8.1%	578	58	27.8	73	0.5%	670
North and Peace	9	16.1%	1,453	161	13.5	254	3.8%	284
Total Region	NR	8.3%	2,076	104	27.8	180	0.7%	954

NR = not reported due to insufficient sample size and to maintain respondent confidentiality.

4.2.2.3 Pasture Forage Species Composition

Similar to hayland, the **forage species composition** blend on pasture impacts productivity (for both the forage and the grazing livestock), forage quality, and environmental benefits. As previously discussed, grass species contribute to high biomass production and longevity, whereas legumes enhance livestock nutrition and soil fertility. Seeding a blend of grasses and legumes is recommended as a best practice to optimize both forage production and quality while promoting soil health. Increasing forage species diversity on pasturelands may increase soil organic carbon while improving animal productivity, even in the absence of cattle grazing management on pasture (Alemu et al., 2019).

In the survey, respondents were asked to consider only the largest perennial tame pasture management area on the operation in 2022. There were 257 respondents actively completing the survey at this stage, with 219 reporting pastureland as part of their operation in 2022. The range of area reported as the largest perennial tame pasture was between 2 and 2000 acres, with an average of 184.3 acres, a median of 100 acres, and a SD of 293.5 (Table 20).

Table 20. Respondent details on largest tame pastureland managed, by region in 2022.

Region	Count	Total acres	Average acres	Median acreage acres	SD acres
South	42	12,345	242	160	339
Central	108	20,582	177	100	264
North and Peace	42	7,444	143	73	304
Total Region	192	40,371	184	100	293

Respondents ranked the **abundance of tame pasture species** growing on their largest tame pasture area. Brome grasses were most abundant on the largest pasture areas, as reported by 47.2% (n = 92) of producers. Wheatgrasses, fescues, timothy, and alfalfa were also often ranked in the top five most abundant species (Figure 25).

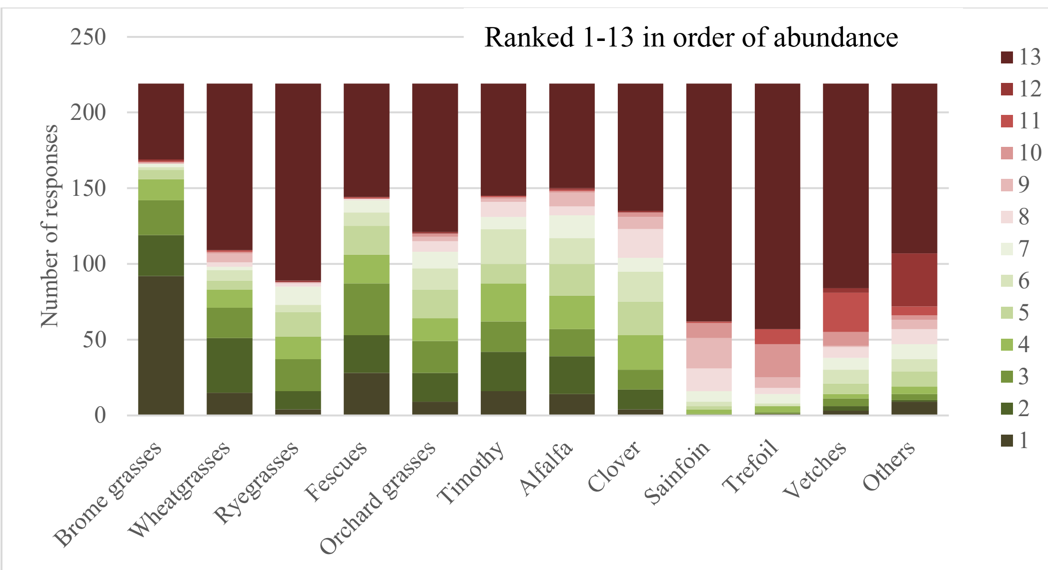


Figure 25. Proportion of tame forage species reported on producer pastureland in 2022, ranked 1-13 in order of abundance.

4.2.2.4 Tame Pasture Nutrient Management

Similarly to managed haylands, fertilizer application on pastureland can improve the standing forage yield and quality, while also improving soil condition, without the need for re-seeding. Omokanye et al. (2018) found that fertilizer application significantly increased forage yield in Northern Alberta pastures by up to 2000 kg/ha.

Applying fertilizer below the soil surface is generally preferred over broadcasting to minimize nitrogen losses to the atmosphere and enhance the efficacy of phosphorus, which moves slowly in the soil. Banding is most effective when performed during plant dormancy and when the soil is moist, reducing the risk of plant injury from root disturbance.

The rate of fertilizer application has economic considerations as it is a costly expense for producers. Studies have found little benefit to applying less than 50 lbs/acre of nitrogen, with the greatest yield response occurring with 100 lb/acre applied; however, this is dependent on the location and soil condition, which should be pre-evaluated using soil testing (BCRC, 2023b).

Among the respondents indicating managed pastureland in 2022, 28.3% (n = 62) reported applying **fertilizer** (synthetic, manure, or compost) to their largest pastureland area. The collective area (i.e., the largest pastureland area with fertilizer applied) represented 10,472 acres or 25.9% of the respondents' total tame pasture managed in 2022 (Table 21). These producers managed 40.9% (n = 12,751) of total respondents' beef cows and yearling grassers, and 18.9% (44,484 acres) of total respondents' grazed pastureland. Of these respondents, 80.6% (n = 50) applied fertilizers in the spring of 2022, 46.8% (n = 29) in the summer, 22.6% (n = 14) in fall, and 11.3% (n = 7) in winter (Figure 26).

Table 21. Respondent adoption/use of fertilizer application on largest tame pasture area, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number of beef cows and yearling grassers
South	9	17.6%	1,325	147	130	117	10.7%	492
Central	33	28.4%	4,255	129	100	104	20.7%	3,537
North and Peace	20	38.5%	4,892	245	120	468	65.7%	8,722
Total Region	62	28.3%	10,472	169	100	280	25.9%	12,751

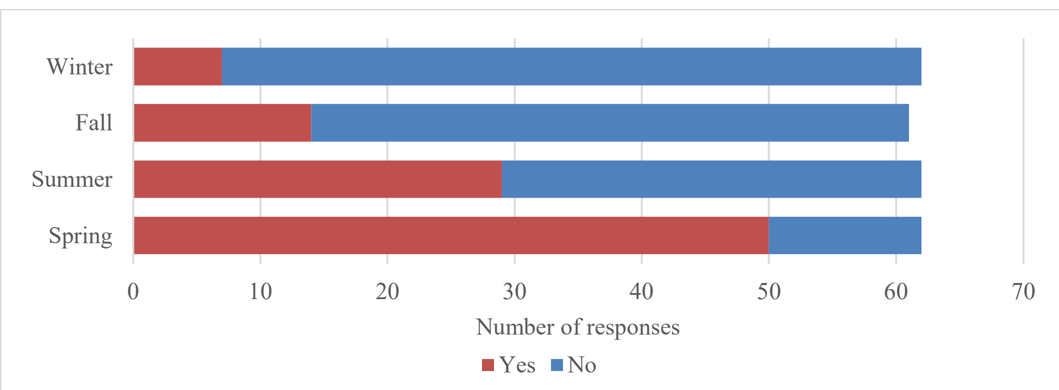


Figure 26. Seasonal timing of tame pastureland fertilizer application in 2022.

Manure and urea (46-0-0) were reported as the main sources of nitrogen (Figure 27) with producers most often using surface broadcasting for application across all seasons (Figure 28). Manure was applied most often in the spring and fall seasons, with the application rates higher in the fall (Table 22).

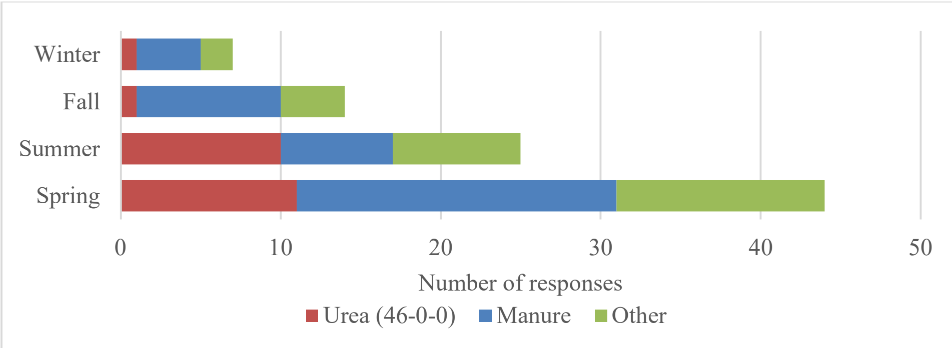


Figure 27. Nitrogen sources for pastureland nutrient management by season.[6]

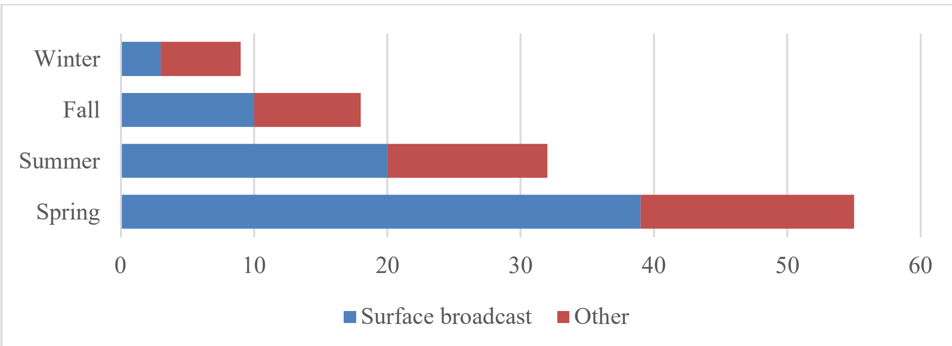


Figure 28. Fertilizer application method on pastureland by season.

Table 22. Manure application to the largest tame pasture area by season in 2022.

Season	Count (manure)	Count (manure with useable responses)	Average lbs/acre	Median lbs/acre	SD lbs/acre
Spring	20	8	679	175	1,510
Summer	7	4	153	150	144
Fall	9	4	8,894	6,614	9,935
Winter	NR	NR	NR	NR	NR

NR = not reported due to insufficient sample size and to maintain respondent confidentiality.

4.2.3 Grazing Management

Proper grazing management practices, such as rotational grazing and rest periods, play a crucial role in pasture and hayland rejuvenation. By adopting rotational grazing systems, producers can optimize forage utilization, promote plant regrowth, and prevent overgrazing. Rest periods allow forage plants to recover and rejuvenate, leading to improved productivity and long-term sustainability of pasture. Grazing management BMPs involve planning and monitoring of grazing intensity, duration, and timing to ensure sustainable utilization of forage resources. Techniques such as rest periods, stocking density adjustments, and extended season grazing help maintain healthy pasture ecosystems and protect water quality.

[6] Other" responses included using cattle, bale grazing, chicken tractors, floated with bar, and spread by hand.

Grazing management practices differ across regions and are influenced by herd size, the type of farming operation, and the quality and type of forage grazed. Producers were asked about rotational and non-rotational grazing management practices, and while brief definitions were provided within the survey, it should be noted that there is a broad spectrum of definitions for rotational grazing even among producers in similar regions.

4.2.3.1 Continuous Grazing

Continuous grazing practices, where beef cattle are permitted to graze in the same pasture throughout the grazing season, have specific implications for soil and forage health. Over time, this practice can lead to uneven forage utilization, with some areas being overgrazed while other areas are underutilized. This can result in soil compaction and erosion, reducing the soil's ability to retain water and nutrients. Soil structure degradation subsequently may compromise plant growth and diversity, leading to a decrease in pasture productivity and forage quality. Continuous grazing may reduce the resilience of the pasture ecosystem, making it more susceptible to weed invasion and less supportive of biodiversity when compared to rotational grazing.

Respondents with pastureland (n = 216; 231,061 acres), were asked if any cattle continuously grazed on these lands. In total, 54.2% (n = 118) of these producers had at least some cattle continuously grazing on their managed pasturelands in 2022[7]. Continuous grazing was used on 31.1% (71,953.2 acres) of the total area of respondents' grazed pastureland. These producers owned 44.3% (102,421 acres) of the total respondents' pastureland and 40.3% (n = 12,567) of the total respondents' beef cows and yearling grassers. These respondents[8] reported between 1% to 100% of their pastureland being used for continuous grazing (average = 70.6%, median = 80.0%, SD = 30.8%). A geographic breakdown is provided in Table 23, with the highest use occurring in the South region with 64% of respondents utilizing continuous grazing. Southern producers also reported the largest average pasture size, which may be related to the higher use of continuous grazing as any rotational grazing requires additional inputs including labour and fencing.

Table 23. Respondent adoption/use of pastureland used for continuous grazing, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number beef cows and yearling grassers*
South	32	64.0%	41,003	1,281	283	2,414	43.4%	3,531
Central	57	50.0%	21,313	381	200	617	20.5%	5,135
North and Peace	28	53.8%	9,638	344	140	610	29.6%	3,901
Total Region	117	54.2%	71,953	620	200	1,417	31.1%	12,567

* Total number of beef cows and yearling grassers managed by respondents who used continuous grazing. This number may not be the actual number of cattle that are continuously grazed.

Most respondents (92.3%; n = 108) continuously grazed their cows (with or without calves), almost half (47%; n = 55) continuously grazed their replacement heifers in 2022, and a smaller proportion of producers continuously grazed yearling grassers and grass-finished beef cows (Figure 29). Over half the respondents (57%; n = 45) who grazed cows with and without calves in a continuous grazing system and reported the number of beef cows managed in 2022 had smaller herds (100 animals or less), while 43% (n = 34) managed larger herds (more than 100 animals) (Figure 30). This may indicate fewer resources available to the producers, such as additional labour, to move to a rotational system.

[7] These same producers may have reported that they used rotational grazing on different pastures / land.
[8] Outliers and non-responses removed, reducing the sample size by 4.

However, it should be recognized that there was overlap in the producers reporting use of continuous grazing (n=117) and rotational grazing (n=144). Total n=208, therefore 66 producers or 31% used both.

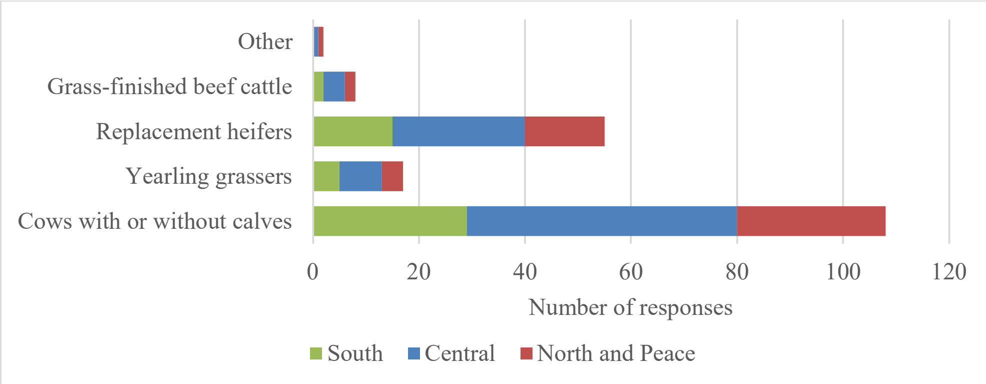


Figure 29. Reported classes of cattle on pastures under continuous grazing in 2022.

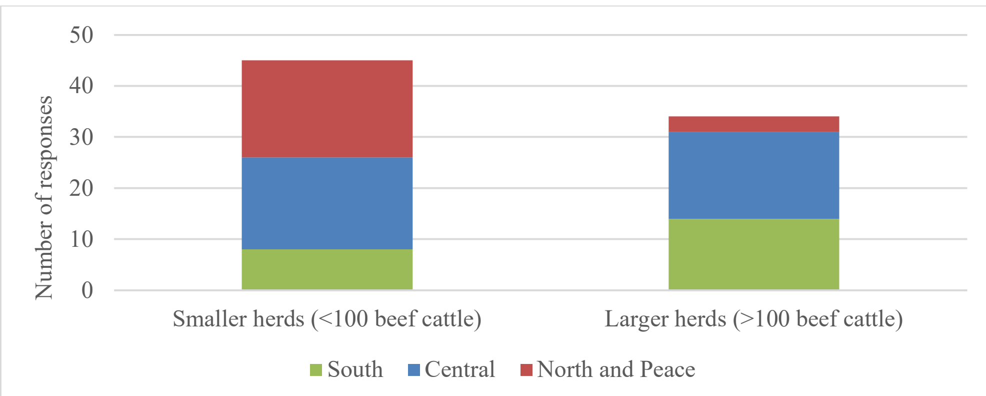


Figure 30. Cows with and without calves managed with continuous grazing, by herd size

Respondents who used continuous grazing reported **start and end dates** for the grazing season. After removing outliers using the IQR method (Zijlstra et al., 2007), May (36.2%; n = 33) and June (55.3%%; n = 52) were the most common months to begin continuous grazing and September (20.2%; n = 19) and October (67%; n = 63) were the most common months to end continuous grazing. The grazing period ranged from 71 days to 196 days, with an average of 135.6 days and a median of 136 days (SD = 26).

4.2.3.2 Rotational Grazing

Rotational grazing involves periodically moving livestock between designated grazing areas over time, allowing vegetation to recover and regenerate between grazing periods. This practice optimizes forage utilization by preventing overgrazing and promotes healthier pastures with high-quality forage. This method ranges from intensive strategies with multi-day rotations to more extended periods of up to three weeks or more, known as extensive grazing.

This approach contrasts with continuous grazing, where livestock graze in a single pasture for the entire season. According to the 2021 Canada-wide Farm Environmental Management Survey, 26% of beef cattle farms across various ecoregions graze their paddocks once per year, 37% graze twice, 19% graze three times, 7% graze four-times and 10% graze five-times per year (CRS, 2024). Recognized as a beneficial management practice, rotational grazing enhances pasture productivity, soil health, and biodiversity more effectively than season-long grazing. The benefits extend to carbon capture, with the adoption of improved grazing practices, including rotational or short-duration grazing, increasing soil carbon sequestration by an average of 0.28 Mg/ha/year (Contant et al., 2017).

Of 208 survey respondents, 144 producers (69.2%) indicated that they used rotational grazing on approximately 57.1% (128,542 acres) of total pasture acres during the 2022 grazing season. These producers managed 79.29% (n = 178,473 acres) of total respondent's pastureland and 75.5% (n = 23,530) of all beef cows and yearling grassers by all survey respondents in 2022. These respondents reported between 10% and 100% of their pastureland being used for rotational grazing (average = 73.2%; median = 80%; SD = 30%). Variations by geography are provided in Table 24, with the highest use occurring in the Central region of Alberta with 74.5% of respondents utilizing rotational grazing. The North and Peace regions had a similar respondent adoption rate at 72%. These regions had a smaller average and median pasture acreage when compared to the Southern respondents, which intuitively makes sense for moving cattle.

Table 24. Respondent adoption/use of pastureland used for rotational grazing, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number beef cows and yearling grassers
South	26	54.2%	42,923	1,651	1,050	1,923	47.3%	3,870
Central	82	74.5%	65,415	808	250	1,499	63.8%	11,950
North and Peace	36	72.0%	20,204	561	143	1,708	63.3%	7,710
Total Region	144	69.2%	128,542	899	250	1,665	57.1%	23,530

* Total number of beef cows managed by respondents who used rotational grazing. This number may not be the actual number of cattle that are rotationally grazed.

The **length of the rotational grazing season** was calculated using the reported start and end dates, and outliers in the data were removed. In 2022, May (44.7%; n = 55) and June (35%; n = 43) were the most common months to start and October (51.2%; n = 63) was the most common month to end rotational grazing. The rotational grazing period ranged from 48 to 244 days, with an average of 145.3 days and a median of 143 days (SD = 39.2). The means for grazing period (time) for continuous and rotational grazing are not statistically different (see Appendix 7.2.1).

The **vegetative stage of forage** influences both the nutritional quality of the pasture and its regrowth capacity. Young, vegetative plants are generally more nutritious and palatable to livestock, promoting better animal health and productivity. As forage matures, its nutritional value decreases, and fibrous components increase, making it less digestible and less appealing to livestock. By systematically moving livestock between different pasture sections to allow for periods of grazing and rest, rotational grazing ensures that forage is utilized at an optimal stage of growth. This practice maximizes the nutritional benefits to the livestock and supports regrowth of plants, thereby enhancing pasture resilience and sustainability.

Almost half of respondents (49.0%; n = 71) indicated that pastures/paddocks were rested between 30 to 60 days before they were grazed again (see Figure 31 for a regional breakdown of responses). Almost half of the respondents (49.7%; n = 72) moved their cattle according to a time-based schedule and 47.6% (n = 69) moved their cattle depending on the forage availability and condition (Figure 32). Out of the respondents that reported that cattle were moved on a time-based schedule, 0% moved multiple times a day (n = 0), 9.7% moved once every one to three days (n = 14), 17.9% moved once a week (n = 26), 11.7% moved once every two weeks (n = 17) and lastly 10.3% moved once more than every two weeks (n = 15). Moving cattle to the next pasture was mostly triggered by either the current pasture having the top 50% of the vegetation grazed (37.2%; n = 54) or 80% grazed (35.9%; n = 52) (Figure 33). Most survey respondents indicated that forage was typically grazed at the vegetative (3-4 leaf stage) growth stage (34.5%; n = 50) or the mid-vegetative (post 4 leaf stage to flowering) growth stage (32.4%; n = 47) in 2022 (Figure 34).

