DOW SUSTAINABILITY FELLOWS
UNIVERSITY OF MICHIGAN

Expanding Grass-Based Livestock Production in the Upper Mississippi River Region

By: Emily Brent, Jelena Goldstein, Noah Hellum and Xuesi Hua

Dow Sustainability Fellows Final Report

2024

Introduction

In this report, we examine the current environment for grass-based livestock production in the Upper Mississippi River Basin and identify the key supply chain challenges that hinder its growth. By identifying the current issues that the industry grapples with and potential solutions, we aim to support graziers and other stakeholders in the work to increase the opportunities for pasture and other perennial crops in the region.

This paper builds upon the research done by The Nature Conservancy on the Upper Mississippi River Basin Foodscape. This region spans across six states from Minnesota all the way down to Missouri. For the more than thirty million people who live in the UMR region, the Mississippi River and its surrounding lands provide food and fresh water local families and economies depend on. Additionally, the river basin supports habitats for over 260 fish species, 45 amphibian and reptile species and 57 mammal species. This level of biodiversity heightens the importance of defending the region against the nutrient depletion and water pollution caused by conventional farming practices.

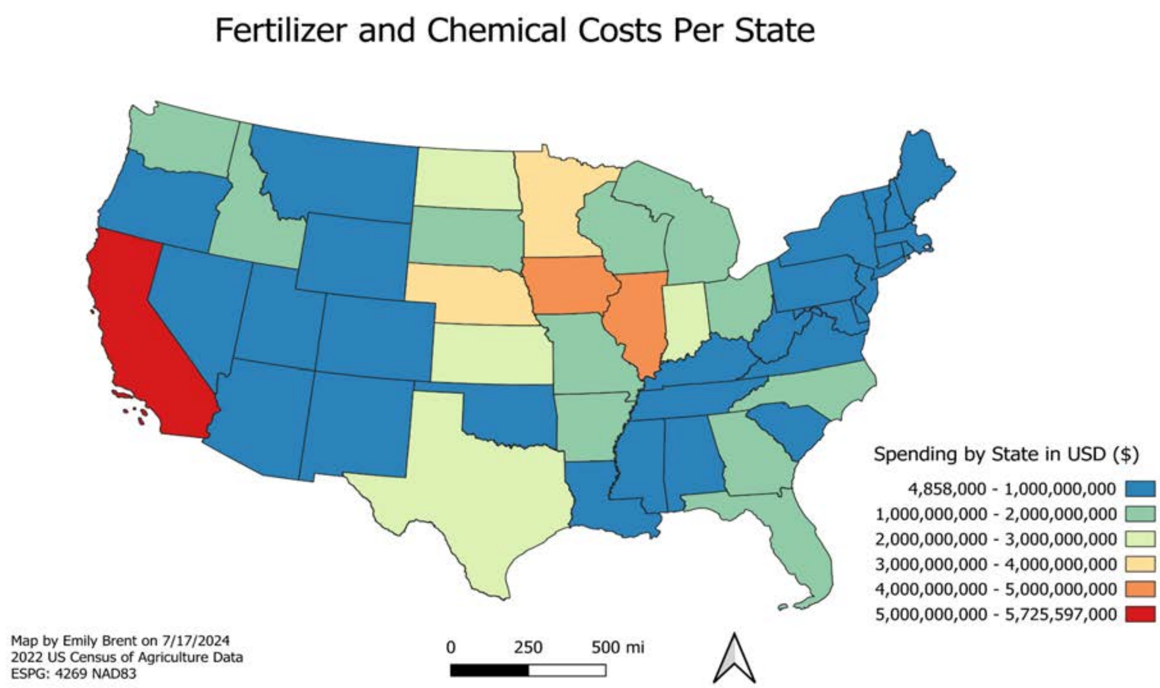
The Upper Mississippi Region (UMR) encompasses a geological expanse of 189,968 square miles that spans northeastern Iowa, northwestern Illinois, southwestern Wisconsin, southeastern Minnesota, and eastern part of Missouri (Lyons et al., 2015). Due to the glacial drift of the most recent Ice Age, the UMR is characterized by spatially and temporally large floodplain-river ecosystems (Houser et al., 2022). The region is composed of three major subsystems: lotic channels, lentic off-channel aquatic areas, and floodplains (Bouska et al., 2018).

Three types of ecoregions dominate the UMR: the temperate forests, northern forests, and great plains (Delong et al 2023). The UMR is historically covered by highly productive fertile soil due to glacier movement, which is ideal for the growth of crops. Soil organic carbon content is highest beneath forests (28 kg-1) and pasture lands (23 kg-1), whereas it measures 21 kg-1 under croplands (Vondracek, 2019). The soil in UMR is also rich in other key minerals, such as nitrogen, phosphorus, and potassium. Approximately 66% of the nearly 1.2 million acres within the Upper Mississippi River floodplain are currently designated for crop cultivation and pastureland. These agricultural areas have been effectively severed from the natural functions of the floodplain due to extensive levee systems that control water flow and prevent flooding (Upper Mississippi River Restoration Program, 2022).

However, unlike the flat plains found in most parts of UMR, the Driftless Area, a geological expanse of 24,000 square miles around the Upper Mississippi Valley, spanning northeastern Iowa, northwestern Illinois, southwestern Wisconsin, and southeastern Minnesota, due to the absence of glacial drift during the last Ice Age 2.6 million years ago, is characterized by an eroded plateau with rugged Karst topography, traditionally less conducive to farming or crop cultivation (Lyons et al., 2015). In addition to the steep topography, wind, and rain erosion, farming activities often concentrate in the flatter valley regions, while the steep hills remain largely untouched.

The soil in the UMR is prone to erosion caused by precipitation and wind, resulting in alterations to both the physical and chemical properties of the soil, diminishing soil quality and water retention. Soil erosion diminishes pore size distribution and reduces water availability to plants and microorganisms (Vondracek, 2019). Furthermore, erosion leads to a decline in soil quality and carbon sequestration, particularly in the top layers where organic matter is most abundant (Adamczewska-Sowińska et al., 2020). These all pose challenges for pastureland and crop production.

Corn and soybeans, the predominant crops grown in the UMR, require substantial nitrogen inputs to achieve commercially acceptable yields. The prevalent two-crop monoculture practice combined with intensive tillage, depletes soil nitrogen levels and reduces soil quality, exacerbating the reliance on nitrogen fertilizers, which can have detrimental environmental impacts when not managed carefully (Adamczewska-Sowińska et al., 2020). In addition to their environmental harm, fertilizer use also burdens farmers financially. Some states in the UMR region, such as Illinois and Iowa, lead the nation in fertilizer and chemical input spending (Figure 1). This is mostly applied to the extensive soy and corn grown mainly for animal feed and ethanol.



.

Figure 1: Illinois and Iowa have very high fertilizer and chemical input costs by state. This is mostly due to the extensive soy and corn grown mainly for animal feed. Transitioning marginal lands to pasture could minimize costs associated with chemical inputs (Greer, K. et al. 2020) and could reduce the need for chemicals that harm the environment and human health (Wepking, C. et al. 2020)

The primary nonpoint source pollutants are phosphorus and nitrogen. According to the 2016 State of the River Report, nitrogen—the primary driver of the Gulf of Mexico's dead zone—mostly originates from agricultural sources in the Upper Mississippi Region (Friends of the Mississippi River, 2016). Nitrogen causes algae blooms; when those algae die, microbes that decompose the algae use the oxygen available in the water column. This results in a hypoxic zone, with oxygen too low to sustain marine life in the bottom or near bottom waters creating a dead zone (Friends of the Mississippi River, 2021). Fish and shrimp leave the area, while immobile species like crabs, worms, and clams die.

Hypoxia is especially severe in summer when photosynthesis peaks, facilitating large algal blooms, rendering millions of acres of habitat unsuitable for fish and bottom species (National Oceanic and Atmospheric Administration, 2020). Toxified fish can pose serious health risks to humans and other creatures that consume them, passing toxins through the food web. The imbalance in species caused by algae blooms disrupts the entire food web, decreasing biodiversity and food availability.

The hydrology of the Upper Mississippi Region is marked by a notably high baseflow stream, largely attributable to substantial groundwater recharge and the water-holding capacity of sandstone. The groundwater recharge can reach 23,000 million gallons per day (U.S. Geological Survey., 2020), which is far sufficient for the local needs. It is estimated that a large groundwater resource in the UMR is not being fully utilized.

However, given the humid continental climate prevailing in this area, summer rainfall is significant, averaging 4 inches per month, resulting in heightened flood risk (Bendorf et al, 2021). Surface runoff and soil erosion have also become more prevalent, posing challenges to crop and pasture growth. Moreover, the rapid runoff velocities often lead to the formation of gullies that bypass the permeable hillslopes, thus reducing groundwater recharge (Friends of the Mississippi River, 2016). With less water being preserved underground, the area becomes increasingly susceptible to drought, particularly when rainfall patterns become unpredictable. Heavy rainfall can carry fertilizers from this region into the Mississippi River, which channels nutrients from its vast watershed into the Gulf of Mexico, 1,500 miles south. It is estimated 52% of the nitrogen load to the Gulf of Mexico from the Mississippi watershed runs off from corn and soybean fields (Ritter, W. F., & Rao Chitikela, S, 2020) (Figure 2).

