Healthy Soils Policy in a Rangeland Context

Texas as a Case Study

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Food Systems and US Environmental Law

LAW 8421 L

Fall 2019

EXECUTIVE SUMMARY

In Part I, this paper analyzes the potential for rangeland grazing practices to serve as a net carbon sink. In Part II, it makes the case for the ecological advantages of rotational grazing over continuous grazing systems. In Part III, this paper analyzes the economic consequences for ranchers in switching from continuous grazing practices to rotational grazing practices, by using ranching in the state of Texas as an example. It also considers noneconomic obstacles to making the transition. In Part IV, this paper offers policy solutions aimed to help rangelands managers overcome the obstacles previously highlighted in Part III. It also examines gaps between current levels of federal funding for ecological grazing and what is actually needed by ranchers to make the transition. The paper will conclude with an assessment of the carbon sequestration potential of rangeland grazing as compared to other land-based negative emissions technologies.

KEY FINDINGS:

1) Climate-smart grazing may have the potential to store 0.5% - 3% of annual global GHG emissions in rangeland soils until such soils are saturated with carbon.

2) The main obstacles that ranchers in the U.S. face when considering a transition to improved grazing practices is their perception of additional labor requirements.

3) Rotational grazing systems do, in fact, exact a much higher labor demand on ranchers than continuous grazing systems do.

4) There is little evidence that rotational grazing is more profitable to ranchers in the short term. Models suggest that it can be highly profitable in the long term, however.

5) Policies aimed to incentivize climate-smart grazing should compensate increased labor costs, invest in training programs, and advance research on economic profitability.

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INTRODUCTION: OVERVIEW OF HEALTHY SOILS POLICIES

Theory of Change

1. **"**Healthy soils" policies refer to a series of legislative efforts to incentivize farmers into adopting agricultural practices that sequester atmospheric carbon in soils.[1] The benefits of climate-smart agricultural practices are two-fold: not only can they mitigate greenhouse gas emissions ("GHGs") directly by absorbing atmospheric carbon, but they can also greatly increase agricultural productivity, thereby decreasing demand for synthetic fertilizers and further diminishing the GHGs that arise from food production.[2] By designing policies that compensate, educate, and engage farmers to employ climate-smart agricultural practices, healthy soils policies can turn agriculture into a carbon-neutral, or perhaps even carbon-negative sector.

Economic Importance of Rangelands

2. Rangeland ecosystems occupy between one third and one half of the earth's land area. [3] [4] Over 1 billion people depend on these ecosystems for their livelihoods, typically through livestock production.[5] Any analysis of rangeland management must centralize the role of the livestock farmer and the communities which rely on rangeland grazing, both in terms of their economic dependence on status quo grazing systems, as well as their relative ability to transition

[1] *State Policy – Soil Solutions*. https://soilsolution.org/u-s-state-policy/. Accessed 25 Nov. 2019.
[2] Bai, Xiongxiong, et al. "Responses of Soil Carbon Sequestration to Climate-Smart Agriculture Practices: A Meta-Analysis." *Global Change Biology*, vol. 25, no. 8, 2019, pp. 2591–606. *Wiley Online Library*, doi:10.1111/gcb.14658.
[3] Cook, Seth L., and Zhao Ma. "Carbon Sequestration and Private Rangelands: Insights from Utah Landowners and Implications for Policy Development." *Land Use Policy*, vol. 36, Jan. 2014, pp. 522–32. *ScienceDirect*
[4] Teague, W R. "Forages and Pastures Symposium: Cover Crops in Livestock Production: Managing grazing to restore soil health and farm livelihoods" *Journal of animal science* vol. 96,4 (2018): 1519-1530.
[5] Ibid.

to climate-friendly practices.[6] This paper will outline the potential for climate-smart rangeland grazing to sequester atmospheric carbon and analyze the obstacles that ranchers may face when seeking to adopt such practices.

PART I: RANGELAND GRAZING AND CARBON SEQUESTRATION

Rangelands as a Carbon Source

3. While there is some debate as to how much food production contributes to global greenhouse gas emissions, researchers estimate that food production represents somewhere between 17% and 33% of total GHG emissions.[7] [8] Globally, GHG emissions from domestic livestock production accounts for roughly 12% of global sources, largely from methane releases due to enteric fermentation by ruminants, and much of it occurring on rangelands. [9] [10] [11] In addition, poor grazing management of rangelands can lead to considerable soil and wind erosion which can further release GHGs into the atmosphere.[12] [13]

Rangelands as a Carbon Sink

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[6] Teague, W. R., et al. "Multi-Paddock Grazing on Rangelands: Why the Perceptual Dichotomy between Research Results and Rancher Experience?" *Journal of Environmental Management*, vol. 128, Oct. 2013, pp. 699–717. *www-sciencedirect-com.ezproxy.cul.columbia.edu*
[7] Ferdowsi, Mir A. "UNCTAD – United Nations Conference On Trade And Development." *A Concise Encyclopedia of the United Nations*, edited by Helmut Volger, Brill | Nijhoff, 2010.
[8] Lehner, Peter H. and Nathan Rosenberg, "Chapter 30: Agriculture" *from* Gerrard, Michael, and John C. Dernbach. *Legal pathways to deep decarbonization in the United States*. Washington, D.C: Environmental Law Institute, 2019.
[9] Teague, W. R., et al. "The Role of Ruminants in Reducing Agriculture's Carbon Footprint in North America." *Journal of Soil and Water Conservation*, vol. 71, no. 2, Mar. 2016, pp. 156–64.
[10] Wang, Tong, et al. "GHG Mitigation Potential of Different Grazing Strategies in the United States Southern Great Plains." *Sustainability*, vol. 7, no. 10, Sept. 2015, pp. 13500–21.
[11] Garnett, Tara, et al. *Ruminating on Cattle, Grazing Systems, Methane, Nitrous Oxide, the Soil Carbon Sequestration Question – and What It All Means for Greenhouse Gas Emissions*. 2017, p. 8.
[12] Teague, W. R., et al. "The Role of Ruminants in Reducing Agriculture's Carbon Footprint in North America." *Journal of Soil and Water Conservation*, vol. 71, no. 2, Mar. 2016, pp. 156–64.
[13] Aubault, Hélène, et al. "Grazing Impacts on the Susceptibility of Rangelands to Wind Erosion: The Effects of Stocking Rate, Stocking Strategy and Land Condition." *Aeolian Research*, vol. 17, June 2015, pp. 89–99. *ScienceDirect*, doi:10.1016/j.aeolia.2014.12.005.

