Grazing Practice Choices, Capital Constraints, and the Environment

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Abstract

There is a large literature on "adoption gap" which describes the slower adoption of an apparent win-win technology for profit and the environment. The extent and reasons for such adoption gaps differ across technologies. We examine this adoption gap in the context of rotational grazing. Rotational grazing has the potential to provide both economic and environmental benefits. However, there remains a gap between the set of ranchers that could potentially adopt rotational grazing and the set that actually adopts. To investigate this gap, we use survey data from 874 ranchers on the Great Plains to learn about adoption decisions and motivations. In contradiction to basic economic reasoning, we find that over half (57%) of surveyed ranchers who view rotational grazing as win-win for both profit and the environment do not adopt it. We also find that win-win non-adopters are a very constrained group for most potential challenges to rotational grazing adoption, especially high initial costs, water resource limitations, and ranch conditions. Some of these challenges could be relieved by capital; however, win-win non-adopters have limited borrowing capacity and constrained access to operating capital. They are more willing to adopt rotational grazing than others when a one-time hypothetical subsidy is offered. These findings suggest that win-win non-adopters are an effective target group for investment subsidies to promote the adoption of rotational grazing practices. Consistent with the literature, our analysis shows the importance of understanding the specifics of the adoption gap for effective policymaking.

Keywords: Adoption gap, capital constraints, rotational grazing, win-win

JEL Codes: D91, Q16, Q18, Q57

Introduction

Many conservation practices have been shown to enhance economic profits and improve the environment. They can reduce the negative effects of production on environmental conditions. For example, conservation tillage can enhance overall soil health as well as reduce fuel and labor costs (Hodde et al. 2019); nutrient management practices can mitigate nutrient loss to the environment; and cover crops can help to improve soil quality, alleviate drought stress, and reduce input costs (Bergtold et al. 2019). The U.S. federal government provides financial and technical assistance to promote conservation practice adoption through various programs such as Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP). Other government and nongovernmental entities also have voluntary payment programs to support conservation practices (Claassen, Duquette and Smith 2018). Despite various efforts to encourage conservation practices, and despite a vibrant literature that addresses incentives for conservation practice adoption, there often remains a large "adoption gap" between the set that could potentially adopt a practice and the set that actually adopts (Prokopy et al. 2019).

The adoption gap is not unique to the agriculture sector. A similar phenomenon exists in the energy sector, where a large literature documents the "energy efficiency gap," defined as the difference between actual energy use and optimal energy use (Allcott and Greenstone 2012; Gillingham and Palmer 2014). The gap is often defined more broadly as the slower than socially optimal diffusion rate of energy-efficient products. According to Gerarden, Newell and Stavins (2017), potential explanations for this gap fall into three categories, namely market failures, behavioral explanations, and model and measurement errors. Backlund et al. (2012) also summarize the barriers to energy efficiency, for example, limited access to capital, bounded rationality, and lack of information are potential barriers to energy efficiency technology diffusion.

Many studies have also explored the determinants of "adoption gap" related to conservation practices in agricultural contexts. Prokopy et al. (2019) conduct a comprehensive review of quantitative studies focusing on the adoption of agricultural conservation practices in the United States over 1982-2017. Factors found to be important include farmers' attitudes toward the environment, attitudes towards a particular practice, previous adoption of other conservation practices, social networking, land quality, farm size, and farmer characteristics. Knowler and Bradshaw (2007) also summarize the underlying factors in adoption decisions into three categories, namely farmer characteristics, farm biophysical and financial characteristics, and other factors including government support and price shocks. However, no common answer has emerged across different conservation practices to explain why the adoption gap exists. Carlisle (2016) points out that, in the context of soil health practices, the role of economic factors generally appeared to be secondary rather than primary. This research also notes that while economic factors are unlikely to motivate farmers' adoption of practices, they could be important in removing barriers.

This paper focuses on rotational grazing, which is considered by many researchers to be a profit-increasing, and environment-friendly conservation practice. Rotational grazing can address many of the concerns arising from traditional continuous grazing. Under rotational grazing, pastures are divided into multiple paddocks typically by temporary fencing. Livestock are rotated through paddocks with only one paddock grazed at a time while the other paddocks rest. Due to higher stocking density on each paddock being grazed, the livestock are forced to be less picky and will graze a higher proportion of the less preferred plant species. The practice protects the species that are more productive for beef enterprises and so improves ranch productivity (Chaubey et al. 2010; Teague, Grant and Wang 2015). Beyond environmental benefits, to some extent, rotational grazing can provide higher profit compared with traditional grazing practices (Teague et al. 2009; Jakoby 2015; Wang et al. 2018).

However, the rotational grazing adoption rate was only about 31% in 2017 (USDA NASS, 2017). There was also a declining trend in adoption, from 43% of all grazing enterprises in 2007 to 31% in 2017 (Table 1). At the same time, we can observe the number of rotational grazing operations decreased every five years from 2007 while the total operation number across cattle, goat, and sheep operations also decreased since 2002 but had a slight increase between 2012 and 2017. Similar phenomena can be found at the state level. As is shown in Figure 1, the rotational grazing adoption rates had a declining trend over 2007-2017 in the states of North Dakota, South Dakota, and Texas. Spatial variations also exist, and the practice has become popular over the decade on the small amounts of grassland along the northeastern coast (Figure 2). Figure 3 shows the percentage change in rotational grazing adoption rates between 2007 and 2017, which indicates that adoption rates declined in most counties in 2017 compared with 2007.

In order to investigate the reasons for low adoption rates and ranchers' adoption decisions, we sent out a survey to beef operators on the Great Plains in early 2018. Contrary to basic economic reasoning we find from survey responses that many ranchers who viewed rotational grazing as a win-win practice for their own profit and environmental outcomes did not adopt it. The purposes of this paper are to investigate the factors that resulted in non-adoption decisions among these ranchers and explore possible incentives to encourage them to adopt rotational grazing.

Our paper contributes to the literature in the following ways. First, from a conceptual perspective, we discuss a rancher's decision on whether to adopt rotational grazing considering both economic profits and environmental outcomes. The inclusion of both economic and environmental outcomes extends the literature that emphasizes only one of the two. For example, Basarir and Gillespie (2006) find that beef producers regard environmental goals to be more important than maximizing profit, and also the random utility model on technology adoption with a cost-share by Kim, Gillespie and Paudel (2008). Second, we document the extent of the adoption gap of rotational grazing and further assess the extent of win-win non-adoption in terms of profit and the environment. About 56.5% of non-adopters in our sample regarded rotational grazing as a win-win practice. It is important to note that the win-win views analyzed in our paper are those of the ranchers themselves, this is in contrast to the win-win characterization of a technology by researchers based on lab or field experiments. Given that the win-win views are decision-makers' own perceptions, not external data the decision-makers have learned about, it will be more remarkable if the decision-makers with win-win views do not adopt the technology. Third, we use a relatively large survey sample to identify the main barriers that constrain win-win non-adopters and the factors that induce potential barriers. Our survey sample is larger than other literature on rotational grazing with a survey sample of less than 100 (Nelson et al. 2014; Manson et al. 2016). We also explore ranchers' opinions about rotational grazing using responses from open-ended survey questions rather than relying on secondary data sources. Finally, we investigate the effects of incentive programs on the adoption decisions of the win-win non-adopters in comparison with other non-adopters.

Our findings are as follows. First, there is a large proportion (56.5%) of non-adopters who regarded rotational grazing as a win-win practice, while about 76.4% of adopters viewed rotational grazing to be a win-win practice. Second, win-win non-adopters were a very constrained group for most potential challenges to rotational grazing adoption, especially “high initial costs”, “water resource constraint”, and “ranch conditions”. These challenges could be relieved by capital; however, win-win non-adopters had limited borrowing capacity and constrained access to operating capital. Their concerns about costs and capital are also revealed through the analysis of the open-ended comments. Further, we find that the win-win nonadopters reported themselves to be more willing to adopt rotational grazing than others when a one-time hypothetical subsidy was offered. The findings suggest that these win-win non-adopters may be a suitable target group for investment subsidies intended to effectively promote the adoption of rotational grazing practices, and the policies will be more effective when they adequately address the costs and constraints that ranchers face.

In what follows, we consider ranchers’ decision to choose a grazing practice in terms of both own profits and environmental outcomes from a conceptual perspective. We then describe the survey’s implementation and data. After that, we identify how potential barriers constrain win-win non-adopters and other groups. Next, we use open-ended comments to analyze the ranchers’ views on rotational grazing. After comparing responses to hypothetical subsidies by win-win non-adopters and by other groups, we conclude with some brief comments on how our findings can be placed in the policy arena.

Conceptual Considerations

This section describes how a rancher makes a decision on whether to adopt rotational grazing considering both economic profits and environmental outcomes from a conceptual perspective. Let $A_i \in \{ext, int\}$ denote the potential decision choice set, where *ext* represents continuous grazing practice, and *int* represents rotational grazing practice. We assume each grazing practice choice has two attributes, i.e., economic profit (π) and environmental benefit (*E*). The utility function is given as $U(\pi(A_i), E(A_i))$ and it is assumed to be monotonic. Figure 4a depicts the two attributes along with an indifference curve that indicates the trade-off between profit and environmental benefits for an individual farmer. Suppose point *x* in the figure is the profit and environmental benefits of continuous grazing. Then the whole area can be divided into four quadrants for rotational grazing in terms of profit and environmental outcomes, relative to those of continuous grazing: win-win, win-loss, loss-loss, loss-win. The four quadrants represent four possible cases with regard to ranchers' opinions and choices on rotational grazing. The decision in the win-win case and the loss-loss case is clear while the decisions in the other two quadrants are less clear. We will describe each case below.

(1) Loss-loss case: If rotational grazing is a loss-loss practice in terms of profit and the environment compared to continuous grazing, then $U(\pi(ext), E(ext)) \geq U(\pi(\text{int}), E(\text{int}))$ holds for any utility function U , so ranchers will keep applying continuous grazing.

(2) Win-loss case: If rotational grazing is a win-loss practice in terms of profit and the environment, then it is not clear whether a rancher will derive higher utility from rotational grazing and adopt it. For those who think profit outcomes are more important than environmental benefits, i.e., their utility functions have steeper indifference curves. Figure 4b provides an example of steeper indifference curves, which is presented by the orange-colored line. This kind of ranchers will be more likely to choose rotational grazing. On the other hand, ranchers who care more about the environment, represented by flatter indifference curves, will be more likely to keep continuous grazing, as is shown by the green line in Figure 4b.

(3) Loss-win case: Contrary to the second case, if rotational grazing is a loss-win

practice in terms of profit and environment, which is represented in the upper left region compared to point *x*. Still applying the indifference curve examples in Figure 4b, ranchers who put more weight on the environment than profit will be more likely to choose rotational grazing. The corresponding indifference curves are just like the green line. Otherwise, those who treat profit as more important than the environment will be more likely to keep continuous grazing.

(4) If rotational grazing is a win-win practice for both profit and environment, then $U(E(ext), \pi(ext)) < U(E(\text{int}), \pi(\text{int}))$ holds for any utility function form. The rational choice of those ranchers should be rotational grazing. However, there can be a variety of reasons that ranchers with win-win views will not adopt rotational grazing, including (i) financial, physical, or other tangible constraints, (ii) measurement errors, or (iii) behavioral reasons. Measurement errors might be possible in our case because our measurement of win or loss is based on survey data that asked farmers to state the economic and environmental impacts. This subjective statement might exaggerate the actual benefits or losses. Behavioral reasons are not evident, which have many possibilities including ranchers' retirement status, or personality disposition of keeping the status quo. Ranchers who are about to retire, might not like to try a new practice due to potential uncertainties. In our paper, we focus on the likely effects of financial and physical constraints for not adopting decisions, because these constraints have traditionally been the focus of policy interventions and also because different types of research methods would be required to examine the other two reasons.

