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# How Montana's Farmers and Ranchers can be at the Forefront of Addressing Climate Change

1MT ONE MONTANA

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# ABOUT ONE MONTANA

One Montana is a 501 (c) (3) nonprofit, nonpartisan organization based in Bozeman, Montana, dedicated to moving Montana forward and ensuring a positive future for both rural and urban communities – helping them work together toward success.

*One Montana's mission is to create a vibrant Montana by connecting rural and urban communities.*

As our country has become more and more divided it has become increasingly difficult to address serious problems and find creative solutions. And the division between rural and urban has become one of the widest we face. Rural and urban populations feel disconnected from one another – unacknowledged, irrelevant. The "rural-urban divide" is a real barrier to a healthy future for our state and our coun¬try. Action is needed to help us understand our vital connection. We must have tools to enable us to recognize each other's unique challenges and to work together to solve them. This is One Montana.



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**Montana's temperature and precipitation trends** are forcing the folks who steward our land to take notice and consider management responses. Science isn't necessarily needed to tell these individuals to adapt – many family operations have made a living by adapting to variable climate conditions, which are inherent in Montana. But science is needed to help agricultural producers on how best to adapt so that they can continue to be natural resource stewards in a sustainable and profitable manner.

Agriculture practices are based in science. And that holds true when it comes to addressing climate change both to effectively address significant precipitation and temperature trends and also confront the issues of excess carbon dioxide and methane. This is why the former CEO of Cargill, Greg Page, said in his keynote address at the 2016 Montana Farm Bureau convention that agriculture "must be at the table" when addressing the climate change issue and all its perceived and real ramifications.

And that is why One Montana made the decision to develop this white paper. Agriculture has to be viewed as part of the solution, and not just part of the problem. This way of thinking and acting applies to all of us no matter what economic sector of which we see ourselves being a part. Montana agriculture had to be at the table. It wants to be a strong leader in successfully addressing precipitation and temperature trends occurring in our state.

This paper is an important step forward in identifying how agriculture can be a leader in addressing and adapting to climate issues facing land and natural resource stewards going forward. In many ways this is a beginning document, articulating a variety of agricultural adaptation strategies. But most importantly, it underscores the fact that agriculture and science have always been partners and that must continue when dealing with issues going forward that are directly related to climate variability.

Sincerely,

Dr. William J. Bryan
President, One Montana

# Table of Contents

## Introduction

Ever since Nelson Story drove Texas Longhorns up to Montana and early settlers plowed the first fields, agricultural families across the state have faced irregular weather and climate patterns, shifting markets, and economic highs and lows. The multi-generational Montana families that remain in agriculture today bear the legacy of adaptability, innovation, and resilience. And the success of those who are new to the industry will depend, at least in part, upon their ability to observe, adapt, and adjust to the many challenges that come with Montana's variable climate.

As has long been the case, today's farmers and ranchers remain key stewards of Montana's diverse working landscapes. From the grain producers of the Golden Triangle to the ranchers of the Mussellshell and the cherry farmers of the Flathead, agriculturalists are at the frontline of coping with escalating climatic variability and increasing temperatures, and are doing so in innovative ways. The farmers and ranchers who manage 27,800 farm operations across approximately 60 million acres of land, nearly 65% of Montana's total area, contribute $4.2 billion annually to the State's economy. These land stewards are crucial players in adapting to the impacts of climate change and mitigating its root causes. Today's agriculturalists, many of whom manage multi-generational operations, are experiencing different weather conditions than previous generations, which has prompted changes, or consideration for changes in management.

### Adaptation vs. Mitigation

Adaptation occurs when natural or human systems adjust to climatic changes or their impacts. Mitigation, rather, is a human intervention to reduce the release of greenhouse gas emission (e.g. carbon dioxide, methane, nitrous oxide) or to enhance greenhouse gas sinks (e.g. re-vegetation, enhancing soil carbon sequestration).

These agriculturalists, however, are often sidelined in discussions on climate change. Farmers and ranchers are already undertaking various efforts to both adapt to a changing climate and, in some cases, even mitigate greenhouse gas emissions. Given its unique position in Montana's economy and on its landscape, the industry is inherently forced to the forefront of addressing climate change. Therefore, farmers and ranchers need to be a critical voice in the broader discussion on climate change in Montana.

In this report, we highlight some of the key adaptation and mitigation strategies that Montana's farmers and ranchers are already implementing, regardless of whether they use climate change to express and frame their management strategies. This report draws on peer-reviewed literature to first illustrate the adaptation and mitigation actions that farmers and ranchers are undertaking. We focus on grain and livestock systems because they are principal economic sectors in Montana. We conclude with a discussion of the diverse ways farmers and ranchers are contributing to the scientific understanding of the local climate change impacts in the state by generating local data.

## Adaptation on Montana's Farms and Ranches

Montana's farmers and ranchers are already facing the effects of climate change. Over the last 100 years, the average annual temperature in western Montana has increased 2.4 degrees Fahrenheit with three times as many days above 90°F.[1] Across the Great Plains, the duration of the growing season has expanded by 12 days as spring breeding and blooming dates occur five days earlier on average.[2,3] These climatic trends impact Montana's agriculturalists. Certain adaptations in agricultural production systems, such as flexible field scheduling, crop diversification, mixed crop/livestock systems, and changing crop varieties, can help offset declines in net farm income under shifting climate conditions.[4] In this section, we highlight some of these adaptive strategies being employed in the state for both grain and livestock production systems.

## Crop Diversification and Changes in Crop Sequencing

Within the last thirty years, there has been a dramatic expansion in pulse crops across the Great Plains, particularly dry pea, lentils, and chickpeas. Pulse crops enable producers to diversify their production and cope with increasing variability in temperature and precipitation.[5,6] Additionally, pulse crops can have substantial rotational benefits for wheat and barley production including improved soil fertility, increased water use efficiency, and disruption of pest and disease cycles. Wheat crops generally benefit from a preceding pulse crop through the conservation of soil moisture and nitrogen.[7] Additionally, by replacing the summer fallow with pulse crops, farmers are able to increase cropping intensity while improving soil health

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1 Pederson, G., L.J. Graumlich, D.B. Fagre, T. Kipfer, and C.C. Muhlfeld. 2010. "A Century of Climate and Ecosystem Change in Western Montana: What Do Temperature Trends Portend?" *Climatic Change* 98: 133-54.