4. The agricultural sector has immense potential to sequester atmospheric carbon. A recent Food and Agriculture Organization of the United Nations report refers to agriculture as the only sector that has the potential to remove GHGs from the atmosphere in a safe and cost-effective manner without negatively affecting productivity.[14] One estimate places the sequestration ability of soil carbon storage practices at 12-13% of annual global GHG emissions[15] [16] Rangelands, in particular, are estimated to represent up to 25% of all potential carbon sequestration in agricultural soils.[17] It is therefore estimated that rangelands can store 0.5% - 3% of annual global GHG emissions if managed with this goal in mind.[18] On the high end, that is on par with annual GHG emissions stemming from all waste and waste management practices globally[19]

Net Sink or Net Source? Engaging the Debate

5. While it is important to consider the benefits of transitioning to climate-smart rangeland management, there is a debate as to whether even the most sustainable form of grazing on rangelands would constitute a net sink or net source of carbon (i.e. if carbon sequestration potential of healthy grassland soils is greater than the methane emissions that ruminants release). [20] [21] There is also a debate as to whether improving grazing is the most climate-savvy approach

[14]Chiriacò, Maria Vincenza, et al. *Koronivia Joint Work on Agriculture: Analysis of Submissions*. 2018.
[15] Velasquez-Manoff, Moises. "Can Dirt Save the Earth?" *The New York Times*, 18 Apr. 2018. *NYTimes.com*, https://www.nytimes.com/2018/04/18/magazine/dirt-save-earth-carbon-farming-climate-change.html.
[16] Smith, Pete. "Soil Carbon Sequestration and Biochar as Negative Emission Technologies." *Global Change Biology*, vol. 22, no. 3, 2016, pp. 1315–24. *Wiley Online Library*,
[17] Teague, W. R., et al. "The Role of Ruminants in Reducing Agriculture's Carbon Footprint in North America." *Journal of Soil and Water Conservation*, vol. 71, no. 2, Mar. 2016, pp. 156–64.
[18] Lorenz, Klaus, and Rattan Lal. "Carbon Sequestration in Grassland Soils." *Carbon Sequestration in Agricultural Ecosystems*, edited by Klaus Lorenz and Rattan Lal, Springer International Publishing, 2018, pp. 175–209. *Springer Link*, doi:10.1007/978-3-319-92318-5_4.
[19] "Sectoral Greenhouse Gas Emissions by IPCC Sector." *European Environment Agency*, https://www.eea.europa.eu/data-and-maps/daviz/change-of-co2-eq-emissions-2. Accessed 23 Nov. 2019.
[20] Teague, W. R., et al. "The Role of Ruminants in Reducing Agriculture's Carbon Footprint in North America." *Journal of Soil and Water Conservation*, vol. 71, no. 2, Mar. 2016, pp. 156–64.
[21] Garnett, Tara, et al. *Ruminating on Cattle, Grazing Systems, Methane, Nitrous Oxide, the Soil Carbon Sequestration Question – and What It All Means for Greenhouse Gas Emissions*. 2017, p. 8.

to rangeland management. The debate hinges on a number of factors, including the emissions consequences of land use change, time to soil carbon saturation, additional time that animals must spend on rangelands in order to be finished on grass as opposed to feedlots, and soil carbon sequestration as a technology compared to alternative carbon mitigation strategies.[22]

6. In order for the practice of grazing livestock to serve as a net carbon sink, ranchers must refrain from converting forest land into grazing land—particularly in tropical climates.[23] Furthermore, researchers agree that the carbon sequestration potential of soils is limited—once soil are saturated with carbon they lose their ability to further remove carbon from the atmosphere.[24] Once this occurs, the activity of ruminant grazing is more likely to function as a net source. The question is how long that will take. However, most researchers agree that rangelands soils are, in general, not close to saturation, and will not be for some time.[25] [26]

7. There is also a debate as to whether or not finishing cattle on grassland is preferable to finishing cattle in a feedlot as far as GHG emissions are concerned. This debate hinges upon the amount of GHGs associated with growing grain to feed cattle in a feedlot, compared to the extra

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[22] Ibid.
[23] McAlpine, C. A., et al. "Increasing World Consumption of Beef as a Driver of Regional and Global Change: A Call for Policy Action Based on Evidence from Queensland (Australia), Colombia and Brazil." *Global Environmental Change*, vol. 19, no. 1, Feb. 2009, pp. 21–33. *ScienceDirect*, doi:10.1016/j.gloenvcha.2008.10.008.
[24] Lorenz, Klaus, and Rattan Lal. "Carbon Sequestration in Grassland Soils." *Carbon Sequestration in Agricultural Ecosystems*, edited by Klaus Lorenz and Rattan Lal, Springer International Publishing, 2018, pp. 175–209. *Springer Link*, doi:10.1007/978-3-319-92318-5_4.
[25] Ibid.
[26] Teague, W. R., et al. "The Role of Ruminants in Reducing Agriculture's Carbon Footprint in North America." *Journal of Soil and Water Conservation*, vol. 71, no. 2, Mar. 2016, pp. 156–64.

amount of time an animal must live to be finished on grass (and the methane emissions associated with that extra time). More research is required to conclusively answer this question.[27]

8. Finally, there are promising land management practices—beyond grazing—that can enhance soil carbon sequestration on rangelands. It is important to consider these strategies when designing incentive programs that can enhance soil carbon storage on agricultural lands. However, this paper argues that the first order problem to solve is improving current grazing practices, before considering ways to incentivize techniques such as biochar or bioenergy capture and storage (BECSS), which require whole new systems of infrastructure to implement.[28]

Boundaries of this Analysis

9. This paper will focus on incentivizing climate friendly grazing practices by using the state of Texas as an example. In light of the issues highlighted in paragraphs 6-8, this paper will operate under three key assumptions:

1) Conversion of forest into rangeland is not a significant issue in Texas

2) The most economically and politically feasible way to use rangelands to address climate change in the short term is to improve grazing practices

3) There is no substantial and pervasive difference between rotational grazing and continuous grazing systems in terms of how cattle are finished.

[27] Teague, W R. “Forages and Pastures Symposium: Cover Crops in Livestock Production: Managing grazing to restore soil health and farm livelihoods” *Journal of animal science* vol. 96,4 (2018): 1519-1530.