Turning to Figure 4c, with the blue solid indifference curve, the traditional theory would rancher preferring *x* to A where A is private (E, π) pair but society would prefer B to *x* where B is public (E, π) pair. For these two points, profits are the same as society place extra value only on the environment. The traditional policy would try to twist the indifference curve down so that

A is preferred to x, just as changing from the blue solid line to the dashed one. Promoting environmental protection knowledge among ranchers might be one example. But if A is in the (Win, Win) quadrant then there is no need to shift the indifference curve. Other subsidized incentive policies might help in this regard.

Survey Description

In early 2018 we sent out a survey to beef operators in 49 North Dakota and 58 South Dakota counties as well as 81 counties in Central and North Texas. The areas were chosen because they are the northern and southern extremities of the U.S. Great Plains and incorporate a relatively higher proportion of livestock operations than the Central Plains, where irrigated crop production dominates. The screening criterion for rancher selection is that each respondent operated at least 100 non-feedlot cattle.[1] We purchased contact information for 4,500 randomly selected ranchers in three states from Survey Sampling International.[2] The survey was implemented by following the Dillman mail survey administration method (Dillman, Smyth and Christian 2014). During the period from late January 2018 to early April 2018, we sent out an advance letter of notification, two survey questionnaire mailings, and two postcard reminders. In late June 2018, a final survey packet was re-sent to secure a higher response rate.

[1] To account for the differences in the number of qualified ranches in each county, we used proportional sampling to select 1,500 ranches in each state. The sample size for each county is obtained from multiplying 1,500 by a ratio, the ratio being the number of qualified farms for each county over the total number of qualified farms in all the selected counties of each state (Wang et al., 2020).

[2] The company has gone through a merger and re-branding, and it is now part of Dynata. https://www.dynata.com/press/announcing-new-name-and-brand-research-now-ssi-is-now-dynata/.

A total of 874 recipients completed and returned the survey questionnaires with an overall response rate of 20.6%. Among all respondents average grassland acres, both native rangeland and improved pastures, was about 2,807 and average cattle herd size was 364. The percentage of respondents' total household income from ranching operations was between 20% and 40% on average. About 59% of respondents were currently practicing rotational grazing while the residual had either never adopted or had discontinued the practice.

Ranchers were asked to indicate whether rotational grazing was a win-win practice in terms of its effects on both the economic profit and the environment. For economic profit, adopters were asked about "How has your adoption of rotational grazing or MIG affected (or will likely affect) the economic profit of your ranch during the first 5 years?"; while non-adopters were asked about "To what degree do you think that rotational grazing or MIG might affect the economic profit of your ranch in the first 5 years?". They both had five option choices with 1="significantly decrease", 2="slightly decrease", 3="no influence", 4="slightly increase", and 5="significantly increase". We refer that a rancher believed rotational grazing is a "win" practice for the profit if the rancher chose "slightly increase" or "significantly increase" for the above questions.

For the environment, ranchers were asked about "whether or not you have adopted, please indicate what you observe or expect regarding the following possible benefits associated with rotational grazing or MIG practices on your ranch or neighboring ranchers". The proposed potential benefits include "increased percentage of desirable grass", "decreased runoff and erosion", and "increased drought resilience/faster drought recovery". They had four option choices for each benefit with 1="none", 2="slight", 3="medium", and 4="significant". We refer that a rancher believes rotational grazing is a “win” practice for the environment if the rancher chose “slight”, “medium” or “significant” for any of the above three environmental benefits.

Data Analysis

Win-Win Non-Adopters and Their Constraints

Although adopters and non-adopters expressed diverse views on the profit effects of rotational grazing adoption, the majority in both groups were of the view that rotational grazing was a profit-increasing practice as shown in Figure 5. Indeed, 57% of non-adopters perceived that the practice would increase profits. A greater proportion (83%) of non-adopters thought that rotational grazing would increase the required labor and management time than did adopters (61%). But different perceptions about grassland productivity impacts also explain the less enthusiastic views about practice profitability among non-adopters. Fewer non-adopters reported that rotational grazing would prolong the grazing season, increase stocking rate capacity, increase livestock weight gain, and improve livestock health than adopters (Figure 6). For example, about 96% of adopters and 83% of non-adopters reported rotational grazing would increase livestock weight gain; about 92% of adopters and 73% of non-adopters reported rotational grazing would improve livestock health.

Most adopting (99%) and non-adopting (89%) respondents agreed that rotational grazing would improve the environment by increasing desirable grass production, decreasing runoff and erosion as well as improving drought resilience and recovery (Figure 6). A greater proportion of adopters regarded the above environmental benefits to be significant when compared with non-adopters. Table 2 shows that perceptions about economic and environmental effects align well. Most adopters (76%) regarded rotational grazing as a win-win practice. Among non-adopters, about 57% thought rotational grazing to be a win-win practice. Therefore, ranchers did not adopt rotational grazing not because they had not perceived the potential economic and environmental benefits but because there were other possible reasons that we will discuss later.

It is intuitive that a rancher seeking to stay in business may not adopt a practice if environmental gains are not accompanied by profit. However, the finding that many ranchers viewed rotational grazing as both profit-increasing and environment friendly yet did not adopt goes against basic economic reasoning. To better understand the decision by win-win non-adopters, we first assess how this group compares with win-win adopters in terms of some basic demographic characteristics. As is shown in Table 3, the mean ages were about 66 and 62 for win-win non-adopters and adopters, so non-adopters were slightly older. On average, win-win non-adopters had operated a ranch for about 37 years, which was longer than 37 years among adopters. Win-win non-adopters managed ranches with average grazing acres of about 2200, which were much smaller than adopters' ranches with average grazing acres of about 3100. In addition, within a 1-mile radius of the rancher's location, 44% and 47% of the soil were of LCC I and II, and 44% and 38% of the area had slopes less than or equal to 3% for win-win non-adopters and adopters, respectively.

We asked adopters to rate the potential challenges that they had encountered when practicing rotational grazing, and we also asked non-adopters how these challenges were hindering their adoption decisions. We compared the responses across win-win non-adopters and other non-adopters, and the t-test results are shown in Table 4. The top three constraints for both win-win non-adopters and other non-adopters are "high installation cost", "water source constraint", and "labor/management time constraints", except that they treated the "water resource" and "labor or management time" constraints in reverse order. These findings are consistent with the previous studies that implementing rotational grazing needs additional infrastructure costs and possible labor inputs compared to traditional continuous grazing (Gillespie et al. 2008; Windh et al. 2019). And these three constraints along with “water source constraint” are more constraining for win-win non-adopters than other non-adopters. Turning to Table 5, most of these potential challenges are more constraining for win-win non-adopters than for win-win adopters. One noticeable phenomenon is that win-win adopters ranked “weather/climate factors” as the top second challenge, while non-adopters only ranked as six in the order.

The above differences between win-win non-adopters and other groups are also supported by the cumulative percentage response curves to different rating levels of the top challenges.[3] Taking “water resources constraint” as an example in Figure 7, the cumulative percentage lines show that win-win non-adopters are lower than all other three groups of ranchers, which indicates that win-win non-adopters were a most constrained group when faced with “water sources constraint”. Similar results can be found for other constraints. Although to some extent high initial costs, water resource constraints, and ranch conditions could be relieved by capital, win-win non-adopters are still more constrained by cash flow. These findings reveal that more constrained situations are one possible reason for not adopting rotational grazing among win-win non-adopters.

Ordered Logit Estimations for the Constraints among Different Groups of Ranchers

In this section, we examine how perceived constraints for adoption might be affected by rancher

[3] More figures for cumulative percentage response curves to different rating levels of top challenges can be found in the Appendix A.

and ranch characteristics. As responses to the constraint variables take five ordinal categories (1="not a challenge", 2="minor challenge", 3="some challenge", 4="quite a challenge", and 5="great challenge"), the ordered logit model is an appropriate modeling choice. We examine the factors that affect each of the top eight challenges, and the estimated coefficients are presented in Tables 6-9. Generally, for win-win non-adopters, education, liability ratio, lease ratio, land quality, and longitude emerged as important factors. To be specific, win-win non-adopters with a higher liability ratio tended to perceive "high installation cost", "cash flow constraints", "weather and climate factors", and "uncertainty outcomes" to be the most challenging barriers. A higher liability ratio implies a more limited capacity to borrow from lenders and, therefore, restricts the ability to overcome the potential challenges of new practice adoption. Therefore, the capital constraint might aggravate the potential barriers and prevent the adoption of rotational grazing among win-win non-adopters.

Similarly, a higher lease ratio was associated with stronger win-win non-adopters' perceptions about "water source", "labor or time management", "ranch conditions", and "rental agreement restrictions" as constraints. Lessees had little incentive to develop water resources, improve ranch conditions, increase labor inputs on land they did not own and were, therefore, more likely to perceive rental agreement restrictions as challenging when compared to ranchers who own land. By contrast when non-adpoting ranchers had a higher percentage of high-quality land, as indicated by increased proportion of land with LCC I & II, then perceptions that "labor or management time constraint", "weather or climate factors", and "rental agreement restrictions" were challenges decline.

"Water source constraint" was listed by both win-win adopters and win-win non-adopters as the most challenging issue. Specifically, many ranchers had commented on water-related constraints, such as lack of unground water, high costs of drilling new wells. Higher lease ratios were associated with stronger win-win non-adopter perceptions about water sources as a constraint. Lessees had little incentive to develop water resources on land that they did not own, so they were more likely to perceive water resources as a constraint. Specially, when the lease ratio increased by 1 standard error, non-adopters were 7.1% and 30.8% more likely to perceive water resource as “quite a challenge” and “great challenge” and they were 15.7%, 10.8%, 11.3% less likely to perceive it as “some challenge”, “minor challenge”, and “not a challenge” (Table 10).

Comments Analysis

In our survey, besides requesting ratings of potential challenges, we solicited general open-ended comments about rotational grazing practices. Specifically, ranchers were asked “Please record any further comments you have regarding rotational grazing or MIG practices”, after which ranchers were presented with space for any related comments. We categorized these comments into thirteen general themes, relating to (1) water; (2) fencing; (3) cost; (4) labor; (5) government support; (6) rent; (7) retirement; (8) environmental benefits; (9) land characteristics; (10) ranch scale; (11) neighborhood; (12) other cattle type; (13) other comments. Appendix B provides a comment classification rubric as well as example comments in each category.

Table 11 summarizes the frequency of comments in each of the above categories. Of the 392 comments made except for the category of other comments, the largest set (70, about 18% of all comments) mentioned water and related water resource concerns. Other comment categories that featured prominently were fencing, cost, labor, government support, rent, and retirement each made up 5-11% of total comments. The most commonly mentioned categories of comments were consistent with our findings of potential challenges.

Table 12 compares the comment count in each category among win-win adopters, win-win non-adopters, and other non-adopters. There was no significant difference in the frequency of comments between win-win non-adopters and other non-adopters. However, win-win non-adopters provided comparatively more cost-related comments than did win-win adopters, with respective averages of 0.2 and 0.086 per respondent. Win-win non-adopters were less likely than adopters to cite government support and environmental benefits as important comments about rotational grazing practice.

