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Grazing Ruminants: A Long-Term Solution to Agriculture Profitability, Productivity and Climate Change

Ryan Boyd

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NUFFIELD CANADA

Nuffield Canada Agricultural Scholarships

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Scholarships are available to anyone between the ages of 25 and 50 involved in agriculture in any capacity of primary production, industry or governance.

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2. Stand back from their day-to-day occupation and study a topic of real interest;
3. Achieve personal development through travel and study; and
4. Deliver long-term benefits to Canadian farmers and growers, and to the industry as a whole.

Applications are due annually. Visit Nuffield.ca for more information.

SCHOLAR PROFILE

I farm with my family near Forrest, Manitoba orchestrating the conversion of sunlight energy into beef and small grain crops. I first became enamoured with grazing systems as a young farmer obsessed with defining a place on our farm to build a life for myself, and now young family. When I came off the combine to register for university classes one August afternoon, it must have been a decent harvest as I registered for first year agriculture instead of engineering. A farm boy through and through, it did not take long to realize this was the correct decision and a few short years later I graduated from the University of Manitoba in 2005 with an agriculture degree in agronomy. Returning home to my dad and grandpa's side we began the pursuit towards a resilient farming system able to withstand weather and market extremes and give a higher quality of life than what was the current situation. I was drawn to the writings of Allan Nation, Allan Savoury, Jim Gerrish, and Greg Judy and found myself in Edmonton that winter at a Ranching for Profit School lead by Dave Pratt. Holistic management seemed logical and with these influences and the seeds planted in my mind at university it seemed that a grazing system that mimicked the natural prairie ecosystem, employing diversity and grazing ruminants to build fertility and soil organic matter would be a low risk, satisfying means to fulfilling my dream of farming. A plan was conceived to convert our grain farm into a perennial grazing operation with minimal machinery and leverage the biggest asset I had, young energy and a passion for management intensive grazing.

We have tried many new ideas over the years to improve our bottom line and enhance the resources we farm within our holistic context. Some of these ideas have worked well and others not. My insatiable appetite for learning and passion for agriculture is what lead me to Nuffield and prompted my application to the program.

ACKNOWLEDGMENTS

The Nuffield scholarship came at a time when I needed to refocus efforts on the farm and refresh my energy in life. It has been a huge success on both these fronts. I will be forever grateful to my wife Sarah for her incredible support agreeing to let me throw my name in the hat and applying for a Nuffield scholarship and stepping up to the challenge as I embarked on this journey. I fretted being away from the farm, but the most daunting part of this journey was being away for extended periods of time from Sarah and our two young kids, Piper and Bingham. My mom and dad, Jim and Joanne, have always been open-minded and supportive to my wild ideas and the Nuffield scholarship was no exception. Thank you for all the sacrifices you have made and the opportunities you have given myself and to our family!

I would have never taken the Nuffield plunge had it not been for the encouragement of several mentors over the years. Thank you for the gentle nudge that has had such a profound impact.

Thank you to the Nuffield family and agriculture community in Canada and abroad that have been so gracious with your time, hospitality, and wisdom, helping guide my research and travel plans to shape my thoughts on agriculture around the world and how these insights might be applied here in Canada.

SPONSORSHIP

My Nuffield Scholarship was sponsored by the **Western Grains Research Foundation**. With the help of my father-in-law, Bernie Whetter – successful business and community man in the Westman area, we received a great deal of additional sponsorship for my Nuffield experience and global travels. I was overwhelmed by the support given by businesses, organizations, friends, and family as we explained the Nuffield program and the great opportunity that lay ahead.

The many sponsors that stepped forward on my behalf included:
Manitoba Forage and Grasslands Association
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Northstar Seeds
Wheat City Seeds
SGB Agronomics – Steve Beaumont
Foothills Forage and Grazing Association
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EXECUTIVE SUMMARY

Grazing ruminants are an integral part of the long-term success of agriculture production systems. It was grazing ruminants that allowed the deep rich topsoil of the prairies around the world to develop as they migrated across the landscape in concert with a plethora of diversity. The inclusion of grazing ruminants allow diversity to exist on the farm that is unparalleled by any other agriculture production system. It is this diversity in plants and animals that allows soil microbes to thrive sequestering carbon, creating a resilient farming system that can withstand weather extremes and mute pest outbreaks. A more circular farming system is created when grazing ruminants are the focus. Less external costs are realized as water is used effectively and efficiently, nutrients stay on farm and habitat is created and conserved as insects, birds and wildlife thrive in concert with the grazing animals. Beef cattle can add value to the by-products of grain production and can serve as the source of soil fertility for highly productive agriculture systems.

Non-selective, ultra high stock density grazing provides an opportunity to create a profitable enterprise grazing perennial forage while dramatically enhancing the soil and the landscape. To get the most benefit from grazing ruminants, effective water management is critical, including maximizing water infiltration and water retention on the landscape. In addition to a growing demand for these outcomes, pasture raised meats can be marketed and sold within local markets.

DISCLAIMER

This report has been prepared in good faith but is not intended to be a scientific study or an academic paper. It is a collection of my current thoughts and findings on discussions, research and visits undertaken during my Nuffield Farming Scholarship.

It illustrates my thought process and my quest for improvements to my knowledge base. It is not a manual with step-by-step instructions to implement procedures.

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In submitting this report, the Scholar has agreed to Nuffield Canada publishing this material in its edited form.

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 What is all the fuss about grazing ruminants?

Prairies are the breadbaskets of the world and these highly productive soils developed because of incredibly complex grassland ecosystems that depend on periodic grazing of large herds of ruminant animals. The high carbon content of the prairie soils gives them this inherent productivity even after being tilled and losing 30-55% of the soil carbon. (Bork E. , 2019) Crop rotations containing high levels of diversity and increased "perenniality" have shown increased levels of organic matter in the soil. (King & Blesh, 2017)

Even in the absence of grazing ruminants, perennial forage and reduced soil organic matter, modern production systems are very capable of producing the world's needs in terms of bulk commodities. When looking at the current trends, yields are increasing and are showing no signs of faltering in the face of contrasting weather extremes. Technology advancements coupled with increased fertilizer and pesticide use give credit to the unprecedented ability of today's farms to produce.

The same technological revolution that has led to the great efficiencies of our modern agricultural systems that is shedding light on the microbial wonders that are happening in abundance all around us. Soil microbes are responsible for 70% of organic matter in the soil and effectively managed grazing ruminants compliment this microbial life by allowing a diversity of plants to exist in the grasslands and fields. They provide a microbial inoculant to the ecosystem through manure.

Soil carbon is increasingly important as we are coming to terms with the reality of climate change and associated demands for the reduction of greenhouse gas emissions. The Paris Agreement looks to limit global warming to well below 1.5 degrees Celsius and the United Nations' Intergovernmental Panel on Climate Change (UN IPCC) outlines that net zero of greenhouse gas emissions must be achieved by 2050 to reach this goal. (IPCC, 2018) The government of Canada has plans to increase the Carbon tax to $170 per tonne by 2030 to discourage fossil fuel use. (Tasker, 2020) This will present large challenges to the current food production systems, which are heavily dependant on fossil fuel use. Grazing ruminants offer opportunities for systemic change in the way we produce food by allowing less need for fossil fuel derived inputs while sequestering carbon in the soil and enhancing biodiversity on the landscape.

From an agriculture succession viewpoint, new entrants to farming are finding it easier to establish a grazing operation as it does not require major investments in machinery and land, and the local demand for food is creating a viable market to sell pasture raised meats. Are we on the verge of a reversal of the trend started so many years ago by The Dominion Lands Act, aka the "Homestead act," demanding the breaking of prairie for the purpose of growing crops in exchange for land ownership?

In a traditional sense, for those willing to embrace the added complexity of managing grazing animals, there is plenty of opportunity to profitably integrate grazing ruminants into the current production systems to add value to by-products and up-cycle high roughage feedstock that are only of use to ruminant animals. For those looking to rethink the entire production system with a focus on long term resilience, both profitable and ecologically sound, grazing ruminants become a centrepiece to the system.

1.2 Current state of grazing industry in Canada

Grasslands are some of the most biological diverse ecosystems on the planet and cover between 31-43% (41-56 million square km) of the earth's surface. (PCAP, 2019) There is approximately 11 million hectares of grasslands on the Canadian prairies and livestock grazes 90% of this mass. Farmers and ranchers own most of this grassland and market signals for annual crop production are contributing to the declining grassland area in Canada. The World Wildlife Federation estimates 2.1 million acres of North America's great plains were lost in 2018, including 550,000 acres in the northern great plains region. (WWF, 2020) The Statistics Canada 2016 Census of Agriculture shows a 16.6% decline in hay and alfalfa cropland and a 4.4% decrease in pasture area. (Canada, 2017) Alarms are being raised that the prairie ecosystem itself is endangered, not only the many species that live exclusively in the prairie habitat.

A vibrant beef industry is critical to the preservation of grasslands and incentivizing the planting of tame forages. Approximately 80% of Canada's beef production occurs while the cattle consume forage. Winter-feed is the largest cost to cow calf production and a shift to relatively higher yielding corn silage instead of hay has contributed to the decline in perennial forage. Major advances in hay yields have not occurred with yields peaking in 1980's. (BCRC, 2017)

Improved grazing management has been credited with better forage growth and economic outcomes on farm but complex hard to measure interactions between plants, animals, environment and management make it difficult to quantify these gains. (Teague, Provenza, Kreuter, Steffens, & Barnes, 2013) Much of the advancements in grazing management has

come from farmers and ranchers honing their grazing systems through experience and observation and sharing in peer-to-peer interactions, and networking.

Beef consumption in Canada and the US, our biggest market for Canadian beef has declined slightly over the past thirty years. (CanFax, 2020) Demand growth in countries like Japan and China have positive impacts on the Canadian beef market and new trade deals offer opportunity. New trade deals are expected to have more ecological strings attached and Canada will need to continue as a world leader producing environmentally sound agriculture products.