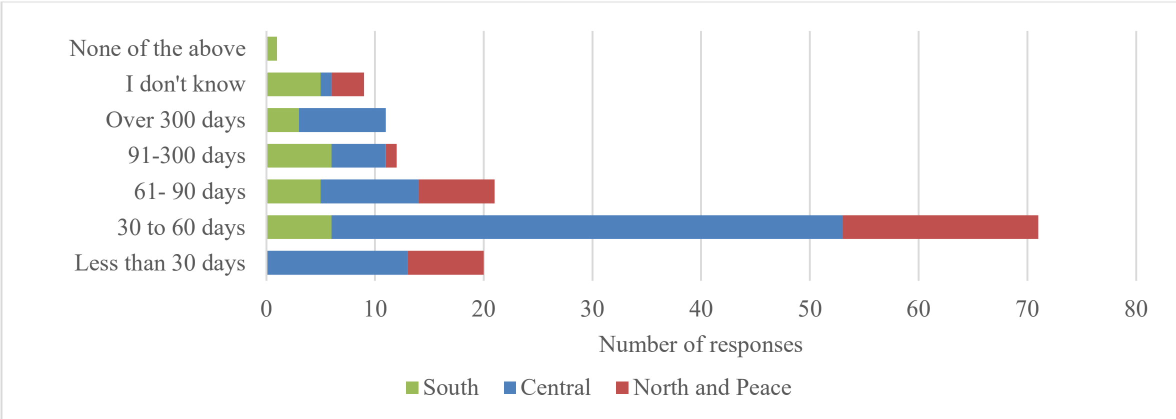


Figure 31. Pasture rest periods between grazing.

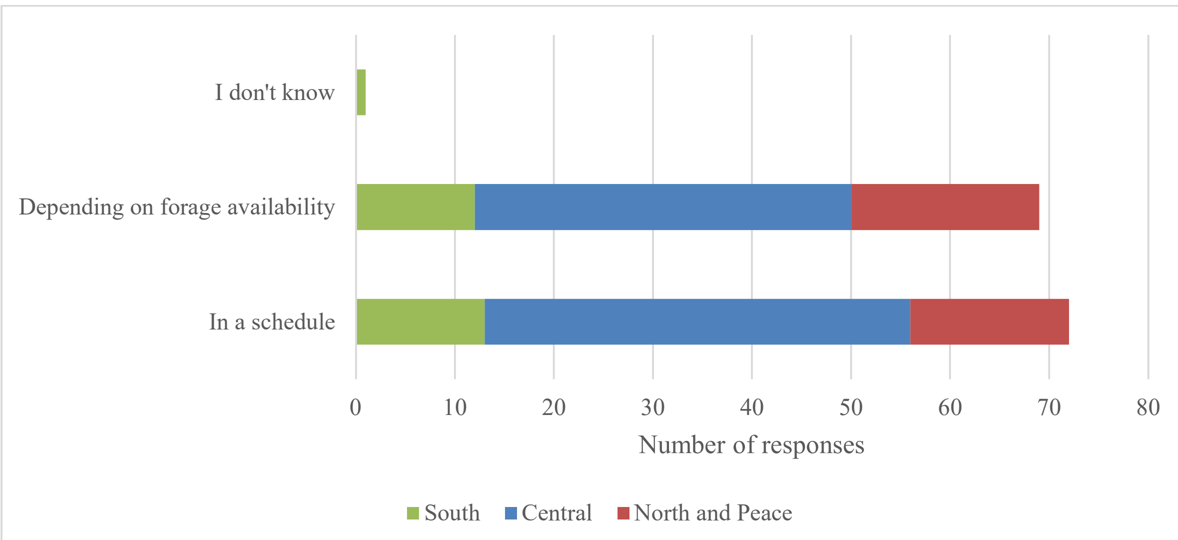


Figure 32. Timing considerations for moving cattle under rotational grazing management.

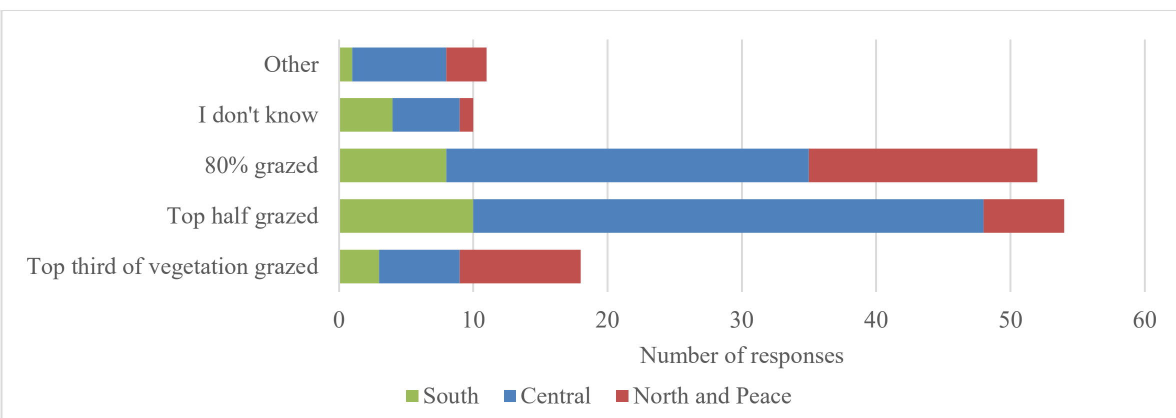


Figure 33. Forage vegetative stage considerations for moving cattle under rotational grazing management.

* 'Other' denotes 50%-75% grazed, drought, movement based on plant growth, water.

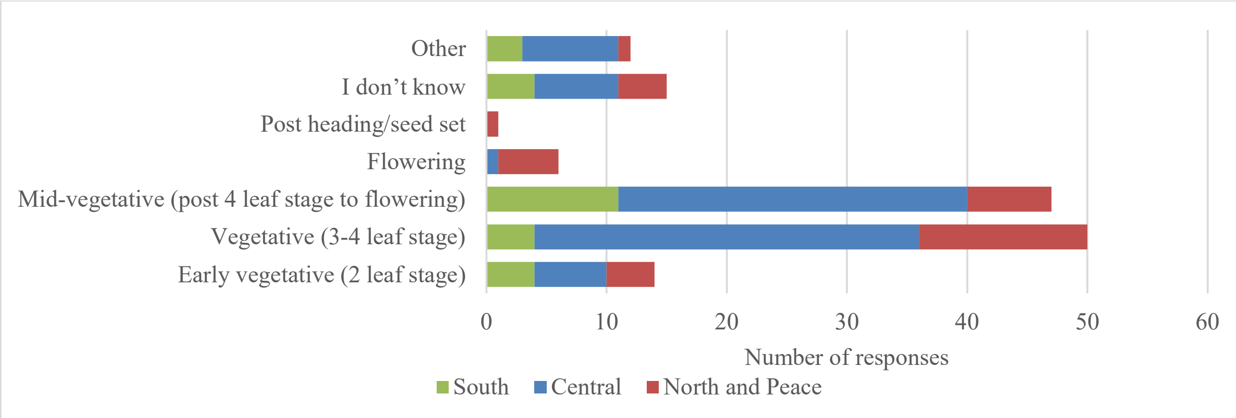


Figure 34. Typical vegetative stage of forages under rotational grazing management.

Land Tenure

The type of **land tenure**, such as whether the land is owned or rented, influences the adoption of various grazing practices. Producers may be less inclined to invest in infrastructure like fencing and water systems on leased land, particularly if restrictions apply, such as with crown lease land or community pastures where individual management decisions are limited. According to the 2017 Western Canadian Cow-Calf Survey, producers are more likely to use continuous grazing on rented or leased pastures (36% on rented tame and 40% on rented native pastures) compared to lands they own (20% on owned tame and 27% on owned native pastures) (BCRC, 2019). It was also found that the practice of renting land has been increasing over time, possibly influencing associated management trends.

Of producers surveyed and indicating the use of rotational grazing, nearly 70% owned the land (89,119 acres) and less than 30% rented (n = 37,166.2 acres) (Table 25). Respondents with land that is rented or "other" were asked about the timeline of the agreement (on a scale of 1 to 5, where 1 is short/insecure and 5 is long/secure) and the relationship with the landowner (on a scale of 1 to 5, where 1 is distant/limited and 5 is close/connected). Figure 35 illustrates that many respondents indicated they have a long/secure agreement for their rented land (39.2%) and have a close/connected relationship with the landowner (44.3%).

Table 25. Land tenure of rotationally grazed pastures.

Region	Count	Owned (deeded)	Rented	Other
Central	125	67.0%	31.3%	1.7%
North and Peace	63	68.9%	31.1%	0.0%
South	58	77.7%	17.8%	4.6%
Total Region	246	69.3%	28.9%	1.7%

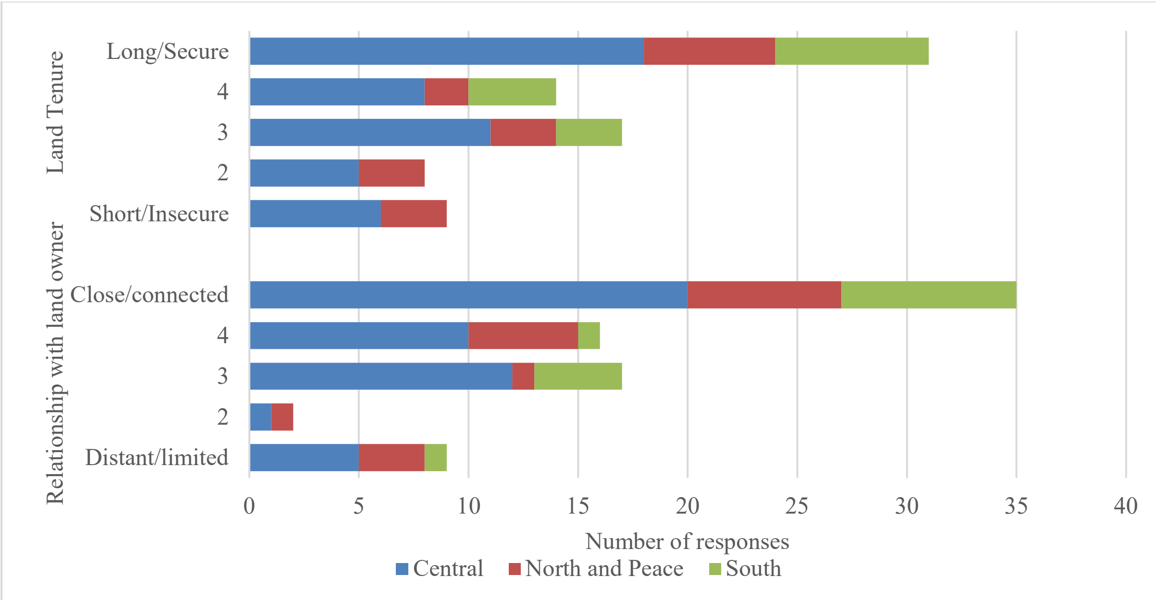


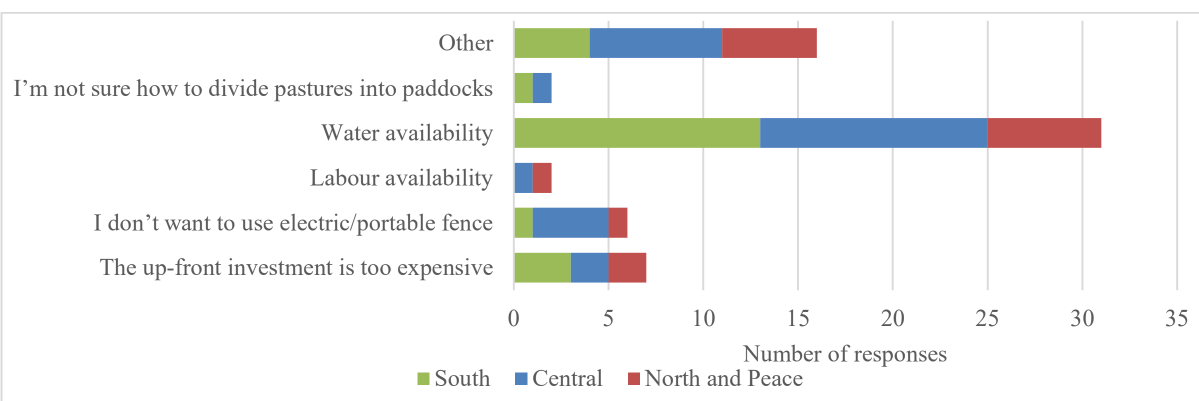
Figure 35. Land tenure timeline and relationship with landowner for producers renting land.

Irrigated Pastures

Seven respondents (4.8% of respondents who reported managing rotationally grazed pastureland) indicated the use of irrigation on rotationally managed pastures, with the use ranging from 7 to 2000 acres of the grazed pasture on the operation for a total of 3,046 acres (2.4% of pastureland used for rotational grazing). The average area of irrigated rotationally managed pastures was 435 acres, with a median of 60 acres, and a SD of 749 acres[9].

Barriers to Adopting Rotational Grazing

Respondents were asked the main reason for not adopting rotational grazing in 2022. Almost half of the producers (48.4%, n = 31) reported lack of water availability as the main reason. Other reasons selected included the up-front investment (10.9%, n = 7) and not wanting to use an electric or portable fence (9.4%, n = 6) (Figure 36). Within the other option (n = 15) in Figure 36, 20% of respondents mentioned they owned sheep as a barrier, while 33% mentioned renter, lease or land agreements as a barrier. These reasons for non-adoption are similar to those discovered in a recent qualitative questionnaire focused on the various financial, agronomic, socio-cultural, and awareness barriers to BMP adoption (Nature United, 2024).



[9] Regional breakdowns are not provided to ensure confidentiality.

Figure 36. Barriers to adopting rotational grazing in 2022, by region.

Stocking Rates

Stocking rate is a key metric in pasture management, defined as the density of livestock on grazing land over a specific period. It is often expressed as the number of animals per unit area (e.g., Animal Units per acre; AU/acre) for a given period. This calculation considers the average weight of the animals to standardize different types or sizes of livestock into AU. The purpose of a stocking rate is to balance the demand for forage by the livestock with the supply of forage available in the pasture, aiming to sustain the health and productivity of both the land and the animals. By determining and adjusting stocking rates, producers can optimize forage utilization, enhance animal performance, and support long-term sustainability of pasture resources.

The impact of stocking rates on grazed pastures has direct consequences for both pasture health and livestock productivity. High stocking rates can lead to overgrazing, where the demand for forage exceeds the supply, causing a decline in plant cover, root biomass, and eventually, soil degradation. This overutilization of the pasture can result in compacted soil, reduced water infiltration, and increased erosion, leading to poorer soil health and decreased forage availability. Conversely, excessively low stocking rates may lead to underutilization of forage, allowing invasive species to establish and reducing the overall quality of the pasture. This imbalance can also result in a decline in the nutritional value of the available forage, as more mature, less palatable plants dominate.

For the purposes of the survey, cows and yearling grassers (i.e., beef cattle who are around 12 months old grazing on perennial pasture) were considered for calculating stocking rates (i.e., bulls and heifers were excluded given that the survey did not include questions on weight for these livestock). Most respondents indicated that the average mature beef cow weight (Figure 37), ranged from 1150 to 1550 pounds, with more than half of producers (57.6%; n = 95) reporting average weights between 1250 and 1450 pounds. Almost a quarter of respondents (24.0%; n = 42) reported having yearling grassers in their operation. The number of yearling grassers ranged between 2 and 1500 head, with an average of 158.6, a median of 30.5, and a SD of 336.8. The average weight of yearling grassers going on grass ranged from 450 to 1300 pounds (average = 716, median = 700, SD = 182), and yearling grassers coming off grass had an average weight from 700 to 1400 pounds (average = 978.4, median = 950, SD = 177) (Figure 38). For stocking rate calculation the average weight of yearling grassers coming to grass and coming off grass was used.

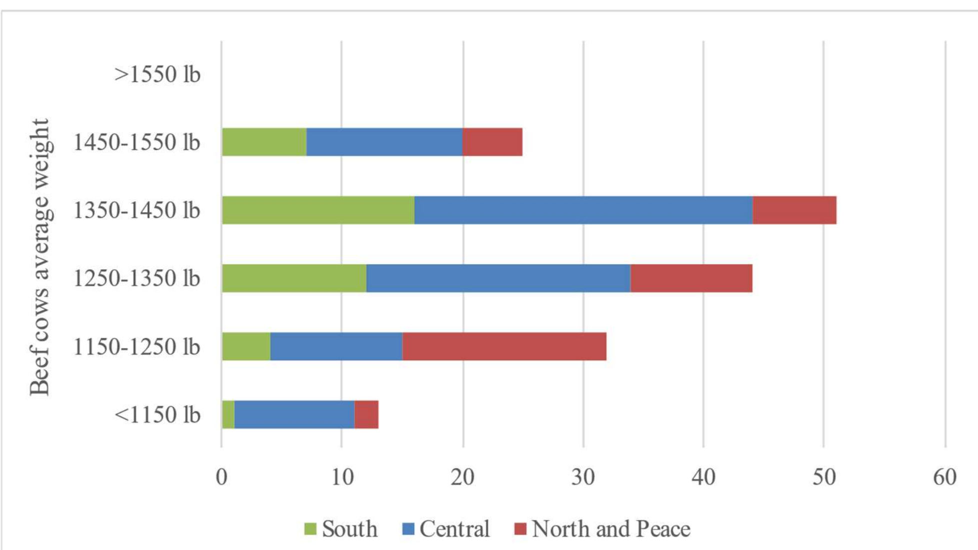


Figure 37. Average mature cow weight provided by respondents.

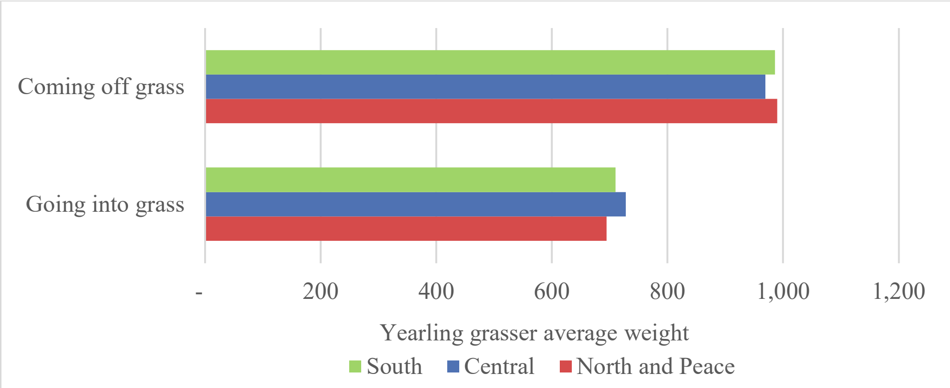


Figure 38. Average yearling grasser weight provided by respondents.

As reported, the **average grazing days** for continuous and rotational grazing were 135.6 and 145.3 days, respectively. However, these calculations include responses from operators that reported practicing both continuous and rotational grazing and it is not possible to infer from the survey results what section of their herd was grazed under what practice, meaning it was not possible to accurately calculate the stocking rate per grazing practice. To address this issue, the data from respondents that reported practicing both continuous and rotational grazing in 2022 were excluded from the following stocking rate calculations.

For respondent only using continuous grazing and not rotational grazing, the average length of continuous grazing in 2022 was 136 days (n = 49), with a median of 136 days, and a SD of 27. And for respondents only using rotational grazing and not continuous grazing, the average length of rotational grazing was 152 days (n = 78), with a median of 152 days, and a SD of 40. A breakdown of the results by region is provided in Figure 39. This suggests that the grazing season under the rotational practice is, on average, 16 days longer than under the continuous practice. A t-test (Appendix 7.2.1) was completed to assess if the means of the average grazing length between continuous and rotational grazing were statistically significant. The results indicate that the grazing length means under continuous and rotational grazing were statistically different for the full sample, and for the South region. The North and Peace, and Central regions did not display a significant difference between the means of continuous and rotational grazing lengths when evaluated individually.

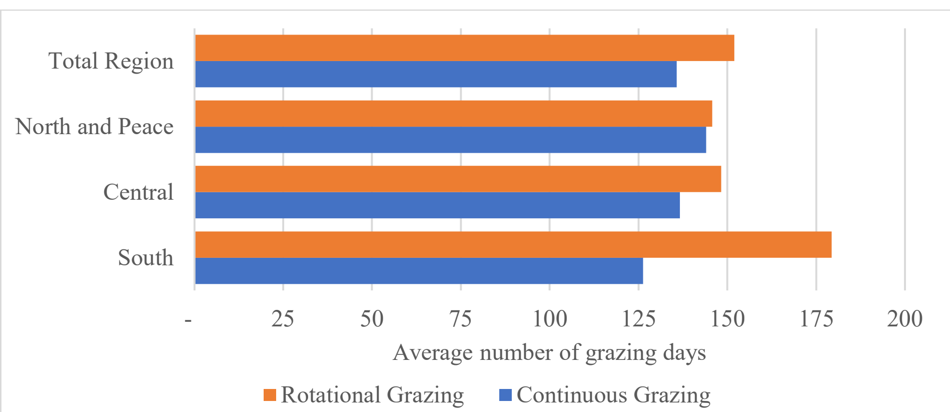


Figure 39. Average of continuous and rotational grazing length in 2022, for respondents who only adopted one practice.

Outliers were eliminated (IQR method) prior to stocking rates calculations. The average stocking rate for respondents (n = 28) who only ***continuously* grazed** cattle in 2022 was 36.7 AU/acre. Stocking rates varied by region from 25.7 AU/acre to 49.8 AU/acre (see Table 26). The total region average stocking rate for respondents who only ***rotationally* grazed** in 2022 (n = 66) was 45.3 AU/acre with a median of 38, and a

SD of 34. Regionally, the stocking rates for rotational grazing varied from 24.1 to 50.1, with lower stocking rates for both types of grazing occurring in the South region.

Table 26. Stocking rate for operations that used continuous or rotational grazing, by region in 2022.

Grazing Method	Region	Number of responses	Average Stocking Rate	Median Stocking Rate	SD Stocking Rate
Continuous grazing	South	9	25.7	22.7	20.8
	Central	9	32.9	31.2	14.3
	North and Peace	10	49.8	48.6	31.3
	Total Region	28	36.7	31.1	25.0
Rotational Grazing	South	9	24.1	16.2	24.6
	Central	37	50.1	43.8	32.2
	North and Peace	20	45.9	39.3	38.2
	Total Region	66	45.3	38.0	34.0

A t-test was run to assess if the means of the stocking rates for the total region were the same under continuous and rotational grazing (see Appendix 7.2.2). The results suggest that there is no statistically significant difference in stocking rate for operations that adopted only continuous or only rotational grazing when comparing the regions as totals. The t-tests were also run per region, and the only region that showed a statistically significant difference between the means of the stocking rates between continuous and rotational grazing was the Central region.