[28] Smith, Pete. “Soil Carbon Sequestration and Biochar as Negative Emission Technologies.” *Global Change Biology*, vol. 22, no. 3, 2016, pp. 1315–24. *Wiley Online Library*,

PART II: CONTINUOUS GRAZING VS. ROTATIONAL GRAZING

10. Rangelands around the world coevolved to form a sustainable, symbiotic relationship between grazing ruminants and ecosystem dynamics which feature frequent fires.[29] Grazing ungulates were constantly in migration, and while grazing at a given site was often very intense, it was also quite brief. Since herds constantly migrated to feed on the richest forage, grazing animals would not return to the same site for considerable periods of time, allowing rangeland plants sufficient time to regrow.[30]

Advantages of Rotational Grazing

11. This dynamic of intense grazing periods followed by a period of rest for forage plants is mimicked by rotational grazing, of which adaptive multi-paddock ("AMP") grazing is an especially management-friendly form.[31] In contrast to continuous grazing, where animals feed continuously within a single boundary, AMP systems ensure that animals do not return to a grazing site for a number of days or weeks until the forage plants have sufficiently regrown.

12. Continuous grazing—which is by far the predominant grazing system in the United States— can negatively affect plant growth and soil health and is more likely to lead to wind erosion, soil erosion and soil carbon loss.[32] AMP systems, on the other hand, provide for

[29] Frank, Douglas A., et al. "The Ecology of the Earth's Grazing Ecosystems." *BioScience*, vol. 48, no. 7, July 1998, pp. 513–21.
[30] Ibid.
[31] Dowhower, Steven L., et al. "Soil Greenhouse Gas Emissions as Impacted by Soil Moisture and Temperature under Continuous and Holistic Planned Grazing in Native Tallgrass Prairie." *Agriculture, Ecosystems & Environment*, vol. 287, Jan. 2020, p. 106647. *ScienceDirect*

[32] Stanley, Paige L., et al. "Impacts of Soil Carbon Sequestration on Life Cycle Greenhouse Gas Emissions in Midwestern USA Beef Finishing Systems." *Agricultural Systems*, vol. 162, May 2018, pp. 249–58. *ScienceDirect*

healthier, larger forage grasses and forbs which are capable of absorbing more carbon dioxide from the air and depositing it deeper into the soil with more extensive and developed plant roots. More robust plant root systems lead to increased soil organic and an enhanced soil microbial community, which improves water infiltration and enhances soil fertility, among a host of other positive consequences.[33]

13. In a host of studies, AMP has proven to sequester more carbon into the soil than other forms of grazing, and is estimated to be a net carbon sink in the short term.[34] Beyond the soil health advantages of AMP grazing over continuous grazing, AMP systems can also improve the quality of grazed forage and, therefore, its digestibility for animals. The improvement in forage quality due to AMP systems is estimated to reduce methane emissions from enteric fermentation in grazing ruminants by up to 30%.[35]

Other Practices to Sequester Carbon in Rangelands

14. While the practice of rotational grazing in multiple paddocks is essential for climate-friendly grazing, there are other management practices that can maximize the carbon sequestration potential of rangeland soil. Lowering stocking rates—the number of cattle per paddock—to a reasonable level would help prevent damages associated with overgrazing. Other rangeland improvements might include removing woody vegetation and planting a diverse mix

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[33] Teague, W R. "Forages and Pastures Symposium: Cover Crops in Livestock Production: Managing grazing to restore soil health and farm livelihoods" *Journal of animal science* vol. 96,4 (2018): 1519-1530.
[34] Wang, Tong, et al. "GHG Mitigation Potential of Different Grazing Strategies in the United States Southern Great Plains." *Sustainability*, vol. 7, no. 10, Sept. 2015, pp. 13500–21
[35] Wang, Tong, et al. "GHG Mitigation Potential of Different Grazing Strategies in the United States Southern Great Plains." *Sustainability*, vol. 7, no. 10, Sept. 2015, pp. 13500–21.

of grasses and legumes that will improve soil health, forage quality and meat quality, as well as enhance the rangeland ecosystem's ability to sequester carbon overall.[36]

Rangeland Management in the United States: Environmental Considerations

15. There is an estimated 336 million hectares of rangeland in the United States, covering about one third of the country.[37] [38] However, some of it is much more conducive to AMP grazing than others. In particular, more arid ecosystems that experience erratic rains and less frequent periods of plant growth are far less suitable to intensive rotational grazing.[39] In fact, studies have shown that AMP-type grazing regimes in semi-arid areas have little impact on improving soil quality and do not show great potential for carbon sequestration via improved grazing.[40]

16. In the United States, AMP grazing is most likely to succeed in grassland regions with sufficient annual precipitation, such as the Great Plains area of the United States, that has historically been home to both tallgrass and mixed prairie (see Figure 1).

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[36] Cook, Seth L., and Zhao Ma. "Carbon Sequestration and Private Rangelands: Insights from Utah Landowners and Implications for Policy Development." *Land Use Policy*, vol. 36, Jan. 2014, pp. 522–32. *ScienceDirect*, doi:10.1016/j.landusepol.2013.09.021.

[37] Chambers, A., et al. "Soil Carbon Sequestration Potential of US Croplands and Grasslands: Implementing the 4 per Thousand Initiative." *Journal of Soil and Water Conservation*, vol. 71, no. 3, May 2016, pp. 68A-74A. *DOI.org (Crossref)*, doi:10.2489/jswc.71.3.68A.

[38] Cook, Seth L., and Zhao Ma. "Carbon Sequestration and Private Rangelands: Insights from Utah Landowners and Implications for Policy Development." *Land Use Policy*, vol. 36, Jan. 2014, pp. 522–32. *ScienceDirect*, doi:10.1016/j.landusepol.2013.09.021.

[39] Teague, W. R., et al. "Multi-Paddock Grazing on Rangelands: Why the Perceptual Dichotomy between Research Results and Rancher Experience?" *Journal of Environmental Management*, vol. 128, Oct. 2013, pp. 699–717. *www-sciencedirect-com.ezproxy.cul.columbia.edu*,

[40] Ibid.