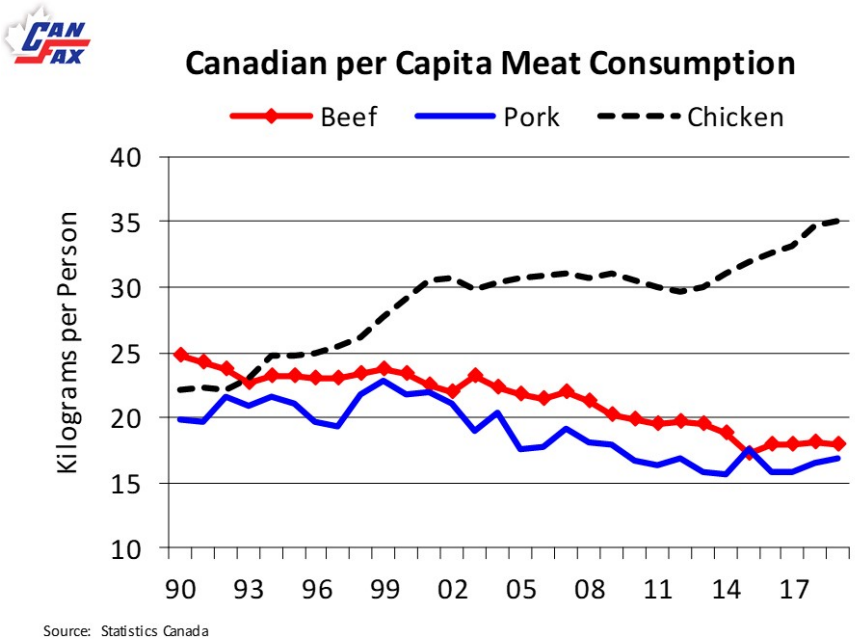


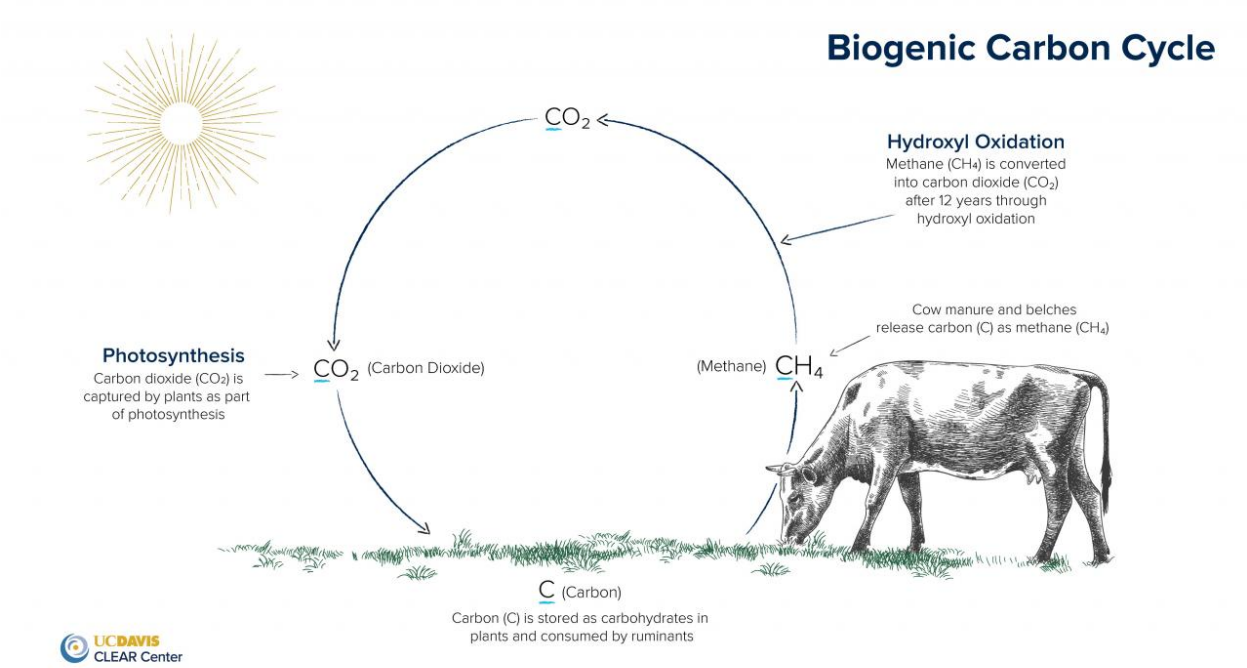
Figure 1: Canadian per Capita Meat Consumption. Source: CanFax

1.3 Beef: the Original Plant Based Protein

Beef is one of the most wholesome, nutritious, ecologically sound foods available, yet alternatives are being developed. The media has not been friendly towards animal agriculture and in particular ruminant agriculture for several unfounded reasons including methane emissions, production efficiencies, and health concerns of red meat.

As a whole, the livestock supply chains worldwide contributes 14.5% of total anthropogenic emissions, including methane production. Upon closer examination, developing countries where efficiencies are not comparable to the developed world are responsible for 70-80% of the global livestock emissions. (FAO, 2017) Agriculture in Canada emits 8% of the countries total emissions and the beef industry makes up 2.4% of the countries emissions. (CCA, 2020)

It is said that, 70% of the beef industry emissions are from methane. It has been shown that adaptive multi-paddock (AMP) grazing on the Canadian prairies reduced methane emissions considerably when compared to non-AMP grazing. (Shrestha, et al., 2020) A complete lifecycle analysis considering carbon sequestration of grass-fed beef produced at White Oak Farms in Georgia showed grass-fed beef was carbon negative. (Thorbecke & Dettling, 2019) Most importantly, methane breaks down into carbon dioxide and water in the atmosphere over a period of 10 years creating a natural cycle with plants consuming the carbon dioxide through photosynthesis and achieving equilibrium when animal numbers remain constant.



https://clear.ucdavis.edu/explainers/biogenic-carbon-cycle-and-cattle

Figure 2: Biogenic Carbon Cycle. Source: UC Davis

The positive environmental impact of grazing ruminants cannot be understated. For decades Allan Savoury has advocated that under holistic grazing, ruminants are the best method to combat desertification globally and regenerate landscapes where productive grasslands once existed. (Savory & Butterfield, 1998) Here on the prairies, it is easy to see the biodiversity that can thrive within the grasslands, both native and tame. Yet, consumers are still bombarded with the notion that cattle are bad for the environment. In the 2020 Eat Lancet Commission Summary Report scientists claimed: "Transformation to healthy diets by 2050 will require substantial dietary shifts. Global consumption of fruits, vegetables, nuts and legumes will have to double, and consumption of foods such as red meat and sugar will have to be reduced by more than 50%. A diet rich in plant-based foods and with fewer animal source foods confers both improved health and environmental benefits." When Dr. Frank Mittloehmer questioned

the reports authors on the scientific basis of these claims regarding less meat consumption and associated environmental benefits the authors clarified that "the meat consumption limits proposed by the commission were not set due to environmental considerations, but were solely set in light of health recommendations." (Mittloehmer, 2019) These health recommendations are not without criticism either. Nina Teicholz debunks the health concerns surrounding saturated fat and red meat in her book "The Big Fat Surprise". (Teicholz, 2014) Beef is a nutrient dense food and a growing body of scientific evidence is shedding light on many health benefits of red meat that previous generations seemed to know instinctively.

Recommended reading for more info about why we should include beef in the diet and the positive impact this has on the landscape:
The Big Fat Surprises, Nina Teicholz
The Carnivore Diet, Shawn Baker
The Carnivore Code, Paul Saladino
The Sacred Cow, Diana Rogers and Robb Wolf
Defending Beef, Nicolette Hahn Niman

1.4 Regenerative Agriculture

The soil health movement has been gaining momentum for the last 15 years thanks to the likes of Gabe Brown, Jay Fuhrer and the hub for soil health supporters they have created in Burleigh County, North Dakota. Livestock integration is one the five key principles of soil health and becomes a goal of most farmers who are pursuing healthier soils. The USDA estimates that less than 1% of acres in the US are managed using all five of the soil health principles. I would suggest that this number is not much different internationally and the most illusive principle of soil health on cropland is livestock integration.

The soil health movement has recently broadened into what is being referred to as Regenerative Agriculture. Regenerative Agriculture assumes that we can effectively grow food in a manner that is continually enhancing the resources in which we farm. This includes improving soil quality, biodiversity, profitability, health and well being of the farmers, resiliency of the farming system and the vibrancy of the local communities; all very noble and ambitious goals. Farmers open to regenerative agriculture agree that we have reduced the diversity of our farming systems to the point where they have become vulnerable to pest and disease pressure and rely heavily on external inputs to maintain the current and increasing productivity. This has led to many external societal costs including degraded water quality, increased extremes in stream and river flows and a loss of biodiversity.

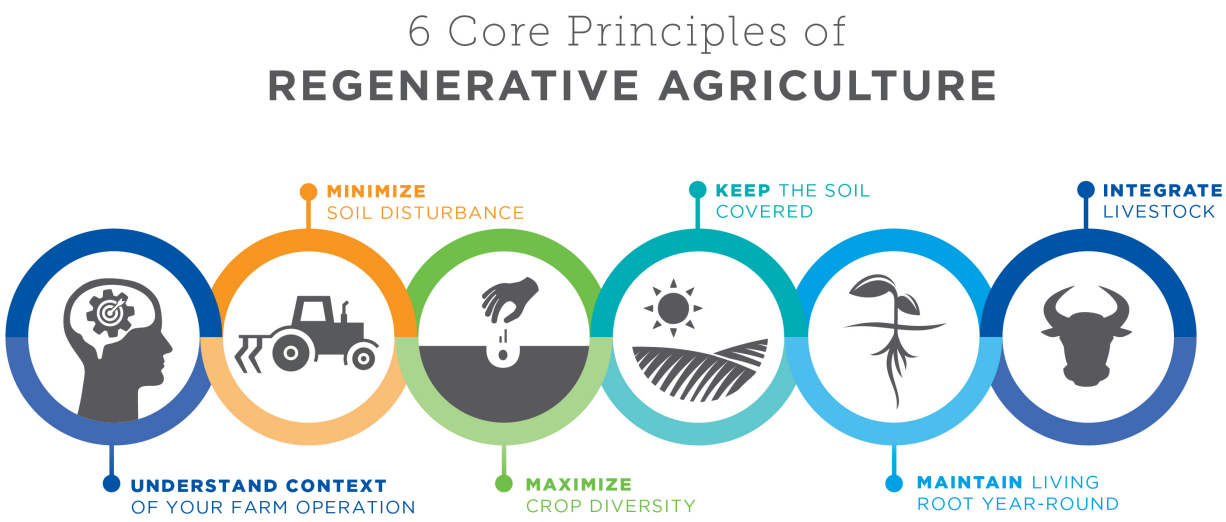


Figure 3: Core principles of regenerative agriculture. Image credit: General Mills

There is growing interest in regenerative agriculture at both the grassroots level on the farm and with consumers and from industry leaders around the world. General Mills, international food industry giant, has committed to regenerating 1 million acres of farmland by 2030. (General Mills, 2020) This is significant considering only 1 million acres of oats were grown in the USA in 2020 and the projects initiated by General Mills are documenting outcomes of the regenerative systems that they are helping farmers adopt. Data will ultimately drive further adoption and verify what early adopters have been experiencing for decades.

The greatest challenge to implementing a regenerative strategy is how to add diversity and complexity while maintaining the efficiency and effectiveness of the system at scale. Many farmers are using cover crops, intercropping, and low disturbance direct seeding with varied rates of success. In the northern latitudes, we need to carefully consider our options for regenerative agriculture given our short growing season and often limited precipitation. Grazing ruminants offer unparalleled opportunity to add diversity to the system and many agronomic and ecological benefits come with this addition of diversity while providing an extremely valuable nutrient dense food source.

Can grazing ruminants be competitive with annual cash crops from a profitability standpoint on good quality arable land? Or should grazing ruminants be utilized only to add value to by-products of crop production in regions with higher quality soils and kept on marginal lands where soils are too sensitive for annual cropping?