4.2.3.2 Extended Grazing

In-field winter feeding systems offer an alternative fertilization strategy alongside chemical fertilizer or composted manure; this practice enhances forage productivity by depositing nutrients through raw manure and bale waste, eventually becoming available to plants via soil microbes (BCRC, 2023c). Prolonged grazing seasons may also contribute to enhanced animal welfare by providing continuous access to fresh forage, reducing stress associated with abrupt dietary changes or confinement, which can result in healthier, more resilient cattle populations and improved production outcomes.

In Canada, extended grazing is most common in the Prairie provinces, with over a quarter (28.9%) of farms in Alberta reporting in-field winter grazing and feeding in 2020 (St Pierre and McComb, 2022). The 2022 Farm Management Survey (CRS, 2023b) reported producers in Alberta and BC extending their grazing season by an average of 7.5 weeks without additional feed brought on site, and an average of just under 11 weeks when feed was mostly brought on site. There are multiple methods of extending the grazing season, and the adoption is often contingent on region, rainfall, expected snowfall, and expected temperatures. For instance, in regions with significant snowfall swath grazing may not be possible.

Extended/winter grazing practices surveyed included **bale**, **swath**, **stockpile** and **corn** grazing. Bale grazing was defined in the survey as the practice of allowing cattle to graze on baled forages in a field or wintering site. Swath grazing was defined as the practice of swathing annual forages (e.g., barley, oats, triticale, or mixtures) crops in the fall for cattle to graze in the field during winter months. Stockpile grazing, or deferred grazing, was defined as the practice of saving certain forage pastures or paddocks for grazing in the fall or winter after forage growth has stopped due to cold weather. And corn grazing was defined as standing corn that is grazed by cattle, typically during the fall and winter.

Table 27 provides the respondent adoption rate for each extended grazing practice, common start and end dates, and average and median days using each practice among survey respondents in the winter season of 2022-23. Bale grazing was reported to have the longest length, commonly starting in November (55.3%; n

= 21) and completing in April (23.7%; n = 9) and May (23.7%; n = 9) with an average of 139 days (median of 149 days) in use. Swath grazing had the shortest frequency of use, with an average of 80 days (median of 51 days), commonly starting in October (38.5%, n = 10) and ending in December (40%, 8 = 10).

Table 27. Respondent adoption/use of extended grazing, by practice in 2022.

Grazing Type	Respondent adoption rate (%)	Most Common Start Month	Most Common End Month	Range (length in days)	Average length in days	Median length in days	SD length in days
Bale	15.5%	November	April/May	9-257	139	149	66
Stockpile	19.3%	October	December	3-261	87	60	67
Corn	4.5%	November	March	25-216	95	98	56
Swath	11.2%	October	December	14-211	80	51	62

Bale Grazing

With bale grazing, bales can be grazed where they are harvested or strategically placed in pastures or paddocks to extend the grazing season. With management of bale placement, manure is dispersed across the pasture, enriching the soil, reducing the need for additional fertilizers, and eliminating the need for manure removal. Manure was demonstrated to be a rich nutrient and organic matter source, particularly with bale grazing and high stock density grazing, which concentrate manure (Omokanye et al., 2018). While not all nutrients in manure are immediately available, the improvements in forage yield and quality typically last for at least two to three years.

Research has demonstrated the positive impact of bale grazing, with an Alberta study finding forage dry matter increased up to 219% on bale grazed sites when compared to control sites (Omokanye et al., 2018). Similarly, in Saskatchewan research has shown dry matter yield increases in forage of up to 4.7 times greater when cattle are winter bale grazed, when compared to conventional drylot overwintering (Jungnitsch et al., 2011). Bale grazing improves soil conditions (e.g., infiltration, soil moisture, compaction) and enhances nutrient cycling (BCRC, 2023a).

Producers were asked if cattle bale grazed on the operation in the winter of 2022/23. Thirty-nine producers (15.9%) indicated that bale grazing occurred on 3,808 acres, representing about 1.7% of the total pastureland operated by all producers who participated in the survey. These respondents accounted for 31.1% (n. = 9,708) of the total beef cattle and yearling grassers recorded in the survey. Herd size for producers using bale grazing ranged from 2 to 5,300 head, with an average of 273.5 and a median of 78 (SD = 887.4) and acreage used for bale grazing ranged from 1 to 640 acres with an average and median of 97.6 and 40 acres, respectively. Regional variations are provided in Table 28; the highest adoption of bale grazing occurred in the South with 24.1% and the lowest adoption in the Central region with 9.6% of producers indicating the use of bale grazing in the winter of 2022/23.

Table 28. Respondent adoption/use of bale grazing, by region in winter 2022/23.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number beef cows and yearling grassers
South	14	24.1%	2,692	192.3	100	207	3.0%	1,529
Central	12	9.6%	525	43.8	20	53	0.5%	1,747
North and Peace	13	21.0%	591	45.5	32	54	1.9%	6,432
Total region	39	15.9%	3,808	97.6	40	147	1.7%	9,708

Swath Grazing

For swath grazing, spring seeded annual forages (e.g., barley, oats, triticale, or a mixture) are cut in the fall for cattle to graze directly during the winter months. This extends the grazing season but also utilizes crop residues that may have been wasted after harvest. Swath grazing provides cattle with a nutrient-dense forage source, promoting animal health and performance during the winter. Swath grazing saves producers up to 48% in feeding costs when compared to drylot winter feeding (BCRC, 2023a). From an emissions perspective, lower GHG emissions per unit of dry matter intake compared to feeding cows in drylot system have been attributed to swath grazing along with a reduction in on-farm energy use ranging from 45-56% (Alemu et al., 2016).

Producers were asked if cattle swath grazed on the operation in the winter of 2022/23, with 27 producers (11.2%) indicating the practice occurred. Swath grazing was used on approximately 1.5% (3,399 acres) of the total cropland owned by these respondents. These producers owned 29.7% (n = 9,261) of total beef cows and yearling grassers represented in the survey. Producers indicated swath grazing cattle on 4 to 320 acres, with an average of 125.9 acres and a median of 120 acres (SD = 84.2). Cattle herd sizes, among respondents using swath grazing, ranged from 6 to 5,300 head, with an average of 402.7 (SD = 1,078.5) and median of 135. Regional variations are provided in Table 29. The highest adoption of swath grazing occurred in the Central region with 14.5%; results for the North and Peace region are not reported separately due to low sample size.

Table 29. Respondent adoption/use of swath grazing, by region in winter 2022/23.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number beef cows and yearling grassers
South	7	12.5%	1,285	184	160	86	1.4%	1,146
Central	18	14.5%	1,979	110	100	77	1.9%	2,770
North and Peace	NR	NR	NR	NR	NR	NR	NR	NR
Total region	NR	11.2%	NR	126	120	84	1.5%	NR

NR = not reported due to insufficient sample size and to maintain respondent confidentiality.

Stockpiled Grazing

Stockpiled grazing allows animals to continue foraging on pasture without the need for supplemental feed during the winter months, reducing feed costs and labor associated with winter feeding. Stockpiled grazing helps improve soil health by reducing soil compaction and erosion that can occur in conventional drylot winter feeding. Biodiversity and wildlife habitat is also promoted when adopting stockpile grazing as the vegetation matures and goes to seed before being grazed, which benefits native grasses, insects, and wildlife in the ecosystem. In terms of economic benefit, when compared with drylot feeding with round bale hay, stockpiled perennial forages decreased total system costs by 14% over a three-year period (Kulathunga, 2016).

Respondents were asked if they used stockpile grazing during the winter of 2022/2023. In total, 19.3% (n = 47) of respondents[10] indicated that cattle stockpile grazed on 8.8% (19,811 acres) of total respondents' pastureland (Table 30). Producers indicated stockpile and deferred grazing cattle on 2 to 6,000 acres, with an average of 431 acres and a median of 95 acres (SD = 1,137). These producers owned/managed 37.3% (n = 11,639) of total respondents' beef cows and yearling grassers. Herd size for producers using stockpiled and deferred grazing ranged from 6 to 5,300 head, with an average of 470.9 head and a median of 185.0 head (SD = 1,252.4). The highest adoption of stockpiled and deferred grazing occurred in the South region

[10] From a valid survey sample of 243.

with 26.3% (n = 15) and the lowest adoption in the North and Peace region with 9.7% of producers indicating the use of stockpiled and deferred grazing in the winter of 2022/23 (Table 30). As mentioned, excessive snow cover may impede extended season grazing, and it is hypothesized that this is related to the regional differences as South and Central regions are more arid and receive proportionally less snowfall than the North and Peace region.

Table 30. Respondent adoption/use of stockpiled/deferred grazing, by region in winter 2022/23.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number beef cows and yearling grassers
South	15	26.3%	10,767	717.8	300	1,498	11.9%	2,928
Central	25	20.2%	8,464	338.6	50	1,012	8.3%	3,139
North and Peace	6	9.7%	580	96.7	60	101	1.8%	5,572
Total region	46	18.9%	19,811	430.7	95	1,137	8.8%	11,639

Corn Grazing

Corn residues provide a high-energy forage source that can be used in areas of high snowfall due to the height of the crop, and grazing corn has similar benefits as swath grazing in reducing use of harvest equipment and distributing manure over the grazed fields, improving soil health by incorporating organic matter and nutrients back into the soil. However, it should be noted that corn is a higher input crop, a consideration for evaluating its overall environmental benefit when used in extended season grazing (BCRC, 2022).

Corn grazing was used by 4.5% (n = 11) of respondents on 0.5% of total respondents' cropland (1,068 acres) in 2022 (Table 31). A range of 18 to 300 acres were used for corn grazing (average = 97.1 acres, median = 85 acres, SD = 84.43). These producers owned/managed 23.7% (n = 7,395) of total respondents' beef cows and yearling grassers, and 4.2% (8,360 acres) of total respondents' croplands in operation in 2022. Herd size for producers using corn grazing ranged from 100 to 5,300 head, with an average of 924.4 head and a median of 260.0 head (SD = 1,779.2). Regional variations are not provided due to small sample size.

Table 31. Respondent adoption/use of corn grazing in winter 2022/23.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number beef cows and yearling grassers
Total region	11	4.5%	1,068	97.1	85	84	0.5%	7,395

4.3 Cattle and Manure Management

The comprehensive management of cattle and manure is fundamental to implementing BMPs in cattle production, encompassing a broad spectrum of activities aimed at enhancing productivity, sustainability, and environmental stewardship. Improving management efficiency on Canadian cow-calf production systems can reduce average emission intensity by 31% through earlier calving, higher calf daily gains, diets with higher digestible energy and crude protein, reduced annual crops for feed, higher culling rates, and avoiding manure composting (Alemu et al., 2017). While there is a trade-off from avoiding manure composting, some benefits that manure application can lead to are; plant productivity, enriches soil organic matter, and improves soil health, leading to better water retention, reduced erosion, and enhanced overall soil quality (BCRC, 2023e)

Effective cattle management strategies include feed testing to ensure nutritional adequacy and safety, optimizing cattle nutrition and rations to meet the specific needs of different cattle classes, determining the primary source of forage to balance between quality and availability, and implementing breeding management practices to improve herd genetics and productivity. Additionally, overwintering practices for cows and heifers are crucial for maintaining health and productivity through harsh conditions, while the use of implants and feed additives can enhance growth rates and feed efficiency.

Manure management involves the appropriate handling, storage, and utilization of manure to minimize environmental impacts and enhance soil health and fertility. Choices regarding manure storage methods—be it solid storage, liquid storage systems, or composting—depend on factors such as farm size, type of cattle operation, and local environmental regulations. The use of manure as a fertilizer or soil conditioner is a sustainable practice that recycles nutrients back into the ecosystem, promoting crop productivity and reducing reliance on synthetic fertilizers.

4.3.1 Cattle Management

Over three-quarters of respondents[11] indicated managing beef cattle (77.1%; n = 185) in 2022. This included 24,508 beef cows, 4,167 first cattle heifers, 32,163 backgrounding cattle, 6,662 yearling grassers, and 47,327 finishing cattle. Most producers with cattle reported owning / managing beef cows (97.7%) and first calf heifers (86.4%) in 2022 (Table 32). Over 50% of producers reported herd sizes under 100 head of cattle, accounting for 3470 head; six producers reported herds 500 head or larger, and these producers accounted for more than 30% of the cattle reported in the survey (Table 33). Over one-third of respondents had a cattle herd size between 100 and 249, making up over 9,000 or 37% of the cattle. Overall, the respondents are skewed to small and medium sized operations, somewhat similarly to the 2021 Cost of Production survey (CRS, 2023a), however, there were more medium size operations accounted for in the current study.

Table 32. Summary of cattle managed by survey respondents in 2022.

Type of Cattle	Count	Number producers reporting	Share producers reporting	Total number of cattle	Average number cattle	Median number cattle	SD number cattle per operation
Beef cows	171	167	97.7%	24,508	149	86	321
First calf heifers	169	146	86.4%	4,167	29	20	45
Backgrounding cattle	180	66	36.7%	32,163	495	60	1,483
Finishing cattle	177	44	24.9%	47,327	1,076	5	4,317
Yearling grassers	175	43	24.6%	6,662	159	31	337

Table 33. Beef cow herd size summary as reported by respondents in 2022.

Herd size	Count	Share producers	Total cattle	Share over total herd size in all operations	Average herd size per operation	Median herd size per operation	SD herd size per operation
500+	6	3.6%	7,400	30.2%	1,233	650	1,294 *
250 - 499	15	9.1%	4,460	18.2%	297	290	45
100 - 249	59	35.8%	9,178	37.4%	156	140	43

[11] Number of responses for analysis in this section = 240.

50 - 99	34	20.6%	2,370	9.7%	70	75	14
1 - 49	51	30.9%	1,100	4.5%	22	20	14

* One very large herd was an outlier, hence the median herd size is more representative

Of the respondents who reported breeding cattle on their operation in 2022, 98.2% reported having **females exposed** and having **calves born alive**; see Table 34 for a regional breakdown. The total number of females exposed was 27,049 and the number of calves born was 25,262 (Table 34). **Conception rate** was 93.4% over the total region, with North and Peace reporting the highest rate (96%) and South reporting the lowest rate (92.1%).

Table 34. Beef cattle reproductive efficiency reported by respondents in 2022, by region.

Region	Count	Share of respondents who reported breeding cattle	Total number of females exposed	Average number of females exposed	Total number of calves born alive	Average number of calves born alive	Conception rate
South	42	100.0%	7,007	167	6,451	154	92.1%
Central	84	97.7%	12,917	154	11,968	142	92.7%
North and Peace	42	97.7%	7,125	170	6,843	163	96.0%
Total Region	168	98.2%	27,049	161	25,262	150	93.4%

Among producers who finished cattle (n = 44), most did not fully **grass-finish** their cattle (75.0%; n = 33). For **diet** comparison in finishing cattle, the producers who indicated that 76% or more of their cattle are fully grass-finished were removed from the finishing cattle analysis to avoid skewing the results as it relates to discussion on concentrate: forage ratios (i.e., 18% of finishing producers were removed from the feed ration analysis; Figure 40).

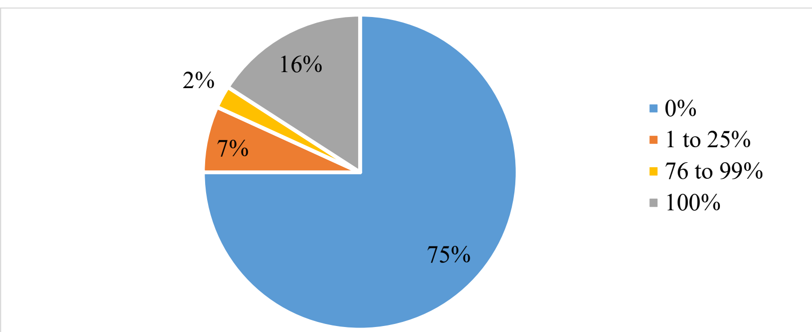


Figure 40. Proportion of cattle fully finished on grass as reported by producers with finishing cattle.

4.3.1.1 Feed Testing

Through accurate analysis of protein levels, energy content, minerals, and other critical nutrients, **feed testing** enables producers to make informed decisions about the diet of their livestock. The development of feed rations is tailored to optimize cattle nutrition by combining various feedstuff into a balanced diet, where the goal is to meet the nutritional needs of different categories within the herd, such as lactating cows, growing calves, and finishing cattle, considering factors like age, weight, and production goals. Properly formulated feed rations contribute to enhanced animal health, improved reproductive performance, and increased weight gain, maximizing the overall efficiency of cattle production.

Respondents were asked how often their feed was tested for quality and how often cattle rations were formulated with guidance from a nutritionist, software program, or other service provider over the past five years. Nearly half of all producers (45.4%; n = 84) who managed beef cattle reported testing their cattle feed every year (Table 35). Over two-thirds of producers (37.8%; n = 70) indicated feed formulation was guided by cattle nutritionists every year (Table 36). A significant proportion of producers indicated they never used feed testing (25.4%; n = 47) or feed formulation (35.7%; n = 66), and less than 25% used these practices only once every several years or when a feed quality issue was suspected (Figure 41).

Table 35. Respondent adoption/use of feed testing by type of operation and region in 2022.

Region	Count	Respondent adoption rate (%)	Grazing pastureland acres	Acreage adoption rate (%)	Number beef cows and yearling grassers	Beef cows and yearling grassers adoption rate (%)
South	21	47.7%	52,670	59.1%	3,652	67.4%
Central	46	47.4%	70,848	69.6%	9,720	90.2%
North and Peace	17	38.6%	25,961	81.7%	9,499	58.7%
Total Region	84	45.4%	149,479	67.1%	22,871	73.4%

Table 36. Respondent adoption/use of nutritionist guided feed formulation by type of operation and region in 2022.

Region	Count	Respondent adoption rate (%)	Grazing pastureland acres	Acreage adoption rate (%)	Number beef cows and yearling grassers	Share over total number of beef cows and yearling grassers
South	16	36.4%	35,600	39.9%	2,873	59.9%
Central	42	43.3%	65,628	64.5%	8,631	88.9%
North and Peace	12	27.3%	20,825	65.5%	9,362	46.2%
Total Region	70	37.8%	122,053	54.8%	20,866	66.9%

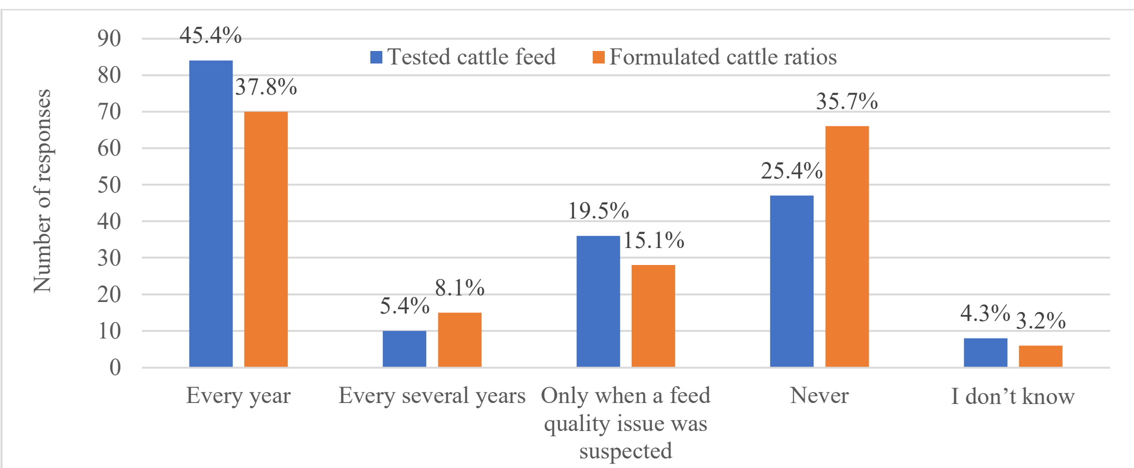


Figure 41. Frequency of feed testing and feed formulation guidance by surveyed producers.

4.3.1.2 Cattle Feeding Rations

Cattle naturally produce methane, a potent GHG, during the digestive process, where the amount of methane emitted can vary based on the diet composition. By optimizing **feed rations** through precise feed testing, it's possible to enhance the efficiency of nutrient uptake and digestion and minimize methane emissions per unit of animal product. Incorporating feedstuffs that are highly digestible and tailored to meet the specific energy and protein requirements of the herd can reduce the fermentation time in the rumen and the overall methane produced. For grain-finished cattle, there is generally a 'warm-up' period, about 21-28 days, for the cattle to adjust to the higher energy diet, lower in forages; this is called the receiving diet, which contains higher forages than the end finishing diet.

Managing cattle diets can lead to significant reductions in methane emissions, with potential decreases of up to 40% depending on the extent and type of intervention implemented (Benchaar et al., 2001). Strategies such as including fats, oils, and certain types of carbohydrates that lead to less methane production during digestion are examples of how feed composition can be adjusted to mitigate GHG emissions (Haque, 2018). Additionally, supplements and additives designed to inhibit methanogenesis—the process by which methane is produced by microbes in the rumen—can further reduce emissions (Króliczewska et al., 2023).

Forages and Concentrates in Overwintered Cattle Diets

Feed quality and digestibility significantly influence ruminant growth and methane production, with the types and amounts of carbohydrates affecting rumen fermentation (Samal and Dash, 2022). Forage-based diets generally lead to higher methane emissions than grain-based concentrates due to nutrient utilization efficiency by rumen microbes.

The formulation of cattle diet rations for overwintering is crucial for maintaining health and ensuring productivity during the colder months when energy demands increase to maintain body temperature. Consequently, the diet may need to be supplemented with feed concentrates (e.g., grains, pellets, meals) to meet elevated energy needs. For cows and first calf heifers, the focus is on maintaining condition and supporting pregnancy, necessitating diets that foster both energy and nutrient density. Backgrounding and finishing cattle, aimed at growth and weight gain, require diets optimized for efficient conversion to muscle, with an emphasis on energy-rich feeds to promote desired weight gains even in the face of colder temperatures.