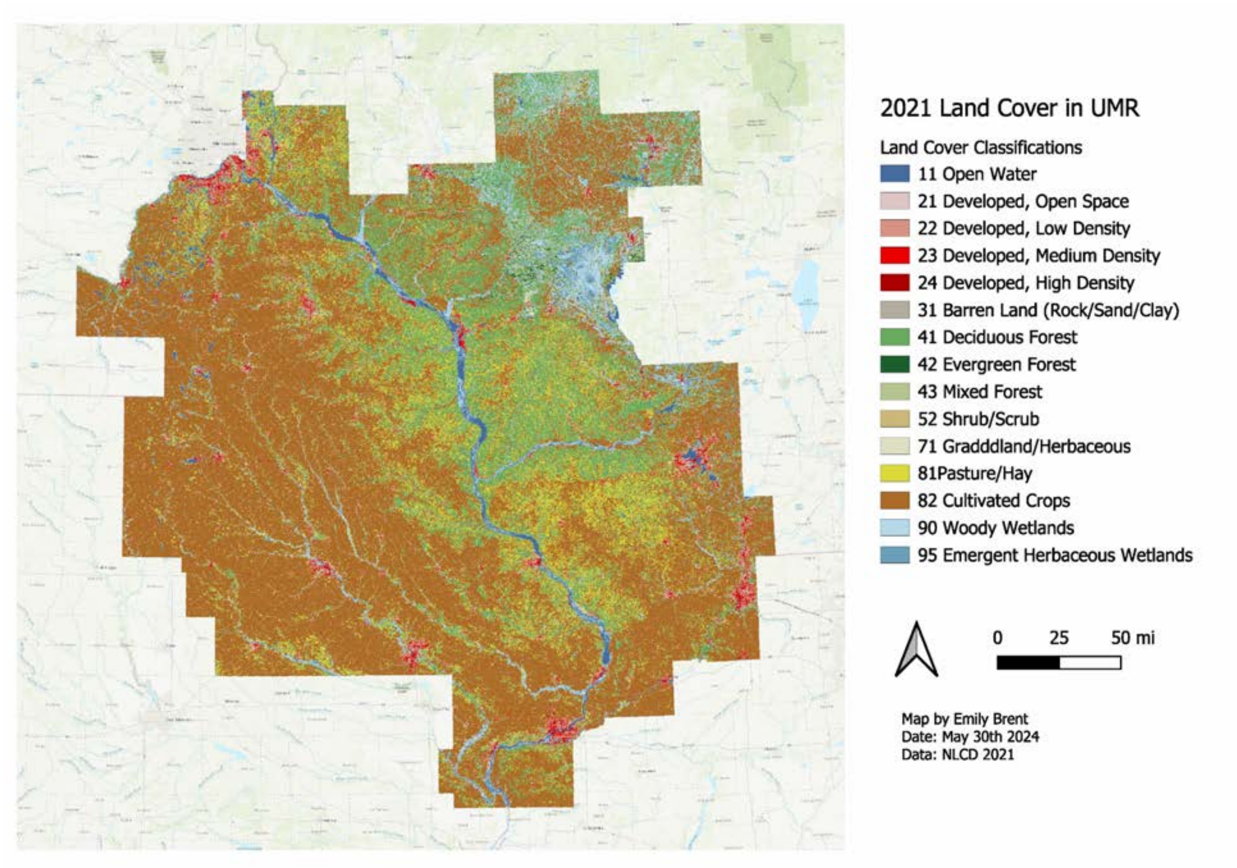


Figure 2: Cultivated cropland dominates the UMR. It is estimated 52% of the nitrogen load to the Gulf of Mexico from the Mississippi watershed is from corn and soybeans. (Ritter, W. F., & Rao Chitikela, S, 2020) Turning some marginal cropland acres into pastureland could help stabilize the soil and cut down on chemical inputs and nutrient runoff into the Mississippi river while simultaneously increasing wildlife habitat value (Wepking, Carl, et al, 2022)

The Mississippi River has experienced notable changes in nitrogen (TN) and phosphorus (TP) fluxes over time, reflecting the combined impacts of human activity and natural factors. Over time, the TN flux exhibited a declining trend, indicating localized reductions likely linked to human-driven efforts such as improved agricultural practices and nutrient management (Wang et al., 2022). Conversely, TP flux showed a significant upward trend. These increases in TP are largely attributed to intensified agricultural runoff and human activity, with human contributions accounting for 59.2%–95.0% of the TP flux increases. Overall, while nitrogen levels have shown slight reductions, phosphorus levels continue to rise, emphasizing the need for targeted nutrient management strategies in the Mississippi River Basin (Figure 3).

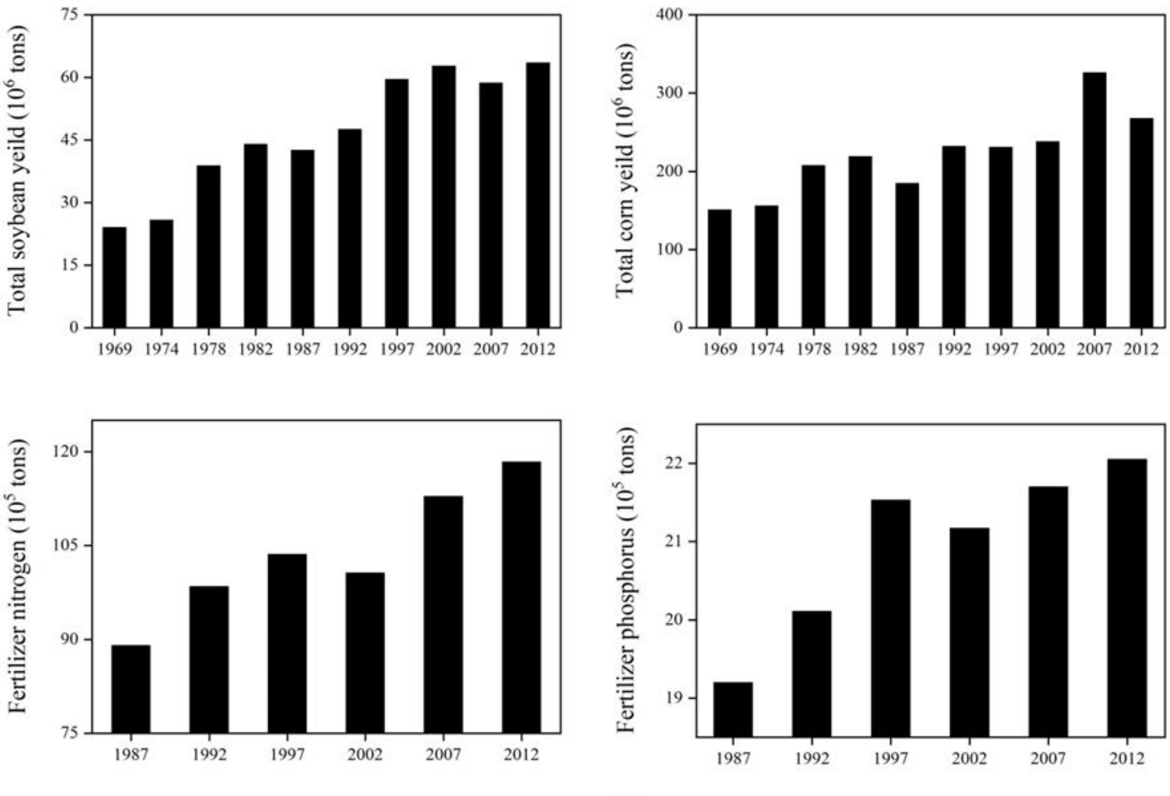


Figure 3: Annual production of soybean and corn, fertilizer nitrogen and phosphorus application (Wang et al., 2022)

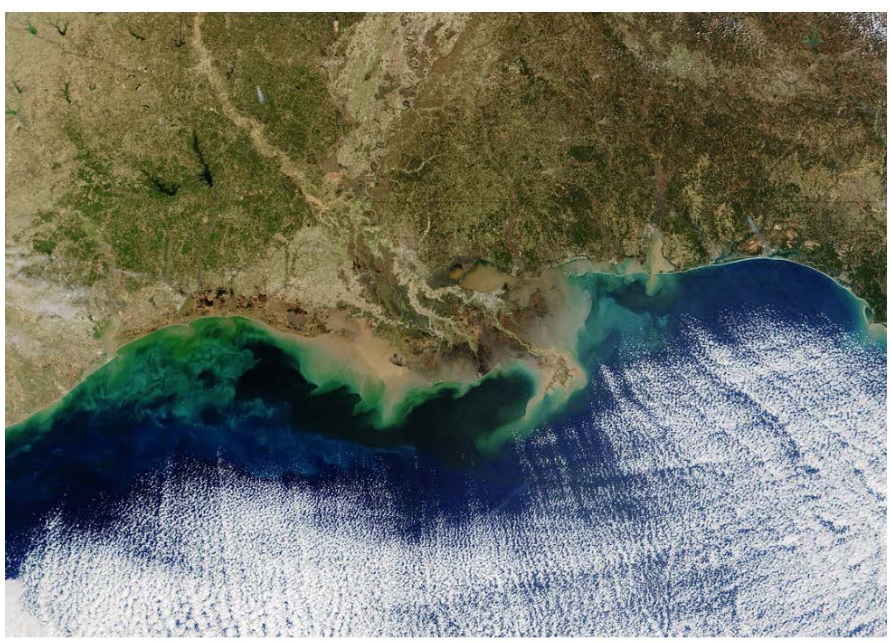


Image: NASA.

The teal blue area indicates the hypoxic zone along the Louisiana coast. Fertilizer and excess nutrients from intensive row cropping and other sources enter the Mississippi river watershed to flow out into the Gulf of Mexico.