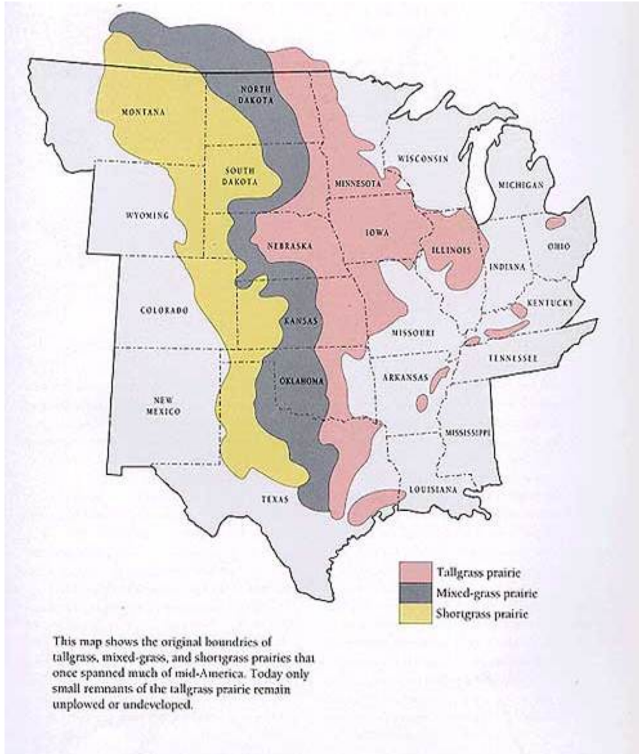

Figure 1: Prairie ecosystems in the United States[41]

17. Beyond precipitation, soil type and topography play a large role in determining how effective different grazing strategies can be at enhancing ecosystems and sequestering carbon. While soil types are incredibly diverse and can be difficult to adapt practices to, it is important to consider the topography of grazing areas, as grazing on slopes can more quickly lead to soil degradation and wind erosion instead of soil revitalization. [42] In this sense, policies that incentivize grazing on sloped areas could lead to adverse outcomes.

18. A rangeland manager's ability to plant seeds to improve forage is an important issue to consider as well. A highly productive AMP grazing system is ideally built upon a strong

[41] *North American Short Grass Prairie | Wrangle*. https://wrangle.org/ecotype/north-american-short-grass-prairie. Accessed 23 Nov. 2019.
[42] Teague, W. R., et al. "Multi-Paddock Grazing on Rangelands: Why the Perceptual Dichotomy between Research Results and Rancher Experience?" *Journal of Environmental Management*, vol. 128, Oct. 2013, pp. 699–717. *www-sciencedirect-com.ezproxy.cul.columbia.edu*,

foundation of grasses and legumes. In places where native grasses and forbs have been replaced by invasive species, a highly productive AMP grazing system depends upon the managers ability to introduce more productive plant mixes into the grassland. This process requires sufficient precipitation for seed germination and can be aided by mechanical seed drilling techniques. In some circumstances, tillage may be a desirable way to clear the ground for new seed plantings. However, tillage can release a high amount of soil carbon through oxidization and should be avoided as much as possible, especially in the semi-arid and xeric ecosystems that many rangelands exist on.[43] Furthermore, many ranchers who employ continuous grazing practices do not have the equipment or time to manage their rangelands in such an intensive manner.[44]

Texas as a Test Case

19. States that hold the highest potential to successfully implement adaptive multi paddock grazing practices, given the aforementioned environmental considerations, are the Great Plains states of Texas, Oklahoma, Kansas, Nebraska, South Dakota, and North Dakota. Texas has the most cattle at 13% of all cattle in the U.S., followed by Nebraska and Kansas, who each possess 6-7% of all U.S. cattle respectively.[45] Furthermore, roughly 80% of the 12.5 million cattle in Texas are raised, in some part, on rangelands. Texas also has the highest number of individual farms and ranches in the United States, as well as the most amount of land in agriculture of any state, much due to extensive grazing over wide swaths of the Southern Great Plains. Due to the

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[43] Barbera, V., et al. "Long-Term Cropping Systems and Tillage Management Effects on Soil Organic Carbon Stock and Steady State Level of C Sequestration Rates in a Semiarid Environment." *Land Degradation & Development*, vol. 23, no. 1, 2012, pp. 82–91.
[44] Conversation with Jerry Ford, Network Coordinator for the Sustainable Farming Association with 15-year's experience grazing cattle in an adaptive multi-paddock system. Date: 11/18/2019
[45] *USDA - National Agricultural Statistics Service - Texas - Livestock Reports*. https://www.nass.usda.gov/Statistics_by_State/Texas/Publications/Livestock_Reports/index.php. Accessed 24 Nov. 2019.

fact that much of Texas' rangeland is suitable to AMP, as well as the fact that the state of Texas is the most impactful state when it comes to grazing practices, this paper will examine the potential impact of healthy soils policies in Texas.

PART III: BARRIERS TO TRANSITION FOR TEXAS RANCHERS

Ranch and Rancher demographics

20. The average age Texan farmers and ranchers is 59 years, and 37% of Texan farmers and ranchers are women.[46] Roughly 40% of all rural landowners in Texas depend on their operation for their livelihood. 95% of all land in Texas is privately owned "working lands".[47] Average ranch size in Texas is a bit over 500 acres, although the median working ranch tends to be between 2,000 acres and 20,000 acres. [48] [49]

Economic Barriers for Healthy Soils Policy

21. The financial sustainability of a ranch depends on six factors: 1) overhead expense; 2) enterprise selection; 3) production per unit; 4) value per unit; 5) direct cost per unit; and 6) the number of animal units grazed, i.e., the stocking rate. [50]

22. Differences in value per unit, while important to consider, are negligible in this comparison since it assesses the economics of two systems which produce products that could

[46] *Texas Ag Stats*. https://www.texasagriculture.gov/About/TexasAgStats.aspx. Accessed 24 Nov. 2019.
[47] *Home | Texas Land Trends*. http://www.texaslandtrends.org/#texaslandfacts. Accessed 24 Nov. 2019.
[48] Texas Land Trends - Ownership Size | Data Basin. https://databasin.org/datasets/693c2bee47194f649815ae6c8460dfa4. Accessed 24 Nov. 2019.
[49] *What Is the Average Size of a Texas Ranch? - Ask an Expert*. https://ask.extension.org/questions/217801. Accessed 24 Nov. 2019.
[50] "Stocking Rate Decisions - How Many Acres Do You Need per Cow?" *Texas A&M AgriLife Extension Service*, https://agrilifeextension.tamu.edu/library/ranching/stocking-rate-decisions/. Accessed 24 Nov. 2019.

both be marketed as "grass-fed". There is no current widespread certification to distinguish continuous grazing products from rotational grazing product in the marketplace, and therefore there is currently no price premium to be gained from transitioning to AMP systems. However, the transition from continuous grazing to AMP results in significant changes in the following:

1) Direct costs per unit— including infrastructure investment and cost of increased labor

2) Production per unit— specifically, any impact that AMP has on production rates