Where does it make the sense to integrate grazing ruminants on the agriculture landscape and what are the best means to capitalize on these opportunities?

“Production is vanity, profit is sanity.” Craig Mckenzie, N Sch. New Zealand

1.5 Travel Details

I set out on a journey to find farmers and researchers who were having success with grazing ruminants and tried to identify common themes between different environments, markets and political circumstances. The willingness to embrace the management complexities that are involved with grazing animals, capitalizing on marketing opportunities, and effective water management were all paramount to successful integration of grazing ruminants on the farms I visited.

My Nuffield scholarship began with what is referred to as a Global Focus Program in which I travelled with six other new Nuffield friends from various countries including New Zealand, Australia, UK and Ireland. We visited the United States, Mexico, Brazil, the Netherlands, and New Zealand meeting with researchers, producer groups, businesses, and government representatives to understand the current state of agriculture affairs in each country. It was a real eye opener for this prairie boy and an experience that has left lasting effects on how I view agriculture and the world.

On the personal studies component of my scholarship, I travelled within Canada, United States, Australia, New Zealand, and the United Kingdom. Most of my time was spent on farms looking at different grazing systems and visiting grazing consultants and researchers.

Travel plans were cut slightly short with the Covid-19 pandemic taking grip of the world mid March of 2020.

2.0 Grazing Ruminants

Farmers are drawn to improving the soil. There is something about healthy soil that is obvious when you see it, hold it in your hands and smell it. Soil is alive and something about this life resonates with us. This is what draws people to soil health and regenerative agriculture and eventually leads them to the notion that grazing ruminants are necessary. This can be dangerous because when drawn to grazing ruminants for the soil health benefits it is quite easy to lose focus on economics. The most successful farmers I visited had an exceptionally good handle on economics and made management decisions accordingly. Grazing ruminants offer a unique balance between our need for increasing biodiversity on the landscape and a viable business foundation to produce high quality nutritious food.

Top managers around the world are realizing the benefits that grazing ruminants bring to the system. Most frequently, this occurs on soils and environments that are less than ideal. Brazilian farmers in the Mato Grosso region on lighter land are utilizing a short perennial phase in their crop rotation to improve soil quality and boost overall profit in rotation with soybean crops by 20%. In West Australia, the Fowler family utilize cattle and sheep in their cropping system grazing cash crops of canola and cereals in their vegetative state and grazing crop residues during the summer. Andrew Fowler attributes the consistent success of their operation to this integrated system which has seen their land base shift over the last 20 years from two thirds pasture and one third crop to two thirds crop and one third pasture while not sacrificing stocking rate on the farm. With results like this you would suspect that these methods would be standard practice for these regions but that is not necessarily the case. Richard Teague, grazing systems researcher from Texas, noted in an ongoing study comparing neighbouring farms showed clearly that adaptive multi-paddock grazing (AMP grazing) was positive in most all the metrics that they measured including overall profitability and forage growth. (Teague, 2020) Increased profit from improved forage and animal productivity was not enough, it was when researchers demonstrated that there was an increase in birdlife on the farm with AMP grazing that the owner of the conventionally grazed property became most interested in the results and considered making changes. In this case, the farmer was an avid hunter and potentially improved quarry was ultimately what resonated with him. It can be hard to break loose from our current paradigms, requiring more than simple profit metrics in some cases.

On the flip side, just because grazing ruminants are included in the farming system does not mean by default that the system will be successful and have all positive outcomes. This was obvious in New South Wales, Australia that was coming out of an intensive multi-year drought. Paddocks where sheep had been allowed to overgraze were very vulnerable to erosion whereas

appropriate management set paddocks up for explosive growth when the rain returned. By contrast, in the wetter climate of the Canterbury Plains of New Zealand where grazing animals were an integral part of their cropping systems, farmers were challenged by excess nitrates passing through the soil profile into the ground water.

It is obvious that there is plenty of room to tweak the current production systems around the world, including Canada, to continue to improve and stabilize production. Simple crop rotational benefits can lead to substantial gains. Conservation agriculture, or zero-till as we refer to it, can lead to significant benefits. While visiting CIMMYT (International Maize and Wheat Improvement Center) near Obregon, Mexico, yield gains of wheat from breeding have plateaued and the current breeding focus is centred on staying ahead of ever evolving disease pathogens. However, a plot showcasing simple crop rotations and reduced tillage resulted in yield gains of 20% and greater. Nothing new or shiny about crop rotation or conservation tillage, Dr. Dwayne Beck has advocated for the benefits of crop rotation for years showing similar results on his field scale trials near Dakota Lakes, South.

Once we open our minds, the potential to create a farming system that utilizes grazing ruminants as an integral part become broad, including silvopasture systems for timber or fruit production, cover crop grazing, relay cropping, "stock cropping", or pasture cropping. If we are to be successful making grazing ruminants a centrepiece of the farming systems in Canada it must be just that, a part of a diverse, intentional, outcome-based system.

2.1 Where are the opportunities

Ruminant animals "up-cycle" high roughage forage in their unique digestive tract, which begins with the microbial active rumen, creating high value meat, milk, fibre, and fertilizer via manure. Most cattle in western Canada are performing this role on native rangeland and where grain production is predominant, ruminants consume grain by-products including straw, chaff, protein meals, and poor quality grains. There is plenty of opportunity to expand on these already occurring practices.

The biggest opportunity for grazing ruminants in our agriculture systems is to function as soil building architects while providing high value meat. With thoughtful management, the production of grazing ruminants can be financially competitive on highly productive soils and second to none in the ecosystem services provided by a food production system.

Figure 4: Loran Steinlage showing off his no-till corn grown with no synthetic fertilizer or chemicals in an old hay field near West Union, Iowa. Photo credit: Ryan Boyd

Many farmers are working on developing complex systems integrating cover crops and more diversity into the cash cropping system and there is good potential from different pasture cropping regimes, which seek to grow an annual crop within a perennial pasture. Pasture cropping would be a breakthrough for cropping systems as it enables the benefits of perennial plants to persist through the cash crop sequences, whereas the perennials would normally be terminated to make way for the annual crops causing soil carbon and its associated benefits to decline. To establish the annual crop in the perennial pasture some level of disturbance is required either mechanical, chemical or grazing, or any combination of these three. The success of this technique is very dependant on the dormancy of the perennial and adequate moisture giving an opportunity to establish the annual plants. The short, intense growing season here in Canada requires careful calculation of cost and the consideration to the risk that small windows of opportunity present when trying to time disturbances and establishment.

Figure 5: Cereal rye established in an orchard grass pasture in Scotland on Andrew and Bob Brewster's farm. Photo credit: Ryan Boyd

A mixture of annual forages planted in the spring and allowed season long growth is one method to rapidly change soil structure and function. These mixtures can be cost effective, high quality feed during the late fall and winter. Perennial forage will always be the most economical forage during the growing season. It is difficult for annual forages to compete with perennial pasture during periods of adequate moisture and rapid growth on a cost basis. The lack of warm season crops in current crop rotations in western Canada, coupled with the ability of the warm season annuals to grow significant tonnage make them an ideal choice for winter feed, especially when legumes are added to provide protein to balance the ration in the dormant season. If a crop rotation were adopted utilizing perennial pastures it would be plausible to use the annual forage crop as a cover crop to establish the perennial forage. This mimics natural succession as the diverse annual planting act as pioneer species preparing the soil for the higher successional perennial plants. If there is any weed pressure in the annual crop, those weed issues will be taken care of in subsequent years grazing the perennial forage.

In short growing seasons here in northern latitudes an intensive grazing system of perennial forage coupled with a diverse mixture of annual forage for winter-feed is where the biggest opportunity lies. Perennials could be grazed indefinitely or as a part of a crop rotation with annual crops. Imagine combining the pristine sod our forefathers had the opportunity to farm with modern machinery and the technology that exists today.

2.2 Perennial Forage

Feed cost, and thus stocking rate, is the biggest factor determining profitability of a grazing operation. Higher stocking rates generally do not increase direct costs substantially and reduce overhead costs per unit of production. For example, if you increase stocking rate by two times, and your beef production per unit stayed constant or at least does not reduce by 50% per unit then you are more profitable. When determining a baseline goal of production on your pastures one should consider the dry matter yield of a crop of hay. Most will be surprised to find that their pastures are under producing considerably when compared to hay crops under similar conditions. This is due to inefficient harvesting via grazing and an increased trample that is never realized by additional grazing or improved growth.

2.2.1 Severe, Non-Selective Grazing

The most efficient forage utilization that I witnessed was in Florida on a ranch managed by Jaime Elizondo. Jaime was able to achieve dramatic increased stocking rates, 2-4x conventional, by practicing severe, non-selective grazing. Ultra high density grazing (UHDG) enables animal densities of 500,000 pounds live weight per acre or more, he moved his cattle up to four times per day and incorporated very long recovery periods, up to one year. Jaime refers to this type of grazing system as “Total Grazing”. Not only has Jaime had success on this operation in Florida, he has also consults on ranches all over the world achieving similar results and he owns a successful grass based dairy in Mexico. At first observation this type of grazing appears extreme as 80-90% utilization of forage can be achieved in a single grazing event. Similar to mob grazing but unique in that Total Grazing is focused on remarkably high utilization, as opposed to graze half/leave half grazing philosophy some employ. By grazing this way all plants are grazed evenly, including some plants that otherwise go ungrazed with selective grazing with lower utilization rates.

After a few months of using ultra high density, severe, non-selective grazing on our farm in southwestern Manitoba, I am convinced that an increase in 2x the stocking rate is achievable with reasonable animal performance when compared to a lower utilization rate.

Those experienced with UHDG suggest that cattle densities over 800,000 pounds live weight per acre during grazing result in dramatic shifts in ecology, quality, and productivity of pastures. At these densities, cattle graze differently, more aggressively, enabling higher dry matter intake resulting in a myriad of implications that cannot be replicated in a laboratory or a simple experiment.

Figure 6: Ultra high density, non- selective grazing on South Glanton Farms near Forrest, Manitoba. Photo credit: Ryan Boyd

2.2.2 New Paradigm of Total Grazing

Root reserve-based regrowth of perennial grasses is what happens naturally and the desire for photosynthetic based regrowth is misguided. Consider the origins of best management practice to never radically defoliate a pasture. The argument for taking 50% or less while a plant is actively growing is based on research from university trials in Missouri in 1950 done by clipping plants on a short graze interval of one month or less between clippings. (Crider, 1955) The clippings were also of young plants grown in monocultures that had not been given a chance to develop a full root system prior to clipping. The clippings were taken with scissors, void of the stimulatory effect grazing action has on plants, including the tugging action on the roots, plant growth promoting effects of saliva and manure and the hoof action placing litter in contact with the soil surface. It is also a fallacy that animals will graze evenly. Animals will graze selectively given the opportunity and the residual forage will be dominated by unpalatable species and forage with low leaf to stem ratio.