Survey respondents were asked to indicate the percentage of winter diets that were forage and to indicate the forage type (e.g., alfalfa hay, barley sileage/baleage, corn silage/baleage, grass hay, mixed hay, oat silage/baleage, wheat silage/baleage, or other forage). Respondents across all operation types reported that the primary source of forage used in winter diets was mixed hay (38.7%, n = 120) (Figure 42). Where producers indicated a different primary forage was used, barley silage/baleage, grass hay, and other types of forage (e.g., alfalfa hay, mixed hay, oats baleage, grass hay/corn silage blend) were most often reported. Operations reporting larger numbers of finishing cattle (i.e., over 100 animals) reported barley, wheat, or corn silage/baleage as the main forage used in their operations. Table 37 indicates the primary type of forage used in overwintered cattle, by type of cattle, and by region. Cows most often received mixed hay as their primary forage source in over winter diets (n = 72), followed by backgrounding cattle with 33.8% (n = 22), first calf heifers with 33.3% (n = 15), and finishing cattle with 31.4% (n = 11)[12].

[12] This includes grass-finished cattle.

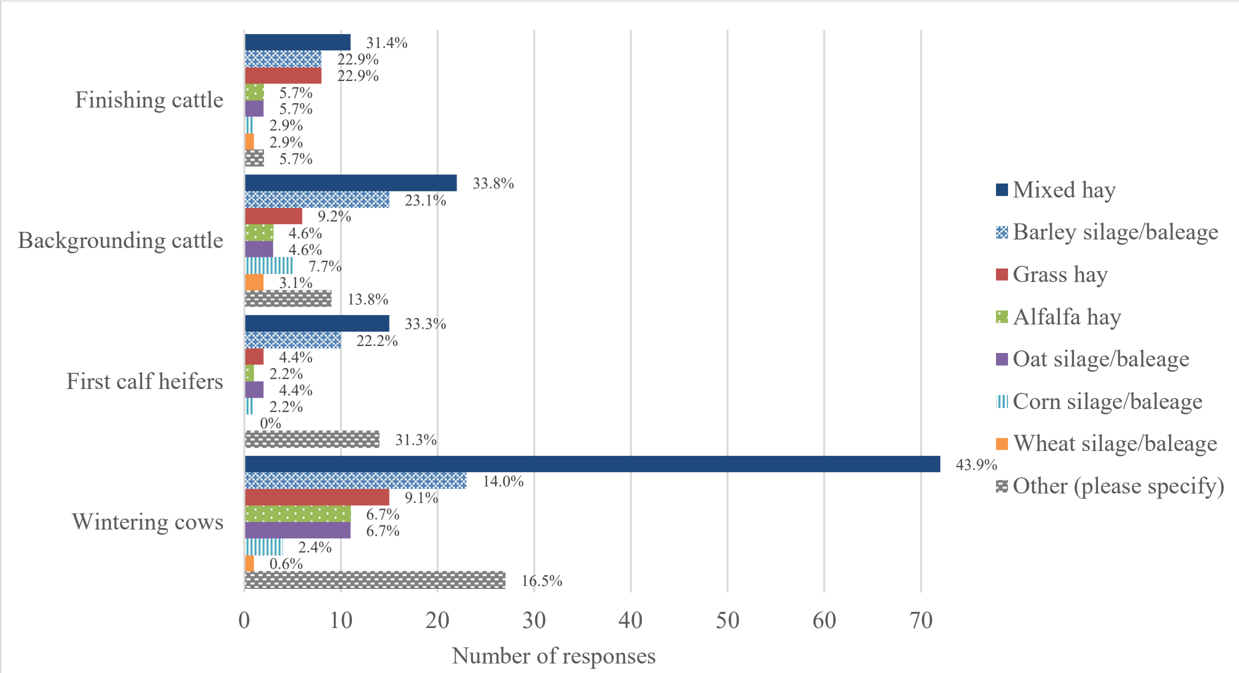


Figure 42. Primary forage sources for over-wintered cattle in 2022/23, by cattle type.

Table 37. Primary forage sources for overwinter feeding by type of cattle in winter 2022/23.

Type of cattle over wintered	Barley silage or baleage	Wheat silage or baleage	Corn silage or baleage	Oat silage or baleage	Alfalfa hay	Grass hay	Mixed hay	Other
Cows	n = 23 (14.0%)	NR	NR	n = 11 (6.7%)	n = 11 (6.7%)	n = 15 (9.1%)	n = 72 (43.9%)	n = 27 (16.5%)
Fist calf heifers	n = 10 (22.2%)	NR	NR	NR	NR	NR	n = 15 (33.3%)	n = 14 (31.1%)
Backgrounding cattle	n = 15 (23.1%)	NR	n = 5 (7.7%)	NR	NR	n = 6 (9.2%)	n = 22 (33.8%)	n = 9 (13.8%)
Finishing cattle	n = 8 (22.9%)	NR	NR	NR	NR	n = 8 (22.9%)	n = 11 (31.4%)	NR

NR = not reported due to insufficient sample size and to maintain respondent confidentiality.

Many producers fed only forages over winter; 43% (n = 65) of producers with beef cows, 40.5% (n = 53) with first calf heifers, and 13.5% (n = 7) with backgrounding cattle, fed only a forage-based diet (i.e., no added concentrates) over the winter of 2022/23[13]. Eight respondents reported fully grass finishing or grass finishing between 76 and 99% of their finishing cattle[14].

Producers were also asked about including concentrates in the overwinter diet (e.g., grain, pellets, meals) as concentrates can help support the overwinter conditioning of cattle. Table 38 provides the average overwinter diet composition by type of cattle and region[15]. Overwintered cows and first calf heifers in the South and Central regions received a higher percentage of concentrate in their diets when compared to cattle

[13] Finishing cattle results are not provided due to small sample size.
[14] These categories were combined for reporting due to small sample size; these were removed from the analysis on diet to avoid skewing the results.
[15] Responses indicating 76-100% of cattle being grass-finished were removed from the feed concentrate analysis.

in the North and Peace region. Adoption rates for including concentrate in cow and first calf heifer winter diet varied by region, with producers in the Central region most often adopting this practice (Table 39).

Table 38. Average overwintering diet composition (concentrate and forage) by type of cattle in winter 2022/23 (cows, heifers, backgrounding) and 2022 (finishing).

	Cows		First Calf Heifers		Backgrounding cattle		Finishing Cattle*	
Region	Forage share (%)	Concentr. share (%)	Forage share (%)	Concentr. share (%)	Forage share (%)	Concentr. share (%)	Forage share (%)	Concentr. share (%)
South	90.5% (n=36)	9.5% (n=21)	86.1% (n=31)	13.9% (n=21)	76.0% (n=19)	24.0% (n=15)	43.9% (n=32)	56.1% (n=7)
Central	92.9% (n=79)	7.1% (n=46)	92.6% (n=69)	7.4% (n=41)	83.0% (n=32)	17.0% (n=24)	50.7% (n=16)	49.3% (n=12)
North and Peace	97.1% (n=37)	2.9% (n=20)	96.2% (n=31)	3.8% (n=16)	76.3% (n=10)	23.8% (n=7)	51.3% (n=8)	48.8% (n=8)
Total Region	93.4% (n=151)	6.6% (n=87)	91.9% (n=131)	8.1% (n=78)	79.5% (n=61)	20.5% (n=46)	49.0% (n=32)	51.0%** (n=27)

*Grass finished cattle are removed from these averages as they received a 76% to 100% forage-based winter diet.
** This number should be used with caution. It may have been impacted by operation size, the inclusion of step-up diets averaged over the entire feeding period, or other factors. Of the 36 responses, 16 answered that concentrates were below 50%.

Table 39. Respondent adoption/use of concentrate in overwintered cows and first calf heifers, by region in winter 2022/23.

	Cows				First calf heifers			
Region	Count	Respondent adoption rate (%)	Number of cows	Cattle adoption rate (%)	Count	Respondent adoption rate (%)	Number of first calf heifers	Cattle adoption rate (%)
South	21	58.3%	3,375	59.7%	21	67.7%	599	60.3%
Central	46	58.2%	6,261	55.8%	41	59.4%	1,437	64.4%
North and Peace	20	54.1%	6,834	89.8%	16	51.6%	743	79.0%
Total Region	87	57.2%	16,470	67.2%	78	59.5%	2,779	66.7%

Oils and Oilseed Meals in Overwintered and Finishing Cattle Diets

Oilseed meals, besides providing a high-energy component, also contribute valuable protein, supporting muscle development and maintenance. Supplementing winter feed with oils can help maintain optimal body condition and support growth during the challenging winter months but also can contribute to more efficient feed conversion rates, reducing the overall cost of feeding while maximizing productivity. Additionally, increasing dietary fats in cattle diets can decrease methane emissions, with the reduction being consistent regardless of the fat's form (oil or seed), the type of fatty acids, or the source of the fat (e.g., canola, coconut, or soy), and with the methane emission reduction being maintained over time with continued fat supplementation (Grainger and Beauchemin, 2011).

Survey respondents were asked about vegetable oils or oilseed meals used in cattle diet rations for cows, first calf heifers, and backgrounding cattle in the winter of 2022/2023 and for finishing cattle in 2022. Of producers managing beef cows, first calf heifers, and backgrounding cattle, 3.7% (n = 6; total producers overwintering beef cows = 164), 5.6% (n = 8; total producers overwintering first calf heifers = 146), and 7.7% (n = 5; total producers overwintering backgrounding cattle = 67), respectively, incorporated vegetable oils or oilseed meals into diets in winter 2022/23 season[16]. Less than 6% of producers with finishing cattle

[16] Further regional breakdown is not provided due to the sample size

(both receiving and finishing) diet[17] incorporated vegetable oils or oilseed meals into finishing diets in 2022 (number not reported due to insufficient sample size). Among all types of cattle production, canola oil was used most often (n = 9), followed by canola meal (n = 5) and soybean meal (n = 5)[18].

Regarding total fat concentration fed on a dry matter basis during winter and to finishing cattle, across all cattle types managed, 34 respondents were not sure of the amount and 10 respondents fed cattle between 4-6% fat[19].

When asked about the main reason for not including oils or oilseed meals in overwintering or finishing diets, most respondents across all operation types indicated that cattle nutrition needs were met without this addition in the ration (Figure 43). There was also some indication of the oils and oilseed meals being too expensive and difficult to incorporate in the diets, particularly for cows and first calf heifers.

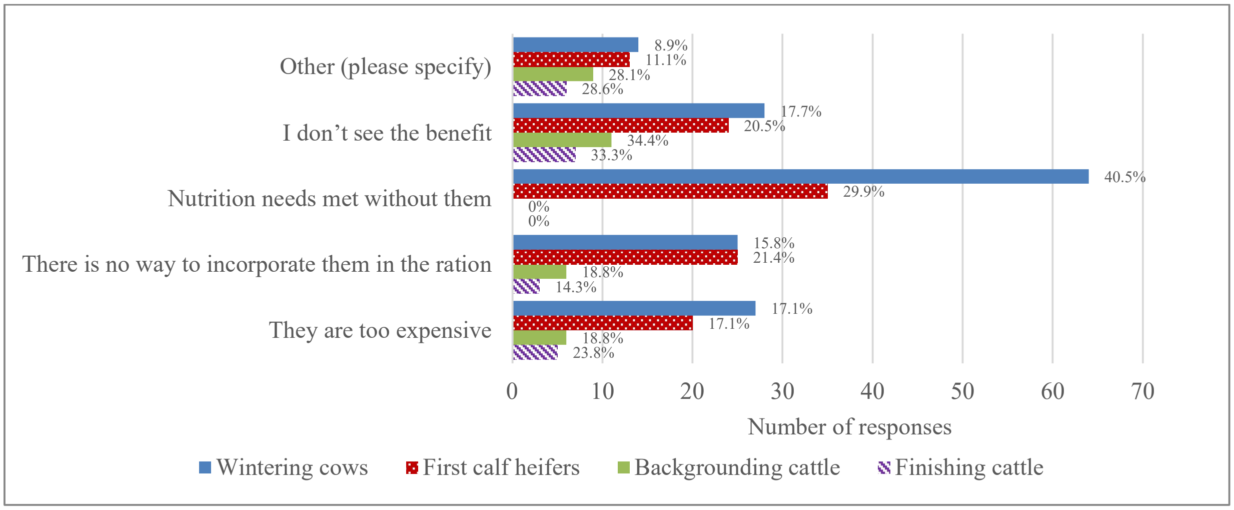


Figure 43. Reasons for not including oils or oilseed meals in overwintering and finishing rations by type of operation in winter 2022/23 (cows, heifers, backgrounding) and 2022 (finishing).

4.3.1.3. Feed Additives and Implants

Ionophores, beta agonists, and hormone implants represent a suite of feed additives and growth promotants that can be considered environmentally beneficial practices within beef production due to their ability to improve feed efficiency, growth rates, and overall yield. Ionophores reduce methane emissions by altering rumen fermentation, indirectly inhibiting methanogenesis and enhancing the rumen's feed processing capabilities. Beta agonists improve the efficiency of feed conversion into lean muscle, rather than fat, reducing the resources needed per unit of meat produced. Hormone implants promote faster and more efficient growth, thereby reducing the environmental footprint by decreasing the amount of feed required over the animal's lifetime and lowering the greenhouse gas emissions per kilogram of beef produced. Collectively, these practices contribute to a more environmentally sustainable beef production system by optimizing resource use and minimizing waste and emissions.

Ionophores

[17] Producers with finishing cattle were asked about both receiving and finishing diets to account for potential differences during the transition from a forage- to grain-based diet. These results are reported together due to insufficient sample size to report independently.
[18] Breakdown by type of operation and additional responses regarding oils and oilseed meals types are not provided due to insufficient sample sizes.
[19] The remaining results are withheld due to insufficient sample size

Ionophores are antimicrobial compounds often added to feed to modify feed intake and improve feed efficiency by altering ruminal fermentation patterns (Haque, 2018). Monensin is a commonly used ionophore that can reduce methane emissions by up to 30% by inhibiting methanogenic bacteria (Ranga Niroshan Appuhamy et al., 2013), and it is also used to prevent coccidiosis (Króliczewska, 2023). However, its effectiveness varies with diet composition, ionophore type, dose, and adaptation of the microbiota over time, with the effect on methane reduction often returning to baseline levels after six weeks due to microbial adaptation (Króliczewska, 2023).

Survey participants were asked if ionophores were included in rations fed to overwintered cattle in 2022/2023 and finishing cattle in 2022. Producers with overwintered cows, first calf heifers, and backgrounding cattle could respond with 'always', 'sometimes', or 'no', while producers with finishing cattle could only respond in the affirmative or negative. For beef cows, 20.7% (n = 34) of total respondents used ionophores in their diets (sometimes or always), where these producers owned/managed 45.7% (n = 11,205) of total beef cows. For producers with first calf heifers, 23.9% (n = 25) used ionophores in diets (sometimes or always), where these producers owned/managed 47.5% (n = 1,981) of first calf heifers. Of producers with backgrounding cattle, 33.8% (n = 22) used ionophores in diets (sometimes or always), where these producers owned/managed 79.3% (n = 25,503) of all backgrounding cattle. For finishing cattle, 36.1% (n = 13) of these producers used ionophores in diets, where they owned/managed 99.5% (n = 47,086) of all finishing cattle represented in the survey.

Table 40 provides the breakdown of adoption rate of ionophores by region and type of operation. The remaining 79.2, 76.1, 66.2, and 63.9% of producers owning/managing beef cows, first calf heifers, backgrounding cattle, and finishing cattle, respectively, did not use ionophores in overwintering or finishing diet rations.

Table 40. Respondent adoption/use of ionophores in diet rations by type of operation and region in winter 2022/23 (cows, heifers, backgrounding) and 2022 (finishing).

	Adoption Rate, in respondents (%)				**Adoption rate, in number of cattle (%)**			
Cattle type	Cows	First calf heifers	Backgr. cattle	Finish. cattle	Cows	First calf heifer	Backgr. cattle	Finish. cattle
South	20.0% (n=8)	22.9% (n=8)	33.3% (n=17)	33.3% (n=3)	24.2% (n=1,365)	19.0% (n=189)	18.9% (n=893)	39.0% (n=76)
Central	22.9% (n=19)	25.0% (n=18)	29.4% (n=10)	26.3% (n=5)	36.4% (n=4,090)	51.1% (n=1,142)	86.3% (n=16,900)	99.8% (n=41,200)
North and Peace	17.1% (n=7)	22.9% (n=8)	50.0% (n=5)	62.5% (n=5)	75.5% (n=5,750)	69.1% (n=650)	98.2% (n=7,710)	99.2% (n=5,810)
Total Region	20.7% (n=34)	23.9% (n=34)	33.8% (n=32)	36.1% (n=13)	45.7% (n=11,205)	47.5% (n=1,981)	79.3% (n=25,503)	99.5% (n=47,086)

Implants

While castration reduces aggression, improves welfare, prevents unplanned breeding, and enhances meat quality by eliminating reproductive hormones, it also reduces the naturally occurring hormones that contribute to faster and more efficient growth and greater lean muscle development in bulls when compared to steers or heifers. Hormone implants, inserted under the skin of the ear in steers and heifers, replenish or augment these hormones, leading to improved growth rates, feed efficiency, and carcass composition, while avoiding the undesirable behaviors and meat quality issues associated with intact bulls (BCRC, 2023d). Implants can be used to boost average daily gains in calves, backgrounding cattle, and finishing cattle, with up to a 16% increase when compared to non-implanted counterparts (BCRC, 2023d). Improved feed conversion related to implant use reduces the time taken to finish cattle and reduces the resources required when compared to non-implanted cattle, thus reducing greenhouse gas emissions and improving producer margins from cow-calf through to finishing (Capper et al., 2021).

Among survey participants[20] who had beef cows, producers were asked if calves were implanted before weaning in 2022, with the majority of respondents (70.8%; n = 121) indicating they did not implant their calves before weaning, 14.0% (n = 24) indicated that all calves were implanted before weaning, 9.9% (n = 17) implanted some calves before weaning, and the remaining 5.3% (n = 9) did not know the implant status.

Among respondents with backgrounded cattle, 33.9% (n = 21) reported that implants were used in 2022, with these producers owning/managing 84.5% (n = 27,095) of backgrounded cattle represented in the survey. Among respondents with finishing cattle, 37.2% (n = 16) indicated that implants were used, representing 99.6% (n = 47,121) of the total finished cattle represented in the survey. Table 41 provides the breakdown of adoption rate of hormone implant use by region and type of operation.

Table 41. Respondent adoption/use of using hormone implants by type of operation and region in 2022.

	% adoption (respondents)			**% adoption (cattle)**		
Region	Calves (as reported via mother cows)	Background-ing cattle	Finishing cattle	Calves (as reported via mother cows)	Background-ing cattle	Finishing cattle
South	42.9% (n=18)	45.0% (n=9)	50.0% (n=6)	42.8% (n=2,417)	72.1% (n=3,405)	54.9% (n=107)
Central	19.8% (n=17)	27.3% (n=9)	33.3% (n=7)	32.2% (n=3,620)	81.9% (n=16,040)	99.8% (n=41,209)
North and Peace	14.0% (n=6)	33.3% (n=3)	30.0% (n=3)	4.4% (n=336)	97.4% (n=7,650)	99.1% (n=5,805)
Total Region	24.0% (n=41)	33.9% (n=21)	37.2% (n=16)	26.0% (n=6,373)	84.2% (n=27,095)	99.6% (n=47,121)

Beta Adrenergic Agonists

Beta adrenergic agonists (or beta-agonists) are feed additives that enhance lean muscle gain, growth rate, and feed efficiency in livestock, enabling cattle to grow more rapidly and require less feed for each pound of weight gain. Beta-agonist growth promotants have been commercially available in Canada since 2004 and are unique from antimicrobials and hormones as the additives work at the cellular level, focusing on protein synthesis. Beta-agonists approved for use may be administered at the end of the feeding period for finishing cattle, a time when natural muscle growth decelerates, fat accumulation accelerates, and feed efficiency declines (BCRC, 2023d). The advantages of beta-agonists can be negated if they are fed for an extended period or if there's a prolonged interval between the cessation of feeding these additives and the slaughter of the animals (BCRC, 2023d). By optimizing growth rates, beta-agonists contribute to reducing the overall greenhouse gas emissions per unit of beef produced, making beef production more environmentally friendly.

Survey respondents indicting ownership/management of finishing cattle were asked if beta-agonists were included in their finisher diets, including the dose and days fed. As there were limited responses affirming use of beta-agonists, these results will not be summarized in this report due to insufficient sample size.

[20] Numbers of survey respondents were not consistent throughout the sections on beef cattle management, resulting in 238 respondents summarized in the beef cow section, 235 in the first-calf heifer section, 233 in the backgrounding cattle section, and 232 in the finishing cattle section.

4.3.1.4. Wintering Cattle Housing

The type of environment in which cattle overwinter influences the sustainability of beef production, affecting animal welfare to resource utilization and environmental impact. Indoor confined areas offer protection from adverse weather, potentially improving animal health and feed efficiency, but may require significant energy for heating and ventilation, along with concentrated manure management. Outdoor confined areas, such as drylots, allow for some exposure to natural conditions with less infrastructure investment, though they can lead to issues with mud management and localized nutrient loading from manure.

Small outdoor pastures or paddocks provide cattle with more natural living conditions and can facilitate better manure dispersion, reducing the environmental load on any single area and enhancing soil health through nutrient recycling. However, they may require more active management to ensure adequate feed and water access and to prevent soil compaction and localized nutrient loading. Large outdoor pastures or paddocks, especially those allowing for extended grazing, may be considered more sustainable as they reduce the need for infrastructure, encourage natural behaviors, and use cattle movement to disperse manure over a wide area, reducing nutrient concentration and promoting soil fertility.

In Canadian Prairie operations overwintering beef cows accounts for up to 71% of production expenses, due to feed, bedding, and pasture costs (Alemu et al., 2016). When compared to drylot winter feeding, extending grazing into the winter on annual forages can slash winter feeding costs and significantly reduce greenhouse gas emissions from enteric fermentation and manure and emissions from energy use for farm activities related to winter feeding including feed production and processing, feed and bedding delivery, and manure removal (Alemu et al., 2016).