2 Zhou, L., C.J. Tucker, R.K. Kaufmann, and R.B. Mynemi. 2001. "Variations in Northern Vegetation Activity Inferred from Satellite Data of Vegetation Index from 1989 to 1999." *Journal of Geophysical Research* 106(20): 20,069-20,083.

3 Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosezweig, and J.A. Pounds. 2003. "Fingerprints of Global Warming in Wild Animals and Plants." *Nature* 421: 57-60.

4 Prato, T., Z. Qiu, D. Fagre, G. Pederson, L. Bengston, and J. Williams. 2010. "Potential Economic Benefits of Adapting Agricultural Production Systems to Future Climate Change." *Environmental Management* 45: 577-89.

5 Zentner, R.P., D.D. Wall, C.N. Nagy, E.G. Smith, D.L. Young, P.R. Miller, C.A. Campbell, et al. 2002. "Economics of Crop Diversification and Soil Tillage Opportunities in the Canadian Prairies." *Canadian Prairies Journal of Agronomy* 94: 216-30.

6 Miller, P.R. and P.A. Holmes. 2005. "Cropping Sequence Effects of Four Broadleaf Crops on Four Cereal Crops in the Northern Great Plains." *Agronomy Journal* 97: 189-200.

7 Cutforth, H.W., S.M. McGinn, K.E. McPhee, and P.R. Miller. 2007. "Adaptation of Pulse Crops to the Changing Climate of the Northern Great Plains." *Agronomy Journal* 99: 1684-99.

and increasing soil moisture retention.[8] The soil moisture benefits are particularly important in light of the projected impact of climate change. Current climate models generally predict that summer precipitation will decrease while winter, spring, and fall precipitation will increase. Chickpeas, dry peas and lentils consume less water than spring wheat making them well adapted to increasingly arid summer in Montana.[9]

The negative impacts of climate change on pulse crops such as heat stress and increased pathogens will be partially offset by carbon dioxide. An elevated level of carbon dioxide is predicted to increase yield and reduce water use, particularly in warmer and dry areas like Montana.[10]

Lastly, pulse crops enable producers to build economic resilience by diversifying market outlets; therefore, reducing vulnerability to market volatility. In diverse crop sequencing and rotation strategies, a crop rotation of continuously alternating lentils and wheat crops has been found to be the most profitable.[11,12] In Montana, pulse crops have offered farmers in the Golden Triangle a viable, high-value cash crop with opportunities to access alternative markets that has bolstered on-farm resilience to water stress.[13]

## Changes in Crop Varieties

Elevated temperatures under climate change reduce the maturity time for spring wheat, potentially resulting in yield losses of 20%.[14] While the negative impact of elevated temperatures can be partially offset by the positive benefits of elevated carbon dioxide levels, many Montana grain farmers are now relying more on winter wheat than spring wheat, partially because winter wheat yields are less sensitive than spring wheat to increasing temperatures.[15,16] Winter wheat yields are projected to remain the same or increase under climate change scenarios.[17]

The development and use of high-yield spring-sown pulse crop varieties will be crucial due to increasing temperatures and aridity under climate change. In particular, priority needs to be placed on breeding varieties for the earliness to flower and mature in order to take advantage of earlier springs and avoid late-summer drought due to extended growing seasons. Additionally, there is increasing attention on breeding to produce cold-tolerant pea and lentil varieties that can be seeded in the fall. Fall seeding would enable improved seedling establishment when there are warmer and drier field conditions, create more balanced field labor

8 Larney, F.J., C.W. Lindwall, R.C. Izaurralde, and A.P. Moulin. 1994. "Tillage Systems for Soil and Water Conservation on the Canadian Prairie." In *Conservation Tillage in Temperate Agro-Ecosystems*. 305-28. Boca Raton, FL: CRC Press.

9 Angadi, A., B. McCarthy, D. Ulrich, H.W. Cutforth, P. Miller, M. Entz, S.A. Brandt, and K. Volkmar. 1999. "Developing Viable Cropping Options for the Semiarid Prairies." Project Rep. Agric. Swift Creek, SK: Agri-Food Canada.

10 Cutforth, "Adaptation of Pulse Crops to the Changing Climate of the Northern Great Plains."

11 Miller, P.R., A. Bekkerman, C.A. Jones, M.H. Burgess, J.A. Holmes, and R.E. Engel. 2015. "Pea in rotation with wheat reduced uncertainty of economic returns in southwest Montana." *Agronomy Journal* 107(2): 541-50.

12 Zentner, R.P., C.A. Campbell, V.O. Biederbeck, P.R. Miller, F. Selles, and M.R. Fernandez. 2001. "In Search of Sustainable Cropping Systems for the Semiarid Canadian Prairies." *Journal of Sustainable Agriculture* 18: 117-36.

13 Carlisle, L. 2014. "Diversity, flexibility, and the resilience effect: Lessons from a social-ecological case study of diversified farming in the northern Great Plains." *Ecology and Society* 19(30): 45.

14 Laurila, H. 2001. "Simulation of Spring Wheat Responses to Elevated CO2 and Temperature by Using CERES-Wheat Crop Model." *Agric Food Sci Finl* 10: 175-96.

15 Lanning, S.P., K. Kephart, G.R. Carlson, J.E. Eckhoff, R.N. Stougaard, D.M. Wichman, and L.E. Talbert. 2010. "Climatic change and agronomic performance of hard red spring wheat from 1950 to 2007." *Crop Science* 50(3): 835-41.

16 Thomson, A.M., R.A. Brown, N.J. Rosenberg, R.C. Izaurralde, and V. Benson. 2005. "Climate Change Impacts for the Coterminous USA: An Integrated Assessment-Part 3. Dryland Production of Grains and Forage Crops." *Climatic Change* 69(1): 43-65.