Consider the regrowth of a diverse sward of pasture including plants with ample root reserves due to a long recovery period exploding after these stimulatory effects of severe non-selective grazing at high stock density versus that of a non-diverse pasture where the plants were selectively grazed in attempt to take-half-leave-half. Initially the take-half-leave-half pasture looks better as there is some green material intact and growing while the severe non-selectively grazed plants are sprouting new shoots, fuelled by the root reserves and a flurry of microbial

activity. The regrowth from Total Grazing has a much higher leaf to stem ratio. Forage with a high leaf to stem ratio is much higher in quality and much more photosynthetically efficient.

Be aware that an even graze of a non-diverse stand of immature forages can be achieved at low grazing densities. However, this can result in health issues for the animals because of protein/energy imbalances and a lack of roughage in the forage and does not result in rapid improvement to landscape function that long recovery periods allow. Long recovery periods are critical for Total Grazing to work.

2.2.3 Long Recovery Periods

As important as the disturbance created by intense grazing is to building quality soil, forage, and a healthy functioning ecosystem, the subsequent long recovery periods are even more critical. From a profitability standpoint, Total Grazing enhances stocking rate immediately by increasing forage utilization. The continued enhancement of stocking rate and animal performance comes from increased diversity of plants in the pasture stand and animals willingness to consume some species that they would not otherwise, coupled with higher leaf to stem ratio and tiller density. The long recovery period allows young seedlings to establish that have been recruited from the seed bank. Studies conducted in Texas in the late 1980's demonstrated how long rest periods of 84 days compared to 42 days contribute to secondary succession from short-grasses to mid-grasses. (Taylor, Brooks, & Garza, 1993) These new plant roots and the existing plant roots can grow and have maximum effect on reducing soil bulk density. Warm season grasses have all but disappeared from most pasture stands on the prairies and a long recovery period will allow these plants to re-establish and provide added diversity to the pastures. Warm season grasses are effective at sequestering carbon and providing abundant quality forage when the growth of cool season forages is slowing down mid summer.

A trial done in Alberta considering grass growth in plots under low and high intensity clippings (15 cm and 3 cm clipping heights respectively) at intervals of 3 weeks and 6 weeks showed that tame species of grasses known to be grazing tolerant responded most favourably high intensity low frequency clippings. (Broadbent, Bork, Cooke, & Willms, 2019) Similar field trials were conducted on mixed grass prairies with similar results. (Bork, Broadbent, & Willms, 2017) In both studies neither treatments achieved as much biomass accumulation as the control, which did not get clipped at all and allowed to grow for the entirety of growing season. There is much research to be done to verify what graziers have experienced with UHDG systems employing longer recovery periods than what conventional management intensive grazing protocols might

suggest and include all the stimulatory effects of the animals harvesting the forage. One thing is for certain; seasonal rainfall risk is greatly reduced with long recovery periods.

Long recovery periods ensure that there is adequate litter produced, as the volumes of biomass will be relatively high. The increased forage growth resulting from a long recovery followed by 90% utilization rate under UHDG and the associated increased stocking rate will leave significant litter. The forage that is trampled will be the lowest quality forage and the quality of the forage consumed will be higher than what a forage test might show. The litter will also be pressed against the ground with the hoof action of the animals where it is accessible to the soil life and protecting the soil surface as opposed to a less intense grazing at lower stock densities in which a large portion of the residual forage will be left standing.

2.2.4 How much litter do we need?

Ground cover is important to insulate the soil, buffering temperature extremes, keeping soil cool during hot summer days and warmer as temperatures drop in the fall and winter. Ground cover is necessary to eliminate soil erosion, mitigating the devastating impact of raindrops as they hit the soil destroying soil structure and protecting against searing winds. However, there is a limit depending on the outcomes that we are trying to achieve, and we must not become enslaved by the desire to leave a certain percentage of forage in the field. For example, if we were in a highly productive area producing 10,000 pounds of dry matter per acre would it make sense to leave 50% of this production as residue rotting in the field? This amount of residue would certainly keep the soil cool and limit evaporation, but it will also limit the establishment of new seedlings and the thickening of root density within the soil, which is our ultimate goal. Would it be more reasonable to put a higher percentage of this biomass through the animal, depositing the manure, setting the soil life up with greater potential to sequester carbon and stimulating an even more diverse and productive successive growth? Conversely, grazing for a high residual is unreasonable if production is very minimal, to the point where the pasture is sparse with little biomass. When these situations occur the power of the hoof action to break soil cap allowing water to infiltrate and stimulate new seedlings to grow is much more critical than the amount of residue left behind. Remember, soil organic matter itself has an insulator effect on the soil and dramatically enhances the soils ability to hold water and maintain structure. Surface litter requirements will be different depending on circumstances, but in a grazing system the best soil armour is a dense stand of live green leaves. Regardless of the environment, monitoring should be in place to ensure landscape goals are progressing and that adequate litter cover on the soil is maintained.

2.2.5 Words of Caution when Implementing a System of UHDG

Cattle need to be genetically adapted to make a system of non-selective, ultra high stock density grazing work to its full potential. Although stocking rates have the biggest impact on the overall profitability of a grazing operation, having animals that can be productive under UHDG systems is what really takes this system to the next level. The ability for an animal to grow or maintain body condition and breed while being managed under an UHDG system must be carefully selected for. Not all cattle are created equal and the selection of most cattle have been based on performance data on high concentrate rations, not under intense grazing scenarios. There is a great diversity of genetics and it is imperative that the animals that perform well under non-selective grazing are identified and used as breeding stock. In his book, "Man, Cattle and Veld," Johann Zeitsman details methods to identify and breed for adapted cattle that mature early, maintain good inherent body condition and are highly fertile. (Zietsman, 2014) Over time the selection of efficient animals will be further enhanced by epigenetics and the general experience of the herd under this type of management. (Weidmeier, Villalba, Summers, & Frovenza, 2012) (Provenza F. D., 2008)

As we work to identify and propagate functional cattle it may be necessary to strategically supplement cattle grazing non-selectively at different times of the year. The goal of this strategic supplementation is to keep dry matter intake levels high and allow reasonable levels of performance and thus profits from increased stocking rates. Manure needs to be monitored for desired consistency and supplement given as needed. Needs for supplementation, including both protein and minerals will become reduced over time as the animals become more adapted and the pasture improves in diversity and quality. Diversity is critical in animals' diet and should be maximized when establishing a new pasture stand.

When practicing UHDG there is not much room for error when deciding how much area the herd needs each day. Small changes in the amount of area given each day and the associated growth in that area, impact how much forage is available for consumption. Careful observation of animal's gut fill at the end of each day is critical. Stocking rates can go up dramatically and performance will crash if animals are not allowed to maximize their daily dry matter intake.

Graeme Hand, of Hand for the Land, an Australian holistic management consulting company and overall grazing guru recommends implementing "Safe to Fail" trials to determine what management strategies will lead to improved landscape function in your environment. (Hand, 2021) For example, in a small area graze at various stock density and plant utilization rates and observe the leading indicators of landscape function after various time out of the paddock. Leading indicators of landscape function are soil cover, basal cover of perennial grass, litter

cover, decomposition of litter cover and surface roughness. When these leading indicators are improving the stability of the landscape, water infiltration, and nutrient cycling will be positive.

Fred Provenza suggests that it takes most producers three years to implement major change successfully. (Provenza F. D., 2008) It takes time for the people, animals and the landscape to adapt to major change. The skill it takes to manage something new requires time and there is no replacement for experience. Animals need time to learn the system and offspring will learn from their mothers how to graze differently. The effects of breeding changes will take until the third year to begin to be realized as young animals become productive in breeding herd themselves.

2.2.6 Total Grazing and the Ecological Impacts

Under a system of UHDG and long recovery periods, specific pastures will only be grazed once, possibly twice per year. This means the remainder of the year the diversity explodes back to life following the stimulation that grazing brings. For example: consider a 1,000 acre farm that is in perennial forage production and grazed with UHDG once per year. Assume winter-feeding for 100 days. That leaves 265 days grazing divided by 1,000 acres equals: 4 acres per day. The portion of farm with less than 30 days regrowth is 120 acres or 12%. (Assume 30d to achieve full ground cover of green forage in the growing season.) By allowing this long recovery period of several months or more in the growing season, the habitat that is created and conserved is enormous, especially when comparing this to less intensive grazing systems or annual cropping. Quality feed for soil microbes, insects and wild animals will be available throughout the year. Living roots will be active throughout the year, even beneath snow cover and extreme temperatures, as the dense mat of forage will insulate the ground and soil life. UHDG is an effective marriage between positive ecological outcomes and profitable, low risk production.

A recent Columbian study showed improvements to soil quality within one year with intensive short-duration rotational grazing (IRG). Ranches with four times higher stocking rates than the comparison ranches had soil with lower bulk density and higher water retention capacity. Researchers also speculated that increased soil carbon on one of the IRG farms was a result of the supplement given to the cattle. (Teutscherov´a, et al., 2021) Soil macrofauna such as earthworms and beetles flourished under this type of management and are considered a good indicator of positive change to the soil quality.

AMP grazing research on the Canadian prairies showed increased water infiltration and increased carbon sequestration. (Boyce, 2019) Also, some grassland birds were shown to increase in numbers under AMP grazing when compared to conventional. More research needs

to be conducted to verify graziers' experiences with a Total Grazing system. Ecological outcome verification protocols such as the Savory Institute's EOV Program will help ensure outcomes are desirable across a myriad of environmental conditions and management. (Savory Institute, 2020)

Graeme Hand uses satellite imagery analyzed by FarmMap4D Spatial Hub, an Australian technology company, to monitor changes in percentage of green grass, non-green matter and bare ground on his client's farms and make better management decisions to positively impact landscape function. Neringla, a farm in New South Wales which Graeme has consulted on for 20 years, switched to UHDG with long recovery periods and the forage production and ground cover stabilized at a higher level than was achieved previously when prior management utilized more traditional rotational grazing.

2.3 Compounding and Cascading Effects

Allan Williams, grazing consultant and regenerative agriculture expert in the United States, talks about the compounding and cascading effects of positive management on the ecosystem. This results from a positive injection of energy into the system such as UHDG. The hoof action, evenly distributed manure, and release of the energy bound in the forage breaths new life into soil and pasture. New seedlings germinate and the tiller density increases dramatically creating a denser pasture sward, a larger solar panel and radically more fodder for the livestock above and below the ground. Following each successive grazing and recovery period more components of the system fall into place with nonlinear results.

There is a threshold that must be overcome to get past the first high utilization high density grazing, but this is softened by starting the high density grazing program on pastures that have been allowed to reach maturity later in the growing season. If very little growth exists prior to UHDG, even after a long period of recovery, then it may be necessary to fertilize pastures or employ other tactics such as bale grazing or adding poultry to the system to help prime the biological pump with an injection of nutrients in the feed and resulting manure. Caution must be taken not to present off site risks if nutrients are able to leak from the system but these techniques can work wonders to bring a farm back to life. In Georgia on White Oak Pastures, Will Harris uses a technique he refers to as a "hay bomb" to bring new land into his operation up to speed. The "hay bomb" is a bale grazing treatment that is coupled with a diverse polycrop of annual forages grazed by cattle and followed by pastured poultry prior to establishing perennial forage on fields with a long history of cash crops with synthetic inputs. In Australia on Tathra Free Range near Canberra, Luke Winder has had great success adding free-range ducks to his farming system not only as a major profit center but as a source of

nutrients from their manure turning a mostly abandoned farm into a highly productive grazing operation.