Survey respondents with beef cows, first calf heifers, and backgrounded cattle, were asked about the number of days cattle were kept on various confinement areas over the 2022/23 winter season, including indoor confined areas, outdoor confined areas (e.g., drylot), small outdoor pastures/paddocks, and large outdoor pastures/paddocks (i.e., where there are greater distances between feed and water, manure dispersion, and the producer may use extended grazing). Many producers indicated that multiple types of confinement were used over the season, with most beef cows and first calf heifers spending a higher average number of days in large outdoor pastures, and backgrounded cattle spending more days, on average, in an outdoor confined area (e.g., drylot) (Table 42).

Regional adoption and use rates for each type of overwintering enclosure are provided in Table 43. Rates by number of respondents and number of cattle were high and consistent across all regions for cows that were kept in large outdoors pastures (i.e., 85% plus), suggesting it being a common practice overall. Adoption rates by number of respondents and number of cattle for first calf heifers kept in large outdoors pastures stayed in a 22-33% range for all regions, except for the rate by cattle numbers in the North and Peace region. This means that a similar fraction of respondents who managed first calf heifers in large pastures in each region (between 22-33%), happened to own a larger number of animals in the North and Peace region, suggesting larger herds. In terms of backgrounding cattle kept in outdoor confined areas, the adoption rates by respondents were between 22-40% with the largest values for the North and Peace region. The adoption rates by cattle numbers were much higher for the Central and North and Peace regions (91% and 99% respectively), while on the South region, this rate was 78%. This suggests that most of the backgrounding cattle herd is managed by 22% and 40% of the respondents interviewed in the Central and North and Peace regions, respectively, suggesting larger herds for these respondents, likely feedlots.

Table 42. Summary of overwintering areas by type of operation, days, and estimated number of cattle.

	Average (SD) days			Median days			Number of cattle (n)		
Cattle type	Cows	First calf heifers	Backgr. cattle	Cows	First calf heifer	Backgr. cattle	Cows	First calf heifer	Backgr. cattle
Indoor confined area	12 (28)	16 (33)	38 (45)	3	2	15	2,782	200	150
Outdoor confined area	57 (54)	89 (70)	133 (70)	30	90	120	6,178	685	29,232
Small outdoor pasture	74 (61)	104 (79)	97 (66)	60	90	95	7,026	685	2,597
Large outdoor pasture	152 (83)	141 (93)	115 (71)	150	120	100	21,044	1,390	2,913

Table 43. Respondent adoption/use of overwintering confinement by type of operation and region in winter 2022/23.

	Adoption Rate, in respondents (%)			Adoption rate, in number of cattle (%)		
Cattle type	Cows in large outdoor pastures	First calf heifers in large outdoor pastures	Backgrounded cattle in outdoor confined area	Cows in large outdoor pastures	First calf heifers in large outdoor pastures	Backgrounded cattle in outdoor confined area
South	85.0% (n=34)	22.2% (n=6)	66.7% (n=14)	84.7% (n=4,786)	24.9% (n=247)	78.3% (n=3,695)
Central	85.5% (n=71)	32.7% (n=16)	66.7% (n=24)	81.6% (n=9,159)	26.7% (n=597)	90.8% (n=17,787)
North and Peace	85.4% (n=35)	26.1% (n=6)	50.0% (n=5)	93.2% (n=7,099)	58.0% (n=546)	98.7% (n=7,750)
Total Region	85.4% (n=140)	28.3% (n=28)	26.9% (n=43)	85.9% (n=21,044)	33.4% (n=1,390)	90.9% (n=29,232)

4.3.2 Manure Management

Manure management practices play a crucial role in enhancing the sustainability of beef operations through effective nutrient recycling, reduced environmental impacts, and improved soil health. Different manure storage methods, including stockpiling, utilization of anaerobic digesters, and deep bedding systems where manure is not regularly removed, each have implications for sustainability. Emissions related to manure storage, estimated at 23%, are second only to those associated with enteric fermentation of total farm emissions (Alemu et al., 2017).

Stockpiling manure is a passive approach which places the manure in a designated area where it remains undisturbed, leading to microbial activity and the eventual anaerobic condition of the pile. Optimally, manure should be stockpiled in tall piles or windrows with sloped surfaces to effectively shed precipitation, minimizing the leaching of nitrogen and potassium (BCRC, 2023e). Covering manure stockpiles (e.g., with tarps or within shelters) can preserve up to 85% of N and K, in contrast to only about 75% retention in uncovered outdoor piles (BCRC, 2023e) as well as minimize odor issues. The incorporation of bedding materials such as straw, wood chips, or sawdust into manure stockpiles can aid in moisture absorption and potentially enrich the composting material with carbon, enhancing the final nutrient profile of the manure.

The practice of manure turning varies, with some operations choosing not to turn, while others do so daily or infrequently, influencing the manure's aeration and its subsequent nutrient availability when applied as fertilizer. Aerobic composting can reduce waste volume and produce a valuable organic fertilizer. However, it does pose environmental challenges through the emission of secondary byproducts ammonia, which is influenced by the carbon to nitrogen ratio, temperature, moisture content, aeration conditions, use of additives, pH levels, and the size of the compost pile (Wang et al., 2021). Insufficient aeration can lead to anaerobic conditions, increasing methane and nitrous oxide emissions, whereas excessive aeration may hinder microbial activity by causing loss of heat and moisture, negatively affecting the composting process (Wang et al., 2021).

Regular testing for nutrient content is important for optimizing the use of manure as a fertilizer, ensuring that the nutrient application meets but does not exceed crop needs, thereby minimizing the risk of nutrient runoff. These practices for manure management contribute to the overall sustainability of beef operations by promoting efficient use of resources, enhancing soil fertility, and reducing environmental impacts associated with manure management.

Manure management survey questions were included for respondents with beef cattle on their operations in 2022. More than half of the respondents (55.4%; n = 97) indicated that they stored manure on their operation at some point in 2022 (Table 44). Manure was commonly stored through stockpiling (69.6%; n = 87) and approximately a third of respondents (29.6%; n = 37) reported using deep bedding[21] (see Figure 44). Of these producers, 40.6% (n = 28) reported both stockpiling and deep bedding. The most common methods for stockpiling included wide piles with flat tops (40.2%; n = 39) and tall piles with steep sides (38.1%; n = 37) (Figure 45; Table 44). Several producers indicated 'other' for stockpiling, specifying that they used all of the above but mostly long windrows, both tall and long piles, left manure in deep bedding packs, left manure where cows were fed, or did not disturb the bedding pack. Most respondents reported that the manure on their operation was not turned (79.4%; n = 77); however, 16.5% (n = 16) indicated that the manure stored on their operation was turned infrequently (i.e., not every day but more than once)[22]. Nearly a quarter of producers (23.8%; n = 23) indicated that they do not mix any bedding with their manure, 70.3% (n = 71) reported mixing straw with manure, and 6.9% (n = 7) of producers mixed in sawdust or woodchips[23].

Table 44. Respondent adoption/use of manure storage practices in 2022.

Manure storage practice	Number of respondents	Respondent adoption rate (%)	Number of beef cows & yearling grassers	Beef cow & yearling grasser adoption rate (%)
Manure stored	97	55.4%	14,953	48%
Only deep bedding	37	21.1%	2,928	9%
Both stockpiled & deep bedding	28	16.0%	3,908	13%
Only stockpiled	59	33.7%	8,117	26%
Stockpiled with tall piles with steep sides	37	38.10%	5,630	18%
Stockpiled with wide piles with flat tops	39	40.20%	6,114	20%
Stockpiled with long windrows	16	16.50%	2,969	10%
Stockpiled, other	5	5.20%	240	1%
Manure turned (infrequently)	16	16.50%	1,625	5%

[21] Explained in the survey as fresh bedding being added on top of existing manure pack to keep the pack dry and clean, but manure is not regularly removed.
[22] Remaining methods for manure aeration and producer results on methods for covering manure are not reported here due to insufficient sample size
[23] Results provided in aggregate due to insufficient sample size to report independently

Straw bedding mixed in with manure	71	70.30%	11,696	38%
Woodchip bedding mixed in with manure	5	5.00%	775	3%
Some testing of nutrient levels in manure (every few loads, annual random sample, random sample every few years)	6	6.10%	350	1%

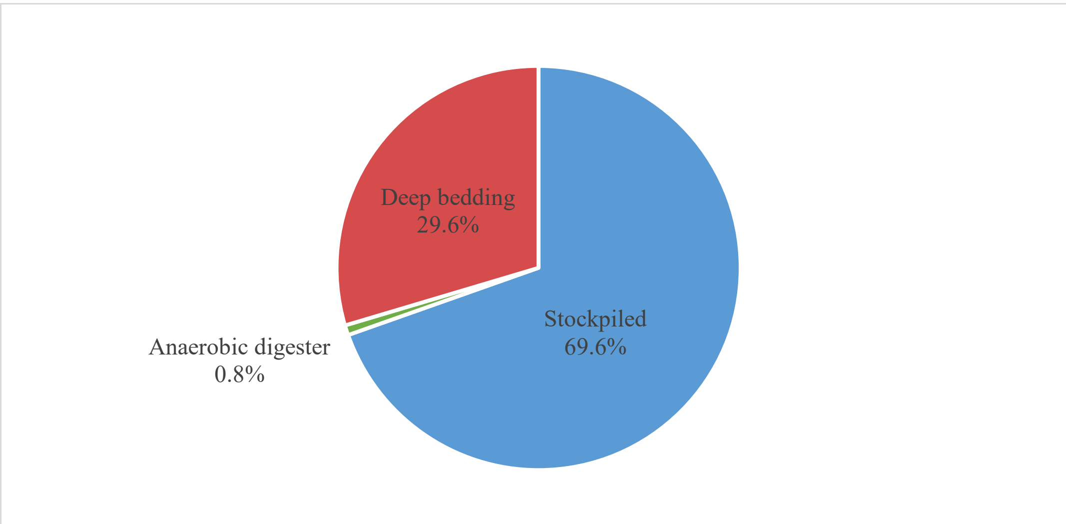


Figure 44. Manure storage practices reported by surveyed producers with beef cows on their operations in 2022.

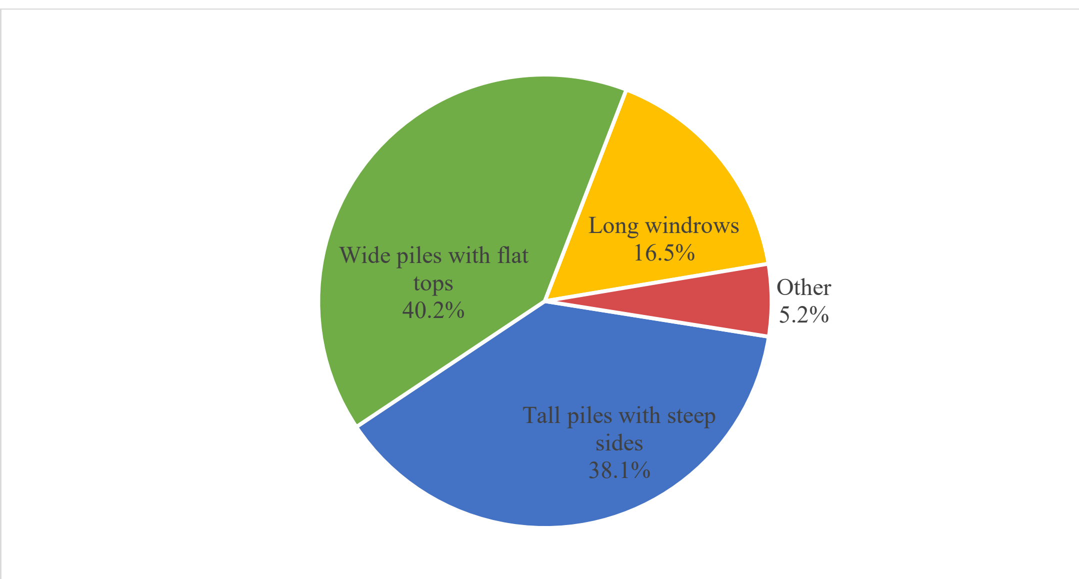


Figure 45. Manure stockpiling methods reported by surveyed producers with beef cows on their operations in 2022.

Within the last five years, most producers (90.7%; n = 88) did not test the nutrient content of manure on their operations. Of those who did, (9.3%; n = 9) tested a random sample every few years, a random sample annually, every few loads, or none of the listed options[24].

Roller Compacted Concrete at Feedlots

Roller compacted concrete (RCC) in feedlots presents a strategic advantage for both manure management and cattle health. RCC is a low-maintenance, high-strength pavement that facilitates easier and more efficient manure collection and removal, reducing the time and labor associated with manure management. The impermeable surface of RCC minimizes the accumulation of waste and prevents the seepage of contaminants into the soil. RCC may also benefit cattle health with anecdotal improvements noted among feedlot operators in hoof health and cattle mobility and comfort, potentially leading to improved weight gain. Additionally, the ease of cleaning RCC surfaces contributes to improved hygiene in feedlot areas, further supporting animal health by reducing the incidence of disease and infection.

When asked about roller compacted concrete (RCC) in feedlot pens, 88.2% of finishing cattle respondents (n = 30)[25] indicated there were no RCC pens. Of the producers who did have RCC pens on their feedlots, the percentage of pens with the RCC ranged from 8-25%[26] .

4.4 Crop Management

The agriculture industry continually seeks to improve sustainability and environmental stewardship while maintaining economic viability. This section of the report delves into the various BMPs implemented in cropping systems to offer insights into the practices that producers are implementing and highlight any BMPs that might be interconnected between beef and crop production. The survey analysis includes a range of factors influencing BMP adoption, including land tenure (i.e., whether cropland is owned or leased, along with the lease duration), soil testing practices, the strategic use of summer fallow, nutrient management, multi-cropping, and residue management.

As previously reported, when survey respondents were asked if crops (hay, cereals, oilseeds, pulses) were grown for mechanical harvest in 2022, 72.7% (n = 165) indicated yes, with the average, median, and total acreage of these respondents representing 1,225, 500, and 199,667 acres, respectively. Of the group that reported crops for mechanical harvest, 40.6% also indicated that they grew cereals, oilseeds, and/or pulses on managed cropland. On average, respondents who reported growing cereals, oilseeds, and pulses managed approximately 91.1% or 181,933 acres of all mechanically harvested cropland. Of respondents who grew these crops for mechanical harvest, 69.9% also owned beef cows and/or yearling grassers, which represented 74.7% (n = 22,994) of these types of cattle.

Respondents were asked to indicate the two most commonly grown crops in 2022 (Figure 46). Canola (54.0%; n = 58), barley (48.4%; n = 52), wheat (40.9%; n = 44), and oats (34.4%; n = 37) were the most reported top two crops. The most common "other" response was triticale. A K-S test was completed to evaluate if there was a statistical difference in the cropping acreage mean in mixed operations, and crop-only operations; the results indicated that the means are not statistically different with 95% confidence level for a two-tailed K-S test. As such, the survey responses are analyzed together.

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[24] Results provided in aggregate due to insufficient sample size to report independently.
[25] Respondents indicating 76-100% grass-finished cattle were removed.
[26] Results provided in aggregate due to insufficient sample size to report independently.

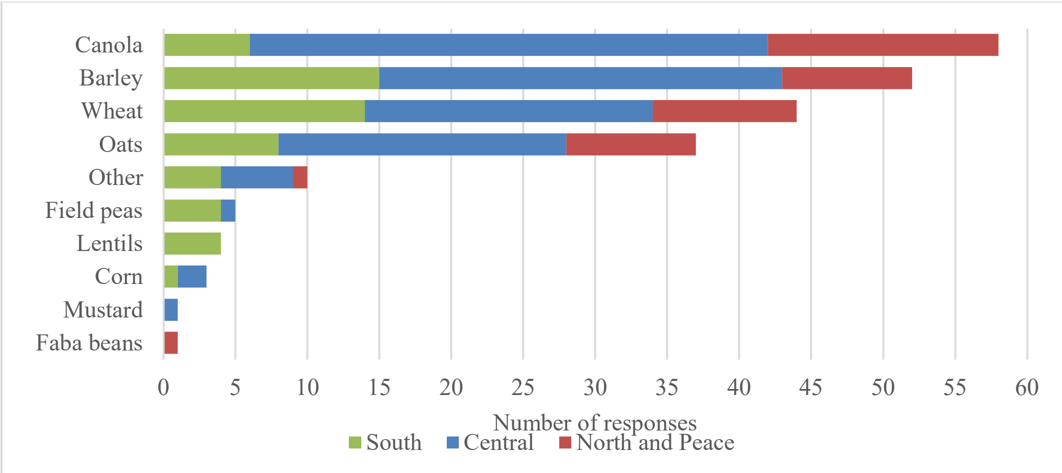

Figure 46. The top two most grown crops in 2022 as reported by survey respondents.

Land Tenure

From 2001 to 2021 farmland area rented or leased increased from approximately 41% to over 45% of total farmed land in both Alberta and BC (Statistics Canada, 2024). This shift in ownership is influenced by increases in land values with elevated farm income and robust demand and limited supply of farmland, including increased non-farmer ownership by investors (FCC, 2024). Assessing if farmers are more likely to adopt BMPs if they own versus rent the land is nuanced and variable. Operators may implement different practices based on whether the land is owned or leased and the lease's duration. These decisions are often aligned with broader management goals aimed at improving soil quality, optimizing the use of standing crops for grazing, ensuring sustainable harvests for livestock feed, engaging in cash crop production, minimizing erosion, and enhancing overall environmental sustainability. Research in Canada has indicated that farmers who own or rent are equally as likely to adopt practices with short term benefits, such as minimal or zero tillage (Deaton et al., 2018). And while farmers were less likely to adopt conservation practices such as cover crops on rented land, this effect diminished with an increased rental relationship and when the landowner had a farming background (Deaton et al., 2018).

Respondents were asked to indicate the percentage of cropland that was owned, rented, or other (Table 45). In general, 146 operators reported owning all or part of their cropland, while 89 operators reported renting all or part of their cropland. Five operators reported "other" arrangements. The average percentage of land owned was 69% of the land rented was 29.3%, and land operated under other arrangements was 1.7%. The region with the largest share of owned cropland was North and Peace (70.1%), and the region with the largest share of rented land was South (32%)[27]. Respondents managing cropland as rented or "other" land (n = 94) were asked about the timeline of the agreement, ranging from short/insecure to long/secure and on the relationship with the landowner, ranging from distant/limited to close/connected, both on a scale from one to five. Most respondents indicated they have a long/secure agreement for their rented land and have a close/connected relationship with the landowner (Figure 47).

[27] Data from three respondents were removed for exceeding 100% and from two respondents whose total percentages were less than 100%).

Table 45. Tenure of land used for crops grown for mechanical harvest in 2022.

	Region	Number of respondents that reported type of tenure	Average share of cropland acreage by tenure	Median of share of cropland acreage by tenure	SD share of cropland acreage by tenure
Owned (deeded)	South	33	66.4%	81.0%	38.0%
	Central	74	69.6%	75.0%	32.7%
	North and Peace	39	70.1%	85.0%	35.2%
	Total region	146	69.0%	81.0%	34.4%
Rented or Other	South	23	32.0%	19.0%	37.3%
	Central	45	29.0%	22.0%	31.2%
	North and Peace	21	27.8%	0.0%	34.5%
	Total region	89	29.3%	16.5%	33.4%
Other	South	1	1.6%	0.0%	9.3%
	Central	2	1.5%	0.0%	9.2%
	North and Peace	2	2.2%	0.0%	10.1%
	Total region	5	1.7%	0.0%	9.4%

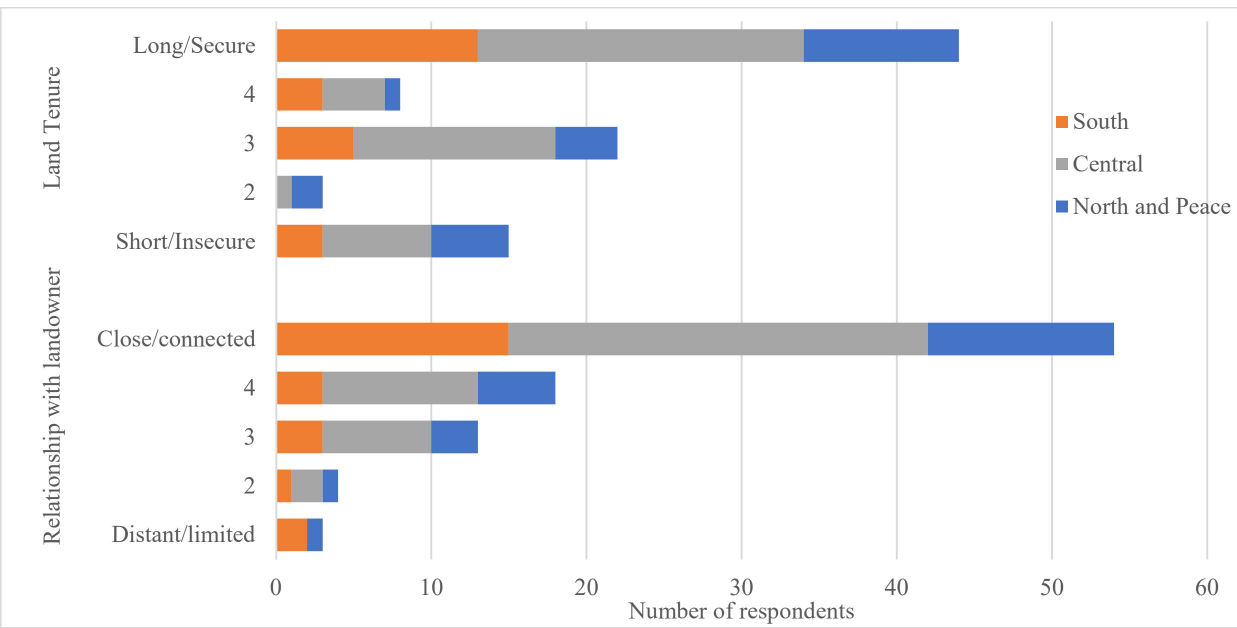

Figure 47. Relationship with landowners on cropping operations.