17 Izaurralde, R.C., N.J. Rosenberg, R.A. Brown, and A.M. Thomson. 2003. "Integrated Assessment for Hadley Center (HadCM2) Climate Change Impacts on Agricultural Productivity and Irrigation Water Supply in the Coterminous United States." A*griculture for Meteorology* 117: 97-122.

requirements between fall and spring, and improve yield by avoiding high temperatures that quicken maturity.[18]

## Flexible Scheduling

Under climate change, the growing season is expected to expand. A longer growing season and less harsh winter presents opportunities for Montana's farmers particularly for market garden farmers producing vegetables for local markets. Increasingly, farmers are planting spring-sown crops earlier. Earlier seeding dates can help offset the negative impact of higher temperatures by avoiding higher temperatures altogether, taking advantage of faster maturity rates, and avoiding late-season drought that reduces yields.[19,20] An earlier sowing date has also resulted in an earlier harvest date, shifting farm labor scheduling. An expanded season may enable additional cuts of hay or the cultivation of alternative crops across Montana. However, a longer growing season must be considered in combination with water requirements. With earlier snowmelt and less late growing season water available for irrigation, hay production may be limited. In addition, there is evidence that warming summer temperatures are creating more evapotranspirational stress leading to lower production on non-irrigated hay. Thus, there is likely to be greater future reliance on irrigated hay production in Montana, but less water available for that production.

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[18] Cutforth, "Adaptation of Pulse Crops to the Changing Climate of the Northern Great Plains."

[19] Lanning, "Climatic change and agronomic performance of hard red spring wheat from 1950 to 2007."

[20] McGinn, S.M. and A. Shephard. 2003. "Impact of Climate Change and Scenarios on the Agroclimate of the Canadian Prairies." *Canadian Journal of Soil Science* 83: 623-30.

## Managing Weeds, Pests, and Disease in a Warmer Climate

The warming associated with climate change is expanding the range of some invasive plant species and pests. An expansion of weeds into higher latitudes and elevations under climate change is due to both the ability of weeds to exploit warmer temperatures as well as their ability to evolve quickly to new climatic conditions.[21] The range of pests is also expected to expand due to seasonal changes and warming temperatures resulting in higher populations, pest growth rates, overwintering and geographical movement.[22] Beyond the expanding range of invasive weeds and pests, existing populations, which are currently small, are expected to grow and have a negative economic impact.[23,24] Cheatgrass, or Downy Brome, is an example relevant to Montana farmers, as it is already present in our region. Cheatgrass is expected to expand and cause more damage through the evolution of weedy genotypes and potential for positive fire feedbacks resulting in annual weedy grass monocultures under climate change.[25,26] Weed management and pest suppression is going to require new and novel approaches as weeds like cheatgrass (Downy Brome) and Canada Thistle become more prevalent and more competitive. Under these conditions, early detection is going to be crucial to managing weeds.[27]

**Field trials have found that glyphosate and glufosinate were less effective in managing canadian thistle in elevated carbon dioxide (Menalled, 2014).**

In order to adapt to increased pest pressure, researchers have examined strategies such as strip-cutting alfalfa during harvest which encourages the emigration of natural pest enemies to non-harvested sections,[28] planting grasslands at field margins to provide habitat for natural enemies,[29] and planting pulse crops in place of summer fallow to disrupt pest and disease cycles.[30,31] Generally, multiple studies found that increased diversification is an important strategy for improving the ability of farmers to suppress pest outbreak and reduce pathogen transmission. Lastly, continued breeding programs that produce varieties better adapted to a warmer, drier climate and with increased disease resistance will be crucial.[32]

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21 Clements, D.R. and A. DiTommaso. 2011. "Climate Change and Weed Adaptation: Can Evolution of Invasive Plants Lead to Greater Range Expansion than Forecasted?" *Weed Research* 51:227-40.

22 Lin, B. 2011. "Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change." *BioScience* 61: 183-93.

23 McGinn, "Impact of Climate Change and the Scenarios on the Agroclimate of the Canadian Prairies."

24 McDonald, A., S. Riha, A. DiTommaso, and A. DeGaetano. 2009. "Climate Change and the Geography of Weed Damage: Analysis of U.S. Maize Systems Suggests the Potential for Significant Range Transformations." *Agriculture, Ecosystems & Environment* 130(4): 131-40.

25 Taylor, K., T. Brummer, L.J. Rew, M. Lavin, and B.D. Maxwell. 2014. "Climate drive Bromus tectorum positive feedback with fire." *Ecosystems* 17: 960-73.

26 Valliant, M.T., R.N. Mack, and S.J. Novak. 2007. "Introduction to the History and Population Genetics of the Invasive Grass Bromus Tectorum (Poaceae) in Canada." *American Journal of Botany* 94:1156-69.

27 Izaurralde, "Integrated Asessment for Hadley Center (HadCM2) Climate Impacts."

28 Hossain, Z., G. Gurr, and S.D. Wratten. 2001. "Habitat Manipulation in Luceme (medicago Sative L.): Strip Harvesting to Enhance Biological Control of Insect Pests." *International Journal of Pest Management* 47: 81-88.

29 Thomas, M.B., S.D. Wratten, and N.W. Sotherton. 1991. "Creation of 'Island' Habitats in Farmland to Manipulate Populations of Beneficial Arthropods: Predator Densities and Emigration." *Journal of Applied Ecology* 28: 906-17.

30 Krupinsky, J.M., K.L. Bailey, M.P. McMullen, B.D. Gossen, and T.K. Turkington. 2002. "Managing Plant Disease Risk in a Diversified Cropping System." *Agronomy Journal* 94: 198-209.