3) Stocking rate— differences between AMP and continuous grazing

Direct Costs

23. Start-up costs: To set up an AMP system where none exists, initial investments are required to create new paddocks. The key new elements to introduce are fencing and water distribution lines. Researchers have estimated a wide range of costs associated with installing new fencing and water lines. Conservatively, per acre costs of installing an AMP system were estimated at $70-100/acre, which includes the cost of installing new livestock lanes for efficient herd movement. [51] [52] This did not include the cost of labor in installing the new infrastructure, under the assumption that most ranching crews would be able to install the new fencing within their normal work schedule. It is important to note that such costs are highly variable based upon such factors as whether the fencing is temporary or permanent, electric or nonelectric, and how efficient the watering systems are designed to be.[53]

[51] Wang, Tong, et al. "Evaluating Long-Term Economic and Ecological Consequences of Continuous and Multi-Paddock Grazing - a Modeling Approach." *Agricultural Systems*, vol. 165, Sept. 2018, pp. 197–207. *ScienceDirect*, doi:10.1016/j.agsy.2018.06.012.
[52] *Fencing and Watering Systems, Webster County | University of Missouri Extension*. http://extension.missouri.edu/webster/fencing-watering.aspx. Accessed 24 Nov. 2019.
[53] Hyland, John J., et al. "Factors Underlying Farmers' Intentions to Adopt Best Practices: The Case of Paddock Based Grazing Systems." *Agricultural Systems*, vol. 162, May 2018, pp. 97–106. *ScienceDirect*, doi:10.1016/j.agsy.2018.01.023.

24. Operating costs: Few studies have adequately considered the labor costs of managing a complex multi-paddock system. Research from rotational grazing schemes in the Gulf Coast region estimate the difference in per acre labor costs between low intensity continuous grazing and high intensity rotational grazing at 6.6 additional hours per acre per year (see Appendix 1). [54] This is due to the increase in amount of time associated with maintenance and repairs of fencing, as well as frequency by which the herd has to be moved.[55] At an estimated $13/hour for a hired ranch hand, the associated per acre costs of increased labor from moving from continuous to AMP is roughly $86/acre in 2018.[56] [57]

Production per unit and profitability

25. Some researchers have used predictive models to indicate that multi-paddock grazing systems will lead to higher per unit production than continuous grazing.[58] However, one study of rotational grazing systems in the Gulf Coast region found a relative decrease in mean animal weight at time of finishing compared to continuous grazing systems.[59] Given the difference in grazing conditions between the Gulf Coast and the Great Plains, particularly in forage quality, that study may not be valid in the relevant context. Overall, there is little scientific proof that

[54] Gillespie, Jeffrey M., et al. "The Roles of Labor and Profitability in Choosing a Grazing Strategy for Beef Production in the U.S. Gulf Coast Region." *Journal of Agricultural and Applied Economics*, vol. 40, no. 01, Apr. 2008, pp. 301–13.
[55] Ibid.
[56] Holmgren, Lyle, and D. Feuz. *2015 Costs and Returns for a 200 Cow, Cow-Calf Operation, Northern Utah*. p. 4.
[57] *Wages for Ranch Hands*. https://work.chron.com/wages-ranch-hands-22506.html. Accessed 24 Nov. 2019.
[58] Wang, Tong, et al. "Evaluating Long-Term Economic and Ecological Consequences of Continuous and Multi-Paddock Grazing - a Modeling Approach." *Agricultural Systems*, vol. 165, Sept. 2018, pp. 197–207. *ScienceDirect*, doi:10.1016/j.agsy.2018.06.012.
[59] Gillespie, Jeffrey M., et al. "The Roles of Labor and Profitability in Choosing a Grazing Strategy for Beef Production in the U.S. Gulf Coast Region." *Journal of Agricultural and Applied Economics*, vol. 40, no. 01, Apr. 2008, pp. 301–13.

moving from continuous grazing to AMP systems will increase enterprise profitability, especially in the short term. That said, there are many anecdotal cases of ranchers who believe that these practices improve their overall profitability over time as their soils become healthier and their grasslands more productive.[60] [61] [62] More long-term research is needed on this topic.

Stocking Rates

26. One of the previously considered strategies for improving the carbon sequestration potential of soil is to adjust stocking rates to a level that reduces the risk of soil erosion, which is generally believed to be slightly lower than the current average.[63] Naturally, there is a strong economic incentive to increase stocking rates, since higher stocking rates tend to decrease the cost of production per unit, thereby increasing profitability.[64] In continuous grazing systems however, higher stocking rates expose ranchers to higher levels of drought risk and expose ranchers to much higher catastrophic loss potential. AMP systems are able to mitigate risks associated with high stocking rates by providing spatial flexibility in variable weather conditions and by encouraging the growth of deep-rooted plants that are more drought resistant.[65] [66]

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[60] Lawrence, Meredith. "Can Raising Cattle Be Environmentally Friendly? These Texas Ranchers Say Yes." *Dallas Observer*, 17 Sept. 2019, https://www.dallasobserver.com/news/texas-ranchers-seek-ways-to-cut-carbon-preserving-grazing-land-11753776.
[61] Velasquez-Manoff, Moises. "Can Dirt Save the Earth?" *The New York Times*, 18 Apr. 2018. *NYTimes.com*, https://www.nytimes.com/2018/04/18/magazine/dirt-save-earth-carbon-farming-climate-change.html.
[62] Sandra Postel. "Replenish: The Virtuous Cycle of Water and Prosperity." *Food Tank*, 1 Nov. 2017, https://foodtank.com/news/2017/11/replenish-sandra-postel/.
[63] Wang, Tong, et al. "Evaluating Long-Term Economic and Ecological Consequences of Continuous and Multi-Paddock Grazing - a Modeling Approach." *Agricultural Systems*, vol. 165,
[64] Becker, Wayne. *Effect of Rancher's Management Philosophy, Grazing Practices, and Personal Characteristics on Sustainability Indices for North Central Texas Rangeland*. p. 228.
[65] Ibid.
[66] Norton, Brien E., et al. "Grazing Management Can Improve Livestock Distribution: Increasing Accessible Forage and Effective Grazing Capacity." *Rangelands*, vol. 35, no. 5, Oct. 2013, pp. 45–51. *ScienceDirect*, doi:10.2111/RANGELANDS-D-13-00016.1.