4.4.1 Cropland Management

The adoption of soil testing, summer fallow in rotation (especially in response to drought conditions), and multi-cropping systems (including intercropping, companion or nurse cropping, polyculture or cover cropping, relay or double-cropping), reflects a strategic approach to land management. Additionally, crop rotations with the inclusion of pulses in cereal rotations, the integration of perennial forages into annual rotations, and effective crop residue management are practices that contribute to soil health, break disease cycles, pest management, and economic resilience.

4.4.1.2 Soil Testing

Soil health is foundational to successful cropping systems. Soil testing provides crucial insights into the soil's physical and chemical properties, informing strategies for nutrient management, crop selection, and overall land management (Sims et al., 2000). Of note when considering adoption of BMPs in general, are findings from a recent survey of farmers indicating that soil testing was the most commonly reported BMP and it was frequently correlated with cover crop (see section 4.4.4 Multi-Cropping Systems), crop rotation (see section 4.4.5 Annual Rotations), and tillage BMPs (Shah et al., 2022). Additional research findings indicate that producers are more likely to adopt routine soil testing when soil condition can be linked to farm output (Rhymes et al., 2021).

Producers may utilize random **sampling**, sample every field, use zone sampling, or even an ad hoc method. With random sampling, soil samples are collected from random locations within a field. While this may provide a general overview of soil health, it may not capture the variability present across the field, potentially leading to less precise management decisions. In sampling every field, the variability due to differences in crop history, soil texture, topography, and previous management practices may be more accurately reflected, which may enhance the accuracy of nutrient management plans tailored to each field's specific needs. With zone sampling, further refinement is undertaken by segmenting a field into areas (i.e., zones) with similar characteristics based on factors such as soil type, yield potential, and historical data. Zone sampling enables highly targeted management practices that can optimize inputs and improve environmental outcomes.

The **frequency** of soil testing is vital to capturing temporal changes in soil properties and adjusting management practices accordingly. Best practices suggest testing every two to four years, although this can vary based on factors such as crop rotation, the intensity of land use, and previous soil amendment applications. Regular testing allows for the timely adjustment of fertilization strategies, reducing both the risk of nutrient deficiency and the potential for over-application that could lead to environmental harm.

The **depth** of soil testing is critical for accurately assessing the soil's nutrient status and understanding the root zone's environmental conditions. Standard soil tests are often conducted at a depth of 15 to 60 cm, reflecting the typical root zone of most annual crops. However, deeper testing (e.g., up to 48 inches or 120 cm) may be necessary for perennial crops or to assess subsoil characteristics, such as salinity or the presence of deeper nutrient reserves.

Survey respondents managing cropland were asked about their use of soil testing, including sampling techniques, frequency, and depth of testing as a proxy to understand the baseline use of soil information for other on-farm decisions. Almost two-thirds of respondents 62.4% (n = 103) had their soils tested on their managed cropland since 2018. Producers using soil testing managed 85.5% (170,624 acres) of total cropland in 2022[28].

Over a third of respondents (36.9%; n = 38) reported conducting soil sampling on every field, while another third (35.0%; n = 36) conducted random sampling, and 20.4% (n = 21) completed their sampling by zones (Figure 48). Almost half of the operators (46.6%; n = 48) reported doing soil sampling every year, while 37.9% (n = 39) did so every several years and 7.8% (n = 8) tested soils only when a soil fertility issue was suspected. Soils were most commonly tested at 6 to 12 inches deep (n = 67), followed by less than 6 inches deep (n = 30), and 13 to 24 inches deep (n = 29).

[28] Producers were only asked about soil testing on lands where crops were grown for mechanical harvest, including hay, cereals, oilseeds, and pulses.

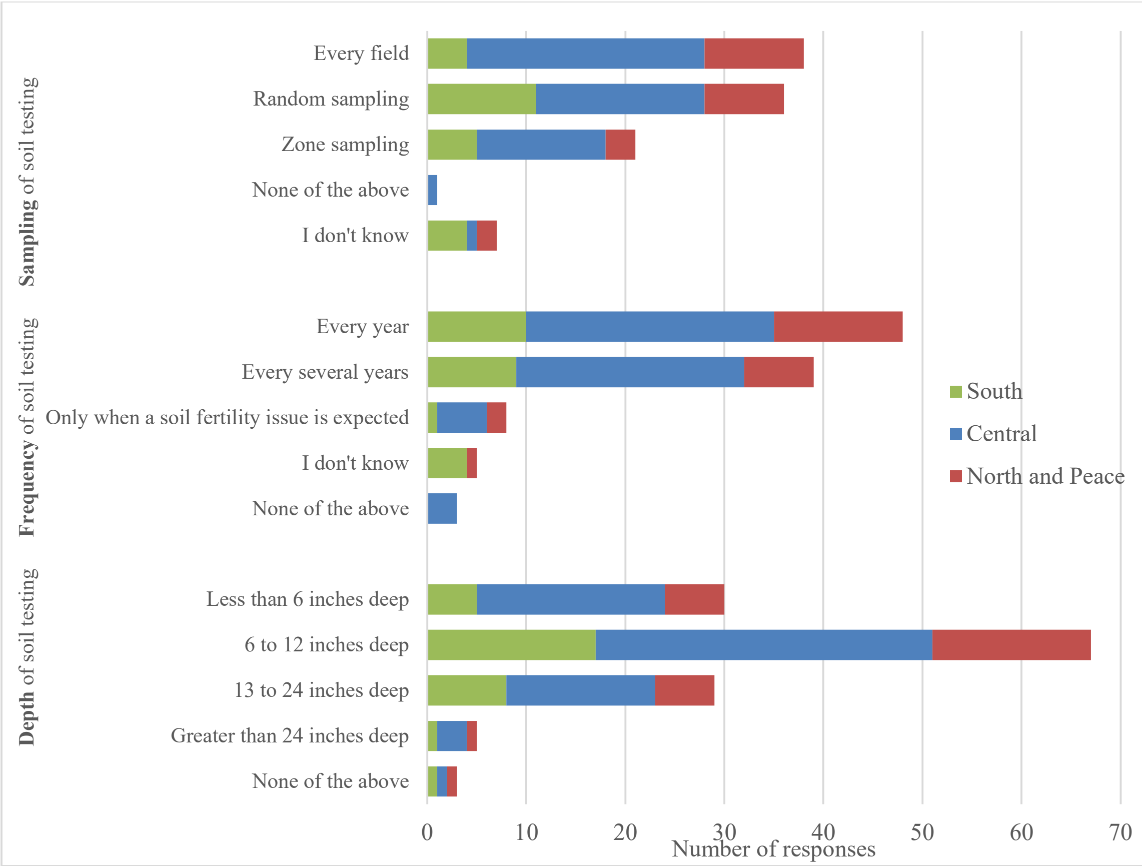

Figure 48. Soil testing practices reported in 2022, by region.

4.4.1.2 Summer Fallow

Summer fallow has been used as a method to conserve soil moisture and manage weeds (Nadeem et al., 2019). However, its role and impact on cropland, particularly within the framework of BMPs have evolved due to changing perspectives on soil health and sustainability. Potential downsides of summer fallow on soil health include erosion risks and depletion of soil organic matter. Bare fallow land is vulnerable to wind and water erosion, particularly in areas without natural barriers or cover crops to protect the soil. This can lead to significant loss of topsoil and the degradation of land productivity over time. Without crops growing and contributing root biomass and residues, soil can gradually lose its organic content, reducing its fertility and structure. Fallowing may also be used to control weeds by disrupting their life cycles; however, the absence of a crop may allow more aggressive weed species to dominate. Similarly, the absence of crops can either disrupt pest cycles or allow pests to find alternative hosts and build up in numbers, potentially impacting future crops. Fallowing may also reduce biodiversity on cropland, as the absence of plants affects not only soil organisms but also above-ground wildlife dependent on crop habitats.

Soil degradation and erosion became more prominently featured as a concern in Canadian agriculture in the 1980s, with research driving national awareness and conservation efforts (Badreldin and Lobb, 2023). As a result, there have been noted improvements in soil erosion rates that are associated with BMPs. Badreldin and Lobb (2023) estimate that areas subject to moderate to very high annual soil erosion rates decreased from 5.5% to 1.5% between 1971 and 2015, as a direct response to the adoption of conservation tillage practices and a decline in the use of summer fallow, where adoption of no-till climbed to about 60% of the cropped area across the country, and summer fallow dropped from about 14% to 3%.

The impact of summer fallow in crop rotations on net greenhouse gas emissions (i.e., considering soil carbon sequestration and associated machinery emissions) varies with management practices such as including leguminous cover crops and no-till. Considering the challenges associated with traditional summer fallow, alternative practices such as cover cropping and reduced- or no-till farming are gaining interest. Planting cover crops during traditional fallow periods can protect the soil, improve its organic matter content, and manage weeds and pests more effectively. Reduced and no-till farming minimizes soil disturbance, maintains soil structure, and reduces erosion risks.

Incorporation of cover crops related to net carbon is not yet well understood (Wang et al., 2022). Liebig et al. (2010) found that there was no net greenhouse gas benefit from incorporating a cereal (rye) cover crop during the fallow phase of a dryland cropping system under no-till management, while other studies indicate a range of outcomes, such as leguminous cover crops providing nitrogen benefits and fertilizer savings to subsequent crops (Plaza-Bonilla et al., 2018). Still other studies concluded that the increases in nitrous oxide may outweigh the benefits to soil organic carbon (Mitchell et al., 2013).

Respondents were asked if any part of their operation was in summer fallow in 2022, with 6.1% (n = 10) indicating yes. There was a total of 2,586 acres of summer fallow in all operations managed by respondents, with a range of 1 to 1,200 acres per operation. The average size of summer fallow acreage per operation was 259 acres (median = 100, SD = 374). Respondents who included summer fallow in their operation managed 641 head of beef cows and yearling grassers (2.1% of total heads reported by all operators).

Eight of the 10 respondents claimed the decision to have summer fallow on their operation was influenced by drought in 2022. Three operators reported having more summer fallow acreage after the 2022 drought, four claimed to have about the same acreage, and one reported having less.

The two most commonly grown crops by respondents who had summer fallow in their operation included barley (41.7%), wheat (25%), canola (16.7%), and oats (16.7%). From the respondents with summer fallow who answered the questions about fertilizer application (n = 6), all of them said they applied fertilizer to their main crop in 2022.[29]

4.4.2 Cropland Seasonal Nutrient Management

The primary strategy for controlling nitrogen and phosphorus involves nutrient management, commonly guided by the 4Rs principle: applying the Right rate, at the Right time, from the Right source, and in the Right place. Adhering to these principles is crucial for minimizing nutrient loss from agricultural fields to both surface and groundwater, and for optimizing crop production and environmental stewardship.

Determining the right amount of nutrients to apply is vital to avoid the over-application which can lead to environmental degradation, or under-application which can limit crop yield. This BMP is related to soil testing as this practice can help determine the existing nutrient levels in the soil, thereby guiding the amount of additional nutrients needed. Application rates should align with the expected crop yield, considering the nutrient needs of specific crops and the soil's ability to supply these nutrients.

Respondents were asked if they applied fertilizer (including synthetic, manure or compost) to the cropland used for the production of their main crop in 2022. From 113 respondents, 94% reported using fertilizer (Table 46). The reported fertilized cropland used to grow respondents' main crop was 101,466 acres, and the average area per operation was 957 acres (median = 400, SD = 2,138). Respondents who used fertilizer on their main crop managed 22,347 head of beef cows and yearling grassers, which represents 73.7% of total cattle reported from this sub-set of producers.

[29] The sample was too small for a regional breakdown

Table 46. Respondent summary of cropland used to grow the main crop that was fertilized in 2022, by region.

Region	Count	Respondent adoption rate (%)	Total acres	Average acres	Median acres	SD acres	Number of beef cows and yearling grassers
Central	55	93.2%	49,165	894	290	2,727	9,731
North and Peace	24	96.0%	22,146	923	313	1,233	9,283
South	27	93.1%	30,155	1,117	600	1,279	3,333
Total Region	106	93.8%	101,466	957	400	2,138	22,347

Applying nutrients, particularly phosphorus and potassium, before or during planting can ensure that the crops have immediate access to essential nutrients as they begin to grow. Applying nitrogen during the growing season, often as a top-dress, can provide a timely nutrient boost to crops during critical growth stages, such as just before tillering in cereals or around flowering in legumes. Operators were asked to provide details about their nutrient management on cropland across the four seasons. The share of operators who applied fertilizer on the cropland used to grow their main crop was 96.3% (n = 103) in the spring, 29.5% (n = 31) in the summer, 14.4% (n = 15) in the fall, and 10.6% (n = 11) in the winter (Figure 49). Over half of the respondents that responded other in spring (n = 20) answered that they do not know what fertilizer blend was used.

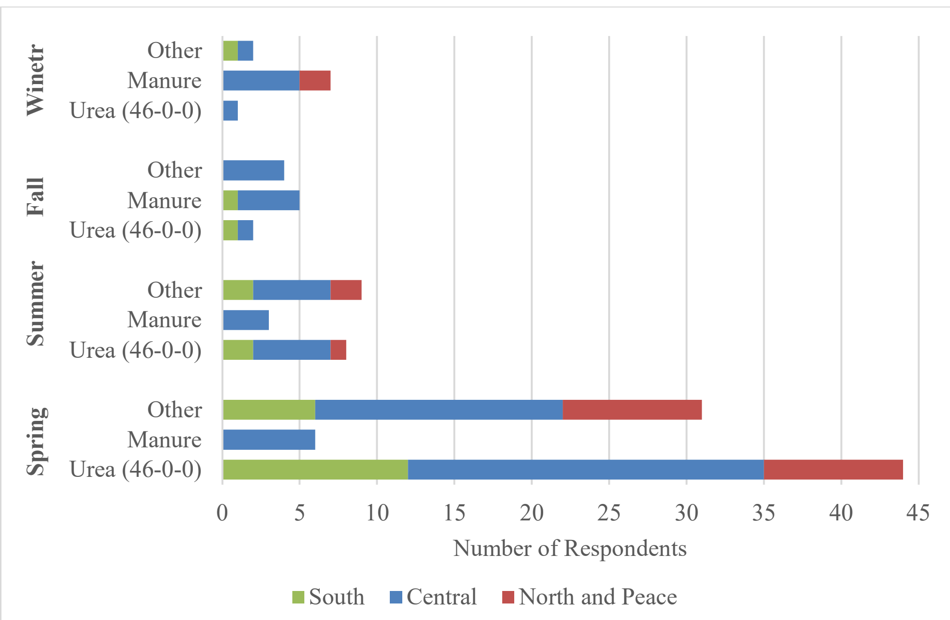

Figure 49. Fertilizer application timing on the cropland where the main crop was grown in 2022.

The source of nitrogen fertilizer plays a significant role in its availability and impact on the environment. Common synthetic sources include urea and ammonium nitrate, which are highly effective but can be susceptible to volatilization and leaching if not properly managed. Controlled release fertilizers release nitrogen slowly, matching more closely with crop uptake and reducing the risk of leaching. Manure and compost provide nitrogen as well as other nutrients and organic matter, improving soil structure and microbial activity. The rate of nitrogen release from organic sources is slower and more dependent on soil conditions.

Operators reported urea (46-0-0) as their main source of fertilizer on cropland during spring and summer, and manure in fall and winter. The number of operators who reported fertilizer rates, fell sharply from spring to summer, and gradually from summer to fall and the winter. Average urea (46-0-0) application rates in spring were 103 lbs/acre in spring, falling to 108 lbs/acre in summer. Average manure application rates in the fall were 35,274 lbs/acre, and only 20 lbs/acre in the winter. Data statistics may not be representative given the small samples in summer, fall and winter (Table 47).

Table 47. Summary statistics of fertilizer rate for cropland used for main crop, by season in 2022.

Season/Main fertilizer	Count of responses	Average (lbs/acre)	Median (lbs/acre)	SD (lbs/acre)
Spring - Urea (46-0-0)	36	103	95	51
Summer - Urea (46-0-0)	7	108	100	58
Fall - Manure	NR	NR	NR	NR
Winter - Manure	NR	20	20	-

NR = not reported due to insufficient sample size and to maintain respondent confidentiality.

The method of fertilizer application can significantly affect nutrient use efficiency and environmental impact. Spreading fertilizer evenly across the entire field with broadcasting is common but can be less efficient as it exposes nutrients to potential runoff and volatilization. Placing fertilizer in a band close to the seed during planting or beside growing plants minimizes exposure to the environment and places nutrients where crops can more easily access them. Applying nutrients directly to the leaves can be effective for quickly correcting in-season deficiencies. Tools like GPS and sensors allow for variable-rate application, adjusting the amount of fertilizer according to the specific needs of different areas within a field. There was a significant variety on application methods used by operators to apply fertilizer on cropland (Figure 50). The most common fertilizer application method was surface broadcast with incorporation with 42 responses across all seasons, followed by deep banding (n = 28), side dressed (n = 26), surface broadcast (n = 24), injected (n = 16), variable rate application (n = 15), and other methods (n = 6).

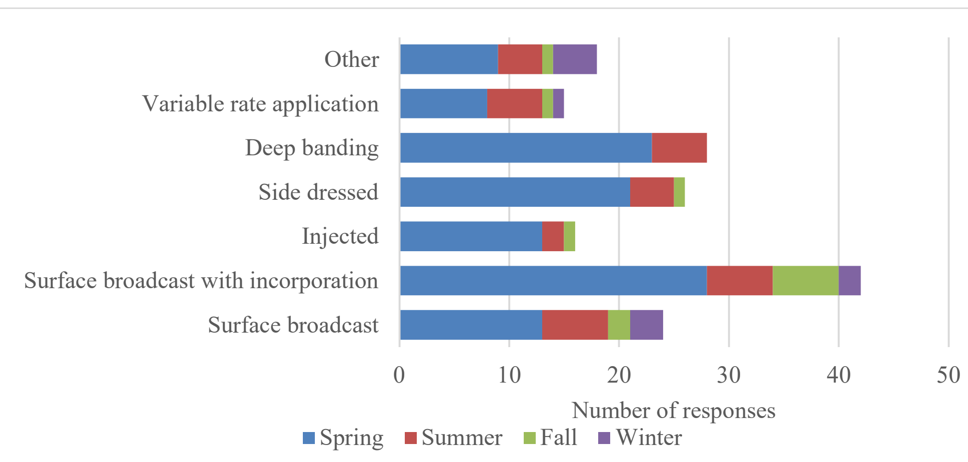

Figure 50. Cropland fertilizer application methods by season in 2022.

4.4.3 Cattle Grazing on Cropland

Integrating grazing cattle on cropland, for grazing either post-harvest or as part of a cover cropping system, can offer symbiotic advantages for soil health, nutrient cycling, and overall farm system sustainability. Natural dispersion of manure facilitates a more efficient cycle of biologically active nutrients. This can reduce the reliance on synthetic fertilizers, lowering input costs and minimizing potential environmental impacts from over-fertilization. Cattle grazing breaks down crop residues, which can accelerate the decomposition process and prevent issues such as residue build-up, which may also reduce the prevalence of crop diseases that might overwinter in undecomposed stubble, promoting healthier crop rotations. Research at the University of Florida found that crop yields following winter grazing are higher than yield increases with cover crops alone, attributed to improved soil fertility, and have lower input costs and improved calf gains (Wright, 2020). And while the benefits are significant, careful management is necessary to avoid overgrazing, which can lead to soil erosion, nutrient depletion, and reduced soil health.

Operators were asked if any crops were grazed by cattle in 2022. From 109 respondents from all regions, 22% (n = 24) reported cattle grazing crops (Figure 51). The South region had the highest rate of adoption with 28.6%, and North and Peace region had the lowest rate of adoption with 8.7%. Respondents were also asked if the cattle grazing the cropland belonged to the operations and all but one operator said yes.

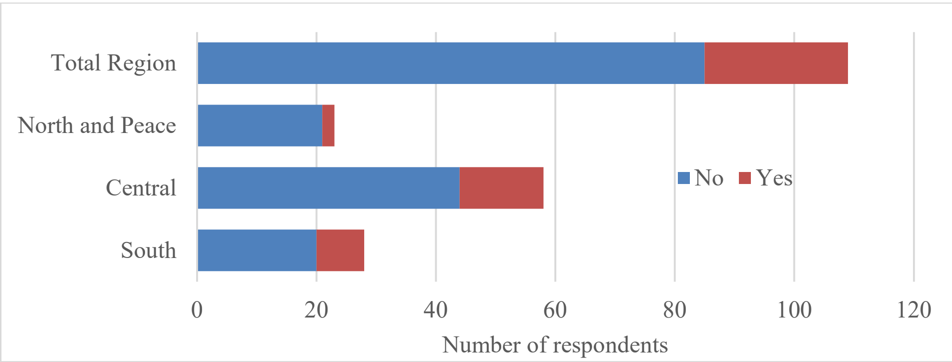

Figure 51. Rate of adoption of crops being grazed by cattle, by region in 2022.

4.4.4 Multiple Cropping Systems

Multiple, or multi-cropping systems, was defined for survey participants and for this report as two or more crops grown together on the same land. Questions were answered the largest area where multi-cropping took place. This includes multiple practices such as: **inter-cropping** where two crops growing on the same land at the same time; **companion or nurse crop**, is an annual crop sown with a perennial forage to provide early soil cover protecting against soil erosion and helps in weed control, also supporting establishment and provides a crop (usually silage or greenfeed) in the first year; **polyculture or cover crop**, growing mixtures of different crops together in order to enhance productivity, reduce the need for chemical fertilizer, and provide natural protection against disease and pests. **Relay or double-cropping** is when one variety is harvested, and another immediately seeded. This second crop provides cover with a living root, and may be harvested, grazed, plowed under as green manure or seeded through the next spring.

While some research indicates that high plant diversity can result in higher and more stable yields when compared to production systems with low plant diversity (Lin, 2011), other work has found lower yields but with higher grain quality (Snapp et al., 2010). Despite outcomes, overall multi-cropping can contribute to the sustainability and efficiency of cropland via enhanced biodiversity, improved soil health, and optimized land use.