31 Cutforth, "Adaptation of Pulse Crops to the Changing Climate of the Northern Great Plains."

32 McGinn, "Impact of Climate Change and Scenarios on the Agroclimate of the Candian Prairies."

## Water Management in a Changing Climate

The models for Montana generally predict that precipitation regime will shift with less rainfall in the summer months and more in the winter and spring. These shifts will present challenges to farmers, particularly dryland farmers who are not able to mitigate drought with irrigation. Dryland farmers are implementing management techniques to increase soil moisture such as no-till techniques. Both tall and short stubble increase water use efficiency by 16% and 8% respectively.[33] While maintaining crop stubble can increase soil moisture it can lead to higher greenhouse gas emissions due to the multiple applications of herbicide that are applied to no-till fallow. Additionally, dryland farmers are increasingly installing crop varieties that are drought-tolerant and well adapted to an increasingly arid environment (e.g. lentils).

**Crop stubble, particularly tall stubble (1 foot), left in the field increases snow catchment and related snow water infiltration, and has also been found to create a supportive microclimate for plant growth.**

Montana has nearly two million acres of irrigated agriculture. For these farmers, irrigation water provides a valuable tool to cope with shifts in precipitation and increased heat stress in plants. For irrigators who depend on surface water, the timing of stream flows is likely to shift due to earlier snowmelt and increased late winter and early spring rains.[34] For basins that have reservoirs, shifts in streamflow timing will likely be buffered by the presence of these reservoirs. In basins, such as the Gallatin, Judith River, and Big Hole, where the total volume of water produced annually is far more than the existing storage capacity, there is interest in augmenting the storage capacity to capture more stream run-off and buffer summer precipitation shortages and/or longer term drought. Natural storage and retention can be enhanced by protecting critical riparian areas and encouraging the recharge of alluvial aquifers for natural water storage. Excess irrigation runoff, particularly from flood irrigation, has historically recharged shallow groundwater aquifers, providing downstream water and storage.[35]

Over the years, farmers have installed irrigation systems and acquired water rights in order to expand irrigation. However, if farmers want to counteract shifts in precipitation patterns through further irrigation expansion, they will likely encounter legal and institutional barriers. Such barriers will include the closure of many basins due to total allocation of surface water rights, burdensome mitigation requirements for new groundwater application, the legal availability of water, and

One tool being used across Montana watersheds is the **Voluntary Water Management Plan model**, which brings together diverse stakeholders to make proactive water allocation decisions during periods of drought. These plans rely on building local relationships, accepting enforcement actions that result in shared sacrifice, and strong community leadership. In basins where this model has gained traction such as the Big Hole, the Voluntary Water Management Plan model has been a successful tool for Montana's irrigators to ensure water access in the face of shifting climate patterns and increasing demands from other sectors.

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[33] Cutforth, "Adaptation of Pulse Crops to the Changing Climate of the Northern Great Plains."

[34] Montana DNRC. 2015. "Montana State Water Plan: A Watershed Approach to the 2015 Montana State Water Plan." *Montana State Water Plan*. Helena, MT: Montana Department of Natural Resources and Conservation.

[35] Krupinsky, "Managing Plant Disease Risk in a Diversified Cropping System."

the cost of installing groundwater wells or surface water infrastructure.[36] Due to these challenges, a greater emphasis has been placed on increased irrigation efficiency as a means to make current water allocations go further. It is worth noting, however, that the 'use it or lose it' legal framework that applies to western water rights often provides a fundamental disincentive against significant gains in water use efficiency. Despite these challenges, irrigators across Montana are already collaborating, through groups like the Musselshell Watershed Coalition, to increase their efficiency and proactively plan for changes in water availability.[37]

Finally, individual farmers are also implementing specific adaptive strategies on their irrigated acres to increase their resilience to water scarcity. On-farm water use efficiency measures, such as upgrading to center pivot irrigation systems, have become more common.

## Adaptation in the Livestock Sector

Another vitally important component of Montana agriculture is livestock production. As one of the largest industries in the state, livestock production is an important player in the state's economy and culture. Ranchers are vital stewards of Montana's natural resources, as they manage the rangeland that comprises over half of the state. In addition to providing forage for cattle, Montana's rangeland provides numerous public benefits such as wildlife habitat, erosion regulation, and other important ecological processes. It is important to note, however, that rangeland is not the only method of raising livestock in Montana, as many ranchers utilize pasture production and crop-derived feeds in their operations. Although ranchers are often inherently adaptive to year-to-year uncertainty and change, extreme climatic conditions and variability are becoming more common and problematic. Expected (and already observed) risks to livestock production include longer, hotter growing seasons with an earlier spring arrival, more extreme weather events, and altered distribution of seasonal precipitation with more precipitation in the winter, fall, and spring and less in the summer.[38] In this section, we are highlighting adaptation strategies that ranchers are employing to confront these changes.


## Variable Stocking Rates

Many ranchers in Montana are already facing extreme climate variability, which stresses both the land they are managing and their livestock. Although these impacts can bring severe consequences, many stockgrowers are already adapting to these climate stressors. Adaptation in livestock production can take many forms, depending on where the rancher is located in the

[36] Ibid.

[37] Montana DNRC, "Montana State Water Plan."

[38] Derner, J., L. Joyce, R. Guerrero, and R. Steele. 2015. "USDA Northern Plains Regional Climate Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies." United States Department of Agriculture.

state and the climatic and environmental stressors he or she faces. One possible adaptive strategy is to incorporate a variable stocking and herd size in a given year. These factors may be viewed as being detrimental to an operation, especially if the stocking rate and herd size are reduced. However, variability is inherent in the ranching business, and many producers already employ this strategy in response to factors like the market and pricing for their product. Historically, market prices for both livestock and crops have been greater drivers of adaptive strategies than climate, but the fact that Montana agriculture exists on the edge of economic viability has aided the development of adaptive strategies (like those found under "Recommended Practices") related to climate.