In addition to comparing comment frequency, we investigate the relationship between respondents' comments and adoption decisions in the win-win group. We generate a binary variable to indicate adoption decision in the win-win group (i.e., 1=win-win adopters, 0=win-win non-adopters). The comment frequencies and rancher-specific characteristics are included as independent variables. The logit regression results in Table 13 show that there is a significant relationship between adoption decisions and cost-related comments, which support the idea that high installation cost is a great constraint for win-win non-adopters. In addition, win-win non-adopters made more comments related to land characteristics than did win-win adopters, which is also consistent with the finding that win-win non-adopters were more constrained by ranch conditions.

Subsidy Responses

The findings in the earlier sections indicate that win-win non-adopters belong to a very constrained group when faced with potential barriers to rotational grazing, especially for high initial costs, water resource constraints, and ranch conditions. These constraints are particularly severe for ranchers with a greater liability ratio. Therefore, we conjecture that win-win non-adopters are more sensitive to subsidies which would relieve the potential constraints.

In this section, we first compare the willingness to adopt RG and MIG between win-win non-adopters and other non-adopters when a hypothetical one-time subsidy. Then we further examine the subsidy responses within these two groups. As is shown in Figure 8, win-win non-adopters were more willing to adopt both RG and MIG than were other non-adopters when faced with a one-time subsidy. To be specific, the elasticity of RG adoption was about 1.5% additional adoption per 1% increase in one-time subsidy among win-win non-adopters, which was greater than the elasticity of 1.2% among other non-adopters. The elasticity of MIG adoption was about 1.1% additional adoption per 1.1% per 1% increase in one-time subsidy among win-win non-adopters, which was also greater than that for other non-adopters (0.7%).

We also examine the non-adopters' likelihood of adopting either RG or MIG when a one-time subsidy is provided. The logit estimation results in Table 14 show that win-win non-adopters are responsive to a one-time subsidy. When compared with other non-adopters, their adoption decisions were significantly affected by initial costs, which is consistent with the finding that win-win non-adopters were more constrained by high installation costs. The capital constraints associated with the potential barriers can be relieved by the incentive subsidies. In addition, win-win non-adopters were more likely to adopt RG and MIG when a lower proportion of their ranch consisted of good-quality soil and flatter lands. This suggests that these ranchers were more willing to improve the ranch conditions and cared more about the environmental outcomes of grazing operations. Consistent with this finding, Basarir and Gillespie (2006) emphasized that beef producers regard environmental goals as an important factor influencing decision making. Fewer operating years were also associated with a stronger willingness to adopt RG, so the incentive subsidies will be more effective among the relatively new grazing operators. Therefore, these findings suggest that win-win non-adopters may be a suitable target group for incentive subsidy programs to increase the adoption rate of rotational grazing, especially those with poor soil conditions and shorter operating years.

Conclusion

The phenomenon that many non-adopters view the practice as win-win is not unique for rotational grazing. It has been commonly found that there often remains a large gap between optimal and actual adoption of conservation technology. Energy efficiency technology is an example, and an energy efficiency gap exists between actual energy use and optimal use (Backlund et al. 2012; Gerarden, Newell and Stavins 2017). To promote conservation technology adoption, it is important to identify whether the practice is actually win-win for potential adopters. If the practice can provide economic and environmental benefits under certain conditions, then win-win non-adoption might be caused by some constraints. By understanding win-win non-adopters' decision mechanisms and potential barriers of adoption, targeted incentive policies can be proposed to realize the win-win possibilities for more people.

This work first identifies a large proportion of non-adopters who regarded rotational grazing as a win-win practice. Our survey sample allows us to identify the main barriers that constrain win-win non-adopters, including high installation costs, water resource constraints, and ranch conditions. These constraints cannot be relieved since the non-adopters in question likely had limited borrowing capacity and little access to operating capital. Our open-ended comments analysis also reveals their concerns about costs and limited capital. We also explore how the win-

win non-adopters responded to a hypothetical one-time subsidy program. They were more likely to adopt rotational grazing when the subsidies were provided, especially those with poor soil conditions and shorter operating years.

Our findings provide some policy implications. First, incentive policies are likely to be more effective when they adequately address the costs and constraints that ranchers face when deciding to adopt rotational grazing. Second, those promoting strategies will be better able to reach and persuade ranchers when there is a common understanding of the factors that ranchers consider and the specific circumstances they face. Third, win-win non-adopters may be a suitable target group for investment subsidies intended to ultimately realize the win-win possibilities for more ranchers. Finally, beyond the grazing practices on the Great Plains, our findings could apply to many other landscapes where livestock production is prevalent. Our research also provides a basis for other research aimed at identifying the factors that generate the adoption gap and at promoting adoption of conservation practices or technologies in a broader field.

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Reference

Allcott, H., and M. Greenstone. 2012. Is There an Energy Efficiency Gap? *Journal of Economic Perspectives* 26 (1): 3-28.

Backlund, S., P. Thollander, J. Palm, and M. Ottosson. 2012. Extending the Energy Efficiency Gap. *Energy Policy* 51:392-396.

Basarir, A., and J.M. Gillespie. 2006. Multidimensional Goals of Beef and Dairy Producers: An Inter-Industry Comparison. *Agricultural Economics* 35(1):103–114.

Bergtold, J.S., S. Ramsey, L. Maddy, and J.R. Williams. 2019. A Review of Economic Considerations for Cover Crops as a Conservation Practice. *Renewable Agriculture and Food Systems* 34(1):62–76.

Carlisle, L. 2016 Factors Influencing Farmer Adoption of Soil Health Practices in the United States: A Narrative Review. *Agroecology and Sustainable*. *Food Systems* 40(6): 583-613.

Chaubey, I., L. Chiang, M.W. Gitau, and S. Mohamed. 2010. Effectiveness of Best Management Practices in Improving Water Quality in a Pasture-Dominated Watershed. *Journal of Soil and Water Conservation* 65(6):424–437.

Claassen, R., E.N. Duquette, and D.J. Smith. 2018. Additionality in U.S. Agricultural Conservation Programs. *Land Economics* 94(1):19–35.

Dillman, D.A., J.D. Smyth, and L.M. Christian. 2014. *Internet, Phone, Mail, and Mixed-Mode Surveys: The Tailored Design Method*. John Wiley & Sons.

Gerarden, T.D., R.G. Newell, and R.N. Stavins. 2017. Assessing the Energy-Efficiency Gap. *Journal of Economic Literature* 55(4):1486–1525.

Gillespie, J.M., W. Wyatt, B. Venuto, D. Blouin, and R. Boucher. 2008. 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* 40 (1): 301–313.

Gillingham, K. and K. Palmer. 2014. Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence. *Review of Environmental Economics and Policy* 8(1,): 18-38.

Hodde, W., J. Sesmero, B. Gramig, T. Vyn, and O. Doering. 2019. The Predicted Effect of Projected Climate Change on the Economics of Conservation Tillage. *Agronomy Journal* 111(6):3130–3139.

Jakoby, O. 2015. Adapting Livestock Management to Spatio-Temporal Heterogeneity in Semi-Arid Rangelands. *Journal of Environmental Management*11.

Kim, S.-A., J.M. Gillespie, and K.P. Paudel. 2008. Rotational Grazing Adoption in Cattle Production Uuder a Cost‐Share Agreement: Does Uncertainty Have a Role in

Conservation Technology Adoption? *Australian Journal of Agricultural and Resource Economics* 52(3):235–252.

Knowler, D., and B. Bradshaw. 2007. Farmers' Adoption of Conservation Agriculture: A Review and Synthesis of Recent Research. *Food Policy* 32(1):25–48.

Manson, S.M., N.R. Jordan, K.C. Nelson, and R.F. Brummel. 2016. Modeling the Effect of Social Networks on Adoption of Multifunctional Agriculture. *Environmental Modelling & Software* 75: 388–401.

Max, R., and H. Ritchie. 2013. *Technological Progress.* Published Online at ourworldindata.org. Retrieved From: https://ourworldindata.org/technological-progress.

Nelson, K.C., R.F. Brummel, N. Jordan, and S. Manson. 2014. Social Networks in Complex Human and Natural Systems: The Case of Rotational Grazing, Weak Ties, and Eastern US Dairy Landscapes. *Agriculture and Human Values* 31 (2): 245–259.

Prokopy, L.S., K. Floress, J.G. Arbuckle, S.P. Church, F.R. Eanes, Y. Gao, B.M. Gramig, P. Ranjan, And A.S. Singh. 2019. Adoption of Agricultural Conservation Practices in the United States: Evidence from 35 Years of Quantitative Literature." *Journal of Soil and Water Conservation* 74(5):520–534.

Teague, R., B. Grant, and H.-H. Wang. 2015. Assessing Optimal Configurations of Multi-Paddock Grazing Strategies in Tallgrass Prairie using a Simulation Model. *Journal Of Environmental Management* 150:262–273.

Teague, W.R., U.P. Kreuter, W.E. Grant, H. Diaz-Solis, and M.M. Kothmann. 2009. Economic Implications of Maintaining Rangeland Ecosystem Health in a Semi-Arid Savanna. *Ecological Economics* 68(5):1417–1429.

Wang, T., H. Jin, U. Kreuter, H. Feng, D.A. Hennessy, R. Teague, and Y. Che. 2020. "Challenges for Rotational Grazing Practice: Views from Non-Adopters across the Great Plains, USA." *Journal Of Environmental Management* 256:109941.

Wang, T., W. Richard Teague, S.C. Park, and S. Bevers. 2018. Evaluating Long-Term Economic and Ecological Consequences of Continuous and Multi-Paddock Grazing - A Modeling Approach. *Agricultural Systems* 165:197–207.

Windh, J.L., J.P. Ritten, J.D. Derner, S.I. Paisley, and B.P. Lee. 2019. Economic Cost Analysis of Continuous-Season-Long versus Rotational Grazing Systems. *Western Economics Forum* 17 (1837-2019–947): 62–72.

USDA National Agricultural Statistics Service. 2017. NASS - Quick Stats. USDA National Agricultural Statistics Service. https://data.nal.usda.gov/dataset/nass-quick-stats. Accessed 2019-11-03.