The Benefits of Regenerative Grazing

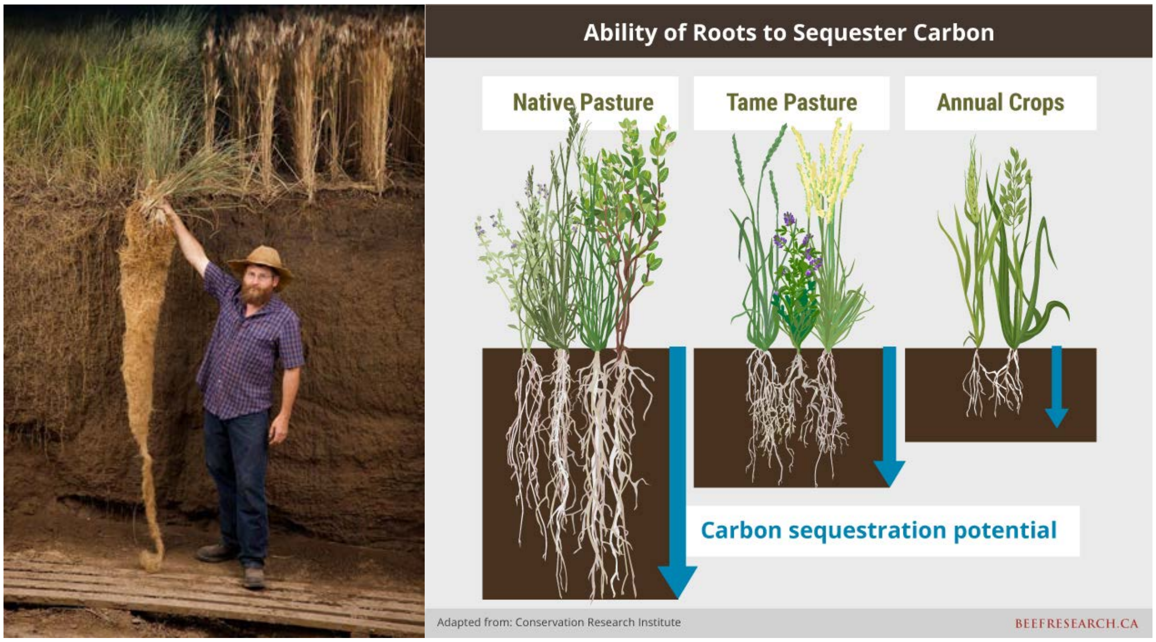
Environmental Stewardship

Regenerative agriculture, producing food in a manner consistent with positive environmental and social impacts, offers promising solutions to these challenges (Newton et al, 2020). By focusing on building soil health and improving water retention, regenerative cropping and grazing practices can mitigate soil erosion, improve soil structure, and promote nutrient cycling. Potential techniques on cropland include cover cropping, organic mulching, reduced or no tillage agriculture, contour agriculture, precision nutrient management and others (Kodaparthi et al., 2024).

Crop diversification - growing multiple crops from different plant families, growing varieties of the same species together, or incorporating noncrop vegetation into a landscape - can help improve overall crop productivity, the stability and delivery of ecosystem services, and the resilience of the agro-ecosystems and farm operations (National Sustainable Agriculture Coalition, 2020; Gaviglio et al, 2020).

Perennial systems have become increasingly common in the UMR region, particularly in soybean and corn production. These systems are projected to increase the proportion of cropland soils protected by living roots and vegetation from 48% in 2023 to 77% by 2050 (University of Minnesota Extension, 2024). As a result, there is potential to reduce nitrogen and soil loss by 23% and 35%, respectively, compared to a traditional corn and soybean cropping system that leaves soils exposed during the winter.

Pasture-crop rotation, a type of perennial system, integrating grain and livestock production, helps preserve soil structure and enhance soil health, promoting ecological intensification of agriculture. A long-term study demonstrated that pasture-crop rotations help maintain soil bulk density and larger aggregates better than continuous cropping systems (Zhao et al., 2024). The rotations also foster diverse and beneficial soil microbiota, including bacteria associated with soil structure maintenance and plant growth promotion, which may contribute to improved nitrogen uptake, accumulation, and oat biomass.



Credit: Reddit and Beef Cattle Research Council of Canada

These images show how root depth can influence soil quality. The long roots of perennial grasses sequester carbon, prevent soil erosion and allow water to penetrate rather than run off. Returning cropland to perennial grass for livestock grazing can satisfy our need for meat while repairing the environment.

Annual crops have shallow roots which are poor at sequestering carbon and do not hold soil together to prevent soil erosion. However, the root length of pasture plants and pasture photosynthesis aid in carbon sequestration and helps prevent soil erosion. For instance, an increase in soil organic carbon (C) from 10 g/kg to 20 g/kg could boost corn yields from 6.7 Mg/ha to 10.4–13.3 Mg/ha, and further increases to 30 g/kg could lead to yields ranging from 14.1 to 19.9 Mg/ha (Liu et al., 2019). In a pasture-crop rotation system, where land is devoted to pasture for 3–6 years out of a 10-year period, total grain production could remain stable while also providing additional forage for grazing, feeding, or biofuel use.

Crop rotations, particularly those involving perennial vegetation, significantly enhance crop productivity compared to continuous monoculture systems. In Georgia, corn grown in rotation with perennial sods achieved 11–24% higher yields than continuous corn, even with minimal nitrogen fertilizer application, and yield benefits persisted for several years (Tiemann et al., 2015). Rotations improve soil organic C levels, which are closely linked to yield gains, while continuous monoculture systems lead to a decline in soil organic C and yield plateaus. Diverse rotations, such as corn-soybean-oat-alfalfa systems, also increase yield stability and precipitation use efficiency compared to monocultures. For instance, in Iowa, a 4-year rotation resulted in higher corn and soybean yields and greater economic returns ($\$701$ ha^{-1} $year^{-1}$) than the typical corn-soybean rotation ($\$690$ ha^{-1} $year^{-1}$) (Tiemann et al., 2015). These findings demonstrate that integrating rotations or pasture into cropping systems enhances soil health, reduces yield variability, and boosts long-term productivity.

Additionally, integrating livestock grazing can increase plant diversity by 5.10%–7.19% and soil organic carbon (SOC) content by 13.70% (Su et al., 2022). In integrated crop-livestock systems significant improvements, including increases in the biomass (28.47%–35.49%), plant diversity (11.38%–14.72%), SOC (16.64%), and soil total phosphorus content (7.05%), as well as higher liveweight gain of total livestock (15.03%) are possible. Notably, the effect of cattle in mixed grazing on aboveground biomass transitioned from negative to positive as grazing duration increased.

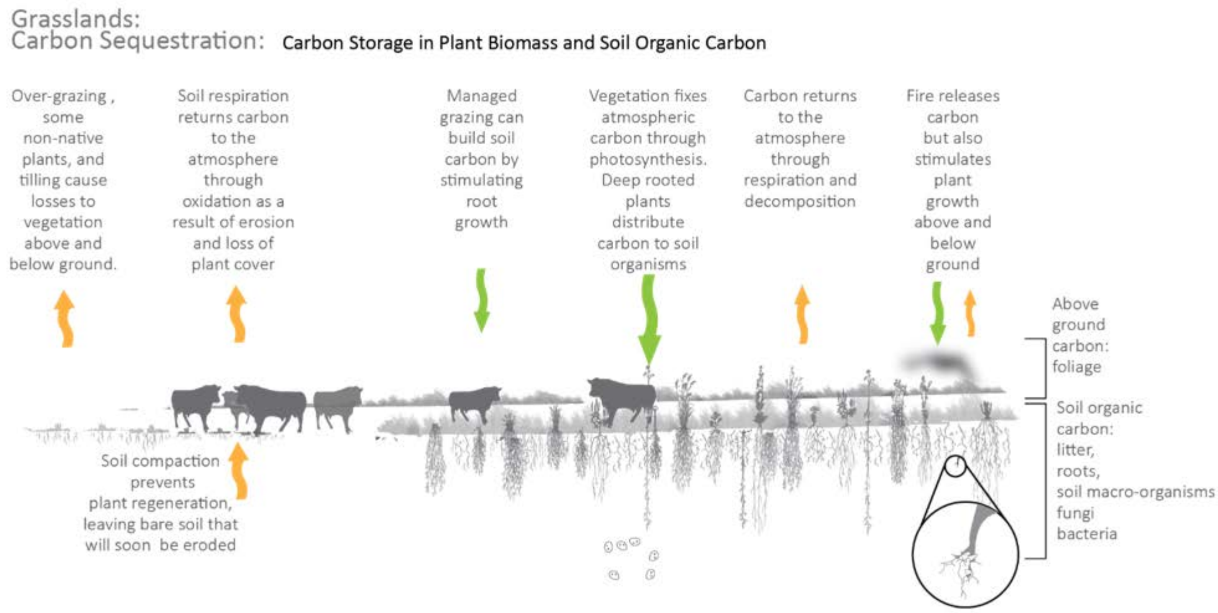
Cattle were more effective at maintaining plant diversity compared to sheep grazing, likely due to their less selective grazing habits (Cuchillo-Hilario et al., 2018). By increasing the diversity in the community, cattle grazing also contributed to a greater variety of insect species (van Klink et al., 2015). Cattle grazing decreased plant height while enhancing overall plant density and altering community functional composition by favoring the growth of forbs and legumes. These shifts boosted community heterogeneity and provided greater trophic resources for pollinators and insect herbivores (Ravetto Enri et al., 2017). This approach not only promotes healthier soils but also offers economic benefits, as forages can be grazed or sold, reducing external energy demands and fostering a more sustainable and productive agricultural system. The adoption of conservation pasture-crop rotations can lead to both environmental and economic advantages, benefiting both soil health and overall farm productivity.

Photo: University of Nebraska-Lincoln

By way of comparison, annual crops have shallow roots which are poor at sequestering carbon and do not hold soil together to prevent soil erosion. The picture above is a corn monoculture farm which has no remaining topsoil. It is estimated that ⅓ of corn-belt farms have lost all their topsoil (E360 Digest, 2021).

For pasture-based livestock systems, rotational grazing, moving animals to portions of the pasture, can prevent overgrazing in certain areas, allow vegetations to recover, and promote crop soil fertilization by animal waste. Together, regenerative practices help to regenerate the land and water system, reduce environmental externalities, improve the overall ecosystem, and further improve the prosperity of the economy in the UMR (Gwin et al., 2012).

A 60% decrease in sediment loads over 17 years in a northern Mississippi experimental catchment (~21 km²) was observed after 20% of the cropland was transitioned to permanent vegetation under the Conservation Reserve Program (Kuhnle et al., 2008). Erosion control measures reduce particulate phosphorus losses, though practices like conservation tillage, can enhance soluble phosphorus availability.



Credit: Minnesota Board of Water and Soil Resources

Perennial pasture has many benefits, the above diagram highlights the role of perennial grass, ruminants and fire in reactivating the grassland.