### Recommended Practices

There are many different practices ranchers can employ to address climate extremes. Some common practices recommended by rangeland specialists include:

- Grass-banking to provide forage during dry periods
- Increasing plant cover to improve soil health and ecosystem resilience
- Incorporating adaptive grazing management to provide flexibility
- Using alternative livestock breeds, classes, or species that are more tolerant of climate extremes like drought
- Planning for contingencies

In the face of climate extremes, more variable stocking rates and herd sizes can be beneficial to producers and the sustainability of their operation. For example, ranchers can decrease stocking rates in the event of higher precipitation intensity, as more intense rains often run-off rapidly and do not effectively support forage yields and supply.[39] And of course, it is not uncommon for producers to reduce their herd size and employ conservative stocking rates when experiencing prolonged drought.[40] In summary, more flexible stocking strategies may allow ranchers to more effectively utilize forage, reduce stress on the land, and improve the resilience of the landscape and their business.[41]

However, it is important to note that factors outside of forage production may provide barriers to the successful uptake of these types of strategies. For example, a producer may want to plan for more flexible stocking rates, but does not properly take into account an animal's weight, size, and resulting forage requirements. This type of oversight can result in gross overgrazing and poor performance from the animal, causing the producer to employ a set stocking rate based on the animal, not the available forage. Recent improvements in animal productivity, health, and live-weight gain rates also allow producers to make breed or genetic changes to more efficient animals so they can graze fewer cattle or have a smaller herd size while still ensuring the profitability and sustainability of their operations.[42] Ultimately, producers must look at more than just the environment when determining stocking rates and take into account what works best for their given operation.

## Mixed-Crop and Livestock Systems

On a larger scale, agriculturalists have demonstrated shifting land use as a form of adaptation. Instead of having an operation that focuses solely on livestock production, ranchers operating in more moisture-prone regions have shifted to a mixed-crop livestock system. Mixed-

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39 Mu, J., B. McCarl, and A. Wein. 2013. "Adaptation to Climate Change: Changes in Farmland Use and Stocking Rate in the U.S." *Mitigation and Adaptation Strategies for Global Change* 18: 713-30.

40 Roche, L. and K. Tate. 2014. "Drought: Ranchers' Perspective and Management Strategies." Rangeland Watershed Laboratory, UC Davis.

41 Derner, J., D. Augustine, L. Poresnky, M. Eisele, K. Roberts, and J. Ritten. 2016. "Flexible Stocking Strategies for Adapting to Climatic Variability." United States Department of Agriculture.

42 Herrero, M. 2016. "Greenhouse Gas Mitigation Potentials in the Livestock Sector." *Nature Climate Change 6*: 452-61.

crop livestock systems are more resilient to climate extremes due to greater system and income diversity. Researchers have shown that a 50% shift to mixed-crop livestock systems by 2045 would lower projected climate adaptation costs by 0.8%. In comparison, it is anticipated that adaptation costs will amount to 3% of total agricultural production costs in 2045 if no shift occurs. Alternatively, in areas experiencing decreased precipitation and water scarcity, rangeland livestock production is a more drought-resilient option than the mixed crop-livestock system.[43] As extreme summer temperatures become more frequent, many agricultural producers also reduce cropland and increase grazing land. This shift is due to the fact that crop yields often experience more harm from extreme heat, while forage yields usually less sensitive to extreme heat.[44] Thus, depending on the conditions and projections for a given year, producers could manage their land on a gradient of practices ranging from solely crop production to a mixed-crop livestock system to solely livestock production.

## Coping with Drought

Although there is not a strong climatic change signal pointing to increasing drought in Montana, drought response has always been among the biggest challenges that ranchers face in our region. There are a number of strategies that many are already using to address drought and water scarcity. For example, producers along the Rocky Mountain Front have boosted their resiliency to the uncertainty in prices and climate by investing in water system improvements (like shifting from flood to sprinkler irrigation), diversifying operations, starting supplemental outfitting and agritourism businesses, and reducing operational inputs.[45] In other states experiencing drought, such as California, ranchers have responded by incorporating both cow-calf pairs and stocker cattle into their operations, weaning calves earlier, and letting pastures rest periodically.[46]

When adapting to drought (as with all climate extremes and variability), there is no single answer or formula. For example, a short term strategy for drought could be to reduce animal density, secure additional feed, and plant drought tolerant forages that have longer roots for

[43] Weindl, I., H. Lotze-Campen, A. Popp, C. Müller, P. Havlik, M. Herrero, C. Schmitz, and S. Rolinski. 2015. "Livestock in a Changing Climate Production System Transitions as an Adaptation Strategy for Agriculture." *Environment Research Letters* 10.

[44] Mu, "Adaptation to Climate Change: Changes in Farmland Use and Stocking Rate in the U.S."

[45] Yung, L., N. Phear, A. DuPont, J. Montag, and D. Murphy. 2015. "Drought Adaptation and Climate Change Beliefs among Working Ranchers in Montana." *Weather, Climate, and Society* 7: 281-93.

[46] Roche, "Drought: Ranchers' Perspective and Management Strategies."

grazing purposes. However, a longer term but more expensive strategy could be to add more pasture land and apply organic matter to that soil to increase soil water holding capacity. Ultimately, ranchers must evaluate adaptive strategies based on the individualized costs and benefits, the time scale they want to operate on, and the risk they are willing to take in implementing those practices.[47]

## Feedlots and A Warmer Climate

Livestock production in Montana also occurs through confined animal operations that utilize crop-derived feeds rather than grazing systems. Confined livestock systems are not only subject to the same risks as production on rangeland and pasture, but must be able to adapt to climatic impacts on crop production which supplies the feed. Cattle in confined operations are also more susceptible to pest pressures caused by warmer growing seasons and altered distribution of seasonal precipitation, as well as water runoff and quality issues caused by higher frequency of intense precipitation events such as more intense rains and floods. Adaptation strategies for confined livestock may differ from those utilized by grazing operations. For example, confined livestock producers can increase shelter availability and shade, improve the ventilation and temperature regulation of housing systems, and shift the placement and finishing timing of feeder animals to reduce heat stress. Confined livestock operations can also boost resiliency by shifting to the aforementioned mixed-crop livestock system, where producers can utilize cover crop grazing and post-harvest grazing on crop residues in addition to feeds.[48]

## Advances in Technology

New technologies are also being studied as ways of helping livestock producers make adaptive management decisions. One example is the use of the GLOBIOM (Global Biosphere Management Model). The GLOBIOM can be beneficial to adaptation because it lets livestock producers adjust the areas dedicated to different activities (grazing, watering, night use, etc.) according to the identification of more or less productive land.[49] Improvements in rangeland monitoring practices, such as recent advances in GPS collars, remote sensing and aerial imagery for monitoring, can also help ranchers adapt through increased knowledge of animal behavior trends and changes over time in their operations. With both of these approaches, producers are better able to determine the state of their operations and more efficiently utilize their financial and natural resources to adapt to climatic changes.