Figures and Tables

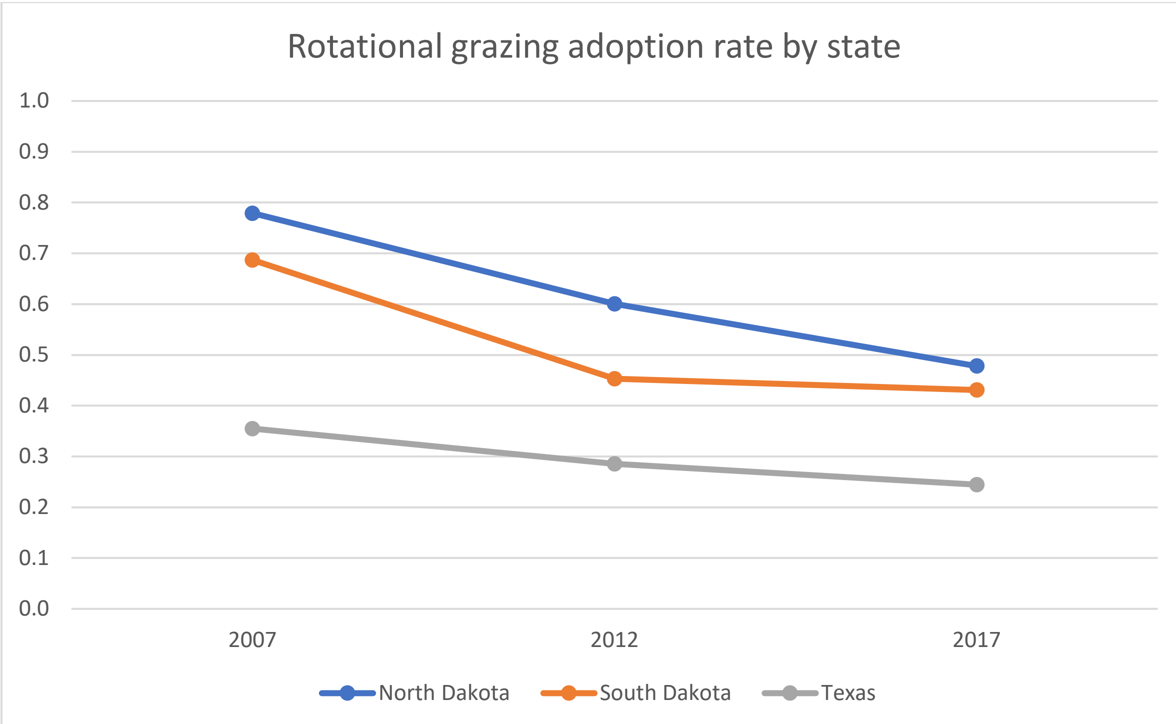


Figure 1 Recent rotational grazing adoption rates in North Dakota, South Dakota, and Texas
Note: Adoption rate is calculated by dividing the number of rotational grazing operations over the total number of cattle, goat, and seep operations within each state

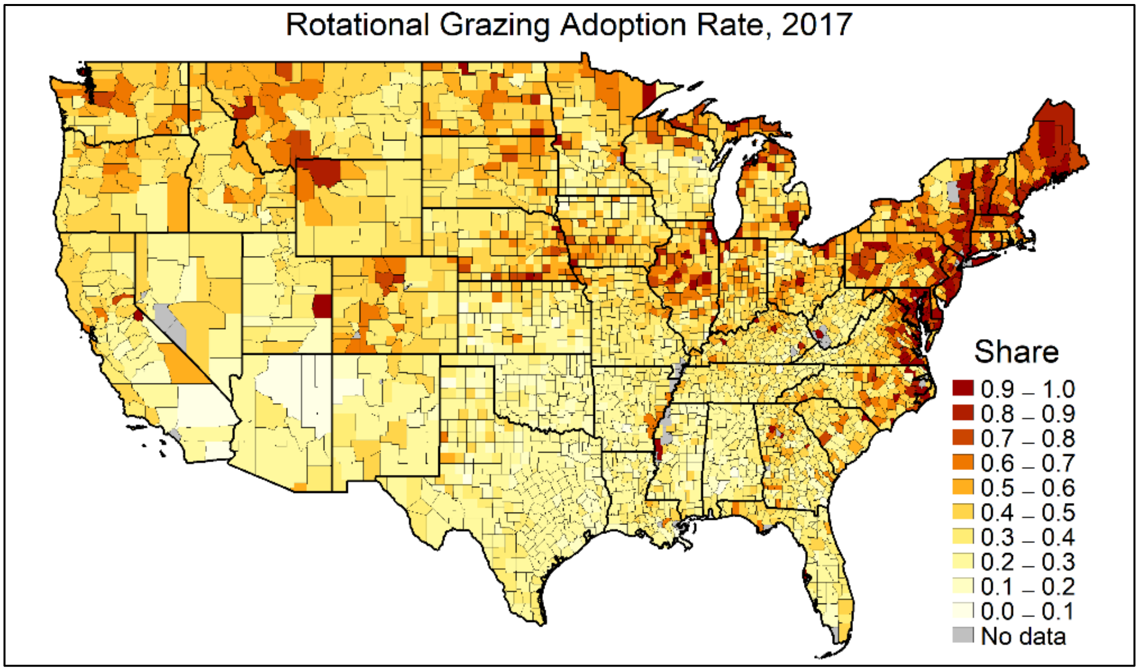


Figure 2 County-level rotational grazing adoption rates in 2017

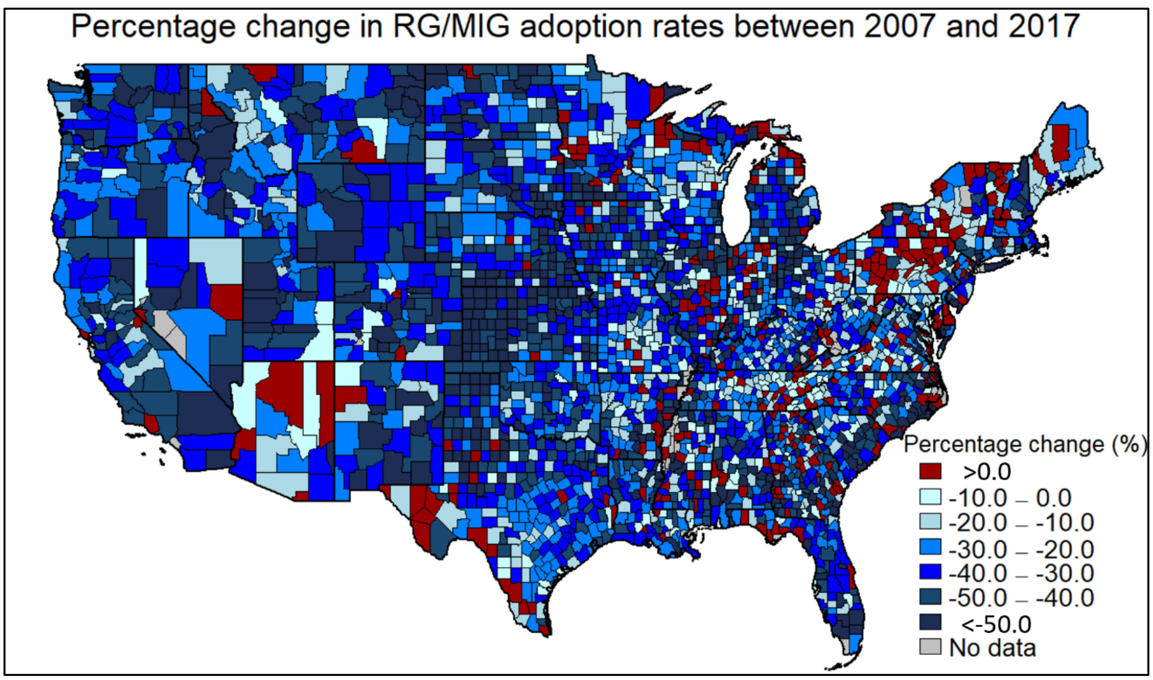


Figure 3 Percentage change in rotational grazing adoption rates between 2007 and 2017
Note: Percentage change is calculated by dividing the difference in adoption rates between 2017 and 2007 by the adoption rate in 2007