27. In sum, any policy that seeks to incentive AMP systems over continuous grazing systems must consider the fact that AMP systems are considerably more expensive. While AMP systems are more likely to reap the economic rewards of healthier soils and higher forage quality as grasslands improve over time, they are not likely to be very profitable in the short term.[67]

Noneconomic barriers for Healthy Rangelands policies in Texas

Belief in Climate Change

28. Texas agriculture faces a unique and serious level of risk due to climate change.[68] In 2019, Texas farms and ranches received nearly $400M in crop insurance payments from the USDA Risk Management Agency, the second highest of any state in the country.[69] Still, many Texans do not believe in climate change, or believe it unfairly lays blame on the beef industry. [70] Climate change in Texas is a strictly partisan and contentious issue, with the majority of respondents either saying that the government should "do a lot" or "do nothing" about it.[71] Given the rural-urban partisan divide in Texas, it can be inferred that the majority of rural Texans, and therefore the majority of ranchers, want the government to "do nothing" about climate change.[72]

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[67] Wang, Tong, et al. "Evaluating Long-Term Economic and Ecological Consequences of Continuous and Multi-Paddock Grazing - a Modeling Approach." *Agricultural Systems*, vol. 165,

[68] *Where's the Beef? Predicting the Effects of Climate Change on Cattle Production in Western U.S. Rangelands | Rocky Mountain Research Station*. /rmrs/wheres-beef-predicting-effects-climate-change-cattle-production-western-us-rangelands. Accessed 24 Nov. 2019.

[69] Evich, Helena Bottemiller. "'I'm Standing Right Here in the Middle of Climate Change': How USDA Is Failing Farmes." *POLITICO*, https://www.politico.com/news/2019/10/15/im-standing-here-in-the-middle-of-climate-change-how-usda-fails-farmers-043615. Accessed 24 Nov. 2019.

[70] Lawrence, Meredith. "Texas Cattlemen Push Back on U.N. Climate Report." *Dallas Observer*, 19 Aug. 2019, https://www.dallasobserver.com/news/texas-cattlemen-push-back-on-new-un-climate-report-11734484.

[71] Ramsey, Ross. "Texans Don't See Eye-to-Eye on Climate, Health Care or Taxes, UT/TT Poll Finds." The Texas Tribune, 4 Mar. 2019, https://www.texastribune.org/2019/03/04/texans-disagree-on-climate-health-care-taxes-uttt-poll/.

[72] "Texas Has Political Divide, and Urban-Rural Split Is Threat to Business, Too." *Dallas News*, 11 Nov. 2016, https://www.dallasnews.com/business/economy/2016/11/11/texas-has-political-divide-and-urban-rural-split-is-threat-to-business-too/.

For this reason, any attempt to incentive better grazing practices in Texas should exclude language referring to carbon sequestration, and instead specifically focus on the environmental benefits of soil and water quality, as well as the long term financial sustainability and risk mitigation that better grazing practices can provide to ranchers.

Perceptions of Increased Labor

29. A study of barriers to rotational grazing in Northeastern dairy farms showed that the main barriers to AMP for farmers who were already grazing, were, in order of importance: 1) concern about the amount of work to implement and maintain a rotational system, 2) concerns over a decrease in production and profits, 3) lack of on-farm technical assistance, and 4) lack of information on how to manage the new system.[73]

30. The main concern of grazers is not necessarily the cost of implementing the new system, but rather the work required to install and maintain it. It is important to consider policies that help farmers overcome this concern. Such policies, such as rancher training programs, increased on farm technical assistance, and extra funding to cover the labor of the implementation phase, will be discussed in Part IV.

[73] Winsten, J. R., et al. "Barriers to the Adoption of Management-Intensive Grazing among Dairy Farmers in the Northeastern United States." *Renewable Agriculture and Food Systems*, vol. 26, no. 2, June 2011, pp. 104–13. *DOI.org (Crossref)*, doi:10.1017/S1742170510000426.

PART IV: POLICY PATHWAY FORWARD

Farm Bill as the key policy vehicle

31. Before considering any new incentive programs, it is important to assess the incentive programs already in existence. The state of Texas itself offers very little in terms of programs for ranchers outside of providing low-interest financing for business development.[74] [75] While this could be an important service to utilize to finance the cost of transition to rotational grazing, it does not make up for the fact that rotational grazing systems are not demonstrably more profitable in the short-term. On the other hand, numerous incentive programs already exist at the federal level in the Farm Bill which can be effectively utilized to promote carbon-friendly grazing in the state of Texas. Given that the majority of rangeland management programs in Texas operate through Farm Bill provisions, policy recommendations given in this section will reflect the potential for the Farm Bill to serve as the key vehicle that can accelerate the transition to rotational grazing practices for Texan ranchers.

Assessing funding gaps

32. CSP: In 2020, Texan applicants acan receive up to $18/acre in federal payments through the Conservation Stewardship Program in a program called the Grassland Conservation Initiative. [76] This program will compensate ranchers for improving their grazing practices, although it is not tied specifically to AMP systems.[77]

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[74] *Regulatory Programs*. https://texasagriculture.gov/RegulatoryPrograms.aspx. Accessed 25 Nov. 2019.
[75] *Grants & Services*. https://texasagriculture.gov/GrantsServices.aspx. Accessed 25 Nov. 2019.
[76] *Texas Payment Schedules | NRCS.* https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/?cid=nrcseprd1328414. Accessed 24 Nov. 2019.
[77] *Conservation Stewardship Program | NRCS.* https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/. Accessed 24 Nov. 2019.

33. EQIP: Ranchers are also able to receive up to 75% of their costs associated with fencing, water distribution, and livestock channel installation through the Farm Bill's Environmental Quality Incentive Program.[78] [79] Through the Regional Management funding stream ranchers can receive up to $3,476 for developing a grazing management plan. The pool of funding for ranchers is significant— 50% of all EQIP funding is geared to improve livestock operations. [80]

34. Based on the economic costs outline in paragraphs 23-24, and the incentive programs outlined in paragraphs 32-33, the overall outline for existing funding gaps can is highlighted by the following table:

Item	Cost of transitioning to AMP (per acre)	Payments offered in the 2018 Farm Bill	Remaining Costs
Fence, water distribution, and livestock pipeline installations (one-time)	$70/acre	EQIP designed to cover 75% of cost[81]	$17.5/acre
Labor costs due to increased maintenance and frequency of moving (ongoing)	~$86/acre (at $13.00/hour for hired help)	$18/acre offered in the Grasslands Conservation Program	$68/acre
	Total Difference not covered by current incentive programs		**$85.5/acre**
		Average size of Texas farm/ranch	500 acres
		Leftover cost to transition for average ranch	$42,750

[78] "Environmental Quality Incentives Program." *National Sustainable Agriculture Coalition*, https://sustainableagriculture.net/publications/grassrootsguide/conservation-environment/environmental-quality-incentives-program/. Accessed 24 Nov. 2019.
[79] *Fencing and Watering Systems, Webster County | University of Missouri Extension*. http://extension.missouri.edu/webster/fencing-watering.aspx. Accessed 24 Nov. 2019.
[80] "Environmental Quality Incentives Program." *National Sustainable Agriculture Coalition*, https://sustainableagriculture.net/publications/grassrootsguide/conservation-environment/environmental-quality-incentives-program/. Accessed 24 Nov. 2019.
[81]

		Grazing Management Plan	$3,476
		Final cost (per acre for 500 acres)	$39,274 (~$79/acre)

35. One key assumption of this analysis is the number of hours spent managing AMP-type systems as opposed to continuous grazing systems. This paper cites only one source as evidence of the added labor contribution of AMP systems. However, there is no doubt that AMP systems will require more maintenance due to the amount of time spent tending to an increased length of fence-line, a much more complex water distribution system, and an increase in the frequency that cattle need to be corralled and moved into a new paddock.[82] Even if the actual labor requirements/acre are significantly lower than estimated in that study (and used in this analysis), it would still represent a substantial additional cost to ranchers that would not be met if they transitioned to rotational grazing practices.