## Emission Reduction Strategies on Montana's Farms and Ranches

Beyond leading the way in implementing adaptation strategies, agriculture also has the potential to play an important role in the reduction of greenhouse gases and the sequestration of carbon. While adaptation is the ability of an operation to adjust and respond to climate change stressors, mitigation strategies aim to reduce the severity or prevalence of climate change. As mitigation incentive policies continue to be developed, farmers may potentially benefit from incentives that provide supplemental on-farm income in compensation for efforts to reduce emissions and sequester carbon. In this section we present some of the strategies that Montana's farmers and ranchers are already employing to mitigate climate change.

[47] Schmidt, D., E. Whitefield, and D. Smith. 2014. "Adapting to a Changing Climate: A Planning Guide." United States Department of Agriculture.

[48] Derner, "USDA Northern Plains Regional Climate Hub Assessment."

[49] Havlik, P., D. Leclere, H. Valin, M. Herrero, E. Schmid, J-F. Soussana, C. Müller, and M. Obersteiner. 2015. "Global Climate Change, Food Supply and Livestock Production Systems: A Bioeconomic Analysis." *In Climate Change and Food Systems: Global Assessments and Implications for Food Security and Trade*, 176-208. Rome: Food and Agriculture Organization of the United Nations.

## Capturing Carbon in the Soil

Soils are the largest terrestrial pool of organic carbon. For a sense of magnitude, a 10% increase in soil organic carbon is equivalent to 30 years of human-related greenhouse gas emissions.[50] Montana's farmers are using a variety of cropland management strategies to retain carbon in the soil, thus preventing further release of this greenhouse gas. Farmers are able to capture carbon by extending crop rotations and planting perennial crops that capture more carbon below ground and reduce leaving fields fallow.[51] Additionally, the inclusion of cover crops as temporary vegetative cover between agricultural crops can add carbon to the soil and also capture excess plant-available nitrogen that was not used by the previous crop in the rotation, reducing the release of nitrous oxide, another greenhouse gas.[52]

### Estimating my Farm or Ranch's Carbon Input and Output

The USDA has released COMET–farm (CarbOn Management & Emissions Tool), an online tool that estimates a ranch or farm's atmospheric carbon input or output.

No-till or minimal till agriculture has become more common across Montana as weed control methods and farm machinery have improved. These low tillage strategies avoid soil carbon loses by reducing soil erosion and retaining crop residues. There is a scholarly debate about the efficacy of no-till soil management for storing carbon with some researchers arguing that over the long-term and across the soil profile, the potential for soil organic carbon sequestration has been historically overestimated. Regardless of the potential of no-till agriculture to sequester soil carbon, this cropland management technique has been found to increase soil health, reduce soil erosion, reduce on-farm labor, and save fuel otherwise used to till.[53]

## Reducing Emissions through Local and Regional Marketing and On-Farm Fuel Efficiency

The growing consumer interest in local and regional products has some farmers rethinking their operations and their markets. The consumer interest in 'Made in Montana' products has provided farmers and ranchers the opportunity to sell their products at a higher price point while also reducing transportation costs and transportation-related greenhouse gas emissions. Additionally, some farmers are reducing emissions by choosing more fuel-efficient farm equipment when updating machinery and vehicles. Some farmers are also beginning to consider oil seed crops to produce their fuel after it has been reclaimed as cooking oil.

## Optimizing Fertilizer Management

Nitrogen (N) in fertilizer and manure can be converted by microbes to nitrous oxide, a highly potent greenhouse gas. This is then released into the atmosphere. Strategies that im-

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[50] Kirschbaum, M.U.F. 2000. "Will Changes in Soil Organic Carbon Act as a Positive or Negative Feedback on Global Warming?" *Biogeochemistry* 48: 21-51.

[51] West, T.O. and W.M. Post. 2002. "Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Data Analysis." *Soil Science Society American Journal* 66: 1930-46.

[52] Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kuman, B. McCarl, et al. 2008. "Greenhouse Gas Mitigation in Agriculture." *Philosophical Transactions of the Royal Society B* 363: 789-813.

[53] Powlson, D.S., C.M. Stirling, M.L. Jat, B.G. Gerard, C.A. Palm, P.A. Sanchez, and K.G. Cassman. 2014. "Limited Potential of No-till Agriculture for Climate Change Mitigation." *Nature Climate Change 4*: 678-83.

prove the efficient application and uptake of N can help reduce nitrous oxide emissions as well as other greenhouse gases emitted in the production of the fertilizer. One of the key strategies that farmers are using to improve the efficiency and effectiveness of their nitrogen application is precision agriculture. This innovative approach uses a combination of machine mounted crop sensors with aerial or satellite imagery to provide high-resolution spatial data that enables farmers to apply nitrogen differentially across a field based on crop nutrient needs, microclimatic conditions, the cost of the input, and desired yield. Additionally farmers can improve N use efficiency by using slow-release fertilizer or inhibitors. These fertilizers and inhibitors slow the microbial activity to reduce the conversion of N to nitrous oxide and shorten the time between N application and N uptake by plants. They also allow farmers to apply N directly into the soil to make it more accessible to plants and avoid excess fertilizer or manure application.[54]

Less intensive cropping systems can reduce reliance on pesticides and fertilizers. As an example, the inclusion of legumes in the crop rotation can also add plant-available nitrogen, reducing the amount of nitrogen fertilizer that needs to be applied to the soil, and thus avoiding the greenhouse gas emissions associated with producing the fertilizer.