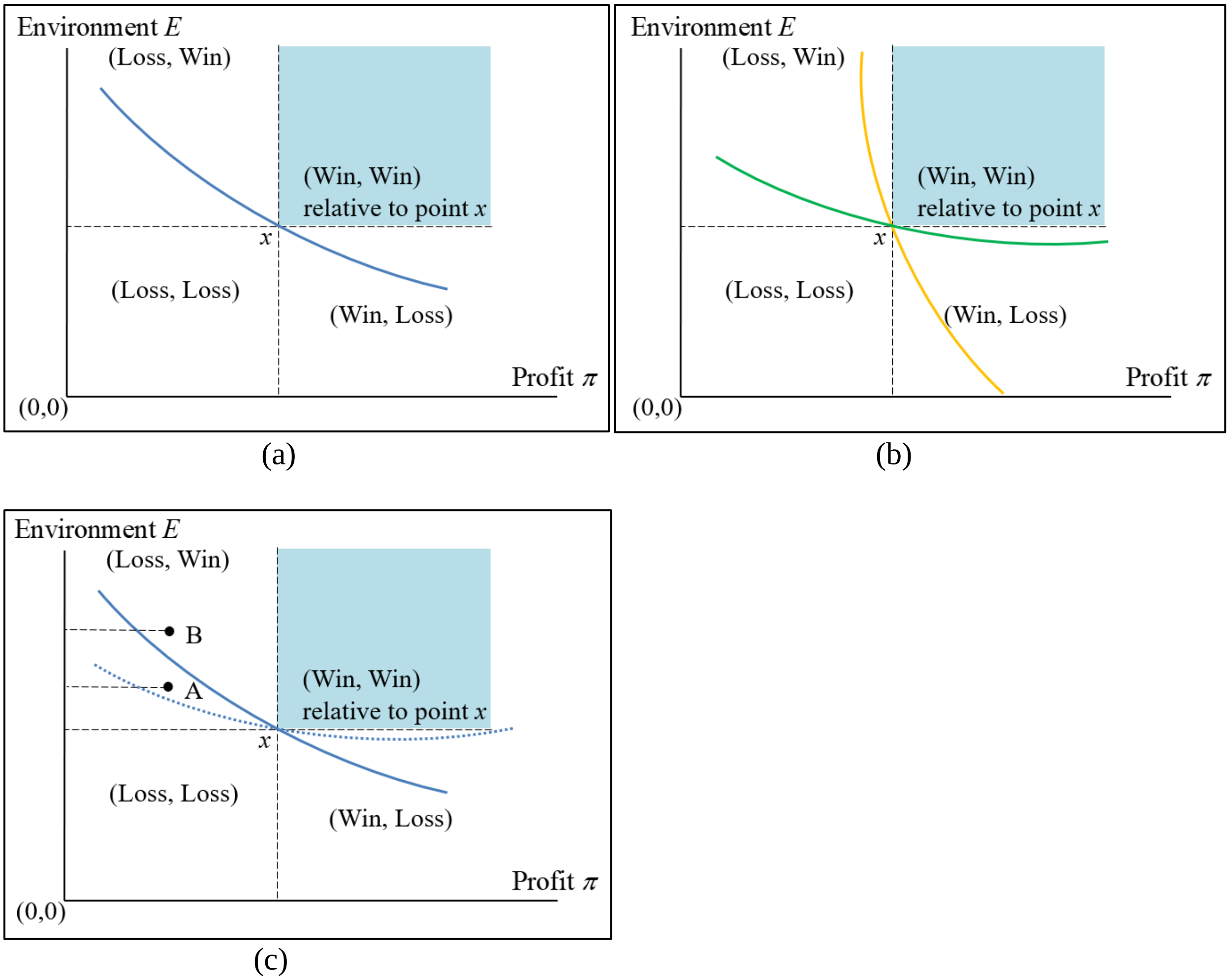


Figure 4 Profit-environment indifference between practices

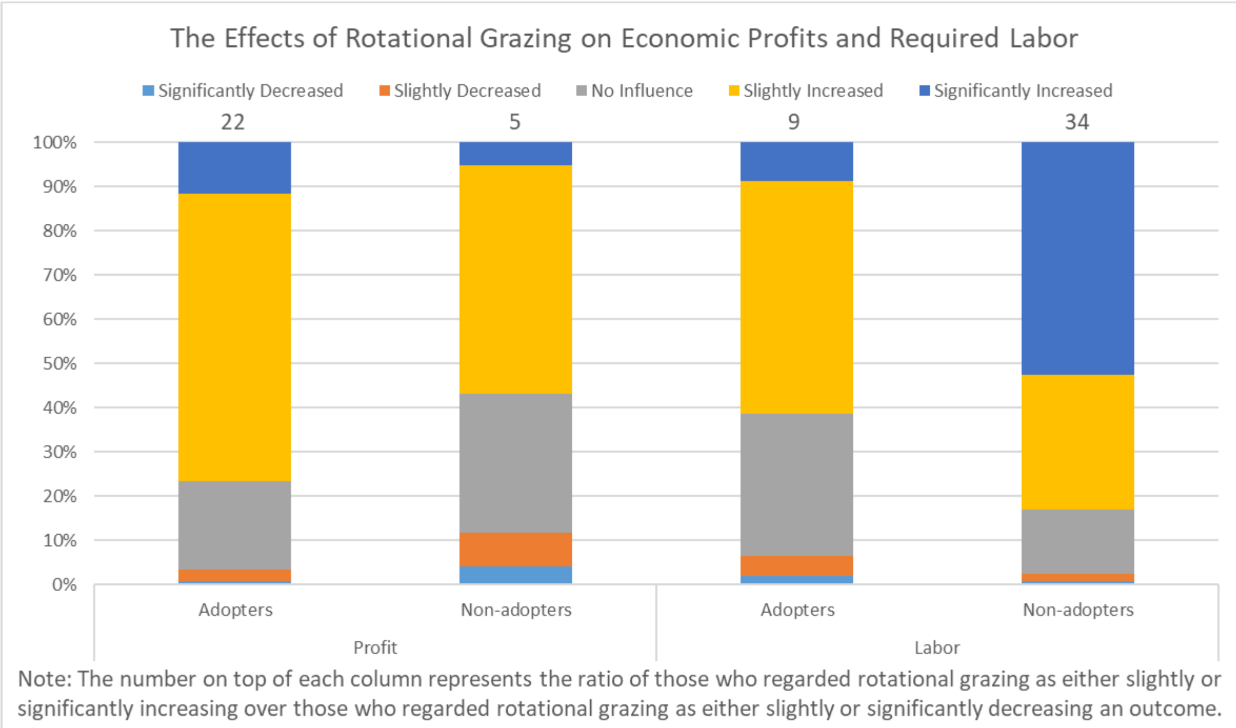


Figure 5 Adopter and non-adopter opinions about the effects of rotational grazing adoption on the ranch profit during the first five years, and on the needed labor and management time

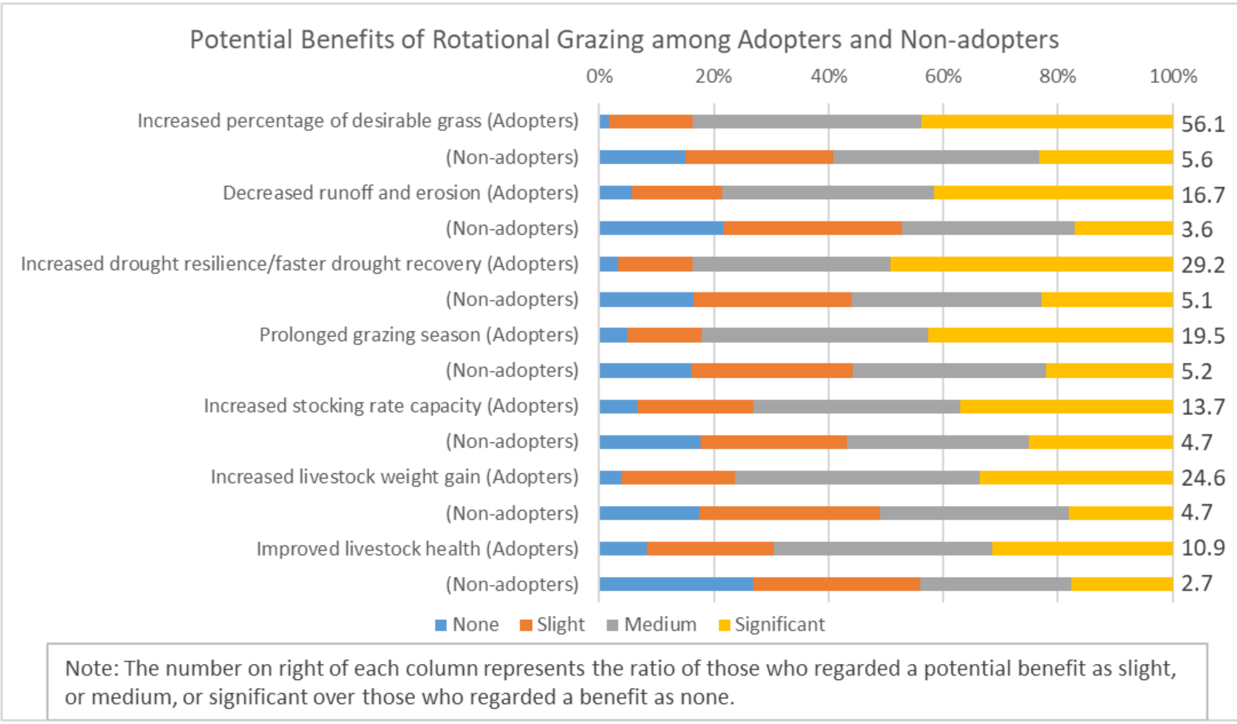


Figure 6 The potential benefits associated with rotational grazing practices among adopters and non-adopters

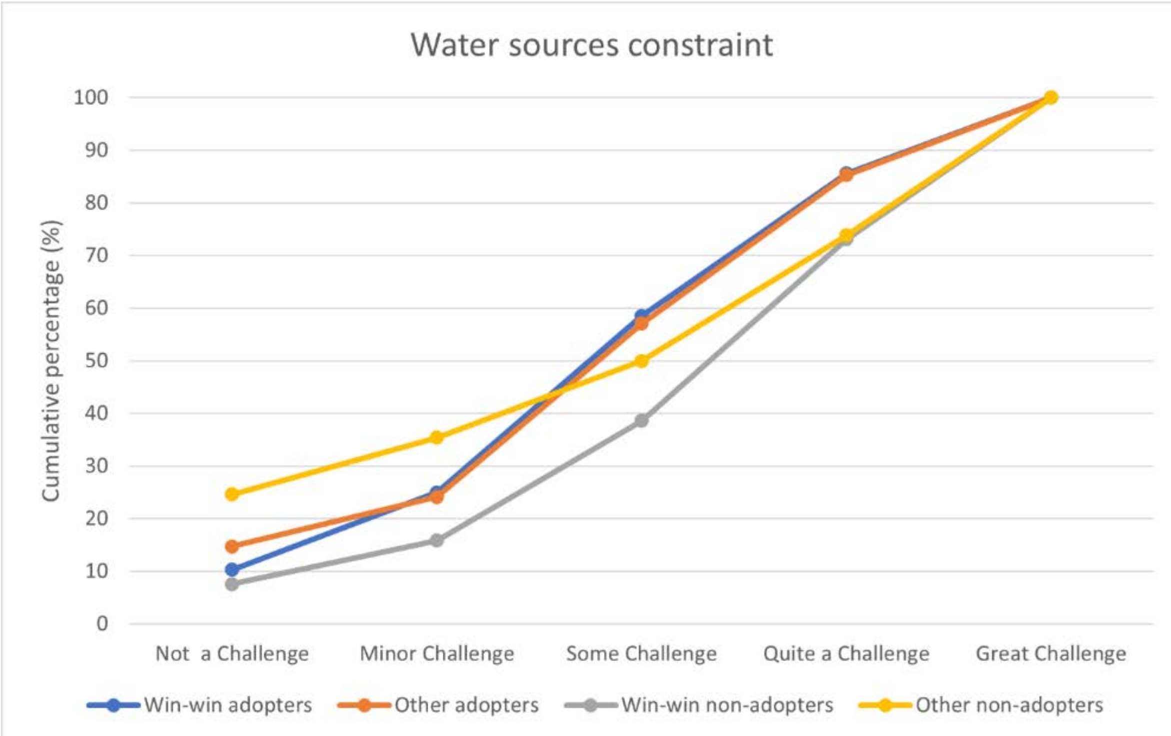
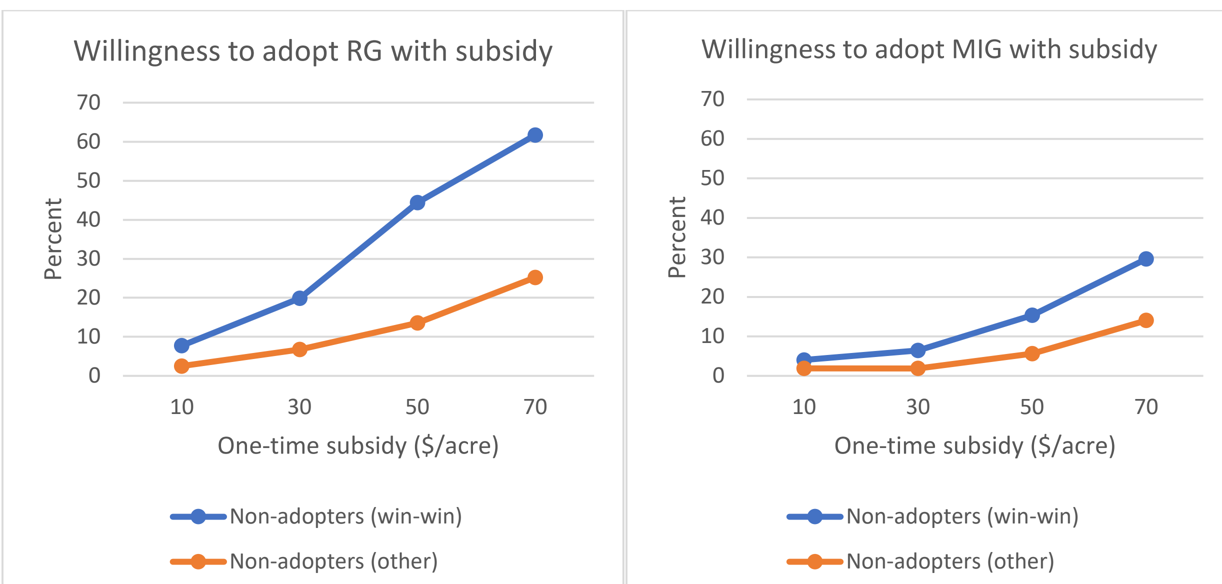


Figure 7 Cumulative percentage of responses to different challenge levels of "water sources constraint" among four groups of ranchers



(a) (b)

Figure 8 Willingness to adopt RG and MIG with a one-time subsidy among non-adopters

Table 1 Rotational grazing operations and adoption rate in the selected states and the United States

Year	Number of rotational grazing operations				Total number of cattle, goat, and sheep operations				Adoption rate			
	ND	SD	TX	U.S.	ND	SD	TX	U.S.	ND	SD	TX	U.S.
2002	N/A	N/A	N/A	N/A	8,249	13,537	143,016	914,205	N/A	N/A	N/A	N/A
2007	5,221	7,473	50,225	388,912	6,701	10,879	141,520	907,228	0.78	0.69	0.35	0.43
2012	3,270	4,485	41,401	288,719	5,447	9,900	144,883	826,719	0.60	0.45	0.29	0.35
2017	3,019	4,449	38,070	265,162	6,316	10,326	155,685	852,907	0.48	0.43	0.24	0.31

Note: The adoption rate is calculated by dividing the number of rotational grazing operations by the total number of cattle, goat, and sheep operations. “N/A” represents that data is not available. Data source: NASS.