Once the soil life is functioning and forage growth is adequate, grazing should be sufficient to continue the progress, compounding and cascading. The compounding and cascading effects that soil microbes have on the soil ecosystem cannot be understated. Current estimates are that 70% of the organic matter in the soil is microbial origin. (Cotrufo, 2021) With this in mind and the marvel of exponential growth that microbes undergo, it is easy to see why regenerative farmers are so fixated on increasing the microbial life in their soils. The best way to increase soil microbes is by having functional diversity of roots growing at all times feeding microbes root exudates. It is roots, not shoots that contribute to stable mineral associated organic matter formation. (Sokol, Kuebbing, Karlsen-Ayala, & Bradford, 2019) Ruminants offer a unique ability to process shoot biomass and deposit manure on soil where it can be accessed by soil microbes and potentially add to the stable forms of soil organic matter.

2.4 Nutrient Cycling

For those wanting to engage traditional soil fertility principles focused specifically on nitrogen, phosphorus and potassium, a simple explanation as to the rapid and elevated growth following a Total Grazing event is due to the even spread of nutrients contained in the manure and urine across the pasture. We know that grazing animals excrete 80-90% or more of the minerals contained in the forage they consume. Under any grazing regime other than one of ultra high density with multiple moves per day nutrients are not spread evenly across the pasture. Managing the grazing is as much an art as it is a science when making multiple moves per day as it is critical to keep the cattle just hungry enough and waiting in the pasture for the next move throughout the day. Ideally the cattle will move into the new break, aggressively graze the available forage, and then ruminate until it is time for the next move. When the next move is given, the cattle will defecate and urinate in the already grazed piece of pasture prior to moving into the new strip of forage to repeat the process. This continues throughout the day until the final move of the day upon which the cattle will be as full as possible once finished grazing that evening. If too much forage is given in a particular move, cattle will soil and trample good forage prior to consuming it. But the biggest issue with giving too large of a break is that the cattle are likely to go lounge in different areas of the pasture, allowing manure to be distributed in an uneven pattern. This can be quite significant considering 12% protein forage consumed in one graze of 125 animal units per acre would contain 60 pounds of nitrogen and 7 pounds of phosphate. Manure applied directly pastures has been shown to greatly reduce Nitrogen losses compared to manure that accumulates in a dry lot and is later spread on the field. (Jungnitsch, 2008) Nutrients that accumulate at high rates in areas where cattle lounge

can lead to environmental issues such as nitrate leaching and greenhouse gas release, thus it is very important the manure from grazing animals be deposited evenly.

Figure 7: Even manure distribution and litter cover following Total Grazing on South Glanton Farms, Forrest, Manitoba. Photo Credit: Ryan Boyd

Manure is not simply a source of mineral nutrients, but more importantly a supply of microbes to the soil, which are essential to a well functioning resilient ecosystem. The finest compost, biological amendments, or the like, cannot rival the impact that simply adding animals to the system and applying fresh manure to the soil. Ultra high density grazing ensures that the soil is uniformly and effectively inoculated with valuable microbial life.

Microbial life is critically important to supplying nutrition to plants. Plants have a symbiotic relationship with the microbes inhabiting the soil and their rhizosphere where they exchange root exudates for nutrients and can even consume whole organisms in a process known as rhizophagy. (White, Kingsley, Verma, & Kowalski, 2018) By grazing non-selectively and producing a pasture sward with a high leaf to stem ratio, the photosynthetic efficiency of the pasture is increased. This allows plants to increase the flow of photosynthate to the roots, increasing the substrate available to barter with soil microbes for nutrients. When plants begin to grow actively and in concert with the soil microbial population, plants will achieve an increased level of health. Rates of photosynthesis can rapidly increase as well as water use efficiency of the pasture. This state is what some graziers refer to as “relaxed grass.” The forage remains vegetative longer and does not devote as much energy into its reproductive phase resulting in larger quantities of high quality forage.

Figure 8: Dense canopy of lush leaves resulting from a Total Grazing on South Glanton Farms near Forrest, Manitoba. Photo Credit: Ryan Boyd

2.5 Managing the grazing system

Stuart Austin, manager of Willmot Cattle Co in New South Wales, Australia and co-developer of the Maiagraze app, and Jim Gerrish, world renowned American grazing consultant, make it clear that for a grazing system to be profitable, it is mandatory to accurately account for forage inventory and predict the future growth with anticipated precipitation. When we implement long recovery periods and practice Total Grazing, it becomes simple to keep an inventory of the forage available on the farm. Observations are made each day of the amount of forage the cattle consume and based on this an inventory of the amount of forage present on the entire farm can be estimated. Decisions to increase or reduce stocking rates will be much easier to make knowing the amount of forage inventory several months in advance. A large buffer of forage will be built into the system eliminating the risk of short, inter season droughts that can have major impacts on a grazing system with shorter recovery periods.

A farmer once told me that he chose to pursue crop farming because he was limited to only one calf per year but the crop yield potential was much more open to the up side. If we know our feed inventory in the field and are confident with our ability to harvest it efficiently, we must be prepared to increase stock numbers when conditions permit increased forage growth. A tall order given the highly seasonal nature of the cattle production and availability of cattle for purchase or custom grazing during the summer months, but with good records of forage

inventory and reliable predictions of future growth related to precipitation, opportunities will present themselves and it is easier to make decisions to mechanically harvest feed for later use. This is especially important when we employ techniques like Total Grazing. Once you have more forage, you must use it or loose it. As Canadian Holistic Management Instructor Ralph Corcoran told me "You have to exercise your grass!"

Not only does the grass need to be exercised but the manager's observational skills need exercise and the relationship between the manager and the environment cannot be understated. The previously mentioned leading indicators of landscape function must be carefully monitored. Effective grazing management is as much an art as it is a science. When the management intensity is increased to multiple moves per day, one must have a good handle on animal performance via routine weighing and accurate accounting of forage productivity and landscape function. Each manager has a unique ability to deal with change and will want to proceed at a pace that is comfortable. Managerial instincts will improve over time with experience.

This instinct and documentation of performance may lead to the adaptation of Total Grazing only at certain times of the year depending on the circumstance. There are times of the year that it might make sense to focus more on individual animal performance and contingent financial circumstances, labour availability, and most importantly, the current context. Even if non-selective grazing is not practiced continually, cattle that have grazed under a non-selective grazing regime will better utilize the pasture or rangeland, as they will have learned to eat some plants that they would not otherwise eat due to naivety of never trying them. This can have positive impacts on stocking rate and animal health. Fred Provenza has documented improved health when animals consume a diverse array of plant secondary compounds. (Provenza, et al., 2009)

Stockmanship skills are of the utmost importance when working with livestock on the land. Not all farmers enjoy working with livestock, but all farms can benefit from inclusion of livestock. Low stress livestock handling is something that should be emphasized. It always shocks me as to how many people consider their cattle to be "hard to handle" or even "wild" when a few low-stress handling techniques would simplify and relax the whole experience for the animals and the people. Bud Williams was an absolute legend in this regard and has passed his knowledge on this subject to many people that are practicing and teaching his techniques today. If livestock is not your passion, relationships should be developed with a willing and able livestock manager to achieve a mutually beneficial relationship. This is a great way to bring new entrants into agriculture, adding the much-needed workforce back on the rural landscape.

2.6 Economics

2.6.1 Enterprise Selection

The elephant in the room, or pasture in this case, is how to make the numbers work. Obviously, if grazing ruminants allowed significant, comparable profit metrics to crop farming the acres in perennial forage would not be declining.

The mixed farms of yesterday typically had a resident cow herd. This is still advisable but the profitability of the cow herd is limited to the amount of inexpensive low quality feedstock that is available to up-cycle through the cow. When looking to add ruminants and the associated diversity they allow to the farming system, consideration must be given to what class of animals will be grazed to provide the best gross margin per unit of land. The highest to lowest value production from grazing animals would be: dairy, grass finishing, breeding stock development, backgrounding, and maintenance. Determining what class of animals we graze and how this varies at different times of year will have a dramatic impact on profitability, especially when grazing high quality productive pasture. This may mean that the beef cow herd is only milking in the green growing season, calves are early weaned and cows dropped to their maintenance requirements to capitalize on crop residues or high stocking rates on dormant forages. Strategic supplementation of stocker animals gives the most versatile and simple grazing enterprise to manage under Total Grazing but can present the most market risk. Careful financial evaluation is recommended to determine what enterprise is best and what supplements have best marginal return within your context.

2.6.2 Backgrounding calves on perennial forage under Total Grazing

The cattle market in Manitoba has been paying an average Value of Gain of $140 per hundredweight (cwt) when selling an 850 pound steer and replacing it with a 350 pound steer on the same market in the September, October, November timeframe between 2018-2020. If calves are on full feed for 181 days through the harshest part of winter and grazed in a system of Total Grazing for 183 days at a stocking rate of 150 animal unit days (aud) per acre (approximately 1 animal per acre for the grazing season), resulting in a gross margin of $350 per acre. Forage quantity and quality will improve with this management to varying degrees depending on conditions. Assuming 200 aud/acre is achievable this would allow 1.3 head per acre or $467 gross margin per acre. Gains should improve over time as pasture quality and grazing skills improve under Total Grazing management, which will also lead to reduced cost and even larger gross margins. See appendix for detailed calculations and relevant data. Gains above 1.3 pounds per day are achievable but would require a second trade during the year to buy back in lighter weight cattle. The strong seasonality of the Canadian cattle markets can

make it difficult to profitably trade cattle with lighter volumes during the summer and strong discounts for heavy feeder cattle in the spring. A critical point to note is that we are achieving gains more than 300 pounds of beef per acre at 150 aud and 410 pounds per acre at 200 aud.

These calves could swath graze or corn graze in the dormant season if adequate shelter is available which could reduce the overall cost of gain and present gross margin per acre similar to the pasture acres during the grazing season. The opportunities for extensive wintering of calves will vary greatly with environment, market and the skill of grazing manager.

2.6.3 Cow Calf Production

Straw, chaff, stover, cover crops, access to relatively inexpensive protein supplement and proportion of farmland unable to be cropped will all combine to create unique opportunities for cow calf production on any given farm. Crop farmers willing to work with graziers should be able to come to a mutually beneficial arrangement to work together. Crop rotational benefits and marketing opportunities that the cattle cycle brings need to be considered which could greatly improve gross margins.

Consistent profitability of the cow calf enterprise is dependant on adapted genetics. There is great opportunity for breeders who are able to supply seed stock that is appropriately selected for UHDG systems.

2.6.4 Environmental Goods and Services

The environmental goods and services that come with the diversity on the landscape that grazing animals allow need to be considered by policy makers, although these are not easily capitalized on and the value not easily defined. As markets for carbon sequestration develop, this could be a major contributor to the adoption of agriculture systems including perennial forages and grazing ruminants.