### Precision Agriculture Research in Montana

The On-Farm Precision Experiment (OFPE) is a research team led by Dr. Bruce Maxwell, an agroecologist at Montana State University. This project received a grant from the Montana Research and Economic Development Program to create a network of farms utilizing precision agriculture technologies. The goal is to develop a Montana specific model for how to optimize N input for maximized net return based on yield, in-field soil nutrient needs as well as volatility in weather, commodity prices, and input costs.

## Mitigation in the Livestock Sector

Most mitigation strategies in the livestock sector relate to the ability of rangeland to store and sequester carbon. Rangelands comprise about half of the earth's land area. They support greater than 10% of terrestrial biomass carbon (in the form of vegetation), and store 10%-30% of the earth's soil carbon. Further, carbon sequestration in rangelands also supports already existing ecosystem services and can lead to increased soil water holding capacity, better soil structure, improved soil quality and nutrient cycling, and reduced soil erosion.[55] Opportunities in Montana for carbon loss prevention and sequestration are high, since Montana alone is comprised of about 65% rangeland and pasture.[56]

## Carbon Sequestration on Rangelands and Pastures

Like adaptation, there are many different recommended strategies for carbon sequestration on rangelands and pastures. For example, some specialists recommend using light grazing instead of heavy grazing to conserve aboveground biomass and reduce erosion potential, as well as increasing the duration that a field is left in pasture for grazing. Some specialists support a shift to permanent grasslands versus temporary pasture, and others support the strategy of

[54] Smith, "Greenhouse Gas Mitigation in Agriculture."

[55] Derner, J. and G. Schuman. 2007. "Carbon Sequestration and Rangelands: A Synthesis of Land Management and Precipitation Effects." *Journal of Soil and Water Conservation* 62(2).

[56] Sommer, E. 2015. "Montana 2015 Agricultural Statistics." Montana Department of Agriculture.

shifting from seeding grass to seeding grass-legume mixtures or multi-species rotational cover crops in small grain production lands for livestock forage.[57] Researchers have found that the addition of nitrogen to the soil has the potential to increase soil carbon. While using nitrogen fertilizer to achieve this goal may seem like an obvious strategy, the emissions associated with nitrogen fertilizer production likely negate any significant positive impacts resulting from its application. Thus, interseeding nitrogen-fixing legumes with grasses is most likely the better means to increase nitrogen in the soil and consequently soil carbon while still producing forage for livestock.[58]

## Manure Storage and Application

Another mitigation strategy that represents a potential for long-term soil carbon gain is manure storage and application. This strategy also has the potential to decrease and manage emissions from livestock, one of the largest greenhouse gas contributions in Montana. Manure storage and application practices can differ between targeted greenhouse gases, with methane and nitrous oxide being the most common. Examples of manure practices that help reduce emissions include appropriate storage or removal of manure slurries, minimizing losses due to volatilization or runoff, and compacting and covering farmyard manure.[59] In pasture production or mixed-crop livestock systems, use of manure as a source of nitrogen, phosphorus, and potassium reduces operational reliance on inorganic fertilizers, which contribute to emissions through their manufacturing, distribution, and application. Appropriate application of manure can also increase soil carbon content. However, it is important to note that while application of manure may reduce reliance on inorganic fertilizers and increase soil carbon content, it also requires the use of tillage which can increase soil erosion and carbon loss.

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57 Soussana, J-F., K. Klumpp, and T. Tallec. 2009. "Mitigating Livestock Greenhouse Gas Balance through Carbon Sequestration in Grasslands." *IOP Conference Series: Earth and Environmental Science* 6(24).

58 Derner, "Carbon Sequestration and Rangelands: A Synthesis of Land Management and Precipitation Effects."

59 Herrero, Greenhouse Gas Mitigation Potentials in the Livestock Sector."

## Livestock Feeding Strategies

Livestock feeding strategies can also impact manure emissions, especially in confined livestock operations. Researchers have demonstrated that when producers optimize the nitrogen content of their animals' diet through the use of feed additives and improved feed digestibility, there is a reduction in methane and nitrous oxide emissions from the animals. Improved feed strategies for mitigation may also focus on a shift from crop-derived feeds to fresh forage or hay in confined operations. Researchers have observed decreased emissions during manure storage and application from cattle fed fresh forage and hay versus those fed crop-derived feeds.[60] Studies have even demonstrated that the addition of certain types of seaweed to cattle feed significantly reduces cattle methane emissions.[61]

Additionally, ranchers can practice mitigation by shifting from a conventional, feed-based confined operation to a "grass-fed" confined operation. In this scenario, the cattle would not be finished on typical feed but on the aforementioned fresh forage or hay, thereby improving both the feed digestibility and reducing the emissions potential of the resulting manure. While promising, further research is needed to more fully understand mitigation potential and implementation feasibility of these feed strategies, as the available literature to support this strategy is limited.

## Carbon Loss Prevention

While many mitigation practices focus on carbon sequestration and decreased emissions, strategies that deal with preventing the loss of carbon may be perceived as being more complementary to existing practices. Improving grazing practices and following best management practices provided by rangeland specialists are one means of reducing soil organic carbon inadvertently lost to grazing. These practices positively impact species composition, forage consumption, nutrient and water inputs, and fire, all of which not only affect rangeland ecosystem services but also impact soil carbon stocks. Importantly, practices that prevent the loss of soil carbon ought to be economically feasible because their implementation also enhances forage production. Thus, instead of separately investing in unrelated mitigation practices, ranchers can invest in practices that both enhance forage production and soil carbon to help balance resilience and profitability.[62]

Carbon-loss prevention is also complementary to both adaptive and

### Conservation Innovation Grants

Through EQIP funding, the NRCS annually awards Conservation Innovation Grants (CIG) to projects that demonstrate innovation in practices and help farmers and ranchers address top natural resource priorities. An example of a 2016 initiative funded through the CIG program is a pilot project being developed by the Climate Action Reserve, a national carbon offset registry. The goals of the program are to conserve grasslands and reduce emissions from land conversion. Landowners will be paid to avoid crop cultivation in conjunction with easement activity, thereby enhancing wildlife habitat, improving watershed health, and preventing the release of carbon.