Table 2 Economic and environmental outcomes of rotational grazing adoption

Adopters		Economic Profit		
		Improved	*Worsened*	*No impact*
Environmental Outcomes	*Improved*	(Win, Win) 76.4%	(Win, Loss) 3.5%	(Win, No change) 19.5%
	No impact	(No change, Win) 0.2%	(No change, Loss) 0.0%	(No change, No change) 0.4%

Non-adopters		Economic Profit		
		Improved	*Worsened*	*No impact*
Environmental Outcomes	*Improved*	(Win, Win) 56.5%	(Win, Loss) 9.7%	(Win, No change) 23.0%
	No impact	(No change, Win) 1.8%	(No change, Loss) 2.2%	(No change, No change) 6.8%

Table 3 Rancher and ranch characteristics summary

	win-win adopters				win-win non-adopters			
Variable	Obs	Mean	Min	Max	Obs	Mean	Min	Max
Age	336	62.07	30	90	160	65.52	19	91
Operating years	338	34.75	2	68	158	37.32	1	67
Education	340	3.26	1	5	160	3.23	1	5
Liability ratio	327	2.65	1	6	152	2.63	1	6
Grazing acres	330	3,077.61	0	55,075	156	2,166.74	0	41,000
% Grazing land	328	0.69	0	1	156	0.66	0	1
Lease ratio	327	0.36	0	1	155	0.29	0	1
LCC I & II	341	46.93	0	100	159	43.84	0	100
Slope ≤ 3%	341	37.84	0	100	159	44.01	0	100
Distance	336	11.15	0	200	156	10.29	0	200
Latitude	341	42.14	30.71	48.84	159	40.59	30.52	48.98
Longitude	341	-99.40	-103.76	-95.87	159	-99.22	-103.49	-95.77
TX	342	0.27	0	1	161	0.40	0	1

Table 4 Mean values and t-tests for the importance of potential barriers among non-adopters

	win-win non-adopters		Other non-adopters		t-test	
Potential Challenges	Mean	Ranking	Mean	Ranking	t	Pr(|T| > |t|)
High installation cost	3.555	2	3.188	2	-2.379	0.018
Water source constraint	3.648	1	3.162	3	-2.958	0.003
Labor/management time constraints	3.552	3	3.313	1	-1.527	0.128
Cash flow constraints	2.945	5	3.031	5	0.536	0.592
Uncertain outcomes	2.785	7	2.924	7	0.888	0.375
Rental agreement restrictions	2.314	8	2.376	8	0.35	0.727
Lack of information/education/support	2.155	9	2.254	9	0.655	0.513
Ranch conditions	3.418	4	3.039	4	-2.226	0.027
Unfavorable neighborhood opinions	1.455	11	1.603	11	1.215	0.225
Unwillingness to take on leadership in new practices adoption	1.819	10	1.896	10	0.551	0.582
Weather/climate factors	2.876	6	2.945	6	0.39	0.697

Table 5 Mean values and t-test for the importance of potential barriers between win-win adopters and win-win non-adopters

	win-win adopters		win-win non-adopters		t-test	
Potential Challenges	Mean	Ranking	Mean	Ranking	t	Pr(|T| > |t|)
High installation cost	2.850	3	3.555	2	6.668	0.000
Water source constraint	3.206	1	3.648	1	3.802	0.000
Labor/management time constraints	2.832	4	3.552	3	6.417	0.000
Cash flow constraints	2.524	6	2.945	5	3.779	0.000
Uncertain outcomes	2.080	7	2.785	7	6.562	0.000
Rental agreement restrictions	1.994	8	2.314	8	2.468	0.014
Lack of information/education/support	1.737	9	2.155	9	4.319	0.000
Ranch conditions	2.761	5	3.418	4	5.514	0.000
Unfavorable neighborhood opinions	1.346	11	1.455	11	1.317	0.188
Unwillingness to take on leadership in new practices adoption	1.465	10	1.819	10	4.141	0.000
Weather/climate factors	2.911	2	2.876	6	-0.257	0.798

Table 6 Ordered logit estimated coefficients for “water source constraint” and “high installation cost”

	Water source constraint			High installation cost		
VARIABLES	Win-win adopters	Win-win non-adopters	Other non-adopters	Win-win adopters	Win-win non-adopters	Other non-adopters
Operating years	-0.019**	0.014	0.007	-0.012	0.011	0.012
Education	-0.056	0.352*	0.418*	-0.079	-0.032	0.499**
Liability ratio	0.017	-0.141	-0.136	0.016	0.355**	0.004
Grazing acres	0.000	0.000	0.000	-0.000	0.000	0.000
% Grazing land	-1.522***	-0.959	-3.060***	-0.771	0.024	-2.079**
Lease ratio	0.449	1.762***	0.489	0.394	0.367	0.470
LCC I & II	-0.000	-0.005	-0.007	0.001	-0.008	-0.004
Slope ≤ 3%	0.000	-0.007	-0.014**	-0.002	-0.007	-0.010
Distance	0.004	-0.002	0.015	0.001	-0.004	0.009
Latitude	-0.049	0.151	0.236	-0.039	0.076	0.024
Longitude	-0.259***	0.209	-0.101	-0.246***	0.333**	-0.038
TX	0.233	1.276	3.095	0.372	0.737	0.818
Observations	311	127	94	310	128	97

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 7 Ordered logit estimated coefficients for "Labor management constraint" and "Ranch conditions"

	Labor management constraint			Ranch conditions		
VARIABLES	Win-win adopters	Win-win non-adopters	Other non-adopters	Win-win adopters	Win-win non-adopters	Other non-adopters
Operating years	-0.018*	0.023	0.015	-0.003	0.012	0.009
Education	0.060	0.136	0.603**	0.092	0.190	0.453*
Liability ratio	0.130	0.100	-0.184	0.079	0.132	-0.255
Grazing acres	-0.000	0.000	0.000	0.000	0.000	-0.000
% Grazing land	-1.221**	0.149	-2.919***	-0.885*	-0.433	-1.913**
Lease ratio	0.144	1.962***	0.491	0.261	1.490***	0.938
LCC I & II	0.001	-0.013**	-0.008	0.003	-0.006	-0.010
Slope ≤ 3%	0.002	-0.006	-0.007	0.003	-0.006	-0.012*
Distance	0.004	-0.008	0.018*	-0.000	-0.002	0.011
Latitude	-0.060	0.203	0.073	-0.114	0.143	-0.036
Longitude	-0.211***	0.202	-0.162	-0.311***	0.252*	-0.385**
TX	-0.704	0.669	1.151	-0.860	1.483	-0.200
Observations	310	126	94	310	128	94

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8 Ordered logit estimated coefficients for "Cash flow constraint" and "Weather/Climate factors"

	Cash flow constraints			Weather/Climate factors		
VARIABLES	Win-win adopters	Win-win non-adopters	Other non-adopters	Win-win adopters	Win-win non-adopters	Other non-adopters
Operating years	-0.016*	-0.003	0.024	0.001	0.010	0.031*
Education	0.062	0.072	0.136	0.211*	-0.084	-0.138
Liability ratio	0.139*	0.431***	-0.001	0.001	0.560***	-0.317**
Grazing acres	0.000	-0.000	0.000	0.000	0.000	0.000
% Grazing land	-0.680	1.036	-1.437	0.108	0.229	-0.418
Lease ratio	-0.039	0.650	0.459	-0.228	-0.309	-0.154
LCC I & II	-0.000	-0.008	-0.004	0.004	-0.013**	-0.005
Slope ≤ 3%	0.002	-0.001	-0.014**	0.004	-0.006	-0.002
Distance	0.007	-0.002	0.018*	-0.002	-0.006	0.008
Latitude	-0.073	-0.118	0.263	-0.146*	0.139	0.179
Longitude	-0.096	-0.101	-0.051	-0.288***	0.280*	-0.145
TX	-0.894	-2.022	3.611*	-1.104	1.538	2.544
Observations	311	127	94	308	127	93

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9 Ordered logit estimated coefficients for "Uncertain outcomes" and "Rental agreement restrictions"

	Uncertain outcomes			Rental agreement restrictions		
VARIABLES	Win-win adopters	Win-win non-adopters	Other non-adopters	Win-win adopters	Win-win non-adopters	Other non-adopters
Operating years	0.001	0.003	0.030*	-0.013	0.012	0.015
Education	0.084	-0.005	0.119	-0.149	-0.205	0.129
Liability ratio	0.138	0.561***	-0.142	0.022	0.112	-0.268
Grazing acres	-0.000	-0.000	-0.000	0.000	0.000	-0.000
% Grazing land	-0.669	-0.424	-1.113	-0.758	-0.298	-1.830*
Lease ratio	-0.527	-0.178	0.927	1.064***	1.406**	1.330**
LCC I & II	0.005	-0.004	-0.002	0.004	-0.014**	-0.011
Slope ≤ 3%	0.004	-0.006	-0.006	-0.001	-0.008	-0.002
Distance	0.001	-0.008	0.017	0.009**	-0.000	0.018*
Latitude	-0.121	-0.116	-0.004	-0.007	0.080	-0.029
Longitude	-0.276***	-0.032	-0.274*	-0.040	0.245	-0.089
TX	-0.980	-1.279	0.297	-0.090	-0.141	0.398

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 10 Marginal effects and standard errors for win-win non-adopter perceived water constraint model

	Not a challenge		Minor challenge		Some challenge		Quite a challenge		Great challenge	
	ME	SE	ME	SE	ME	SE	ME	SE	ME	SE
Operating years	-0.001	0.001	-0.001	0.001	-0.001	0.001	0.001	0.001	0.002	0.003
Education	-0.022	0.014	-0.022	0.013	-0.031*	0.018	0.014	0.010	0.061*	0.035
Liability ratio	0.009	0.009	0.009	0.009	0.013	0.012	-0.006	0.006	-0.025	0.024
Grazing acres	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% Grazing land	0.061	0.047	0.059	0.045	0.086	0.062	-0.039	0.033	-0.168	0.118
Lease ratio	-0.113**	0.049	-0.108**	0.044	-0.157***	0.054	0.071*	0.038	0.308***	0.098
LCC I & II	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	-0.001	0.001
Slope ≤ 3%	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	-0.001	0.001
Distance	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
Latitude	-0.010	0.008	-0.009	0.008	-0.014	0.011	0.006	0.006	0.026	0.022
Longitude	-0.013	0.010	-0.013	0.009	-0.019	0.013	0.008	0.007	0.037	0.025
TX	-0.082	0.094	-0.079	0.089	-0.114	0.126	0.051	0.061	0.223	0.247

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 11 Frequency of comments made in 13 categories

Category	Comment frequency	
	Total comments	Ranchers making at least one comments in category
Water	70	61
Fencing	42	39
Cost	30	29
Labor	23	22
Government support	23	22
Rent	22	18
Retirement	20	18
Environment benefits	9	9
Land characteristics	8	8
Ranch scale	6	6
Neighborhood	4	4
Other cattle type	46	46
Other	152	124
Total	392	283

Table 12 Frequency of comments, by different groups of ranchers.