Animal Welfare & Human Health

Key co-benefits of grass-based livestock production is potentially improved animal welfare and herd health. In the conventional approach to beef production, for example, cattle usually spend the first two stages of cattle production, the cow-calf and stock phases, on pasture or rangeland, but are moved to feedlots at nine to fifteen months of age to complete the finishing stage (Justice et al, 2023). At the feedlots, cattle are fed a high volume of grain-based finishing feed for four to six months in order to gain weight rapidly and develop a proper fat/muscle ratio. Once they have gained sufficient weight, the cattle are slaughtered at sixteen to twenty months.

Unlike conventional beef, however, % grass-fed beef are “primarily or exclusively fed non-grain feedstuffs during its lifetime, with an emphasis on free-range grazing.” This difference mainly appears at the finishing stage. Instead of switching to a grain-based diet, grass-fed cattle continue to graze until they reach their desired weight and yield grade (Daley et al., 2010).

Since grass is less calorically intensive than grain, grass-based finishing takes significantly more time to be completed, with most cattle being slaughtered at twenty-four to twenty-eight months.

The ability of grass-finished cattle to remain on open pastures their entire life allows the animals to engage in stress-reducing behaviors such as grazing, roaming, and socializing with other cattle. In conventional feedlot systems antibiotics are commonly used to prevent disease and promote rapid growth (Carrillo et al., 2016). In grass-based systems, however, the natural diet and less crowded conditions mean that cattle are generally healthier and less prone to infections, reducing the need for antibiotics. This aligns with growing consumer preferences for natural and ethically raised meat.

Grass-fed beef may also offer benefits to human health. Grass-fed beef is generally leaner than grain-fed beef and contains higher levels of omega-3 fatty acids, which have been linked to improved heart health and reduced inflammation (Van Elswyk et al., 2014). Additionally, grass-fed beef contains more antioxidants, vitamins and conjugated linoleic acid (CLA), which have been associated with potential anti-cancer and weight-loss properties (Glenn et al., 2010).

Economic & Social Benefits

While switching to regenerative grazing certainly requires upfront investment and short-term risk, it can offer significant economic benefits to farmers and their communities after regional supply chains and markets for the product have matured. Grass-fed meat, when sold into functioning markets, can offer higher profit margins due to the reduced feed costs that come with pasture compared to expensive feed supplements and the price premiums that grass-fed products secure. In the US market, for example, high-quality grass-fed cuts received price premiums ranging from 150% for filet mignon to 193% for sirloin steak. (Wang & Isengildina-Massa, 2022) The potential for increased margins due to these price premiums is magnified when you take into account the leverage that graziers can pursue by retaining their herds for longer periods of their lives. By retaining their cattle for finishing, graziers can "capture more of the retail dollar of beef." (Deliberto, 2021).

Additionally, grass-fed meat and dairy products often command higher market prices due to growing consumer demand for sustainable, ethically produced food. This price premium allows small farms to achieve better profitability and reduce reliance on industrialized practices (American Grassfed Association, 2023; Bivatec, 2023).

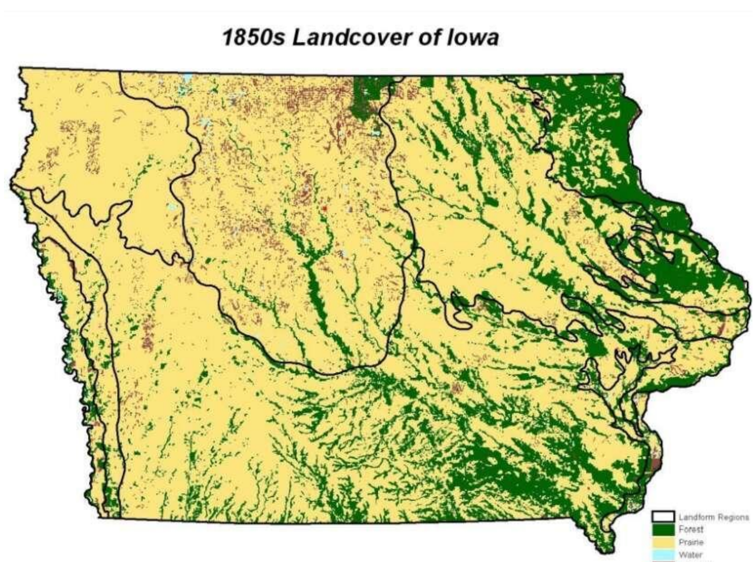
Grass-based livestock operations also can offer significant benefits to the regional communities they work in. Supporting small to mid-sized family farms, which are prevalent in this region (Census of Agriculture, 2022), strengthens local economies by generating jobs and increasing the viability of agricultural businesses. Unlike large-scale corporate operations that distribute profits to investors, the smaller family operations that predominate grass-fed livestock recycle their earnings into the local community and support other businesses such as local butchers and hay suppliers. Additionally, grass-fed livestock operations often rely on rotational grazing practices that directly require more labor on the farm, further stimulating local employment.

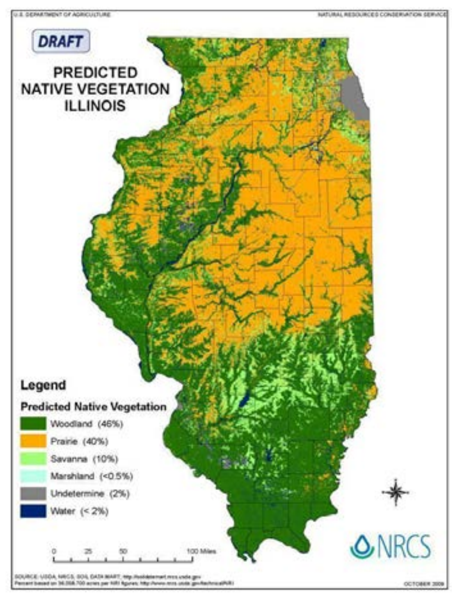
This cycle of reinvestment helps promote a return to rural self-reliance, as farmers become less exposed to the fluctuating swings in feed costs and slaughter fees set by national market forces and become more focused on local transactions. This is another reason why building robust supply chains for grass-fed beef is so important. The supply chain will not only provide economic benefits by funding farmer's regenerative grazing practices and realizing the return potential of grass-fed beef, it will be a benefit itself. New beef marketing collectives and new mid-scale slaughterhouses means more small businesses in rural communities that lag behind the nation in nearly all measures of economic well-being (Redefining Rural, 2021).

Expanding the grass-fed livestock supply chain in the UMR region also brings substantial social benefits, including promoting community health and preserving cultural traditions. Moreover, grass-fed livestock supports sustainable land use, preserving open spaces and promoting biodiversity. This practice aligns with regional cultural values tied to land stewardship and traditional farming methods. By revitalizing these practices, communities can strengthen their connection to agricultural heritage and to nature while fostering educational opportunities about sustainable food systems.

Grass Land Cover in the UMR Region

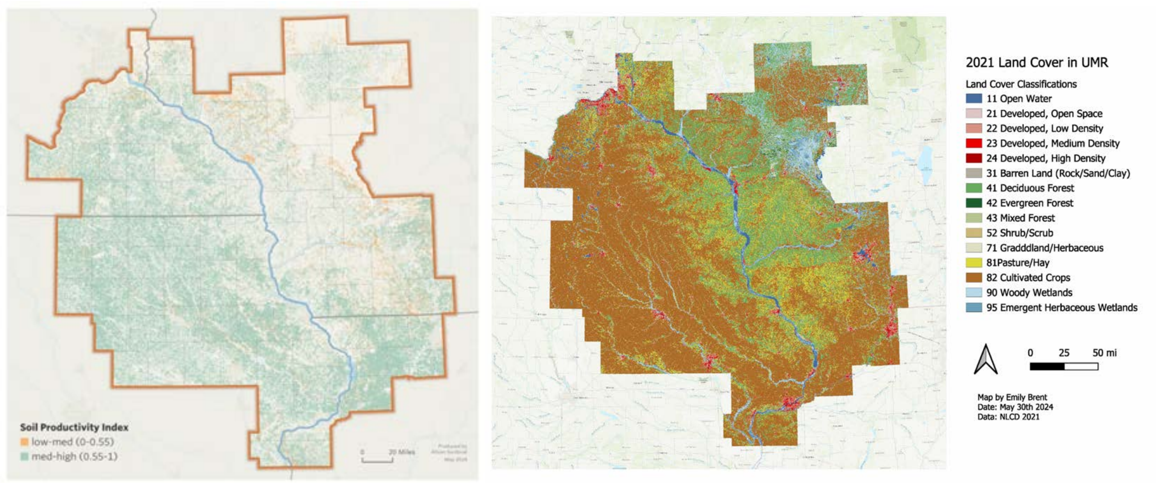
Not surprisingly, grass is the foundation of the supply chain in a grass-based livestock system. It is important to note that grass has an historical significance to the UMR as a large portion of the region was tall and short grass prairie in pre-settlement times. Our current agricultural regime has turned much of the best and most fertile grassland in the Foodscape into cropland. (Wepking, C. et al. 2020). There is, however, a significant amount of land in the UMR that is already dedicated to pasture. Understanding how this pastureland is currently distributed in the foodscape will be useful in order to begin to shift more cropland (back) into perennial pastureland. Transitioning a portion of more marginal cropland into pastureland may be possible within the context of the supply chain resources that are already abundant in the UMR. Because much of the corn and soy in the region are used for feed (Wepking, Carl, et al, 2022), it seems possible to remove the extra steps of growing food for cattle offsite and instead, grow forage for the cattle onsite.