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60 Chadwick, D., S. Sommer, R. Thomas, D. Fangueiro, L. Cardenas, B. Amon, and T. Misselbrook. 2011. "Manure Management: Implications for Greenhouse Gas Emissions." A*nimal Feed Science and Technology* 166-167: 514-31.

61 Kinley, R.D., R. de Nys, M.J. Vucko, L. Machado, and N.W. Tomkins. 2016. "The red macroalgae Asparagopsis taxiformis is a potent natural antimethanogenic that reduces methane production during in vitro fermentation with rumen fluid." *Animal Production Science* 56(3): 282-289.

62 Herrero, "Greenhouse Gas Mitigation Potentials in the Livestock Sector."

mitigation management strategies. One recommended practice is to reduce or stop the conversion of rangelands into crop production and re-establish permanent vegetation, thus increasing the retention of soil organic carbon.[63] Livestock producers also could partner with crop producers to use rotational crops for late growing season forage when rangelands lose productivity. This practice would bring manure to the crop land, allow the rangeland to rest, and spread the manure over the landscape for improved carbon sequestration. And as mentioned previously, producers have already demonstrated shifting from crop production to livestock production in the event of increased summer temperatures assuming they result in drought. Therefore, an adaptive shift to livestock grazing on permanently vegetated rangeland or pasture would also support the storage of carbon in such rangelands.

Greater emphasis has also been placed on ways that ranchers can receive compensation for beneficial soil carbon practices. Practices that operate under the umbrella of pre-existing programs like the National Resource Conservation Service's (NRCS) Conservation Stewardship Program (CSP) or Environmental Quality Incentives Program (EQIP) have the highest chance of being implemented, since many ranchers are either already utilizing them or are familiar with them. Again, these opportunities have the potential to not only retain soil carbon but also be beneficial to the overall profitability and sustainability of an operation through improvements in forage production and ecosystem services.[64]

## Generating Local Weather Data

Data is essential to producing local and accurate weather forecasts as well as climate change projections. Farmers and ranchers have an important role to play in partnering with state meteorologists and climatologists to collect better data. The Montana Climate Office is creating a statewide soil-climate network, called the "Montana Mesonet." The Mesonet, which consists of 30 recently-installed stations located across Montana's agricultural and rangelands, will help provide soil-climate data in order to provide the following decision-making tools: drought monitoring, estimation of crop irrigation demand and irrigation scheduling, planting and harvesting scheduling, predict long-term cropping system dynamics, predict and mitigate pest and disease outbreaks, facilitate prescribed burn planning, and develop new soil moisture accounting methods and risk assessment.

The Montana Climate Office is working with several federal and tribal entities, as well as watershed groups and ag experiment stations, to install the Montana Mesonet. In the future, data from the Mesonet will be made accessible to farmers and ranchers through a smartphone application. With this application, farmers and ranchers will be able to both view data in the field as well as collect additional weather and soil data. Efforts like the Montana Mesonet reflect the substantial public investment being made in increasing local data collection. This public initiative, spearheaded by the Montana Climate Office, maintains the weather station network and provides and processes all data. Stations that are part of the Montana Mesonet

[63] Derner, "Carbon Sequestration and Rangelands: A Synthesis of Land Management and Precipitation Effects."

[64] Mohrmann, B. 2016. "New Grasslands Conservation Opportunity Available for Interested Landowners." *Center for Rural Affairs* (July-August): 4.

### CoCoRaHS

The Community Collaborative Rain, Hail & Snow Network (CoCoRaHS) is a national non-profit, volunteer-driven network used to gather data on rain, hail and snow in communities across the United States. Each CoCoRaHS volunteer is given training and the appropriate measuring tools to collect data on their land or in their backyard. This data is then reported back to CoCoRaHS to be used by various end-users including the National Weather Service, USDA, researchers, and many other organizations and individuals.

will likely include a subscription fee for hosting landowners.

Concurrently, there has been a large growth in private "big data." Many farmers and ranchers have installed one or more weather stations on their property to monitor local weather conditions. This data, which is typically proprietary, characterizes the climatic conditions across large properties. It can then be used for insurance purposes or provided to consultants who offer management suggestions based on microclimatic conditions. This data is becoming increasingly important to management regimes and thus increasingly profitable to large agricultural companies. In 2013, Monsanto acquired the climate data service and weather insurance underwriters, the Climate Corporation, for approximately $930 million. This staggering price tag reflects the recognition by agribusiness of the importance of weather data and related services in the future.

Looking forward, farmers and ranchers will likely engage with both public and private data purveyors, as well as play an active role in collecting weather data themselves. The debate of proprietary versus public data is an active and important one, and farmers and ranchers will be tasked with deciding how they best want to collect, analyze, and share their locally collected climate and weather data. Ultimately, agriculturalists and their locally collected data are key components to improving our understanding of local climate change impacts. On-farm and on-ranch data collection will be become more accessible in the future due to the decreasing cost of weather stations and data loggers. The collection of local climate data will be increasingly important as weather variability grows, and farmers and ranchers need data to monitor and predict weather, making related management interventions. Ultimately, responding to climate change will require the collaboration of publically funded climate specialists, the private sector, and Montana's farmers and ranchers.

## Conclusion

Every year, farmers and ranchers adapt to variable (but generally rising) temperatures, increasing "climate surprises" such as floods and droughts, and shifts in precipitation patterns. The legacy of farming and ranching in Montana has always been one of adaptation and resilience. Innovative land managers across the state are not only at the frontline of addressing climate change impacts through their long history of adaptation, but some are now also integrating greenhouse gas mitigation into their production practices. As the last section suggests, Montana's agriculturalists will play a growing and important role in collecting weather data and improving our understanding of future climate in Montana.

This report seeks to highlight the many ways farmers and ranchers can think about responding to climate change pressures. Perhaps most importantly, we strive to emphasize the necessity and value of including farmers and ranchers as a constructive and collaborative part of the climate change discussion. Rural Montanan agriculturalists are innovators, adapters, and resilient stewards of our critical landscapes. As such, they are an essential part of any durable climate change solutions in Montana.

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