2.6.5 Risk

Systems involving grazing ruminants can be inherently lower risk as they rely on relatively fewer external inputs for production than alternative systems. A perennial system is even more appealing when considering the enterprises that could compliment the grazing system such as pastured poultry in a silvopasture system producing fruit or timber. The prospect of harvesting snow melt and excess runoff water from the landscape also opens a myriad of possible high value crop enterprises. Weather risk can be reduced when a system of Total Grazing is adopted

with perennial forage. Long recovery periods eliminate the vulnerability to smaller mid-season droughts and prepare the landscape to take advantage of large sporadic rain events.

2.7 Water Cycling

Farmers have a love hate relationship with water. Water is the lifeblood of our plants; not enough can be detrimental to yields, and too much can hinder growth due to flooding and make field operations difficult. Grazing systems require forage growth for as much of the year as possible and the risks associated with not enough moisture is much larger than too much. If perennial grazing systems are going to compliment and compete financially with the reduced water demand of annual cropping systems, then the water cycle will have to be managed much more efficiently.

Water infiltration should be the number one priority to fill the soil profile and recharge ground water for later use by growing plants. Secondly, run off due to snow melt and large rain events should be viewed as an opportunity to secure future plant growth by capturing this water resource on the landscape where it can soak into the water table or be stored in retention ponds for later use in irrigation. Once water infiltration has been maximized, low-tech water harvesting techniques like what P.A. Yeoman developed in Australia in 1950's should be considered and landscape scale strategies should be implemented to use our water resources more effectively. Adding hedgerows to the farm can aid in snow capture during the winter as winds blow and hedgerows can act to limit evaporation losses and reduce abiotic stress of growing plants from the wind. The hedges could have other uses including, nitrogen fixation, fruit production, or livestock fodder production.

Figure 9: Hedgerows between fields in the Canterbury Plains, New Zealand. Photo Credit: Ryan Boyd

The more water available for plant growth, the more options exist when choosing crops. Higher value crops can be grown when moisture is more consistent and reliable. The economic potential of this added diversification cannot be understated and should be explored at watershed levels to determine where the opportunities are to make better use of our water resources. It may be determined that pasture cropping systems or other unique methods are viable in northern latitudes if the available water resources are managed successfully.

When water is managed effectively on the landscape everyone benefits. Stream and river flows are more consistent and water quality is greatly improved. It is difficult for the free market to price in these benefits, especially when most of what we produce on farm in Canada is not consumed in local regions but how we manage water on farm will be of ever-increasing importance to society.

Global warming due to increased atmospheric greenhouse gases is a hard concept for people to grasp. Carbon is an abstract thing that does not resonate like the powerful force we can see as water runs across a landscape. Water and carbon go hand in hand. When the focus is on maximizing water infiltration, carbon flow into the soil will be positive. Better water infiltration results as soil structure improves and improved soil structure comes from carbon stabilizing soil aggregates. The carbon that stabilizes soil aggregates comes from photosynthesizing plants and the soil microbes that support plant growth. Once water infiltration improves, more plant growth occurs, and the cycle continues. Significant changes in water infiltration are easy to track and can be noticeable prior to detectable increases in soil carbon.

2.8 Circular Economies

In his book, Civilization Critical, Darrin Qualman describes how our reliance on fossil fuels has led to a linear economy and the need for circular economies to avoid ecological problems (Qualman, 2019) A circular economy aims to minimize waste and externalities that result from continual input of resources.

Fossil fuels have allowed us to decouple from the cycles that exist in the natural world. The simplest means to return to a circular economy in agriculture is to embrace perennial forage harvested by grazing ruminants powered by sunlight energy. Managed correctly, perennial pastures do not require fossil fuel intensive fertilizers and a greatly reduced need for diesel burning tractors. Perennial pasture could be in a rotation with annual crops dramatically decreasing reliance on fossil fuels.

Political desire will be the most likely driver of change to our agriculture production systems. In the short term, it is extremely difficult to compete with the production potential of the current simplified, fossil fuel intense agricultural systems. At some point in the future, we will have to adjust our energy source away from ancient sunlight preserved in fossil fuels to modern day sunlight harvested via photosynthesis.

2.9 Marketing the outcomes of the system

Consumers are becoming knowledgeable in soil health. Non-profit organizations like Kiss the Ground in California are actively educating curious consumers the benefits of improved soil health and the potential of regenerative agriculture. These ideas have moved well beyond the local farmers market as food industry giants like General Mills have pilot projects underway working directly with farmers to document the success of regenerative agriculture and help farmers implement the principles of soil health. The big companies are considering how to manage supply chains to verify the integrity of their products while new start-ups are finding ways to scale up direct to consumer marketing of high attribute products. If the positive outcomes can be verified, then there is big marketing potential. Measured outcomes need not be complex and should be improving over time to indicate whether a farming system is regenerative. Simple metrics such as water infiltration rates can provide enough information to both the consumer looking to support regenerative agriculture and the farmer trying to achieve a regenerative system that they are indeed contributing to positive ecological results. Formal outcome verified systems are starting to be used such as the Land to Market program developed by the Savoury Institute. (Savory Institute, 2020) Many direct marketers have chosen to be completely transparent on their regenerative agriculture journey through social media building a market as they go.

A recent report by Technavio has demand for grass-fed beef forecasted to increase at a compound annual growth rate of 6%. (Technavio, 2020) There are hurdles to overcome to capitalize on this demand as Brenda Tjaden noted in her Prairie Routes blog. Infrastructure is insignificant to create supply of pastured meats at scale (Tjaden, 2020) The local food economy is leading the way connecting conscious consumers to pasture raised meats but faces significant challenges as infrastructure adapts and is developed to fill this need. Online ordering and direct shipping to consumers is allowing farmers to tap into new demand and maintain a larger portion of the value chain, although at a substantially higher financial cost than the traditional supply chain.

Could a decentralized moderate scale meat processing industry servicing domestic demands for pastured protein be the economic driver of a vibrant agriculture-based economy of the future?

3.0 South Glanton Farms – Practical Experience

3.1 Paradigm Shift in Grazing Management

On South Glanton Farms we have been intensively grazing tame perennials pastures for 20 years on reasonably high-quality arable land. The benefits to the soil, landscape function and biodiversity are obvious but consistently producing competitive margins with annual crop production has been elusive. The main reason for this has been sporadic rainfall within seasons and prolonged periods of below average rainfall.

The soils are producing significant quantity and quality of forage, but it can be hard to manage the fast intense growth with much of our production coming in a 45 day window centered around the summer solstice, June 21st. We have tried various grazing methods over the years including a take half-leave half rotation with long recovery periods, holistic planned grazing; in which animals are moved rapidly during periods of fast plant growth and slowed down during periods of slow growth. I had the good fortune of meeting Saskatchewan grazier Neil Dennis early on in my grazing career and witnessed firsthand the dramatic changes to soil quality resulting from mob grazing. We have used mob grazing at densities up to 250,000 pounds of beef per acre were used to strategically impact specific areas that had weed issues or stimulate unproductive areas of the farm.

Given that cows will selectively graze the most palatable plants, we have moved cattle daily for over 15 years trying to reduce the amount of selective grazing and resulting reduction in pasture diversity. Another observation that I have not been able to reconcile with conventional grazing advice is how to determine when a pasture has recovered enough to return for grazing. Most experts will say it is ready to be re-grazed when the grasses begin to flower. Knowing how our grasses respond to grazing in the northern latitudes the production of seed heads and thus flowering is mostly dependant on the time of year. Mid June is when the cool season grasses begin to flower and if grazed at certain growth stages, grass plants will not produce a seed head that growing season. I was also taught that we need to leave as much residue as possible during each grazing, to aid in regrowth and build litter on the soil surface. For these reasons we have tried to graze at stock densities above 40,000 pounds of beef per acre, allow a recovery period of 90 days or more during the growing season and leave residual forage of at least 30% and ideally 50%.

Soil testing via the soil carbon coalition protocol (Soil Carbon Coalition) indicate that this type of management has increased the carbon content of the soil in the top 10 cm of soil by 1%

between 2014 and 2019. Standard feed tests show improved mineral content of the forage also. Animal health has also improved significantly as the incident of foot rot and pink eye occurring in old pasture stands are dramatically less than when they were newly established. Something that has eluded us has been the increase in carrying capacity that many grazing experts would suggest could be achieved with good grazing management. This may be due to the fact we have managed these forages relatively well since they were established at moderate stocking rates.

Two back-to-back years of below normal precipitation in 2017 and 2018 made us realize that we needed to up our game or we would need to rethink the future of perennial forage on our farm. In May of 2019, Connor English joined our farm and took on the task of moving the cattle multiple times per day with a goal of leaving 50% residual forage and targeting 200,000 pounds beef per acre stock density moving quickly during rapid growth and slowing as moisture conditions dried out mid summer. The result was good animal performance as evident by the body condition of the cows. However, the pastures suffered from over grazing as the mid summer drought took hold and we were forced to graze pastures that contained plants that were not adequately recovered. In theory, it makes sense to adjust the recovery period on the fly as plant growth slows down or speeds up, but in practice is very difficult to implement. The desirable species had been selectively grazed when rotating quickly during periods of fast growth and were being overgrazed during the second pass. The resulting stocking rate in 2019 was a meager 60 animal units per acre.

Upon returning home from my Nuffield studies in the spring of 2020, we implemented a system of Total Grazing as Jaime Elizondo advocates and I have detailed in this report. Initially, we had some animal health issues such as pink eye and scours in our calves due to the protein and fibre imbalance in the forages we were grazing. This was also accentuated as we were grazing newly established forage stands with high alfalfa content. We supplemented cereal straw to the cattle on the lush spring pastures, which helped immensely. By mid June we could see that we needed to have much longer time out of the pasture than we had previously allowed to achieve a more balanced ration for the cattle and set up the Total Grazing system for next year. The increased utilization we were getting from the Total Grazing allowed us to fully embrace the paradigm shift away from photosynthetic based plant regrowth to root reserve-based regrowth and we committed to stockpiling forage on nearly half our acres for grazing next spring. By the time July rolled around, we realized we were really onto something when tallying up the grazing days per acre we were able to achieve and observing the regrowth that was occurring in the pastures. Not to mention the biodiversity that was exploding in the pastures that were being stockpiled for next year. Forage harvest of individual pastures ranged from 80-200 animal units per acre of grazing and the stocking rate of the farm was around 120 animal units per acre, not

including the large amount of stockpile we were able to set aside for next spring. We feel that 200 animal units per acre stocking rate is achievable and as animal genetics improve this could increase much further. Increases in stocking rate will come as landscape function improves.