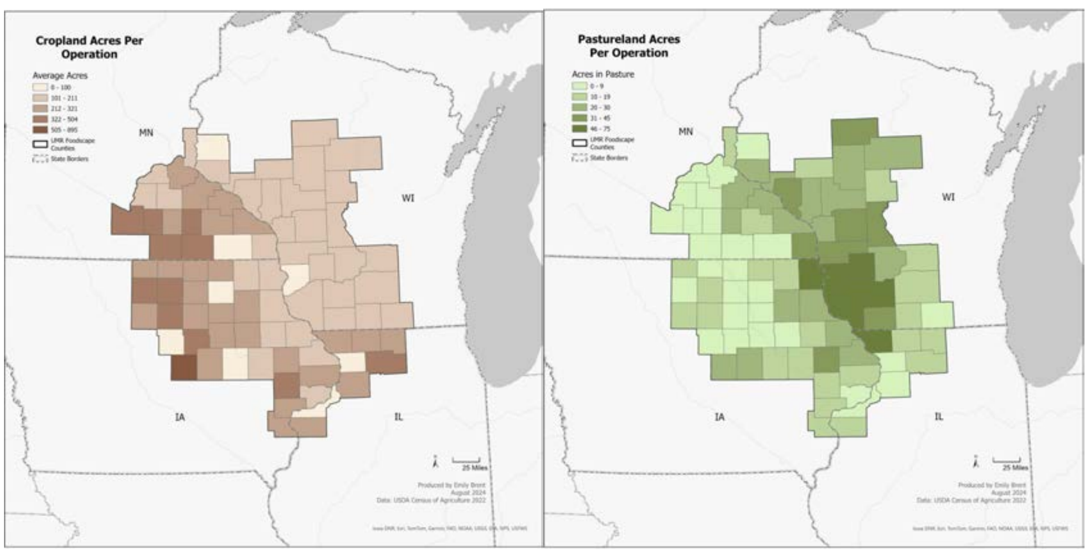


Credit: Natural Heritage Program, Minnesota Department of Natural Resources, University of Wisconsin Geological and Natural History Survey, Government Land Office Original Public Land Survey of IowaNRCS

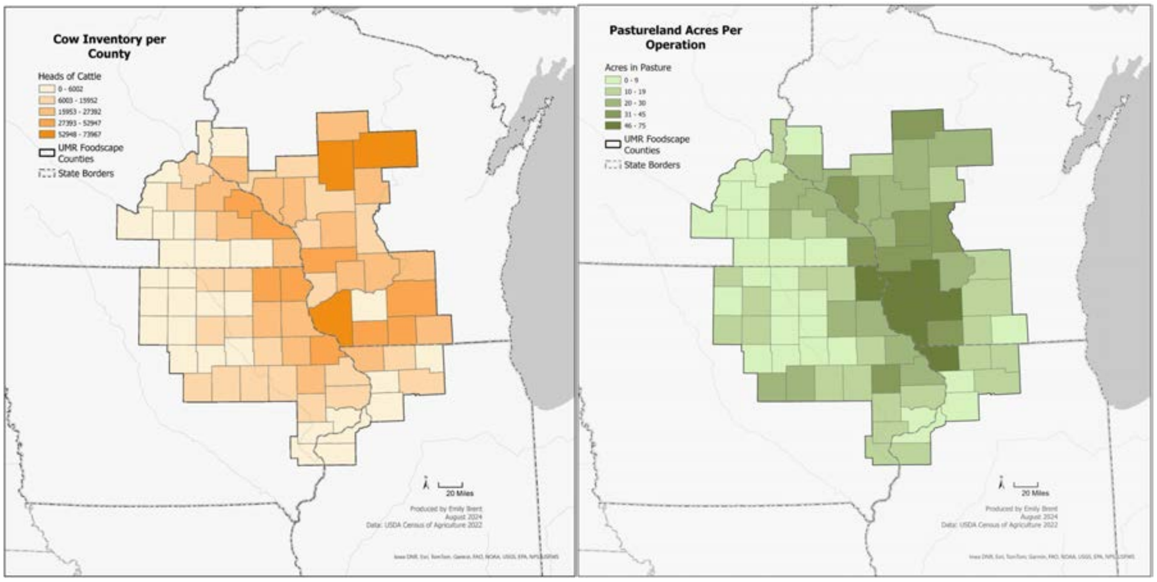
When considering conversion to grassland, looking back at pre-settlement land cover, shows that much of the land in the UMR used to be prairie. This ecosystem co-evolved with grazing buffalo (Knapp, A, et al. 1999). When properly managed, using cattle and other grazing animals to replace the historic role of buffalo in the prairie landscape can improve the heterogeneity of the ecosystem which can enhance biodiversity and positive outcomes for soil, water and wildlife habitat (Fuhlendorf, S, et al. 2001)



The map on the left shows soil productivity in the foodscape. The areas of medium to high productivity correspond roughly to the cultivated crops portion of the land cover map on the right while marginal lands have a more diverse land cover.



These maps show the distribution of cropland acres per operation. Note the high number of cropland acres compared to pastureland acres. Many of the areas that have the most pasture are unsuitable for crop agriculture due to large slopes, forest and riparian natural features or poor soil quality. (Reference Soil Productivity Index Map above).



The map on the left shows the distribution of cow inventory on the per county basis. Some of the highest cow inventory counties correspond to the counties with the highest amount of pastureland per operation, and some do not. These discrepancies highlight the places where large-scale feedlots dominate the beef and dairy industry.

Grass-Fed Beef

The Current State of American Grass-Fed Beef

The market for grass-fed beef, beef that is both raised and finished on pasture, has rapidly grown over the last twenty-five years, but remains a fairly small percentage of the overall beef market. In 1997, grass-fed retail sales totalled less than five million dollars. (Qushim et al., 2018; Williams, 2013) By 2012, they exceeded four hundred million dollars. Since then, overall grass-fed beef sales (including food service channels) have continued to rapidly expand, reaching about four billion dollars in 2019 – that equals about 4% of total beef sales for that year (Cattlemen's Beef Board, 2020). One billion dollars of that value came from sales of beef labeled with a grass-fed marketing claim, while the other three billion dollars came from grass-fed beef sold as unlabeled conventional beef (South Dakota State Extension, 2021). Two main takeaways about the national grass-fed beef market can be discerned from these statistics - whether or they also apply to the Upper Mississippi Region requires greater investigation:

1. A rapidly-growing, yet proportionally small market already exists for grass-fed labeled beef. There is significant room for that market to expand its total share.

2. 75% of grass-fed beef does not receive the market premium that comes from specialized labeling. This results from a combination of (1) certain grass-fed operations lacking the resources or capacity to achieve certification and (2) conventional operations selling meat from cows that were culled before they reached the grain-finishing stage.

The most recent comprehensive survey of grass-fed cattle producers occurred in 2017. In the report “Back to Grass: The Market Potential for U.S. Grass Fed Beef,” the Stone Barns Center for Food & Agriculture identified several key trends and patterns about the composition of grass-fed beef producers. First, the rapid growth of grass-fed beef sales corresponded with a rapid growth in the number of grass-fed operations from 100 in 1998 to about 3,900 in 2017 (Stone Barns Center, 2017). Therefore, the growth in grass-fed beef sales was not exclusively caused by an expansion in the herd size of existing grass-fed operations, but also by the entry of new operations and the transition of conventional operations into the grass-fed model. Within the 3,900 operations 70% kept their cattle from the cow-calf phase all the way to finishing and slaughter. As later sections of this report discuss, this long-term retention presents unique economic considerations for grass-fed operations such as delayed cash flow recovery.

The Stone Barns report also determined that the grass-fed beef industry was split into two distinct operation profiles: small-scale operations producing less than fifty heads annually and large-scale operations producing more than one thousand cattle annually. The small-scale operations, which comprised a “vast majority” of the market at the time of publication, primarily sold direct-to-consumer with a 50% premium over conventional beef prices. The large-scale operations mostly sold their beef through branded retail channels with those sales earning a lower average price premium of 25% (Stone Barns Center, 2017). The branded retail channels accounted for about 81% of grass-fed beef sales, while direct-to-consumer marketing accounted for the other 19%. This divide suggests that while small-scale producers make up a high percentage of total grass-fed beef operations, they make up a much smaller percentage of total sales. Therefore, any statistics about overall trends of the industry should not automatically be inferred to also reflect the current state of small-scale operations.

The Grassfed Beef Supply Chain

The purpose of this section is to highlight the key components of the grass-fed beef supply chain. It shows the typical pathway from birth to market for grass-fed beef products. It also discusses potential supply chain bottlenecks and suggests key areas and methods for expansion. In this section we recommend specific actions to enhance the supply chain for producers of grass-based livestock products.

Cow-Calf Operations

Many grass-fed beef operations begin by sourcing cattle from cow-calf operations, where herd sizes are typically small. Farms with fewer than 100 beef cows play a significant role in U.S. agriculture, representing 90.4% of all farms with beef cattle (USDA, 2023). These smaller operations benefit from relatively low operational costs, as cattle spend much of their time on pasture, requiring minimal resource inputs. Both grass and feedlot finishing operations rely on cow-calf operations for their cattle supply; however, specific challenges arise when these operations serve grass-fed beef producers (Harper et al., 2020).

One challenge is the time and cash flow associated with grass finishing. Finishing cattle on grass takes longer than grain-based finishing, leading to cash flow gaps for cow-calf operations that supply grass finishers (Ager, 2024). Another significant constraint is the suitability of cattle breeds. Grass-fed producers report difficulty finding breeds that can be efficiently finished on pasture alone. After decades of selective breeding aimed at optimizing meatpacker efficiency, most conventional cattle have become larger and require longer periods to finish on grass, which increases production costs. Taller, leaner cattle may take an additional year or more to finish without grain, further straining operational timelines and finances (Gwin, 2009).

To address these challenges, grass-based farmers have experimented with breeds better adapted to grass-only diets, though this approach often requires direct partnerships with cow-calf producers, or managing their own breeding herd (USDA, 2023). Introduction of more grass-friendly cow/calf operations into the grass-based system in the UMR could be a unique way to expand the perennial grass farming business model. Entry into the cow/calf business is relatively low stakes and because of the relatively small average herd size of these enterprises, the work can be done alongside other farm enterprises tasks (USDA, 2023).