Category	Win-win adopters	Win-win non-adopters	Win-win non-adopters	Other non-adopters
Water	0.190	0.244	0.244	0.140
Fencing	0.164	0.133	0.133	0.093
Cost	0.086**	0.200**	0.200	0.116
Labor	0.086	0.111	0.111	0.070
Government support	0.121**	0.000**	0.000	0.000
Rent	0.112	0.089	0.089	0.023
Retirement	0.052	0.067	0.067	0.116
Environment benefits	0.069*	0.000*	0.000	0.000
Land characteristics	0.009***	0.089***	0.089	0.023
Ranch scale	0.000***	0.067***	0.067	0.070
Neighborhood	0.017	0.000	0.000	0.023

Note: *, **, *** denote response frequencies are different at the 10%, 5%, and 1% significance levels.

Table 13 Regression results on each comment frequency on adoption decisions (win-win adopters vs win-win non-adopters)

	Adoption	
VARIABLES	(1)	(2)
Water	0.004	0.068
Fencing	0.556	0.439
Cost	-0.462	-0.573*
Labor	-0.068	-0.104
Government support	-ǂ	-ǂ
Rent	0.910	0.162
Retirement	0.034	-0.238
Environment benefits	-ǂ	-ǂ
Land characteristics	-2.128**	-1.661**
Ranch scale	-ǂ	-ǂ
Neighborhood	-ǂ	-ǂ
Other control variables	Yes	No
Observations	128	135

Note: *** p<0.01, ** p<0.05, * p<0.1.

ǂ The variables are omitted due to probability being perfectly predicted.

"Adoption" is a binary variable (win-win adopters=1; win-win non-adopters=0).

"Other control variables" include rancher and ranch characteristics.

Table 14 Logit regression results of future adoption with one-time subsidy among non-adopters

VARIABLES	Non-adopters (win-win)	Non-adopters (other)	Non-adopters (win-win)	Non-adopters (other)
	RG adoption		MIG adoption	
Subsidy	0.055***	0.063***	0.059***	0.092***
Initial costs	-0.232**	-0.207	-0.769***	0.188
Labor	-0.066	-0.284	0.009	0.044
Operating years	-0.018*	-0.034**	0.009	-0.003
Education	0.185	0.285	0.054	0.324
Grazing acres	0.000*	0.000	0.000	-0.000
LCC I & II	-0.011**	0.007	0.014	0.005
Slope ≤ 3%	-0.009***	-0.006	-0.016***	0.000
Distance	0.008	0.002	0.014	-0.097*
Latitude	-0.051	0.461**	0.193	0.037
Longitude	0.045	-0.120	0.422**	-0.312
TX	-0.936	5.850**	4.790**	-1.156
Observations	493	303	407	262

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

APPENDICES

APPENDIX A: Cumulative Percentage of Responses to Potential Challenge

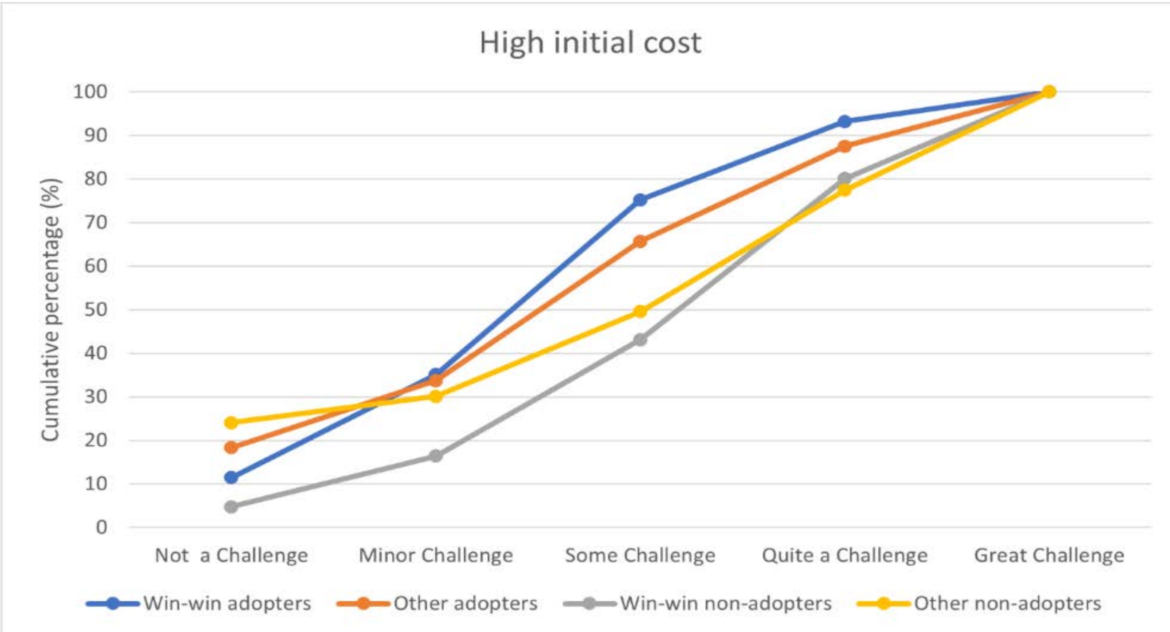


Figure A1 Cumulative percentage of responses to different challenge levels of "high initial cost" among four groups of ranchers

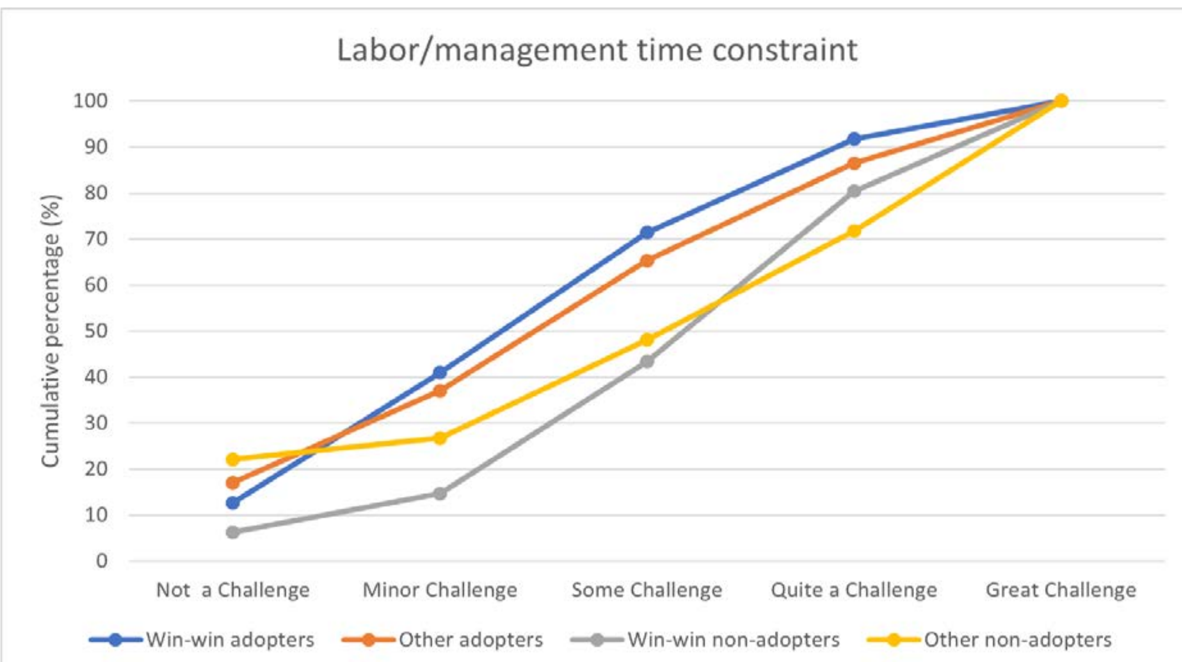


Figure A2 Cumulative percentage of responses to different challenge levels of "labor/management time constraint" among four groups of ranchers

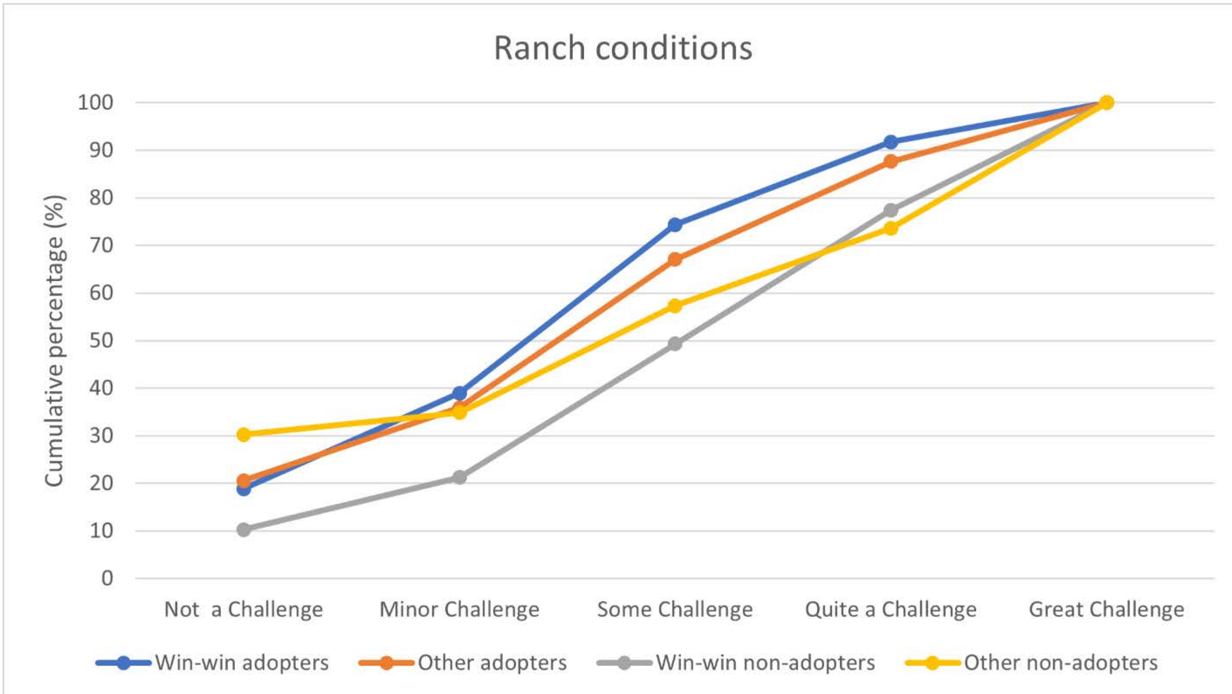


Figure A3 Cumulative percentage of responses to different challenge levels of “ranch conditions” among four groups of ranchers