There is a fine line between high stocking rates and reduced animal performance. For 15 years our heifers were exposed to a bull for 30 days as yearlings and the cow herd had a short calving season of 45 days. Our cattle are relatively fertile. The body condition did reduce slightly under Total Grazing and the conception rate was less than the year prior. We did not fully understand the importance and magnitude of minimal protein supplementation on performance until later in the summer when most of the cool season grasses in our pastures matured. Some would suggest that we should have returned to some of the lush regrowth that was grazed earlier in the summer to address the performance issues but this would put us back into a similar situation in 2019 where we sacrificed landscape function. The economics favour Total Grazing methods with a focus on minimal protein supplementation and identifying genetics in our herd that will adapt to these grazing conditions. This will allow us to maintain a high level of productivity of our pastures and work on continuous improvements to landscape function from a long recovery period. Potentially, the most significant improvements to the pastures will come from the establishment of C4 grasses.

3.2 What the Future Holds for South Glanton Farms

We will continue to focus our efforts on developing a low maintenance cow herd capable of grazing at ultra high stock density by identifying specific animals that perform well under Total Grazing conditions and use these animals as our genetic base.

Crop residue grazing will become a much larger profit centre on our farm in 2021. I have visited with several graziers in western Canada who are achieving 40-60 cow days per acre grazing cereal straw and chaff with minimal protein supplement. The cost of leaving chaff and straw bunched in the field is negligible to a mixed farm. This will greatly reduce or eliminate one of the biggest challenges we face with low disturbance direct seeding in Manitoba, seeding into soggy cold soils covered with a dense mat of residue. All while dramatically reducing winter-feed costs for the cow herd, the biggest expense to our cow calf enterprise.

Relationships will continue being built with neighbouring grain farms to bring the benefits of grazing ruminants to their farms in a mutually beneficial arrangement. By moving cattle off our perennial pastures in the mid summer to fall time, we are able to stockpile more forage for spring grazing and enhance the nutrient cycle on annual crop fields.

The Boyd's Beef brand was born in 2020 and we are developing markets for our grass-fed beef locally. Currently 95% of what we produce flows through the conventional supply chains. There is a growing demand for grass-fed beef and the story behind how it is produced. Boyd's Beef intends to be a reliable source for high quality local food.

Don Campbell, the Holistic Management icon from Meadow Lake, Saskatchewan, gave some sage advice to me several years ago: it does not matter how fast you go but merely that you are going the right direction. We will continue to hone our grazing skills, improve landscape function, and develop a local supply chain for our products to ensure that we end up with desirable outcomes for our family, the farm and the local community.

4.0 CONCLUSION

It is important to work towards your goals. It is also important to not get hung up on certain dogma, such as reluctance to supplement cattle or use fertilizer when appropriate, because you may be missing out on opportunities of small investments that result in dramatic impacts. I have seen this time and time again in my travels and on our own farm when trying to create a natural farming system mimicking nature. A realistic expectation for timeline of results needs to be allowed and one must be prepared for a steep learning curve. Think big, start small, learn fast. With experience, what sounds complex can become relatively simple to manage.

Not only have our landscapes changed over time to include less functioning prairie ecosystems, our generational knowledge and experience in managing landscapes with grazing animals has become greatly diminished. We must work to preserve this knowledge and foster the next generation of experienced and compassionate landscape managers.

Advances in technology and economic decisions has led us to the specialized production systems that are the norm today. It is new technology that is offering us a glimpse into what makes the soil ecosystems function and what makes natural systems so efficient. This understanding is driving the need for grazing ruminants to be an integral part of maintaining the inherent fertility of the world's grasslands as they have done for thousands of years.

Carbon is the focus of much debate worldwide. If water is carefully managed on the farm, the carbon dynamics will be positive. The value of infiltrating water into the soil and keeping excess on farm cannot be overstated and must be measured and managed accordingly.

Grazing ruminants should continue to up-cycle forages grown where annual crops cannot and consume high fibre feedstock unfit for consumption by humans or other animals. Grazing

ruminants should be used to allow high fibre, diverse grasslands to exist on high quality soils to build natural soil fertility while producing environmentally positive nutritious food. A perennial grazing system managed with UHDG and long recovery periods can compete with the profitability of specialized annual cropping systems. Competitiveness of perennial based systems will increase with demands to reduce the use of fossil fuels and circular economies are developed.

Observation is critical to enable adaptive management of the complex agroecosystems in which grazing ruminants are the cornerstone. We must measure outcomes and document change over time to ensure that management is positive. Marketing this progress will allow differentiation both locally and on the international market.

The current food production system is very productive. However, environmental costs associated with our current production system outline the need for more circular economies. Big opportunities lie ahead for those willing to embrace regenerative agriculture systems including grazing ruminants. More complex farming systems will require that more people are involved in primary production on farm. This may be the best outcome of all as local economies benefit and rural communities flourish.

5.0 RECOMMENDATIONS

Here are a few recommendations:

A. Water infiltration needs to be maximized on farm and actively monitored and managed.
B. Grazing ruminants should drive the fertility of farming systems.
C. Non-selective, ultra high stock density grazing of perennial pastures should be considered and researched.
D. Partnerships developed to embrace stockmanship and cropping.
E. Landscape planning to retain and use water resources more effectively.
F. Environmental outcome verification of regenerative agriculture practices.
G. Marketing and promotion of the positive ecological outcomes of beef production.

Agriculture functions extremely efficiently and is a great marvel of modern civilization. The success of the current system is very much dependant on access to fossil fuels as a cheap source of energy. Agriculture will continue to innovate the way we produce and supply food to society. Grazing ruminants will be central to the success of a resilient, productive, and profitable agriculture system of the future.

6.0 GLOSSARY

Adaptive Multi-Paddock Grazing (AMP) – Flexible grazing systems that adapts in response to monitoring of the pasture growth, animal performance and environmental conditions.

Circular Economy – A circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.
Definition Credit: www.ellenmacarthurfoundation.org

Holistic Context – The social, environmental, and economic circumstances you are managing under and the desired context that you want to achieve.

Intercropping – Growing two or more species of cash crop together which will be harvested together and separated post harvest.

Mineral Associated Organic Matter – Stable organic matter that is bound to soil particles derived mainly from the bodies and by-products of micro-organisms and certain plant compounds.

Mob Grazing – Grazing at high stock densities to achieve animal impact on the pasture.

Non-Selective Grazing – Grazing that occurs once a significant stock density is achieved and animals consume all available forage consistently.

Particulate Organic Matter – Partially decomposed organic matter that you can see.

Pasture Cropping – Growing an annual cash crop within a living perennial pasture.

Recovery Period – Time out of pasture between grazing, which allows plants to regrow, replenishing root reserves and new seedlings to establish.

Regenerative Agriculture – A holistic, principles-based approach to farming and ranching that seeks to strengthen ecosystems and community resilience.
Definition Credit: General Mills

Severe Grazing – Grazing that results in defoliation of more than 80% of the plants.

Stock Cropping – Pasturing animals on cover crops within a growing annual cash crop.

Stock Density – How many total pounds of animal weight on a given area during each pasture shift.

Stocking Rate – How many animals a unit of land will support for a given period of time.

Total Grazing – Term used by Jaime Elizondo to describe his system that combines severe, non-selective grazing with a long recovery period.

Ultra High Density Grazing (UHDG) – Grazing at a stock density above 500,000 pounds per acre.

Relaxed Grass – Healthy grass that is growing mainly leaf material in healthy soil under good grazing management.

Relay Cropping – Establishing a cover crop within a growing cash crop.

Rhizophagy – Process in which plants engulf microbes in the rooting zone to obtain nutrients.

7.0 REFERENCES

BCRC. (2017). *Canadian Beef Research and Technology Transfer Strategy 2018-2023.*

Bork, E. (2019). Understanding the Role of Grasslands in Carbon Storage and GHG Mitigation. *2019 MFGA Regenerative Ag Forum.* Brandon, MB.

Bork, E. W., Broadbent, T. S., & Willms, W. D. (2017). Intermittent Growing Season Defoliation Variably Impacts AccumulatedHerbage Productivity in Mixed Grass Prairie. *Rangeland Ecology and Management* , 307-315.

Boyce, M. (2019, December 11). *Scientia*. Retrieved January 20, 2021 from https://www.scientia.global/dr-mark-boyce-adapting-grassland-grazing-to-boost-carbon-sequestration/

Broadbent, T. S., Bork, E. W., Cooke, J. E., & Willms, W. D. (2019). Grass Yields Under Clipping and Watering Explain Varied Efficacy ofManagement Intensive Grazing on Rangelands. *Rangeland Ecology and Management* , 446-453.

Canada, S. (2017). *2016 Census of Agriculture.*

CanFax. (2020). Retrieved December 20, 2020 from https://www.canfax.ca/Report/FullCharts.aspx

CCA. (2020). *Canadian Cattleman's Association*. Retrieved January 10, 2021 from https://www.cattle.ca/cca-resources/environment/

Cotrufo, F. (2021, January 22). (R. Boyd, Interviewer)

Crider, F. J. (1955). *Root Growth Stoppage Resulting From Defoliation of Grass.* Washington, D.C.: United States Department of Agriculture.

FAO. (2017). *Livestock solutions for climate change.* Food and Agriculture Organizations of the United Nations.

Farmmap4D. (2021). *Farmmap4D Spatial Hub*. Retrieved February 10, 2021 from https://www.farmmap4d.com.au/

General Mills. (2020). *General Mills*. Retrieved September 20, 2020 from https://www.generalmills.com/en/Responsibility/Sustainability/Regenerative-agriculture

Hand, G. (2021, February 9). (R. Boyd, Interviewer)

IPCC. (2018). *Global warming of 1.5C.* IPCC. In press.

Jungnitsch, P. (2008). *THE EFFECT OF CATTLE WINTER FEEDING SYSTEMS ON SOIL.* M Sc. Thesis.

King, A. E., & Blesh, J. (2017). Crop rotations for increased soil carbon: perenniality as a guiding principle. *Ecological Applications - Ecological Society of America* .

Mauck, J. (2020).

Mittloehmer, F. (2019, February 19). *GHG Guru Blog*. Retrieved September 20, 2020 from https://ghgguru.faculty.ucdavis.edu/2019/02/19/eat-lancet-report-is-an-epic-fail-and-commission-knows-it/

PCAP. (2019). *Saskatchewan Prairie Conservation Action Plan- Framework 2019-2023.* Regina.

Provenza, F. D. (2008). What does it mean to be locally adapted and who cares anyway? *Journal of Animal Science* , E271-E284.

Provenza, F. D., Villalba, J. J., Wiedmeier, R. W., Lyman, T., Owens, J., Lisonbee, L., et al. (2009). Value of Plant Diversity for Diet Mixing and Sequening in Herbivores. *Society for Range Management* .