Recommendation #1: *Foster greater collaboration between cow-calf producers and grass-based finishing operations to increase the availability of grass-suitable cattle breeds.*

Grass Finishing

Many grass-fed beef operations adopt varying business models; some farmers breed and finish cattle entirely on their farms, while others source calves from cow-calf operations for finishing. Successful grass finishing relies on careful selection and management of forages within a specific context (Raymond, 1963). Many practitioners refer to themselves as grass farmers, highlighting their role as stewards of the land and the emphasis on producing abundant, high quality forage as core to their business model. This approach transforms the animals into effective tools to manage the grasslands and pasture, ultimately promoting the productivity of both the operation and the ecosystem (Flack, 2016).

The UMR is in need of more resources to educate farmers on forage selection and management. Producer-led watershed groups currently and could continue to play a key role in disseminating ideas and resources from trusted peers (Strauser & Stewart, n.d.). Creative ways to bring people together to discuss ideas and share resources are needed to strengthen the connections between farmers and all parts of the supply chain. Jamie Ager of Hickory Nut Gap Meats is on the forefront of this creative conversation and market building.

> "A core value at Hickory Nut Gap is relationships. We want all partners that interact with Hickory Nut Gap to thrive. This includes the land (regenerative practices), the animals (high welfare), and people (farmers and customers). Most folks end up coming to our annual farmers meeting every year and we all spend time getting to know each other."

This is perhaps one of the most pressing challenges, getting all of the stakeholders to come to the table to discuss what works, what does not work and what can be done to strengthen the supply chain from all angles.

Recommendation #2: *Expand education resources for grass cultivation, including types of grasses, methods of planting and the use of grass for livestock production.*

Growing and managing the right forages involves sourcing suitable seeds, planting them, and mastering the specialized skills necessary for optimal outcomes. Rotational grazing is often favored over continuous grazing because it allows grasses the necessary time to rest and recover (Kreuter & Teague, 2020). Providing cattle with strategic access to fields when the grass achieves an ideal balance of carbohydrates and protein is crucial for ensuring animal condition and sufficient weight gain (Gwin, 2009).

Implementing a rotational grazing system also requires specific infrastructure, particularly fencing and water access. Establishing and maintaining an agile fencing system is essential for effectively moving cattle, which may occur anywhere from weekly to several times a day, depending on stocking rates, pasture size and quality, and rainfall conditions (Dinterman, 2024).

Some row crop farmers have begun integrating livestock into their operations by allowing cows to graze on cover crops or crop residue. This practice creates unique opportunities in the market by generating value from row crops while simultaneously providing environmental benefits through continuous soil cover, reducing erosion and runoff (Gardner et al., 1991). Expanding this model could serve as a natural segue for row crop farmers into livestock production, enabling them to enhance their environmental stewardship while maintaining their current agricultural systems. This integration of livestock into row crop systems can facilitate a middle role in the supply chain, similar to that of stockers, or allow cattle to graze on cover crops during winter months. Such practices can reduce the reliance on winter hay supplies for grass-finished operations, optimizing resource use across the entire farming system.

Recommendation #3: *Promote and incentivise (through policy, research and funding) the use of cover-crop grazing as a way to increase the integration of grass-based livestock production into the current cropping systems.*

Finally, providing adequate winter forage is a vital component of a grass-based operation. Successfully managing winter forage can significantly impact profitability; missteps in this area may push an operation into the red. Winter feeding in the UMR region may include a combination of grazing winter annual crops or stockpiled forage, and feeding hay and/or haylage harvested during the growing season. Meeting winter forage demands careful consideration of herd size and the duration for which cattle will require supplemental feed during the non-growing season (Brinkerhof, 2024). Forages can be made on farm or purchased, which allows farmers to reduce their investments in hay production infrastructure and simultaneously import nutrients to replenish those exported in beef products. Additional production of hay resources for an expanded grass-fed market could be a potential source of market expansion in the UMR. Production of hay in the foodscape could encourage row farmers to invest a portion of their land in perennial grasses without having to own livestock.

Recommendation #4: *Dedicate sections of marginal row crop operations to perennial forages to support winter hay for grass-fed cattle.*

Slaughter

Animals must be monitored to ensure they meet target weight and condition before slaughter. Transportation to slaughter is an important aspect of the supply chain. It is necessary to either own or rent trucks and trailers to bring animals to slaughter. In smaller operations, there might not be enough cattle going to slaughter at one time to make investing in this equipment a priority. Therefore, small producers have become increasingly interested in the use of mobile slaughter operations to avoid the burdens of cattle transportation.

The availability and accessibility of processing facilities are significant factors that impact the transition to a grass-based beef supply chain. For many grass-fed beef producers, securing appointments with USDA-approved slaughterhouses is a considerable challenge. Due to high demand, these facilities are often booked months or even a year in advance, making it difficult for small-scale producers to access slaughter services when needed. The consolidation in the meatpacking sector further complicates access, as most USDA facilities are geared toward handling large volumes, often prioritizing appointments for high-volume customers over smaller operations (Brinkerhof, 2024).

For instance, Gillespie et al. found that, on average, grass-fed beef farms raised about forty animals annually, with a median of just sixteen (2016). Given that Grass-fed beef operations tend to be small-scale, typically raising only a few dozen animals to slaughter weight each year, this can create difficulties for producers to compete for space in large slaughterhouses. Furthermore, many producers prefer to slaughter in the fall after the grazing season to avoid the additional costs of overwintering animals. However, fall is also the busiest time for slaughterhouses, adding further strain on appointment availability. Delayed appointments can result in additional costs and disrupt operations.

Another logistical barrier for grass-fed operations is the physical distance to USDA-inspected facilities, which are often located far from small-scale farms. Extended travel times to these facilities can lead to stress for the animals, potentially affecting meat quality and increasing transportation costs for producers.

Additionally, by-product use and distribution is difficult for small producers since there is a lack of demand for less-popular cuts. For example, according to the Stone Barns Report, while the chuck and round comprise “30% of a grass-fed animal’s carcass weight,” they only generate about 6% of total sales. Therefore, in order to collect greater value from each carcass, producers could work with food service operators and grocery chains to develop new value-added products.

Recommendation #5: *Lobby slaughterhouses for retention of less popular carcass components and foster sales channels for them.*

An increased number of small, custom slaughter operations could potentially benefit grass-based producers by providing more flexible access. However, many of these facilities are not

USDA-inspected, limiting resale options to herd-share arrangements, where consumers buy portions of the live animal. While herd-share programs offer a way to sell directly to consumers, they limit market access, as meat from non-USDA facilities cannot legally be sold to retailers or across state lines (Gwin, 2009). Furthermore, small facilities often lack the scale and industry relationships needed to effectively market by-products, resulting in higher operational costs compared to large slaughterhouses. According to the Stone Barns Report, these facilities charge above-market rates of "$150-300 per head for larger branded programs and as much as $400-800 per head for small-scale producers." When coupled with the additional markup charged by specialty meat distributors, these supply chain costs result in a premium for the product that exceeds the intrinsic costs of raising grass-fed beef.

To foster a grass-based beef supply chain in the UMR, more emphasis is needed on developing mid-sized USDA-inspected facilities that can support small producers while complying with federal regulations. Increasing the availability of these facilities would enable small farms to expand their market reach and potentially retain more of the value derived from by-products, making the grass-fed beef market more accessible and economically viable for smaller producers (Draeger et al., 2021).

Recommendation #5: *Build regional networks of small-scale producers to signal and create demand for mid-sized USDA-inspected facilities in their area.*

<u>Labeling</u>

Labeling plays a significant role in determining which variations of grass-fed beef receive the valuable "Grassfed" or "100% Grassfed" labels. The specifics of labeling requirements are important because lax labeling standards could result in beef products that were fed minimal amounts of grass receiving the price and marketing benefits of the label. Stricter labelling requirements, on the other hand, would promote grass-finishing by ensuring that beef producers who raise their cattle entirely grass receive distinct benefits for their approach.

Previous labelling requirements of the USDA's Food Safety and Inspection Service (FSIS), which evaluates and approves meat labels bearing special claims, leaned more lax as they allowed products that weren't entirely grass fed to use the label. However, in August 2024 the FSIS updated its labelling standard in August 2024 to state:

> *FSIS considers "Grass Fed," "Grassfed," "Grass-Fed" and "100% Grass-Fed" to be synonymous terms. These claims may be applied to meat and meat product labels derived from cattle that were only (100%) fed forage (e.g., grass) after being weaned from their mother's milk. This means such animals are never confined to a feedlot. Forage consists of grass (annual and perennial), forbs (e.g., legumes, Brassica), browse, or cereal grain crops in the vegetative (pre-grain) state. Hay, haylage, baleage, silage, corn silage, crop residue without grain, and other roughage sources may also be included as acceptable feed sources. "Grass Fed" animals cannot be fed grain or grain by-products and must have continuous access to pasture during the growing season until slaughter. Routine mineral and vitamin supplementation may also be included in the feeding regimen…*

Notably, this updated definition requires that cattle (1) consume a 100% forage-based diet after weaning and (2) have open access to pasture until slaughter. The first requirement ensures that marketers no longer use the "grass-fed" or "100% grass-fed" labels when their cattle only have a primarily forage-based diet i.e. greater than 50%, but not 100%. The second requirement prevents them from using the same labels when their cattle are fed a grass-based diet via feedlot, not pasture during the finishing stage.

The FSIS's new labeling standards also provided an updated definition for partially grass-fed beef. This definition addresses the various diets that include a heightened amount of forage consumption, but do not meet the heightened requirements for the "grass-fed" label:

> *If, after weaning, an animal's diet consisted of less than 100 percent access forage (i.e., grass), a partial "Grass Fed" claim must accurately reflect the circumstances of raising (e.g., "Made from cattle fed grass and corn"). This includes claims such as "Grass Finished," which is not synonymous with "Grass Fed." Animals that are "Grass Finished" can be fed grain, in which case the claim "Grain Fed, Grass Finished" would be truthful and not misleading.*

While the FSIS sets the requirements for the use of these generic "grass-fed" labels, third-party organizations are also permitted to establish their own labels with heightened requirements for certification. The American Grassfed Association's "American Grassfed" label, for example, not only sets strict standards for diet and pasture access, but also animal welfare, antibiotic use, and American origin. Similarly, A Greener World's "Certified Grassfed" label addresses land management practices as well, prohibiting the clearing of “primary or old growth secondary forests for conversion to agricultural land.”