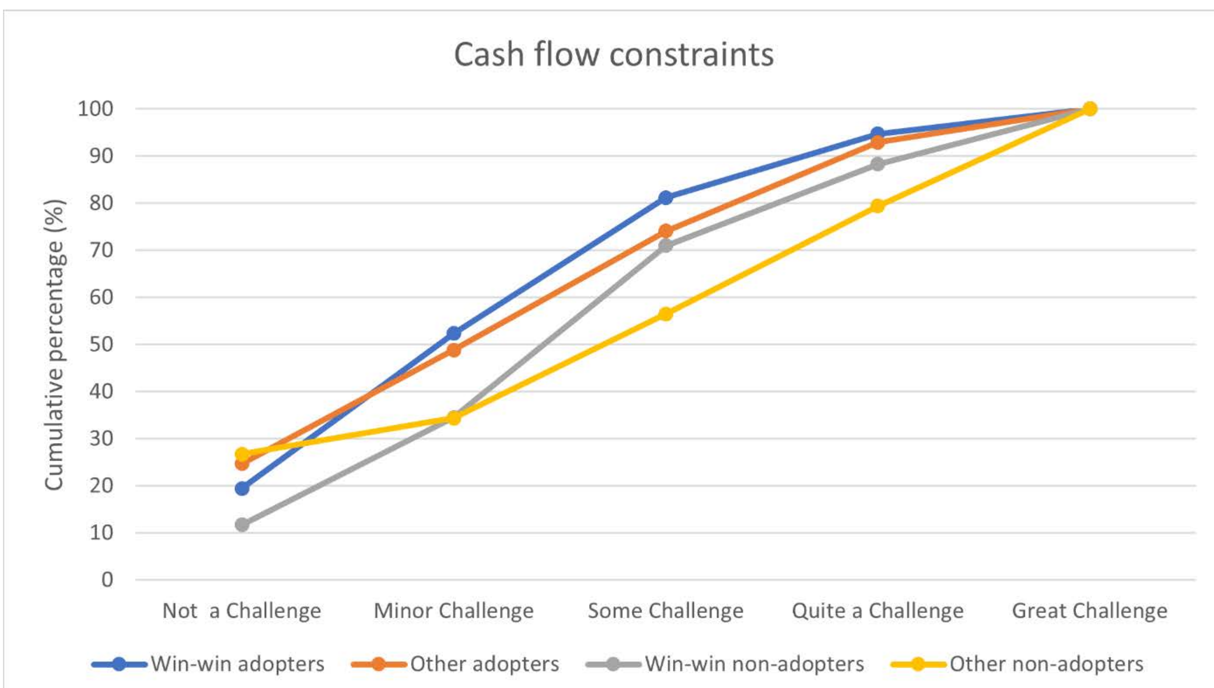


Figure A4 Cumulative percentage of responses to different challenge levels of “cash flow constraints” among four groups of ranchers

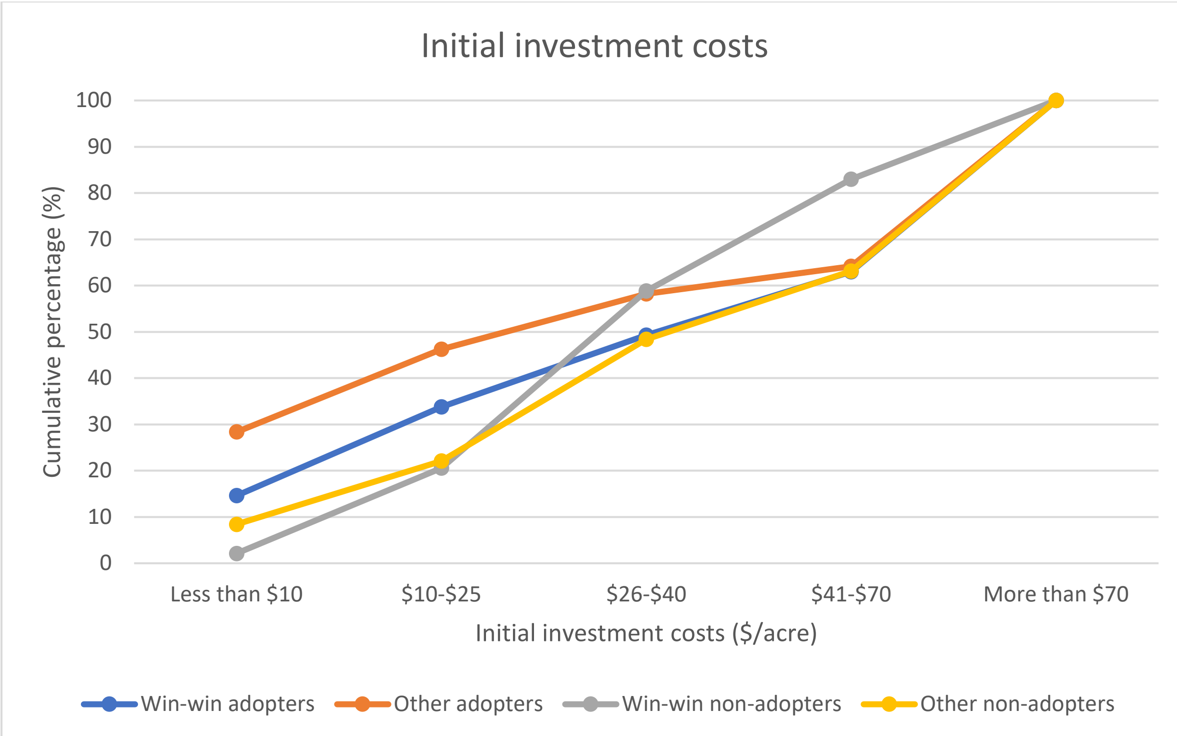


Figure A5 Cumulative percentage of responses to different levels of "initial investment costs" among four groups of ranchers

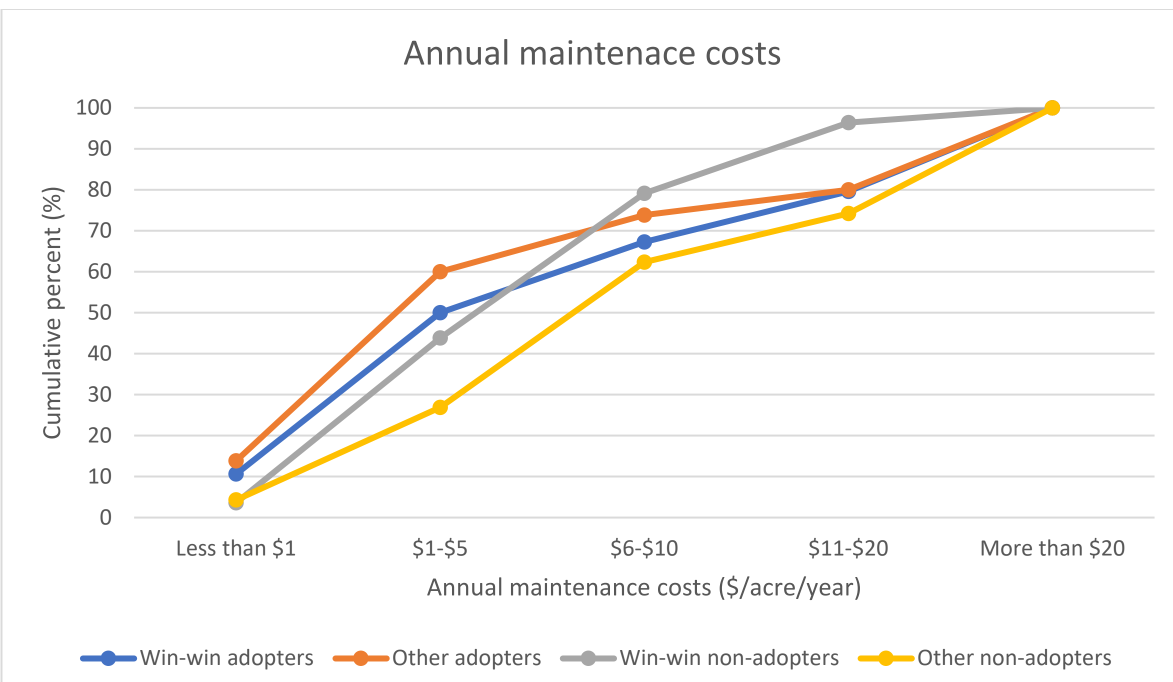


Figure A6 Cumulative percentage of responses to different levels of "annual maintenance costs" among four groups of ranchers

APPENDIX B: Supplemental Tables

Table B1 Mean values and t-test of initial investment costs and annual maintenance costs by group

Category	Win-win adopters	Win-win non-adopters	Win-win non-adopters	Other non-adopters
Initial investment costs	3.393	3.355	3.355	3.579
Annual maintenance costs	2.925	2.770	2.770***	3.323***

Note: *, **, *** denote response frequencies are different at the 10%, 5%, and 1% significance levels.

Table B2 Mean values and t-test of the importance of management goals by group

Management goals	Win-win adopters	Win-win non-adopters	Win-win non-adopters	Other non-adopters
Maintain high economic returns	4.136	4.064	4.064	4.110
Breed high-quality stock	4.299	4.234	4.234	4.100
Improve soil/grassland quality	4.222*	4.082*	4.082	3.944
Improve water quality/wildlife habitat	3.884**	3.667**	3.667	3.586
Be considered one of the best ranchers	2.703	2.748	2.748	2.746
Achieve a desirable work-life balance	3.781	3.748	3.748	3.613

Note: *, **, *** denote response frequencies are different at the 10%, 5%, and 1% significance levels.

Table B3 Mean values and t-test of potential benefits by group

Potential Benefits	Win-win adopters	Win-win non-adopters	Win-win non-adopters	Other non-adopters
Increased percentage of desirable grass	3.330***	3.019***	3.019***	2.331***
Decreased runoff and erosion	3.181***	2.689***	2.689***	2.161***
Increased drought resilience/faster drought recovery	3.363***	2.988***	2.988***	2.265***
Prolonged grazing season	3.298***	3.000***	3.000***	2.235***
Increased stocking rate capacity	3.196	3.100	3.100***	2.191***
Increased livestock weight gain	3.173***	2.851***	2.851***	2.181***
Improved livestock health	2.997***	2.652***	2.652***	2.044***

Note: *, **, *** denote response frequencies are different at the 10%, 5%, and 1% significance levels.

Table B4 Classification rubric for ranchers' comments regarding their ranching practices

Category	Comments containing or pertaining to					Typical comment
Water	water Water moisture	Drought dry	Rainfall Rain			"There is no underground water resources" "Limited by access to water" "The uncertain rainfall and unpredictability of rain hinders MIG"
Fencing	fencing	fence	fences	wire	electronic	"Maintaining fences and water gaps" "Not enough water and cost of fencing"
Cost	cost costs costly	costly expensive extra	money pay	initial	maintenance	"Fencing is expensive, labor is expensive" "I like some rotational grazing but the MIG is too much labor and cost"
Labor	time	labor	management	work		"I don't think MIG would be practical for my situation because of lack of labor. "It is good for land but takes extra work"
Government or agency	government	cost-share	NRCS			"Cost-share agreement uncertainty and speculations and meeting deadlines quite a challenge." "I may do more rational grazing if cost-share programs improve."
Rent	rent	rented	leases	leased	landowner	"Hard to improve rented grow because of cost no long-term leases"
Retirement	renting retired	renters old	leasing age	contract	landlords	"I am reducing herd size and acres because of retirement." "We are too old."

Category	Comments containing or pertaining to					Typical comment
Environment benefits	Better grass	Weed control	good for land			“I have always used rotational grazing, as a management tool for better grass” “It is good for land”
Land characteristics	hilly	steep	soil	rocky	stony	“Our big pastures are on steep river bottom ground which is tough to work with, great challenge.” “We own and rent pastures that are located in rough terrain hill.”
	sandy	terrain	ground	rough		
Ranch scale	size	enough	small	larger	herd	“The size of my pastures is small (Great Challenge).” “I think rotational grazing can have benefits but the size of your pastures have to be fairly large for the costs to be feasible”
Neighborhood	neighbors	other	neighborhood	neighbor		“neighbors' bulls are great challenge” “unfavorable opinion by other ranch partners.”