Policy recommendations

Incentive Payments

36. Since current incentive programs are tied to infrastructure development costs, there is sufficient compensation for ranchers to implement the infrastructure required for AMP systems. However, ranchers need more financial incentives in order to cover the additional cost of labor in implementing and maintaining AMP systems. Simply put, AMP systems require more intensive management, which is more labor intensive, especially early in the transition period. Therefore,

[82] Conversation with Jerry Ford, Network Coordinator for the Sustainable Farming Association with 15-year's experience grazing cattle in an adaptive multi-paddock system. Date: 11/18/2019

any healthy soils policy in Texas, or in the next Farm Bill, should include an AMP or rotational grazing transition incentive program. While there is currently an incentive in EQIP for organic transition (up to $4,266 in Texas in 2020), there is no program to incentive ranchers to transition specifically into rotational grazing.[83] A program of similar magnitude to the organic transition program would help alleviate some of the initial costs associated with increases in labor.

37. In addition, the new Grassland Conservation program should provide additional per acre incentives for ranchers enrolled in the program who seek to transition into multi-paddock systems. Another policy option would be to make enrollment in the new Grassland Conservation program contingent upon actionable plans to transition to rotational grazing systems. Either way, increasing the *per acre* subsidies of this program is key, as it would help ranchers who have to install these systems over wide swaths of land. Enrollment in the program could also make ranchers more accountable to follow through on more complex grazing scheme since it requires consistent contact with local NRCS offices and extension agents.

Targeting policies

37. The main gains of transitioning to AMP from continuous grazing, as far as carbon sequestration is concerned, are for ranchers who currently manage heavy (highly-stocked) continuous grazing systems. Indeed, the carbon sequestration gains for grazers moving from light continuous grazing systems to AMP systems is much lower (see Appendix 2).[84] It is important to

[83] *Texas Payment Schedules | NRCS.* https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/?cid=nrcseprd1328414. Accessed 24 Nov. 2019.
[84] Wang, Tong, et al. "GHG Mitigation Potential of Different Grazing Strategies in the United States Southern Great Plains." *Sustainability*, vol. 7, no. 10, Oct. 2015, pp. 13500–21. *www.mdpi.com*, doi:10.3390/su71013500.

consider the relative policy gains that could be made by targeting this specific population, especially if funding for incentive programs is limited. Furthermore, farmers currently employing heavy continuous grazing systems are the most in need of the ecological, and ultimately financial, resilience that rotational grazing schemes will afford them in the long term.

Education and Outreach

38. Furthermore, the USDA should invest in outreach and education programs that train current ranchers about how to transition to AMP systems. The purpose of these programs will be to engage and educate ranchers about the increased system resilience, ecological advantages, and long-term financial profitability of the transition, and also to alleviate their concerns by directly addressing the issue of workload. It will also put more ranchers in contact with AMP grazing system experts that will be available to assist them as needed.

Research Needs

39. Governments should invest in research to clearly understand the labor costs associated with transitioning from continuous grazing to AMP systems. While the evidence base for the carbon sequestration potential of rangeland soils is robust, more long-term studies conducted on real ranches are needed to assess the profitability of AMP systems over continuous grazing systems. Specifically, the USDA should fund research that follows real-world examples of different grazing enterprises in the same region over a number of 5-10 years. The current body of research that exists focuses too heavy on predictive models, which do not adequately capture many of the complexities associated with ranching and rangeland management.

CONCLUSION

Opportunity costs

40. Some researchers argue that more drastic negative emissions technologies than soil carbon sequestration are required in order to reach the 2°C goal for global mean surface temperatures.[85] Such technologies could be employed on areas of land that are currently used for grazing. In a comparative analysis, soil carbon sequestration was found to require very little energy, use relatively little land, operate at relatively low costs, and possess the potential to contribute substantially to reducing annual GHG emissions globally.

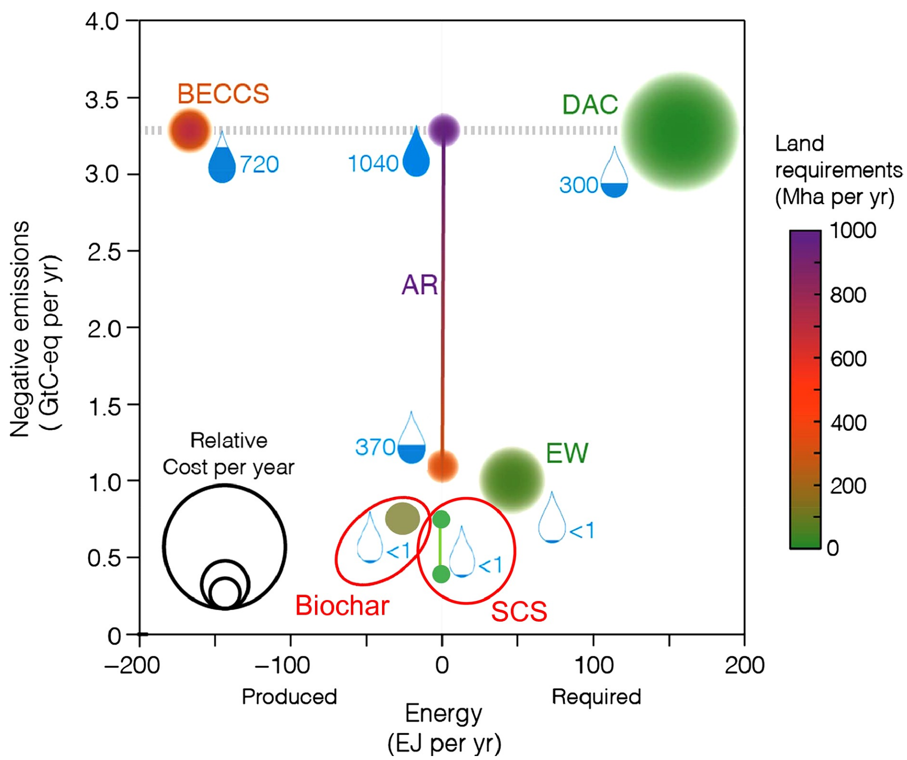

Figure 2:Comparison of the global impacts of Soil Carbon Sequestration and biochar and other NETs on land use, water, nutrients, albedo, energy and cost. Negative Emissions Technologies to which Soil Carbon Sequestration and biochar are compared are BECCS, Direct Air Capture, *Enhanced Weather and Afforestation and Reforestation as assessed by Smith et al. (2015).*