Recommendation #6: *Monitor USDA Food Safety and Inspection Service labelling standards and engage in public comment processes to ensure continued rigor and serve their intended purpose.*

Marketing and Distribution

The next step in the grass-fed beef supply chain is marketing and distributing the meat. Traditionally, most grass-fed beef producers sell directly to consumers. According to Gillespie et al., 96% of producers follow this model. Some producers make herd-share arrangements where consumers purchase a portion of an animal prior to slaughter. This model allows sales of meat processed at more prevalent state-inspected (non-USDA) facilities.

Direct-to-consumer sales usually require producers to build their own customer base which may include individuals, retailers, restaurants, and/or wholesalers. This approach allows farmers to capture a premium price over commodity cattle markets (Harris, n.d.). However, there are challenges. Small farms often struggle to keep up with demand once they establish a loyal customer base. Additionally, since farming is seasonal, there are periods when fresh meat is unavailable. One possible way to help balance supply and demand is to normalize frozen meat in consumer preferences.

Direct to consumer farms must also invest in customer service and advertising, diverting resources from core farming activities. On an industry-wide scale, this fragmented marketing can create inefficiencies, as each farm independently invests in building its customer pipeline. One solution to these challenges is cooperative marketing. Farmer-owned cooperatives allow producers to pool resources, establish a stronger brand, and maintain consistent supply. While co-ops charge members a small fee (typically around 10%) for operating expenses, many offer dividends if the brand exceeds seasonal expectations, providing financial incentives and reducing individual marketing costs. Some examples of successful grass-based livestock product cooperatives include: Grassfed Cooperative, Grass Roots Farmer's Coop, Wisconsin Grass-fed Beef Cooperative, Allegheny Grass Fed Cooperative among others.

Another option is for producers to partner with a branded meat company, a middleman that purchases meat at wholesale prices. This arrangement shifts branding and marketing responsibilities to the middleman, enabling farmers to focus solely on production. It also alleviates supply and demand pressures on individual producers, providing greater stability. Finally, some producers may sell their meat into the broader commodity meat market. In this channel, their meat is mixed with conventional beef in the national supply chain, where any unique grass-fed or natural labels are removed, effectively treating it as standard beef (Harris, n. d.).

To improve marketing and distribution of grass-fed meats in the UMR, more intermediary players are needed. The entry of more branded companies or branded co-ops that aggregate meats are needed. This will allow for more market predictability, less cross-over, fewer competitors and a stronger network of farmers working together (Ager, 2024).

Recommendation #7: *Identify and promote existing branded grass-fed co-ops in the region while working with farmers to create new marketing co-ops in areas where they don't already exist.*

Dairy

Grass-fed dairy and conventional dairy supply chains differ significantly in production practices, processing, distribution, and environmental impact. Grass-fed dairy relies on pasture-based feeding and rotational grazing, promoting soil health and biodiversity, while conventional dairy uses grain-based diets and higher-yield practices that emphasize efficiency. Grass-fed milk often goes through smaller-scale, specialized processing and reaches consumers through niche markets, commanding premium prices due to its perceived health and environmental benefits. In contrast, conventional dairy supports large-scale processing and widespread distribution through mainstream retail channels. The following section provides an overview of the grass-fed dairy supply chain and offers a few recommendations in order to expand grass-fed dairy in the UMR region.

Cows/Breeding Programs

Grass-fed dairy farmers often source their cows through a combination of buying from specialized breeders and maintaining on-farm breeding programs. The approach depends on the farm's scale, goals, and available resources. Many grass-fed dairy farmers initially source cows from breeders who specialize in grass-efficient breeds, such as Jerseys, Guernseys, Normandes, Ayrshire and Brown Swiss which are well-adapted to grazing and have the milk composition that aligns with grass-fed dairy standards. Specialty breeders and regional cattle auctions are common sources for acquiring initial stock or for diversifying genetics, especially for breeds adapted to grass-fed systems. For example, breeders with a focus on pasture-based dairy systems can provide cows that already demonstrate efficient grazing behavior and milk production on forage-based diets (Heins et al., 2012). Once established however, many operations introduce their own breeding program in order to control herd genetics and defray costs associated with acquiring new animals at a regular interval.

Recommendation #8: *While many farms transitioning to grass-fed from conventional dairy might use their current herd genetics, moving to a more grass-friendly genetic make-up will improve outcomes.*

Nutrition Management

Among grazing dairies in the UMR, pasture management and rotational grazing practices are commonplace due to the need to produce highly nutritious forage through the growing season. These practices directly influence milk yield and quality (Schwendel et al., 2015). Farms typically use rotational or management-intensive grazing systems to ensure a steady diet for the cattle, helping maintain milk composition and importantly, animal health. Intensive rotational grazing ensures that summer forage is extremely high in nutrients so that the cattle can be as healthy as possible for lactation and to build condition before the winter months. Dairy farms in this region frequently incorporate specific grasses and legumes into their pastures to ensure adequate nutrition year-round. As in grass-fed beef production systems, hay, haylage and silage is often produced or bought to bolster pasture forage in the winter.

Recommendation #9: *Expand education resources for grass cultivation and nutrition management. Because milking cows need proper nutrition to assure their health, more resources should be available to point newcomers to the market in the right direction.*

Processing

Many farms using the grass-fed model do not use a processing facility but instead market their milk directly to consumers as raw milk. Small, in-house processing facilities can add additional, minimally processed products like yogurt and cheese to the list of products offered. Larger-scale processing adds another layer of specificity. Milk from grass-fed cattle must often be processed separately from conventional milk to maintain its identity and fulfill market expectations. Distinct handling methods and additional quality checks are used to meet standards set by organizations or certifications, such as the American Grassfed Association (AGA), ensuring that grass-fed claims align with consumer expectations and regulatory guidelines (AGA, 2023). Wisconsin and Minnesota are notable for their extensive dairy industries and established infrastructure, which supports a larger number of certified organic and grass-fed farms relative to other states. These states have well-developed processing facilities for smaller, grass-fed dairy producers, helping streamline the processing and distribution of these specialty products. For example, Wisconsin has a strong network of dairy cooperatives and processors specializing in grass-fed and organic dairy, which fosters collaboration and collective bargaining for small to mid-sized producers (LaCanne & Lundgren, 2018).

Recommendation #10: *Encourage the development of cooperatives in the wider UMR using Wisconsin's extensive and successful network as an example.*

Distribution

The distribution component involves careful logistics to maintain the freshness and quality of grass-fed dairy products. These logistics play a critical role in the product's market positioning, often appealing to consumers prioritizing sustainability and supporting local economies (Robinson et al., 2014). Demand for grass-fed dairy products is high in urban centers within Illinois and Minnesota, particularly around Chicago and Minneapolis. This proximity to a large consumer base allows producers to market grass-fed dairy products with relatively short supply chains, often focusing on local branding and environmentally friendly production methods that resonate with consumers. Brands often leverage certifications and labeling to establish transparency, which can enhance consumer trust and willingness to pay premium prices for grass-fed products (Benbrook et al., 2018). Studies have found that consumer awareness of health benefits, such as higher omega-3 content in grass-fed milk, along with concerns about sustainable agriculture, drives a premium market for these products (Winsten et al., 2020).

Distribution networks within this region rely on cold storage and careful scheduling to preserve product freshness. Local cooperatives often play a significant role in managing logistics for grass-fed dairy, ensuring that supply remains consistent and quality standards are met.

Recommendation #11: *Expand cold storage infrastructure in UMR states to ensure that additional product would have cold storage and distribution potential.*

State and Federal Policy

Federal and state programs offer support to grass-based livestock operations primarily through their conservation, nutrient management and biodiversity initiatives. Federal policies focus on overall soil health and water quality goals while state initiatives are more targeted to the priorities of their local landscape. At all levels, financial incentives and educational programs are key for the expansion of grass-based ecosystems.

At the federal level, the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) has put in place programs to improve soil health, reduce erosion, and build biodiversity. The Environmental Quality Incentives Program (EQIP), for example, offers financial incentives and technical assistance to farmers who adopt practices such as reduced tillage and cover cropping. The CSP plays a crucial role in the UMR, where farmers face major challenges in soil erosion and water quality. Also addressing soil health, the Conservation Innovation Grants (CIG) On-Farm Conservation Innovation Trials program analyzes data on nutrient management and provides data to farmers to make informed decisions.

At the state level, practices are tailored to local needs. The Department of Agriculture, Trade, and Consumer Protection (DATCP) provides grants for sustainable agriculture initiatives in Wisconsin. The Producer-Led Watershed Protection Grants promote the formation of peer groups and help to improve water quality through rotational grazing, and nutrient management. Additionally, The Wisconsin Farm to School Program connects schools with local farmers building skills in organic farming, integrated pest management (IPM), and soil health analysis.

In Minnesota, the Farm to School & Institution Program allows for research trials through grants. They provide demonstrations of cropping and soil innovations. Also in the state, the Minnesota Agricultural Water Quality Certification Program (MAWQCP) certifies farms that adopt conservation practices protecting water quality and offers financial support. Iowa's state resources also include a heavy focus on water conservation and quality. Iowa Water Quality Initiative (WQI) and Iowa Nutrient Reduction Strategy (NRS) programs both aim to protect nutrient quality and buffer from run-off. NRS specifically encourages cover cropping and no-till farming and establishes cost share programs for technical assistance. Iowa State University leads Clean Water Iowa that houses both WQI and NRS and provides research support across multiple institutions. Finally, Illinois boasts the Illinois Stewardship Program which supports local food practices in the state. It aids farmers in transition to organic production, by teaching best conservation and marketing practices. Illinois Department of Agriculture (IDOA) also supplies funding for sustainable agriculture implantation through the Nutrient Loss Reduction Strategy.