From a practical perspective, multi-cropping can enhance biodiversity by discouraging the proliferation of pest populations and disease spread, as pests are less likely to find suitable hosts continuously available. Growing multiple crops together can help in more balanced nutrient uptake and reduce the likelihood of nutrient depletion in the soil. The presence of diverse root systems may improve soil structure and prevents soil erosion. And planting multiple crops can buffer against the failure of any single crop due to pests, diseases, or unfavorable weather conditions, thus stabilizing overall yields.

Managing different crop species on the same land increases the complexity of farm operations, including the timing of planting and harvesting, pest and disease control, and fertility requirements. Mechanical harvesting can be more challenging in multi-cropping systems due to different maturity times and physical characteristics of the crops.

Operators were asked if they had any multi-cropped areas within their operation, 22% (n = 15) of the 109 respondents who completed this section said yes. From these 15 producers, only 14 provided details of their multi-cropped areas. The total area of the largest multi-cropped acreage for the 14 respondents summed to 1,954 acres with an adoption rate of 1% in acreage. The average size of operators' largest multi-cropped area was 140 acres per operation, with a median of 100 acres and a SD of 144 acres. The respondents who provided details of their multi-cropped acreage managed 3,086 beef cows and yearling grassers, representing 10.5% of the total number of head (Table 48).

Table 48. Respondent summary of largest multi-cropped area, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acre	Average acres	Median acres	SD acres	Acreage adoption rate (%)	Number of beef cows and yearling grassers
South	NR	11.1%	335	112	100	98	0.4%	170
Central	9	15.5%	1,429	159	100	174	3.9%	2,354
North and Peace	NR	8.3%	190	95	95	35	0.3%	562
Total Region	NR	12.8%	1,954	140	100	144	1.0%	3,086

NR = not reported due to insufficient sample size and to maintain respondent confidentiality.

The most common crops in multi-cropped systems were oats, barley, and field peas (Figure 52). Eight of the 14 producers reported growing only two crops (inter-cropping), while 7 grew four different crops (polyculture). Approximately two thirds of the crops (64.8%; n = 11) were still being grown when the next crop was seeded. The first crop harvested in the year was mostly used for silage (40%; n = 6), followed by grain (33.3%, n = 5), and greenfeed (13.3%, n = 2). Most of the crops (73.3%, n = 11), were not overwintered.

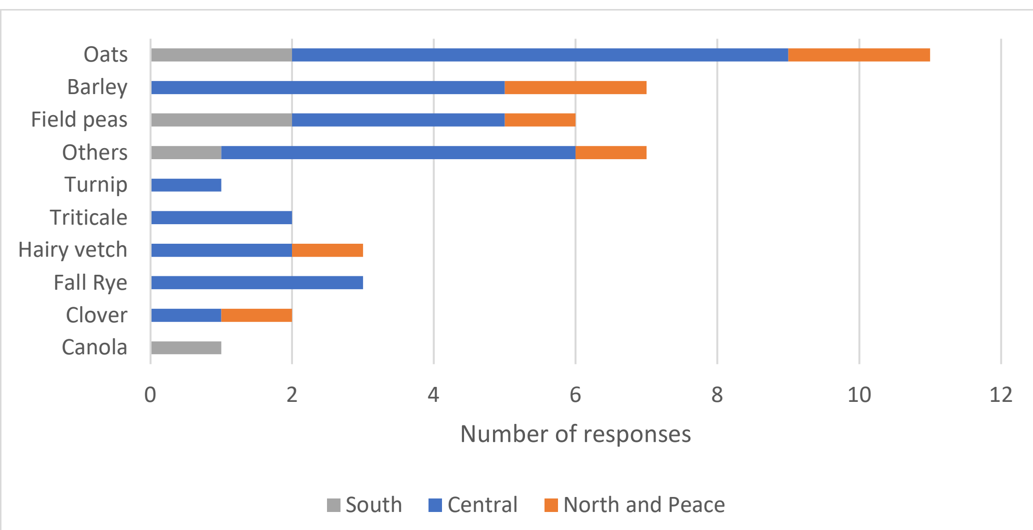

Figure 52. Most common reported crops included in multi-crop systems in 2022.

Operators reported the main reasons for including multi-cropping included harvesting for animal feed (31%, n = 9), improving soil quality (27.6%, n = 8), and reducing erosion/bare ground (13.8%, 4) (Figure 53).

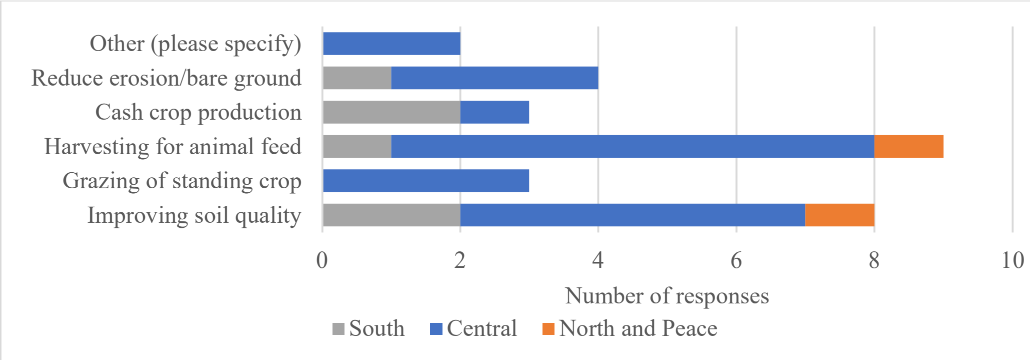

Figure 53. Respondent management goals for adopting multi-cropping systems.

Respondents were asked why they did not practice multi-cropping in their operations. Over half the operators who completed this section reported the main reason as the growing season being too short (51.2%; n = 43), followed by that the practice is unlikely to work on their soil zone or the moisture was too unpredictable (8.3%; n = 7 each), that they do not see the benefit (6.0%, n = 5), and that there was not enough labour availability (2.4%, n = 2) (Figure 54). Other responses included labour demand, weed control and all of the above.

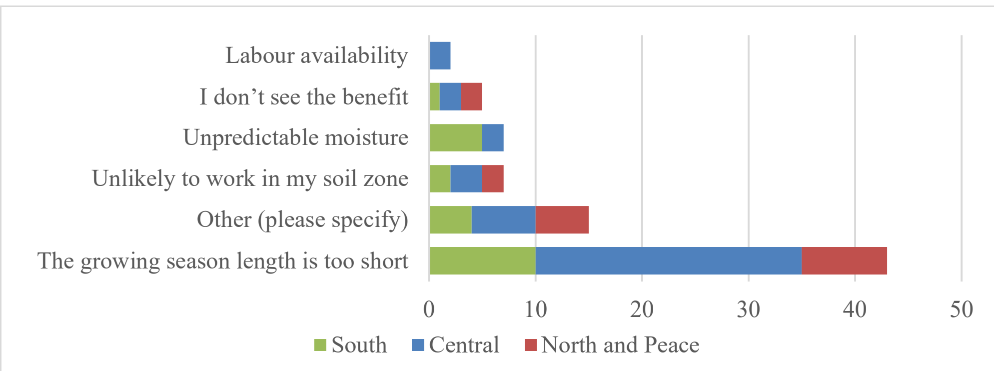

Figure 54. Reported reasons operators did not practice multi-cropping in 2022.

4.4.4.1 Multi-Cropping Systems Seasonal Nutrient Management

One of the objectives of multi-cropping is to reduce synthetic fertilizer use, through improved soil health and fertility. Respondents were asked if fertilizer (including synthetic manure or compost) was applied to the largest multi-cropped area in 2022. Seven operators said yes, and 6 provided details on their fertilizer use. Urea (46-0-0) was the most common fertilizer used in the spring, with an average application rate of 96 lbs/acre. And the most common application technique in the spring was side dressed. No operators reported applying fertilizer in the summer. And only one operator reported fertilizing with compost in the fall with an application rate of 2000 lbs/acre by surface broadcast. A single operator reported applying manure in the winter at 20 lbs/acre application rate by surface broadcast.

4.4.5 Annual Rotations

Annual crop rotations involve alternating the types of crops grown on the same piece of land from one year to the next. Planned crop rotations serve as an effective strategy to enhance soil fertility, control insect pests and diseases, and reduce greenhouse gas emissions (Nadeem et al., 2019). Including legume crops in rotations decreases the need for external nitrogen inputs, which reduces reliance on synthetic fertilizers and minimizes environmental pollution from the volatilization and leaching of applied nitrogen (Stagnari et al., 2017). Rotating crops with different root systems, such as tap-rooted crops with shallow-rooted ones, promotes the efficient use of nutrient resources and helps conserve soil moisture, leading to more productive farming (Nadeem et al., 2019).

Of 153 respondents, 15.7% (n=24) did include a pulse crop in rotation at least once every three years since 2018, 15% (n=23) said "yes, but less frequently" and 69% (n=106) did not. Overall, 30% of respondents (n = 47) with crop operations included a pulse crop in their rotation since 2018 on 25,537 acres (Table 49). Total operational average for adding a pulse crop was 543 acres with a median of 200 acres and standard deviation of 148 acres. Adding pulses into the annual crop rotation was more common in the south with nearly 30% of producers adding a pulse crop here since 2018, with the lowest acreage of pulse crops added occurring in the North and Peace region on 2,400 acres among 11 producers. Adding pulse crops to annual rotations can enhance soil water use efficiency, improve soil nitrogen availability, and increase system productivity (Gan et al., 2015; Lasisi and Liu, 2023). Common pulse crops in the Canadian Prairie provinces include field pea, dry bean, lentil, chickpea, faba bean, and soybean; of these crops, only field pea is frost tolerant. Lentils, chickpeas and dry beans are most commonly grown in the southern areas of Alberta due to geographical suitability, with peas and faba beans suited to all of the south, central, and north regions (Alberta Pulse Growers, 2024).

Table 49. Respondent adoption/use of cropland area with a pulse crop added in an annual crop rotation (every 3 years and less frequently), by region in 2022.

Region	Count	Respondent adoption rate (%)	Total acreage	Average acreage	Median acreage	SD acreage	Acreage adoption rate (%)	Number of beef cows and yearling grassers
South	16	48.5%	17,030	1,064	550	1,501	28.6%	1,322
Central	20	25.3%	6,107	305	155	391	6.6%	3,277
North and Peace	11	26.2%	2,400	218	200	148	6.6%	8,284
Total Region	47	30.5%	25,537	543	200	973	13.5%	12,883

Operators were asked if a perennial forage had been included in an annual crop rotation since 2018, 66% (n = 101) were mixed operations. Of 153 respondents, 27.5% (n = 42) said yes, and 25.5% provided details from their practice. The total cropland used as perennial forages/annual crop rotation in 2022 was 8,942 acres, with each operation having an average area of 213 acres for this practice, with an average of 200 acres, and a SD of 973 acres. These respondents managed 11,146 beef cows and yearling grassers, representing 38.2% of the total number of head managed by all respondents in the survey. Details by region are provided in Table 50.

Table 50. Respondent adoption/use of cropland area with perennial forage in annual crop rotation, by region in 2022.

Region	Count	Respondent adoption rate (%)	Total cropland acres	Average cropland acres	Median cropland acres	SD acres	Acreage adoption rate (%)	Number of beef cows and yearling grassers
South	5	15.2%	3,580	597	550	1,501	6.0%	635
Central	25	32.1%	3,937	151	155	391	4.3%	4,727
North and Peace	9	21.4%	1,425	143	200	148	3.9%	5,784
Total Region	39	25.5%	8,942	213	200	973	4.8%	11,146

Producers were asked for a historic view of the establishment of annual crops from 2012 to 2022. Results (Table 51) show a diminishing affirmative response; it is difficult to determine if respondents simply did not answer, or if the establishment of annual crops was indeed lower in years prior to 2019. Responses are only provided in aggregate due limited responses in two regions. When these respondents were asked why they included **perennial forages** in their operation, 71.8% (n = 28) reported doing so for **hay, greenfeed, or silage, followed by improving soil quality** (56.4%; n = 22), and to **provide grazing** (48.7%; n = 19). See sections 4.2.1.1 (Table 8) and 4.2.2.1 (Table 16) on Land Use and Land Use Change from the livestock operations perspective.

Table 51. Reported years annual crops were established by cropland respondents.

	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
Total region	24	20	19	13	14	10	9	10	7	5	6

4.4.6 Crop Residue Management

Effective crop residue management can significantly influence soil health, moisture conservation, erosion control, and nutrient recycling, making it a critical practice for enhancing the sustainability of farming operations. Retaining residues during dry years can enhance yields by minimizing soil moisture evaporation and providing additional organic matter. However, managing crop residue also involves removing excess residues as an overabundance of residue can cool the soil in spring, hinder seedling emergence, and potentially reduce yields. Strategies such as rotational tillage or targeted removal (i.e., with baling or integrating livestock grazing) can mitigate these risks.

In reviewing numerous published studies, Liu and Lobb (2021) summarize the impact of crop and crop residue management on various hydrological processes, including rain interception, evaporation, transpiration, snow trapping, water infiltration, and runoff, concluding that the effectiveness of these practices is contingent upon the choice of crop types and tillage methods in the short term, while long-term influences include regional climate changes and shifts in cropping systems. Additionally, practices that have good agronomic benefits, including maintaining high stubble and reduced tillage, may also heighten the risk of snowmelt runoff, which has implications for water quality as a wider environmental issue (Liu and Lobb, 2021).

Respondents were asked what **practices** were used on their operations (Figure 55) to better understand the type of crop residue management. The most common practice reported was direct seeding with 24.5% (n = 78) of respondents, followed by harrows (23.6%; n = 75), no-till (17%; n = 54), discs (17%; n = 54), minimal till (14.8%; n = 47), and stripper headers (1.6%, n = 5).

Most operators (58.8%; n = 87) reported **baling** over a third of their cropland area straw/residue on average (38.3%; median = 20.0%; SD = 41.4%). Of the respondents that reported baling, 73.6% (n = 64) of them were mixed operations. These producers managed 17,135 of the beef cows and yearling grassers, representing about 9.1% of the total cattle head in these categories. The second most common management practice of cropland straw/residue was **grazing** with over a quarter of respondents (27.7%; n = 41) using this practice in an average 15.2% of their cropland (median = 0.0%; SD = 30.1%). These producers managed 6,696 of the beef cows and yearling grassers, representing 3.6% of the total number of head managed by all respondents in the survey.

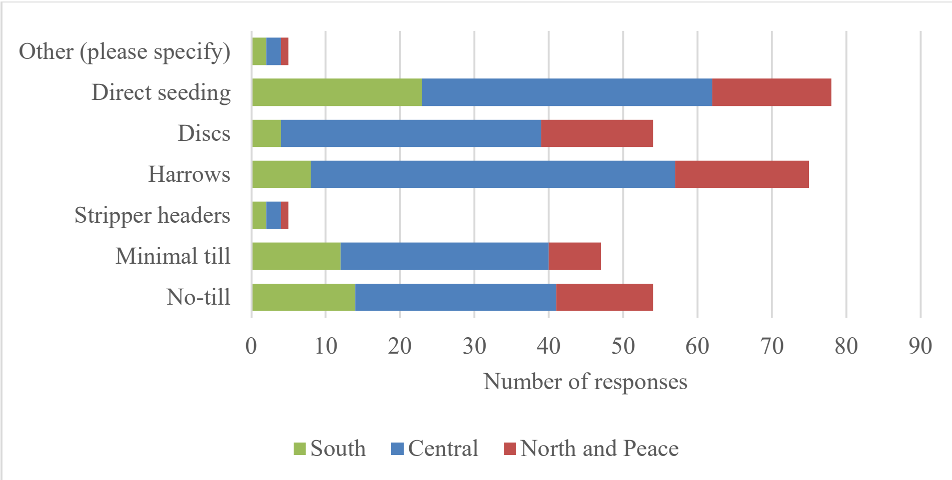

Figure 55. Seeding practices that impact crop residue management, by region in 2022.

A remaining 65 respondents reported tilling and incorporating an average of 27.9% of the crop straw/residue on their cropland in 2022, with a median of 0% and a SD of 39.5% (Table 52). Of the 65 respondents, 66.2% (n = 43) of respondents were mixed operations.

Table 52. Respondents indicating straw/residue left on cropland that was tilled or incorporated, by region in 2022.

Region	Count	Average share of straw/residue	Median share of straw/residue	SD of straw/residue	Number of beef cows and yearly grassers
South	11	22.5%	0.0%	38.1%	782
Central	38	33.9%	2.5%	41.9%	4,344
North and Peace	16	21.2%	0.0%	34.8%	3,326
Total region	65	27.9%	0.0%	39.5%	8,452

5. Conclusions

The benchmarking survey conducted among producers in Alberta and the Peace region of BC provides valuable insights into the adoption and effectiveness of Beneficial Management Practices (BMPs). The findings reveal a positive trend in BMP adoption, with several interconnected practices demonstrating substantial benefits for sustainable agriculture. Synergy between practices underscores the importance of integrated management approaches. And while interconnected impacts were not specifically examined in the survey results, examples from the literature indicate promising interdependencies on how BMPs collectively enhance soil health, productivity, and environmental sustainability. For example, a study examining sod-seeding legumes combined with fertilization significantly increased forage carrying capacity by 57%, a 29% improvement compared to sod-seeding without fertilization (Kopp et al., 2003). Another study found that the overall impact of cropland as a source or sink for carbon dioxide varies based on factors like plant assimilation, harvest removal, and decomposition of residues and soil organic matter (Maas et al., 2013).

Some of these interdependencies were inferred, including the relationship between cattle grazing cropland, crop residue management, soil health, extended season grazing, nutrient management of land, and to some degree this even extends to the practice of cattle grazing for weed control. Similarly, vegetation stage and fertilizer management (product, rate, and method and timing of application) were of importance for grazing and hayland management as it relates to forage quality for cattle management, as well as for annual crop rotations, should perennial forages be added. The addition of legumes has implications for cattle nutrition (harvested and grazed), forage stand health, and nutrient management; all these factors, plus the timing of grazing and forage harvest impact the overall soil health, creating a feedback loop to the health of the operation itself.

The results indicate a higher propensity for innovation among the respondents compared to Rogers' adoption diffusion theory. Specifically, 13.1% of respondents were classified as innovators, 5.4% as early adopters, and 68.3% as the early majority. These figures exceed the theoretical averages, suggesting a more progressive approach to BMP adoption among the surveyed producers. And while significant progress has been made in adopting practices like enhanced efficiency fertilizers, rotational grazing, and precision agriculture, challenges remain in areas such as financial stability and resource availability. Regional variability highlights the need for tailored support and education to promote BMP adoption across different landscapes. By addressing these challenges and fostering a culture of innovation, the industry can enhance its sustainability, productivity, and environmental stewardship.

It is theorized that producers may be more motivated to adopt practices on their own property rather than on rented land, this effect diminishes with a lengthy and positive relationship with landowners, which was the majority in the surveyed respondents. As most respondents indicated that family or inner circle would not continue the operation, this type of long and positive relationship may become less common as land changes ownership. This is a consideration for future efforts related to knowledge extension for BMP adoption. To further improve BMP adoption, targeted education and extension services, improved access to financial resources, and the promotion of collaborative relationships among producers are essential. Addressing these factors will help overcome barriers to adoption and promote the widespread implementation of sustainable practices.

Central to AALL's mission is forging partnerships between producers and researchers to showcase management practices that enhance production, profitability, and environmental sustainability. AALL will focus on continued research and support for innovative practices, as these efforts will be crucial in advancing BMP adoption and achieving long-term sustainability goals in the beef industry. By focusing on the interconnectedness of BMPs and addressing regional variations, the beef industry can enhance its resilience and sustainability, benefiting both producers and the broader environment.

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7. Appendix

7.1 Survey Definitions and Examples

Backgrounding cattle: part of a growing program for feeder cattle from weaning until they are put on finishing rations in a feedlot. Backgrounding cattle may be grown on grass or fed harvested feed.

Bale grazing is the practice of allowing cattle to graze on baled forages in a field or wintering site.

Beef cow: a mature female who has already given birth to at least two calves in her life.

Buffer areas: vegetated areas between production areas and adjacent lands, not including riparian areas

Business planning includes risk management, financial planning, marketing strategies, budgeting, etc.

Continuous grazing is a system that provides unrestricted and uninterrupted access to one large area for cattle to graze throughout the grazing season.

Corn grazing occurs when standing corn is grazed with cattle typically during the late fall and early winter.

Enhanced efficiency fertilizers (EEFs) examples: nitrogen stabilizers, nitrification inhibitors, urease inhibitors, slow or controlled release fertilizers etc.

Feed types:

- Forage: straw, hay, silage, baleage
- Concentrate: grain, pellets, meals

Finishing cattle: beef cattle that are fed a high energy diet with the intention of preparing them prior to slaughter.

First calf heifer: first calvers (roughly 24 to 36 months old), have given birth to her first calf and is not physically mature yet.

Hayland (in hayland section) refers to perennial species grown for mechanical harvest.

Manure storage:

- Stockpiled
- Anaerobic digester: manure is stored in an enclosed vessel and broken down anaerobically
- Deep bedding: fresh bedding is added on top of existing manure pack to keep the pack dry and clean, but manure is not regularly removed

Multi-cropping is when two or more crops are grown together on the same land. If more than one cropland area was multi-cropped in 2022, the next few questions ask you to consider just the largest area where the practice took place.

Native grass is undisturbed pastureland with grasses native to the local ecosystem

Non-workable land is idle land limited for use in agricultural production (e.g., areas with unsuitable soil texture, dense bush/forest, ponds, bogs, marshes, sloughs, coulees, riverbanks, saline areas, eroded areas, buffer strips, riparian areas, or rocky areas). Non-workable land excludes grazing lands.

Overwintering areas:

- An indoor confined area (building)
- An outdoor confined area (corral/drylot)
- A small outdoor pasture/paddock (limited walking between feed and water, manure builds up)

- A large outdoor pasture/paddock where extended grazing or supplemental feeding is practiced, manure is dispersed, and there are greater distances between feed/water

Pasturelands are grazing lands managed by the operation with either native or introduced/tame forage species, that may or may not receive periodic management (e.g. tillage, fertilization, mowing, weed control, and irrigation). Pastureland is specific to grazing land and excludes non-workable land and mechanically harvested cropland areas.