Qualman, D. (2019). *Civilization Critical: Energy, Food, Nature, and the Future.* Winnipeg, Manitoba: Fernwood Publishing.
Savory Institute. (2020). *Savory Land to Market*. Retrieved December 20, 2020 from https://savory.global/land-to-market/eov/
Savory, A., & Butterfield, J. (1998). *Holistic Management: A New Framework for Decision Making.* Island Press.
Shrestha, B. M., Bork, E. W., Chang, S. X., Carlyle, C. N., Ma, Z., Dobert, T. F., et al. (2020). Adaptive Multi-Paddock Grazing Lowers Soil. *Agronomy* .
Soil Carbon Coalition. (n.d.). Retrieved 12 20, 2020 from https://soilcarboncoalition.org/
Sokol, N. W., Kuebbing, S. E., Karlsen-Ayala, E., & Bradford, M. A. (2019). Evidence for the primacy of living root inputs, not root or shoot. *New Phytologist* , 221:233-246.
Tasker, J. (2020, December 11). *CBC News*. Retrieved December 20, 2020 from https://www.cbc.ca/news/politics/carbon-tax-hike-new-climate-plan-1.5837709
Taylor, C. A., Brooks, T. D., & Garza, N. E. (1993). Effects of short duration and high intensity, low frequency grazing systems on forage production and composition. *J. Range Manage.* , 46:118-121.
Teague, R. (2020, February 7). (R. Boyd, Interviewer)
Teague, R., Provenza, F., Kreuter, U., Steffens, T., & Barnes, M. (2013, October 15). Multi-paddock grazing on rangelands: why the perceptual dichotomy between research results and rancher experience? *J Environ Manage* , 128:699-717.
Technavio. (2020, October 12). *Businesswire*. Retrieved January 25, 2021 from https://www.businesswire.com/news/home/20201012005352/en/Grass-fed-Beef-Market-Demand-for-Grass-fed-beef-Products-to-Boost-the-Market-Growth-Technavio
Teicholz, N. (20014). *The Big Fat Surprise: WHy Butter, Meat and Cheese Belong in a Healthy Diet.* Siman and Schuster.
Teutscherov´a, N., V´azquez, E., Sotelo, M., Villegas, D., Vel´asquez, N., Baquero, D., et al. (2021). Intensive short-duration rotational grazing is associated with improved soil. *Applied Soil Ecology* .
Thorbecke, M., & Dettling, J. (2019). *Carbon Footprint Evaluation of Regenerative Grazing at White Oak Pastures.* Quantis.
Tjaden, B. (2020, February 9). *Prairie Routes.* Retrieved February 10, 2020 from Prairie Routes Blog: Forecasting Demand for Grass-fed Beef: https://www.prairieroutes.com/post/forecasting-demand-for-grass-fed-beef
Weidmeier, R. W., Villalba, J. J., Summers, A., & Frovenza, F. D. (2012). Eating a high fiber diet during pregnancy increases intake and. *Animal Feed Science and Technology* , 144-151.
White, J. F., Kingsley, K. L., Verma, S. K., & Kowalski, K. P. (2018). Rhizophagy Cycle: An Oxidative Process in Plants for Nutrient Extraction from Symbiotic Microbes. *Microorganisms* .
WWF. (2020). *2020 Plow Print Report.*
Zietsman, J. (2014). *Man, Cattle, Veld.* BEEFpower LLC.

8.0 APPENDICES

Mineral Content of Forage
Source:

Nutrient Composition of forage		kg per tonne
Protein %	12%	264
Phosphorus	0.10%	2.2
	# per tonne	
Nitrogen	42	
P2o5	5	
Dry matter per acre	5000	
#N/ac	96	
# p2o5/ac	11	

Gross Margin Calculation before Pasture Costs (per head and per acre)
Source: South Glanton Farms

Purchase Price ($/cwt)	$ 256.00		Feed Costs	$	172.22
Purchase Weight (lbs)	350		Yardage	$	72.80
Purchase Price	$ 896.00		Mineral Costs	$	10.92
			Sales	$	20.00
Sale Price ($/cwt)	$ 189.00		Trucking	$	10.00
Sale Weight	850		Health	$	20.00
Sale Price	$ 1,606.50		Tag	$	2.00
			Death Loss	$	35.84
Feed Start	16-Oct		Interest	$	22.34
Pasture Start	15-Apr				
Sale Date	15-Oct		Total Costs	*$*	*366.12*
Days on Feed	*181*				
Days on Pasture	*183*		COG	$	0.732
			Before Profit/pasture costs		
Yardage	0.2		Gross Margin per hd	$	344.38
Feed Cost $/d	0.95		Gross Margin per acre	**$**	**350.92**
Feed Cost cents/lb	6.00				
Feed %bw	3%				
Feed Intake lbs/d	13				
Mineral Cost ($/d)	$ 0.03				
Stocking Rate (aud/ac)	150				
Stocking Rate (ac/hd)	*0.98*				
Stocking Rate (hd/ac)	*1.02*				
Death Loss	4.0%				
Interest	2.50%				
Days	364				
Total Gain (lbs)	500				
ADG (lbs/day)	1.37				

Gross Margin Calculation before Pasture Costs (per head and per acre)
Source: South Glanton Farms

Purchase Price ($/cwt)	$	256.00	Feed Costs	$	172.22
Purchase Weight (lbs)		350	Yardage	$	72.80
Purchase Price	$	896.00	Mineral Costs	$	10.92
			Sales	$	20.00
Sale Price ($/cwt)	$	189.00	Trucking	$	10.00
Sale Weight		850	Health	$	20.00
Sale Price	$	1,606.50	Tag	$	2.00
			Death Loss	$	35.84
Feed Start		16-Oct	Interest	$	22.34
Pasture Start		15-Apr			
Sale Date		15-Oct	Total Costs	*$*	*366.12*
Days on Feed		*181*			
Days on Pasture		*183*	COG	$	0.732
			Before Profit/pasture costs		
Yardage		0.2	Gross Margin per hd	$	344.38
Feed Cost $/d		0.95	Gross Margin per acre	**$**	**467.89**
Feed Cost cents/lb		6.00			
Feed %bw		3%			
Feed Intake lbs/d		13			
Mineral Cost ($/d)	$	0.03			
Stocking Rate (aud/ac)		200			
Stocking Rate (ac/hd)		*0.74*			
Stocking Rate (hd/ac)		*1.36*			
Death Loss		4.0%			
Interest		2.50%			
Days		364			
Total Gain (lbs)		500			
ADG (lbs/day)		1.37			

Manitoba Average Steer Prices and Value of Gain, Fall of 2020
Source: Canfax

Weekly Canfax Report Steer Prices $/cwt				
Weight	18-Sep-20	16-Oct-20	20-Nov-20	Average
300-400	$ 254.17	$ 274.00	$ 280.17	$ 269.45
400-500	$ 238.83	$ 236.50	$ 245.64	$ 240.32
500-600	$ 215.50	$ 215.57	$ 215.79	$ 215.62
600-700	$ 207.63	$ 204.67	$ 198.57	$ 203.62
700-800	$ 196.60	$ 198.14	$ 186.33	$ 193.69
800-900	$ 191.50	$ 189.00	$ 180.20	$ 186.90
900+	$ 174.63	$ 173.50	$ 173.75	$ 173.96
Weight	Value of Gain $/cwt			Average
350				
450	$ 185.14	$ 105.25	$ 124.79	$ 138.39
550	$ 110.52	$ 121.39	$ 81.47	$ 104.46
650	$ 164.35	$ 144.72	$ 103.86	$ 137.64
750	$ 124.91	$ 155.70	$ 106.77	$ 129.12
850	$ 153.25	$ 120.45	$ 134.23	$ 135.98
950	$ 31.24	$ 41.75	$ 118.93	$ 63.97
450-850	$ 138.25	$ 135.56	$ 106.58	$ 126.80
350-850	$ 147.63	$ 129.50	$ 110.22	$ 129.12
350-650	$ 153.33	$ 123.79	$ 103.37	$ 126.83

Manitoba Average Steer Prices and Value of Gain, Fall of 2019
Source: Canfax

Weekly Canfax Report Steer Prices $/cwt				
Weight	20-Sep-19	18-Oct-19	22-Nov-19	Average
300-400	$ 241.88	$ 240.25	$ 256.58	$ 246.24
400-500	$ 231.75	$ 227.25	$ 237.60	$ 232.20
500-600	$ 212.83	$ 213.40	$ 217.17	$ 214.47
600-700	$ 204.05	$ 207.80	$ 201.44	$ 204.43
700-800	$ 200.65	$ 202.88	$ 187.92	$ 197.15
800-900	$ 187.13	$ 192.60	$ 183.25	$ 187.66
900+	$ 174.63	$ 178.50		$ 176.57
Weight	Value of Gain $/cwt			Average
350				
450	$ 196.30	$ 181.75	$ 171.17	$ 183.07
550	$ 127.69	$ 151.08	$ 125.24	$ 134.67
650	$ 155.76	$ 177.00	$ 114.93	$ 149.23
750	$ 178.55	$ 170.90	$ 100.04	$ 149.83
850	$ 85.73	$ 115.50	$ 148.23	$ 116.49
950	$ 68.38	$ 58.65		$ 63.52
450-850	$ 136.93	$ 153.62	$ 122.11	$ 137.55
350-850	$ 148.81	$ 159.25	$ 131.92	$ 146.66
350-650	$ 159.92	$ 169.94	$ 137.11	$ 155.66

Manitoba Average Steer Prices and Value of Gain, Fall of 2018
Source: Canfax

Weekly Canfax Report Steer Prices $/cwt				
Weight	21-Sep-18	19-Oct-18	23-Nov-18	Average
300-400		$ 256.33	$ 249.63	$ 252.98
400-500	$ 236.00	$ 239.88	$ 235.80	$ 237.23
500-600	$ 223.60	$ 222.10	$ 214.10	$ 219.93
600-700	$ 215.75	$ 217.60	$ 198.75	$ 210.70
700-800	$ 208.25	$ 206.40	$ 192.63	$ 202.43
800-900	$ 197.58	$ 196.75	$ 183.10	$ 192.48
900+	$ 182.33	$ 181.17		$ 181.75
Weight	Value of Gain $/cwt			Average
350				
450		$ 182.31	$ 187.40	$ 184.85
550	$ 167.80	$ 142.09	$ 116.45	$ 142.11
650	$ 172.58	$ 192.85	$ 114.33	$ 159.92
750	$ 159.50	$ 133.60	$ 152.85	$ 148.65
850	$ 117.56	$ 124.38	$ 111.63	$ 117.85
950	$ 52.71	$ 48.74		$ 50.72
450-850	$ 154.36	$ 148.23	$ 123.81	$ 142.13
350-850		$ 155.04	$ 136.53	$ 145.79
350-650		$ 172.42	$ 139.39	$ 155.90

Manitoba Average Fall Steer Prices 2018-2020
Source: Canfax

Weekly Canfax Report Steer Prices $/cwt			
Weight	Average 2018-2020		
300-400	$ 256.22		
400-500	$ 236.58		
500-600	$ 216.67		
600-700	$ 206.25		
700-800	$ 197.76		
800-900	$ 189.01		
900+	$ 177.43		

Manitoba Average Value of Gain of Last 100 lbs Steers Fall 2018-2020
Source: Canfax

Average Value of Gain of last 100 pounds	
Weight	$/cwt
350	
450	$ 168.77
550	$ 127.08
650	$ 148.93
750	$ 142.53
850	$ 123.44
950	$ 59.40

Manitoba Average Value of Gain Steers Fall 2018-2020
Source: Canfax

Value of Gain	
Weight	$/cwt
450-850	$ 135.49
350-850	$ 140.52