Despite the perceived availability of government funding, in reality these programs are difficult to participate in. The processes move slowly, often not meeting the short term demand of farmers, and in some cases the standards are too extreme and do not align with the farm's missions. Red tape around procedures may limit the willingness of farmers, especially those new to the markets, to partake. The highest success rates are from the programs that directly involved farmers in developing standards rather than outside policy-makers.

Recommendation #12: *Build information sharing networks to support small producers and establish examples while maining the values of community and local engagement.*

Conclusion

Our work this year included conversations with local farm owners and non-profits with firsthand experience in restorative agriculture. Conversations with these parties highlighted the struggles of small farms in profitability and scalability. These farms regenerative, grass-based business models as a more ethical approach to raising cattle, but struggle to keep up with quotas in later supply chain steps or and often fail to see profit financially. Pasture Project 2.0, an advocate and researcher in restorative agriculture, aims to help small farms scale up to fix these issues. By providing examples of successful farms and keeping new participants involved in the program, they successfully address the needs for support in short and long term settings.

Scaling up regenerative agriculture should not exclusively fall on the producer. Funding and technical assistance programs exist to help farmers enter the market or scale up to larger profit margins.

Simultaneously, there needs to be a significant investment in consumer education and marketing. Helping farmers scale up production, doesn't matter unless there are people to buy their products. Retraining public behavior to diversify their food sources and buy local, could be a first step in consumer education. Establishing programs to support consumers for choosing sustainable options could be effective to build positive patterns, relationships, and knowledge. Finally, a continued focus on supporting relationship building will likely be effective in bringing costs down and providing large scale change. Connecting farms to specialists, community leaders and each other, allows them to bring down input prices with greater market control and build trust in best practice recommendations for environmental concern.

Recommendation Summary

#1: *Foster greater collaboration between cow-calf producers and grass-based finishing operations to increase the availability of grass-suitable cattle breeds.*

#2: *Expand education resources for grass cultivation, including types of grasses, methods of planting and the use of grass for livestock production.*

#3: *Promote and incentivise (through policy, research and funding) the use of cover-crop grazing as a way to increase the integration of grass-based livestock production into the current cropping systems.*

#4: *Dedicate sections of marginal row crop operations to perennial forages to support winter hay for grass-fed cattle.*

#5: *Collaborate with slaughterhouses to secure retention of less popular carcass components and foster sales channels for them.*

#5: *Build regional networks of small-scale producers to signal and create demand for mid-sized USDA-inspected facilities in their area.*

#6: *Monitor USDA Food Safety and Inspection Service labelling standards and engage in public comment processes to ensure continued rigor and serve their intended purpose.*

#7: *Identify and promote existing branded grass-fed co-ops in the region while working with farmers to create new marketing co-ops in areas where they don't already exist.*

#8: *While many farms transitioning to grass-fed from conventional dairy might use their current herd genetics, moving to a more grass-friendly genetic make-up will improve outcomes.*

#9: *Expand education resources for grass cultivation and nutrition management. Because milking cows need proper nutrition to assure their health, more resources should be available to point newcomers to the market in the right direction.*

#10: *Encourage the development of cooperatives in the wider UMR using Wisconsin's extensive and successful network as an example.*

#11: *Expand cold storage infrastructure in UMR states to ensure that additional grass-fed dairy products would have adequate storage and distribution infrastructure.*

#12: *Build information sharing networks to support small producers and establish examples while maining the values of community and local engagement.*

Acknowledgments

We extend our deepest gratitude to our partners at The Nature Conservancy, Lisa Kushner, Regenerative Food Systems Manager, and Luke Peterson, Regenerative Agriculture Specialist, for their invaluable expertise and dedication to this project. We also would like to thank our Dow Mentor, Jens Bogaert, for his guidance on supply chain management practices. This work was supported by the Dow Company Foundation through the Dow Sustainability Fellows Program at the University of Michigan.

Sources

American Grassfed Association (AGA). (2023). *Grassfed dairy standards*. www.americangrassfed.org/aga-grassfed-dairy-standards/.

American Grassfed Association. (2023). *Grassfed production and economic benefits*. www.americangrassfed.org/understanding-the-economic-impact-of-grass-farming-on-rural-communities
/.

American Grassfed Association (AGA). (2023). *Grassfed ruminant standards*. www.americangrassfed.org/aga-grassfed-ruminant-standards/.

Baudracco, J., Holmes, C. W., & Macdonald, K. A. (2013). Normande and Holstein-Friesian dairy cows' performance under grazing and confinement feeding systems. *Animal Production Science, 53*(5), 474-482.

Bauman, P. (2021). *Grass-fed beef: Market share of grass-fed beef*. SDSU Extension. www.extension.sdstate.edu/grass-fed-beef-market-share-grass-fed-beef.

Benbrook, C. M., Davis, D. R., Heins, B. J., & Zimmerman, J. (2018). Enhancing the nutritional value of grass-fed dairy products. *Food and Nutrition Research, 62*(4), 143–160.

Bell, B. R., Bellows, R. S., & Woodford, J. A. (2014). Milk production traits and grazing efficiency of Guernsey dairy cattle. *Agricultural Science Journal, 15*(4), 342-356.

Bivatec. (2023). *The economic benefits of grass-fed livestock farming*.

Capretta, J. C. (n.d.). Agricultural subsidy programs. *The Library of Economics and Liberty*. https://www.econlib.org/library/Enc/AgriculturalSubsidyPrograms.html.

Carrier, T. (n.d.). *Standards for the Certified Grassfed by AGW Seal*. A Greener World. https://agreenerworld.org/certifications/certified-grass-fed/standards/.

Cattlemen's Beef Board. *Production Claims at Retail*. (2017). www.beefitswhatsfordinner.com/retail/sales-data-shopper-insights/production-claims-at-retail.

Deliberto, M. *Economic Considerations for Grass Fed Beef Operations*. (2021). www.lsuagcenter.com/~/media/system/d/5/3/e/d53e3d75457d92013a1ad9d8090f7611/gfb_economic%20considerationspdf.pdf.

Dinterman, C. (2024, June 13). The benefits of rotational grazing: Ranchers are looking to nature for carbon sequestration solutions. *Successful Farming*. Retrieved November 25, 2024.

Flack, S. (2016). *The art and science of grazing: How grass farmers can create sustainable systems for healthy animals and farm ecosystems*. Chelsea Green Publishing.

Gillespie, J., Sitienei, I., Bhandari, B., & Scaglia, G. (2016). Grass-fed beef: How is it marketed by U.S. producers? *International Food and Agribusiness Management Review, 19*(2), 171-188.

Gwin, L. (2009). Scaling-up sustainable livestock production: Innovation and challenges for grass-fed beef in the U.S. *Journal of Sustainable Agriculture, 33*(2), 189–209.

Harris, C. (n.d.). Beef cattle marketing: How to market grass-fed beef. *Grass-Fed Solutions*. Retrieved November 2, 2024.

Hayek, M. N., & Garrett, R. D. (2018). Nationwide shift to grass-fed beef requires larger cattle population. *Environmental Research Letters, 13*(8), 084005.

Knapp, A. K., Blair, J. M., Briggs, J. M., Collins, S. L., Hartnett, D. C., Johnson, L. C., & Towne, E. G. (1999). The keystone role of bison in North American tallgrass prairie: Bison increase habitat heterogeneity and alter a broad array of plant, community, and ecosystem processes. *BioScience, 49*(1), 39-50.

Kreuter, U., & Teague, R. (2020). Managing grazing to restore soil health, ecosystem function, and ecosystem services. *Frontiers in Sustainable Food Systems*.

LaCanne, C. E., & Lundgren, J. G. (2018). Regenerative agriculture: Merging farming and natural resource conservation profitably. *PeerJ, 6*, e4428.

Lu, Y., Muenster, B. K., & Mee, J. F. (2018). Brown Swiss breed adaptation to high-altitude grazing systems. *Journal of Animal Science, 76*(1), 77-88.

Peterson, R. K., Hargrove, W., & Brown, J. R. (2021). Enhancing pasture management in the Upper Midwest through rotational grazing practices: A focus on dairy production. *Agriculture, Ecosystems & Environment, 311*, 107293.

Quishim, B.., Gillespie, J.M., Bhandari, B. D. & Scaglia, G. (2018). Technical and scale efficiencies of U.S. Grass-Fed Beef Production: Whole-Farm and Enterprise Analyses. *Journal of Agricultural and Applied Economics, 50(3), 408-428*.

Raymond, W. F. (1963, December 5). The utilization of grass by ruminants. *The Grassland Research Institute, Hurley, Berks*.

Robinson, J., Gill, B. S., Morgan, D., Bansal, A., & Taranaki, D. (2014). Supply chain management in small dairy farms: Quality control and sustainability. *Agricultural Systems Journal, 27*(3), 241-259.

Schwendel, B. H., Wester, T. J., Morel, P. C., Tavendale, M. H., Deadman, C., Shadbolt, N. M., & Otter, D. E. (2015). Invited review: Organic and conventionally produced milk—An evaluation of factors influencing milk composition. *Journal of Dairy Science, 98*(2), 721-746.

Stone Barns Center for Food and Agriculture. *The Market Potential for U.S. Grass Fed Beef*. (2017). https://www.stonebarnscenter.org/wp-content/uploads/2017/10/Grassfed_Full_v2.pdf/

Stull, D. D., & Broadway, M. J. (2004). *Slaughterhouse blues: The meat and poultry industry in North America*. Wadsworth.

Teague, R., & Barnes, M. (2017). Grazing management that regenerates ecosystem function and grazing land livelihoods. *African Journal of Range & Forage Science, 34*(2), 77–86.

United States Department of Agriculture (USDA). (2022). *Census of Agriculture 2022*. National Agricultural Statistics Service.

Wepking, C., et al. (2022). Perennial grassland agriculture restores critical ecosystem functions in the US Upper Midwest. *Frontiers in Sustainable Food Systems, 6*, 1010280.

Winsten, J., Kerchner, C., Richardson, A., Lichau, A., & Hyman, J. (2020). Sustainable intensification in pasture-based dairy systems: Innovation and outcomes in the Upper Midwest, USA. *Journal of Dairy Science, 103*(6), 5479-5488.