[85] Smith, Pete. "Soil Carbon Sequestration and Biochar as Negative Emission Technologies." *Global Change Biology*, vol. 22, no. 3, 2016, pp. 1315–24. *Wiley Online Library*, doi:10.1111/gcb.13178.

41. Based on this analysis, soil carbon sequestration strategies, such as rotational grazing, should be incentivized immediately. This negative emissions technology is a low hanging fruit in terms of climate change mitigation efforts, since it is relatively inexpensive and is ready to be deployed at scale. However, even though climate change mitigation might be the ultimate policy objective, policymakers in the U.S. should avoid language that explicitly refers to the climate change outcomes of improved grazing practices (e.g. “carbon farming” or “climate-smart agriculture”), and instead frame the policy objectives around the topics of soil and water health, as well as long-term financial resilience. Finally, policymakers should tackle concerns about increased labor costs head on. Only by fully understanding the labor obstacles that ranchers face can policymakers bring them on board to build up the land management workforce required to mount a significant response to the ongoing climate crisis.

Appendix 1

Table 2. Labor Use, Revenue, Expenses, and Returns Over Expenses[86]

Labor Measure	Continuous Low	Continuous Medium	Continuous High	Rotational High	Continuous Low	Continuous Medium	Continuous High	Rotational High
	Per Cow				Per Acre			
Labor Usage (hr)								
Total labor	8.22[a]	6.35[b]	5.81[b]	9.61[c]	3.99[n]	5.13[o]	6.28[p]	10.60[q]
Working cows and calves	4.53[a]	3.44[b]	2.69[b]	2.67[b]	2.20[n]	2.78[n]	2.90[n]	2.94[n]
Checking and routine tasks	1.78[a]	1.82[a]	2.25[a]	2.34[a]	0.86[n]	1.47[no]	2.44[op]	2.58[p]
Forage management	1.26[a]	0.67[bc]	0.48[b]	0.78[c]	0.61[n]	0.54[n]	0.52[n]	0.86[o]
Repairs and maintenance	0.28[a]	0.20[a]	0.13[a]	1.48[b]	0.14[n]	0.16[n]	0.14[n]	1.53[o]
Moving animals and shades	0.22[a]	0.15[a]	0.20[a]	2.53[b]	0.11[n]	0.12[n]	0.37[n]	2.76[o]
Miscellaneous tasks	0.15[a]	0.08[a]	0.06[a]	0.08[a]	0.07[n]	0.06[n]	0.06[n]	0.08[n]
Revenue, Expenses, and Returns Over Expenses ($, Without Labor Included)								
Total revenue	517.95[a]	503.72[a]	475.36[b]	465.87[b]	251.58[n]	406.97[o]	513.95[p]	514.14[p]
Direct expenses	290.09[a]	250.15[a]	264.17[a]	287.32[a]	141.06[n]	202.10[o]	285.67[p]	317.07[q]
Returns over direct expenses	227.86[ab]	253.57[a]	211.19[bc]	178.56[c]	110.51[n]	204.87[o]	228.28[p]	197.07[oq]
Fixed expenses	145.65[a]	118.58[b]	107.57[c]	126.65[d]	70.75[n]	95.80[o]	116.33[p]	139.74[q]
Total specified expenses	435.74[a]	368.73[b]	371.74[b]	413.97[ab]	211.82[n]	297.90[o]	402.00[p]	456.82[q]
Returns over specified expenses	82.20[ac]	134.99[b]	103.63[ab]	51.90[c]	39.76[n]	109.07[o]	111.95[o]	57.32[n]
Expenses and Returns Over Expenses ($, Labor Priced at $7.50/hr Included)								
Direct expenses	354.73[ac]	300.11[b]	309.88[ab]	362.93[c]	172.48[n]	242.46[o]	335.06[p]	400.46[q]
Returns over direct expenses	163.21[a]	203.61[b]	165.49[a]	102.94[c]	79.10[n]	164.50[o]	178.89[o]	113.68[p]
Total specified expenses	500.39[a]	418.69[b]	417.44[b]	489.59[a]	243.24[n]	338.26[o]	451.39[p]	540.20[q]
Returns over specified expenses	17.56[ac]	85.03[b]	57.92[ab]	−23.71[c]	8.35[n]	71.22[o]	62.56[o]	−26.06[p]

Note: Least squares means within a row (and under the same subheading, i.e., "per acre" and "per cow") that have any superscript in common do not differ at the 0.05 level of significance.

Appendix 2

Table 4. Possible (net) carbon emission and sequestration for different transition scenarios.

C Emission/Sequestration ($kg \cdot CE \cdot ha^{-1} \cdot year^{-1}$)	10-Year	15-Year	20-Year
C Sequestration			
HC→MP	3530.0	2353.3	1765.0
HC→LC	2870.0	1913.3	1435.0
LC→MP	660.0	440.0	330.0
C Emission			
HC→MP	350.52	350.52	350.52
HC→LC	181.75	181.75	181.75
LC→MP	350.52	350.52	350.52
Net C Emission			
HC→MP	−3179.5	−2002.8	−1414.5
HC→LC	−2688.3	−1731.6	−1253.3
LC→MP	−309.5	−89.5	20.5

[87]

86 Gillespie, Jeffrey M., et al. "The Roles of Labor and Profitability in Choosing a Grazing Strategy for Beef Production in the U.S. Gulf Coast Region." *Journal of Agricultural and Applied Economics*, vol. 40, no. 01, Apr. 2008, pp. 301–13.

87 Wang, Tong, et al. "GHG Mitigation Potential of Different Grazing Strategies in the United States Southern Great Plains." *Sustainability*, vol. 7, no. 10, Oct. 2015, pp. 13500–21. *www.mdpi.com*, doi:10.3390/su71013500.