Riparian areas: strips of moisture loving vegetation growing along the edge of a waterbody, not including the waterbody

Rotational grazing is a system where cattle are moved from one grazing unit (paddock/pasture) to other grazing units over the grazing season.

Silvopasture is a farm system that combines cultivated trees with grazed pastureland for livestock where both the trees and the livestock provide income to the operation (e.g., orchards, personal timber sales).

Sod seeding is direct drilling of seed into land where little or no seedbed preparation has been made.

Stockpile or deferred grazing is the practice of saving certain forage pastures or paddocks for grazing in the fall and winter after forage growth has stopped due to cold weather.

Swath grazing is the practice of swathing annual forages (e.g. barley, oats, triticale, or mixtures) crops in the fall for cattle to graze on in-field during winter months.

Tame pasture is grazing pastureland that contains perennial plant species typically introduced, at any time, by humans. Tame pasture excludes areas that will be mechanically harvested (e.g. for hay).

Wetlands: areas where the soil is saturated with water, such as a marsh, swamp, bog or slough

Workable land includes all cropland, grazing land/pasture, and summer fallow.

Yearling grassers: beef cattle around 12 months old grazing on perennial pasture.

7.2 Statistical Test Results

7.2.1 Grazing length: Continuous and Rotational grazing

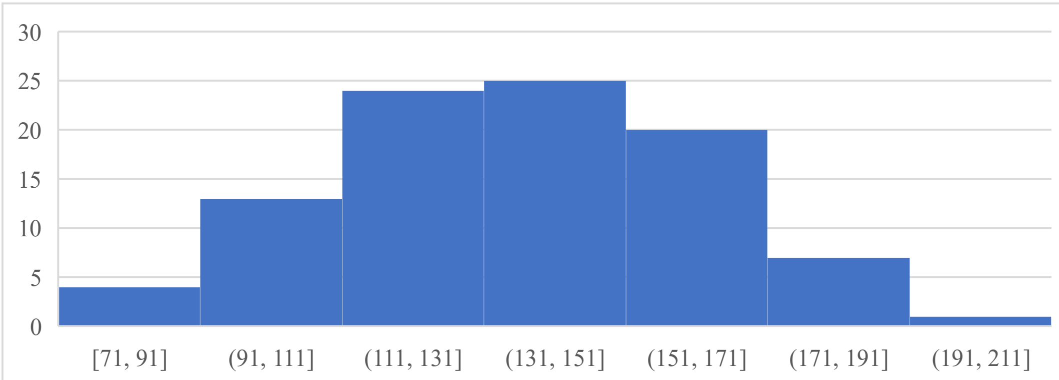

Figure 56. Histogram, continuous grazing length without outliers (using IQR method)

To test normality of continuous grazing length, use Kolmogorov-Smirnov Test Calculator:

Hypotheses:

- H_0: Normal distribution
- H_1: Other distribution

Test Results: We do not reject the H_0, then distribution is normal.

Parameter	Value
p-value	0.06973
D	0.05478
Sample size	94
Average (x)	135.5851
Median	136
Sample Standard deviation	26.046
Sum of squares	63090.8191
K	0.5308
Skewness	0.06338
Excess kurtosis	-0.284

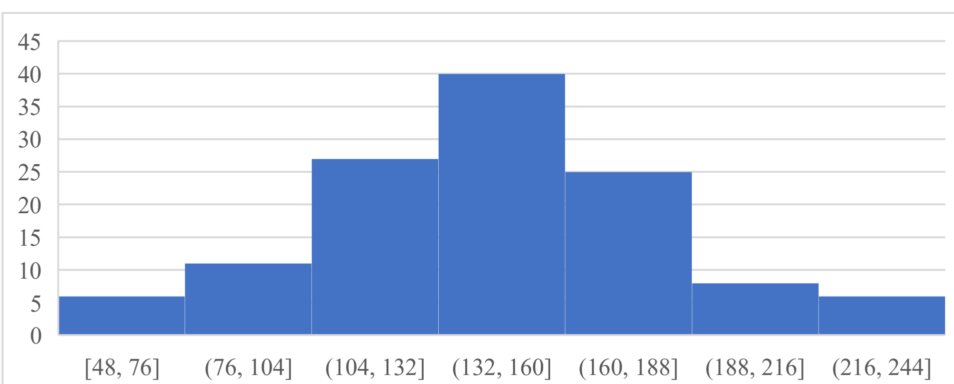

Figure 57. Histogram, rotational grazing length without outliers (using IQR method).

Kolmogorov-Smirnov Test Calculator - To test normality of continuous grazing length

Hypotheses:

- H_0: Normal distribution
- H_1: Other distribution

Test Results: We do not reject the H_0, then distribution is normal.

Parameter	Value
p-value	0.2323
D	0.06483
Sample size	123
Average (x)	145.3496
Median	143
Sample Standard deviation	39.1604
Sum of squares	1877091.9675
K	0.719
Skewness	0.1759
Excess kurtosis	0.128

F-Test Two-Sample for Variances

	Continuous Grazing Length WITHOUT OUTLIERS (IQR)	*Rotational Grazing Length WITHOUT OUTLIERS (IQR)*
Mean	135.7959184	151.9358974
Variance	707.7491497	1612.528305
Observations	49	78
df	48	77
F	0.438906497	
P(F<=f) one-tail	0.001350048	
F Critical one-tail	0.641540435	
Null Hypothesis is that variances equal.		
p-value = 0.0013	Which is less than 0.05	We reject the null hypothesis
Results tells us that the variances are statistically different		
We need to do a t-test for unequal variances.		

t-Test: Two-Sample Assuming Unequal Variances

	Continuous Grazing Length WITHOUT OUTLIERS (IQR)	*Rotational Grazing Length WITHOUT OUTLIERS (IQR)*
Mean	135.7959184	151.9358974
Variance	707.7491497	1612.528305
Observations	49	78
Hypothesized Mean Difference	0	
df	125	
t Stat	-2.723594248	
P(T<=t) one-tail	0.003691031	
t Critical one-tail	1.657135178	
P(T<=t) two-tail	0.007382062	
t Critical two-tail	1.979124109	
Null Hypothesis is that the population means are equal		
p-value 1-tail = 0.0037	Which is less than 0.05	
p-value 2-tails = 0.0074	Which is less than 0.05	We reject the null hypothesis
Results tells us that the means are statistically different.		

Interpretation: there is no difference in terms of central tendency; the means are statistically different between the length (time) for continuous and rotational grazing.

T-test for Grazing Length

Includes responses that did either continuous or rotational grazing

F-Test Two-Sample for Variances	*Continuous*	*Rotational*
Mean	135.59	145.35
Variance	678.40	1533.54
Observations	94	123
df	93	122
F	0.4424	
P(F<=f) one-tail	0.0000	
F Critical one-tail	0.7220	

We reject the null hypothesis, as both the p-values are less than 0.05, therefore the means are statistically different.

t-Test: Two-Sample Assuming Unequal Variances	*Continuous*	*Rotational*
Mean	135.59	145.35
Variance	678.40	1533.54
Observations	94	123
Hypothesized Mean Difference	0	
df	211	
t Stat	-2.2008	
P(T<=t) one-tail	0.0144	
t Critical one-tail	1.6521	
P(T<=t) two-tail	0.0288	
t Critical two-tail	1.9713	

We reject the null hypothesis, as both the p-values are less than 0.05, therefore the means are statistically different.

T-test for Grazing Length by region: North and Peace region

Includes responses that did either continuous or rotational grazing

F-Test Two-Sample for Variances	*Continuous*	*Rotational*
Mean	139.69	138.44
Variance	579.98	1443.71
Observations	26	34
df	25	33
F	0.4017	
P(F<=f) one-tail	0.0105	
F Critical one-tail	0.5257	

We reject the null hypothesis, as the p-values are less than 0.05, therefore the means are statistically different. The below test is for unequal variance.

t-Test: Two-Sample Assuming Unequal Variances	*Continuous*	*Rotational*
Mean	139.69	138.44
Variance	579.98	1443.71
Observations	26	34
Hypothesized Mean Difference	0	
df	56	
t Stat	0.1555	
P(T<=t) one-tail	0.4385	

t Critical one-tail	1.6725
P(T<=t) two-tail	0.8770
t Critical two-tail	2.0032

We do not reject the null hypothesis, as both the p-values are higher than 0.05, therefore the means are not statistically different.

T-test for Grazing Length by region: Central region

Includes responses that did either continuous or rotational grazing

F-Test Two-Sample for Variances	*Continuous*	*Rotational*
Mean	134.91	144.90
Variance	528.34	1301.29
Observations	47	71
df	46	70
F	0.4060	
P(F<=f) one-tail	0.0007	
F Critical one-tail	0.6330	

We reject the null hypothesis, therefore the variances are statistically different

t-Test: Two-Sample Assuming Unequal Variances	*Continuous*	*Rotational*
Mean	134.91	144.90
Variance	528.34	1301.29
Observations	47	71
Hypothesized Mean Difference	0	
df	116	
t Stat	-1.8365	
P(T<=t) one-tail	0.0344	
t Critical one-tail	1.6581	
P(T<=t) two-tail	0.0688	
t Critical two-tail	1.9806	

We do not reject the null hypothesis, as the two-tailed p-value is higher than 0.05, therefore the means are not statistically different. But the one-tailed p-value is lower than 0.05.

T-test for Grazing Length by region: South region

Includes responses that did either continuous or rotational grazing

F-Test Two-Sample for Variances	*Continuous*	*Rotational*
Mean	132.00	160.17
Variance	1177.90	2515.91
Observations	21	18
df	20	17
F	0.4682	
P(F<=f) one-tail	0.0531	
F Critical one-tail	0.4615	

We do not reject the null hypothesis, therefore the variances are not statistically different

t-Test: Two-Sample Assuming Equal Variances	*Continuous*	*Rotational*
Mean	132.00	160.17
Variance	1177.90	2515.91
Observations	21	18

Pooled Variance	1792.662162
Hypothesized Mean Difference	0
df	37
t Stat	-2.0711
P(T<=t) one-tail	0.0227
t Critical one-tail	1.6871
P(T<=t) two-tail	0.0454
t Critical two-tail	2.0262

We reject the null hypothesis, as both p-values are lower than 0.05, therefore the means are statistically different.

7.2.2 Stocking Rates

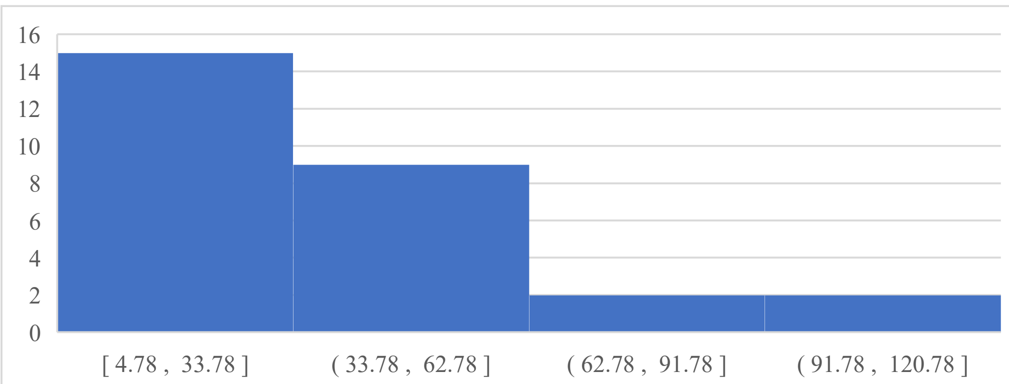

Figure 58. Histogram, stocking rate for continuous grazing without outliers (using IQR method).

Kolmogorov-Smirnov Test Calculator - To test normality of stocking rate for continuous grazing

Hypotheses:

- H_0: Normal distribution
- H_1: Other distribution

Test Results: We reject the H_0, then distribution is not normal.

Parameter	Value
p-value	0.3454
D	0.1227
Sample size	28
Average (x)	36.6596
Median	31.055
Sample Standard deviation	24.98
Sum of squares	16848.0043
K	0.6492
Skewness	1.0204
Excess kurtosis	0.9471

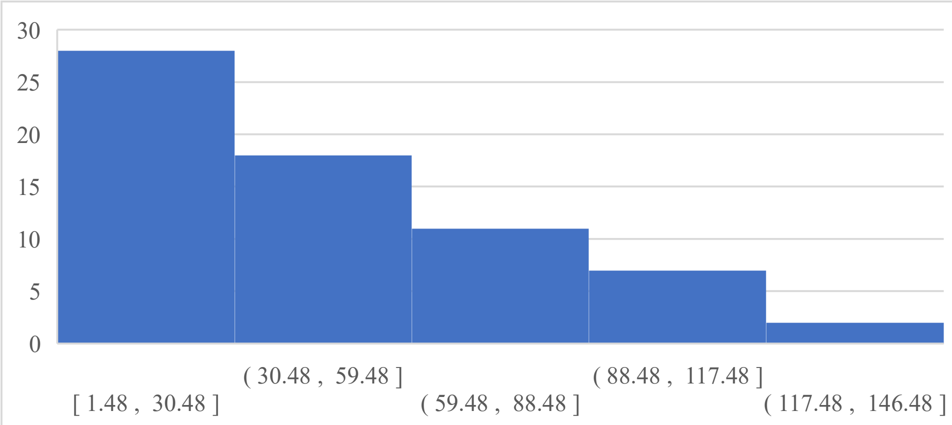

Figure 59. Histogram, stocking rate for rotational grazing without outliers (using IQR method).

Kolmogorov-Smirnov Test Calculator - To test normality of stocking rate for rotational grazing

Hypotheses:

- H_0: Normal distribution
- H_1: Other distribution

Test Results: We reject the H_0, then distribution is not normal.

Parameter	Value
p-value	0.03784
D	0.1124
Sample size	66
Average (x)	45.2836
Median	38.015
Sample Standard deviation	33.9668
Sum of squares	74993.4837
K	0.9128
Skewness	0.6533
Excess kurtosis	-0.664

Mann Whitney Test

To test if means are the same for no normal distributions.

Parameter	Value	
Test statistics W	832	
p-value	0.451599	
Null Hypothesis	$\mu_0 = 0.0$	
Alternative Hypothesis: two sided	$\mu\hat{} \neq \mu_0$	
95% confidence interval	-19.65	7.14
Sample estimate of difference in location	$\mu\hat{} = -4.2250$	

<u>**Interpretation**</u>: there is no difference in terms of central tendency; the means are not statistically different between the stocking rates for continuous and rotational grazing.

T-test for Stocking Rates by region: North and Peace region

F-Test Two-Sample for Variances	*North and Peace Stocking Rate (AU/Acre) - NO OUTLIERS*	*North and Peace Stocking Rate (AU/Acre) - NO OUTLIERS*
Mean	49.83	45.91
Variance	978.47	1462.84
Observations	10	20
df	9	19
F	0.6689	
P(F<=f) one-tail	0.2733	
F Critical one-tail	0.3393	

Null Hypothesis is that variances are equal. p-value is higher than 0.05. We cannot reject the null hypothesis. Results tells us that the variances are not statistically different.

t-Test: Two-Sample Assuming Equal Variances	*North and Peace Stocking Rate (AU/Acre) - NO OUTLIERS*	*North and Peace Stocking Rate (AU/Acre) - NO OUTLIERS*
Mean	49.83	45.91
Variance	978.47	1462.84
Observations	10	20
Pooled Variance	1307.15	
Hypothesized Mean Difference	1	
df	28	
t Stat	0.2086	
P(T<=t) one-tail	0.4181	
t Critical one-tail	1.7011	
P(T<=t) two-tail	0.8363	
t Critical two-tail	2.0484	

Null Hypothesis is that the population means are equal. p-value is higher than 0.05. We cannot reject the null hypothesis. Results tells us that the means are not statistically different.

T-test for Stocking Rates by region: Central region

F-Test Two-Sample for Variances	*Central Stocking Rate (AU/Acre) - NO OUTLIERS*	*Central Stocking Rate (AU/Acre) - NO OUTLIERS*
Mean	32.95	50.09
Variance	204.25	1040.18
Observations	9	37
df	8	36
F	0.1964	
P(F<=f) one-tail	0.0103	
F Critical one-tail	0.3273	

Null Hypothesis is that variances are equal. p-value is less than 0.05. We reject the null hypothesis. Results tells us that the variances are statistically different.

t-Test: Two-Sample Assuming Unequal Variances	*Central Stocking Rate (AU/Acre) - NO OUTLIERS*	*Central Stocking Rate (AU/Acre) - NO OUTLIERS*
Mean	32.95	50.09
Variance	204.25	1040.18
Observations	9	37
Hypothesized Mean Difference	1	

df	30
t Stat	-2.5450
P(T<=t) one-tail	0.0082
t Critical one-tail	1.6973
P(T<=t) two-tail	0.0163
t Critical two-tail	2.0423

Null Hypothesis is that the population means are equal. p-value is less than 0.05. We reject the null hypothesis. Results tells us that the means are statistically different.

T-test for Stocking Rates by region: South region

F-Test Two-Sample for Variances	*South Stocking Rate (AU/Acre) - NO OUTLIERS*	*South Stocking Rate (AU/Acre) - NO OUTLIERS*
Mean	25.73	24.11
Variance	434.09	606.58
Observations	9	9
df	8	8
F	0.7156	
P(F<=f) one-tail	0.3236	
F Critical one-tail	0.2909	

Null Hypothesis is that variances are equal. p-value is higher than 0.05. We cannot reject the null hypothesis. Results tells us that the variances are not statistically different.

t-Test: Two-Sample Assuming Equal Variances	*South Stocking Rate (AU/Acre) - NO OUTLIERS*	*South Stocking Rate (AU/Acre) - NO OUTLIERS*
Mean	25.73	24.11
Variance	434.09	606.58
Observations	9	9
Pooled Variance	520.33	
Hypothesized Mean Difference	0	
df	16	
t Stat	0.1509	
P(T<=t) one-tail	0.4410	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.8820	
t Critical two-tail	2.1199	

Null Hypothesis is that the population means are equal. p-value is higher than 0.05. We cannot reject the null hypothesis. Results tells us that the means are not statistically different.

7.2.3 Mixed operations and pure cropping operations

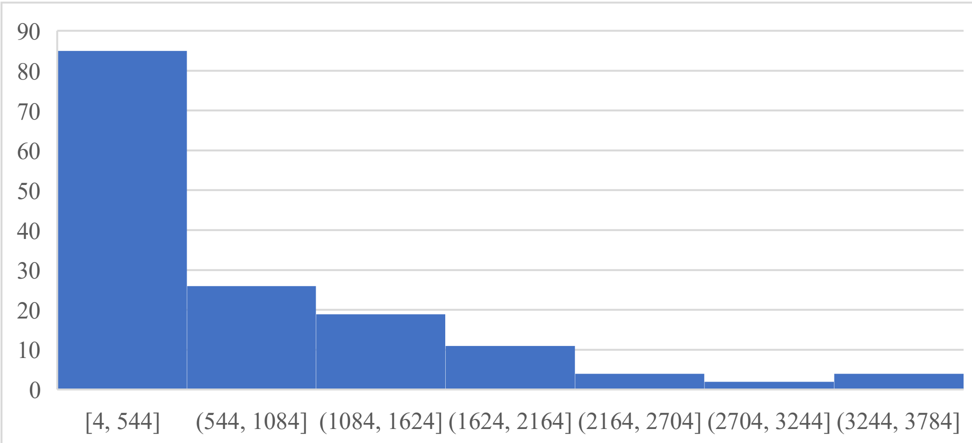

Figure 60. Histogram, acreage of mixed operations without outliers (using IQR method).

Kolmogorov-Smirnov Test Calculator - To test normality of acreage size for mixed operations

Hypotheses:

- H_0: Normal distribution
- H_1: Other distribution

Test Results: We reject the H_0, then distribution is not normal.

Parameter	Value
p-value	$1.062e^{-11}$
D	017.52
Sample size	144
Average (x)	634.4931
Median	400
Sample Standard deviation	697.0846
Sum of squares	56232625.9931
K	2.1023
Skewness	1.0985
Excess kurtosis	0.1101

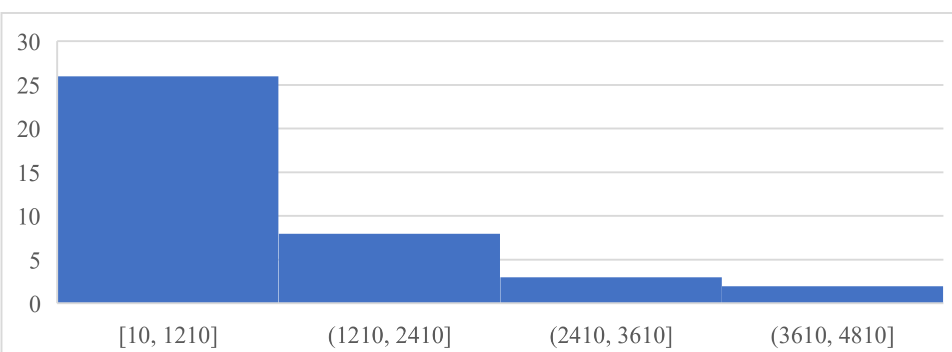

Figure 61. Histogram, acreage of pure cropping operations without outliers (using IQR method)

Kolmogorov-Smirnov Test Calculator - To test normality of acreage size for pure cropping operations.

Hypotheses:

- H_0: Normal distribution
- H_1: Other distribution

Test Results: We reject the H_0, then distribution is not normal.

Parameter	Value
p-value	0.004546
D	0.1736
Sample size	39
Average (x)	1146.641
Median	1010
Sample Standard deviation	1209.3096
Sum of squares	55572084.9744
K	1.0843
Skewness	1.2252
Excess kurtosis	0.954

Mann Whitney Test

To test if means are the same for no normal distributions.

Parameter	Value	
Test statistics W	2583	
p-value	0.238867	
Null Hypothesis	$\mu_0 = 0.0$	
Alternative Hypothesis: two sided	$\mu\text{^} \neq \mu_0$	
95% confidence interval	-570.00	50.00
Sample estimate of difference in location	$\mu\text{^} = -99.999968$	

Interpretation: there is no difference in terms of central tendency; the means are not statistically different between the acreage size for mixed and pure cropping operations.