Producer's willingness to adopt grassland carbon contracts in the southern plains

by

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Abstract

The purpose of this paper is to quantify the willingness of farmers and ranchers within the Southern Great Plains to enter into agricultural carbon credit contracts on marginal grasslands, including as an alternative to the Conservation Reserve Program. A discrete choice experiment was conducted as part of a mail-in survey to agricultural producers in Kansas, Colorado, Oklahoma, Texas and New Mexico. The purpose of the discrete choice experiment was to assess the willingness of agricultural producers to enter into a carbon credit grassland contract as an alternative to the Conservation Reserve Program or as a value-added opportunity for marginal grasslands. Survey participants were asked to consider three independent choice scenarios with differing contract attributes. Contract options were composed of four attributes: (1) average annual payment per acre, (2) year-to-year payment variation, (3) ability to graze livestock, and (4) the length of the contract. To estimate the influence of the different attributes on the willingness of a producer to enter into a grassland conservation contract, we analyzed the stated choice experiment data using a mixed conditional logistic regression model. Survey data was collected during the summer of 2023 with 465 responses and a 12% response rate. The findings of this paper indicate that the average payment level per acre was an important contract attribute in the contract and that producers in the Southern Great Plains strongly value the ability to retain the ability to graze livestock on their marginal cropland when considering a grassland carbon credit contract. Producers also prefer a moderate 30% year-to-year variation in the prices that they receive in their carbon credit contracts.

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I have a particular gratitude to my cohort and fellow graduate students. Without the teamwork and enthusiasm of each student, graduate school would have been much more difficult. I am thankful for the friendships that we created.

Finally, I am eternally thankful for the endless love and support of my family: Robert and Jane Sunderland; Luke, Carlotta and Samuel Sunderland; Jordan and Anna Severson. I am forever thankful for their belief in my passion, encouragement to pursue excellence, and unmatched ability to lift my spirit. These relationships are of the utmost value in my life, and I will forever cherish the love that they unconditionally offer.

Dedication

It is with the utmost gratitude that I dedicate this Master of Science thesis to my late grandparents, Samuel and Janice Roush. In the rural community of Morrill, Kansas, the seeds of an admiration for agriculture were planted deep within me by their endless compassion, love for others, and dedicated work ethic on their farm. Together, they navigated both the joys and challenges of their time on earth, holding fast to a true love for each other and the rural way of life. My fondest memories will forever take me back to the front porch of their humble farmhouse – evenings filled with ice cream, soft laughter, and tales of years past.

Chapter 1 - Introduction

The farmer is perhaps a good example of one working to create an optimal solution with imperfect information. To continue to grow their operation, producers must be able to amply identify opportunities to increase profit in a manner that will not undercut their current business strategy and provide for long-term sustainability. Currently, the carbon credit marketplace holds the potential to add novel cash flow opportunities for farm operators while providing needed environmental stewardship.

1.1 Motivation

With a limited supply of land at their disposal, agricultural producers must be strategic in utilizing their assets to extract the maximum amount of value from their land. Furthermore, farming and ranching must be practiced in a way that can provide value to the farm for the long-term viability and sustainability of the operation. For this reason, agricultural producers typically choose to utilize their land either through electing to put it into crop or livestock production (e.g. pasture), leave it fallow or unused, use it for some other value-added purpose (e.g., hunting), or enroll into a conservation program, such as the Conservation Reserve Program (CRP). Producers and other interested parties, such as agribusinesses and landowners, are now beginning to explore new opportunities, such as carbon grassland contracts, as an alternative way to generate cash flows, while simultaneously generating value for a carbon credit aggregator that they are would enter into a contract with (U.S. Department of Agriculture 2023).

Utilizing agricultural land (marginal, retired or land under active production) for generating carbon credits has certainly made producers hesitant given the newness and past performance of such programs (e.g., Chicago Climate Exchange), impacting their willingness to adopt this practice. There are currently no central marketplaces for “carbon” purchases or trading, and nearly all transactions happen without a mediator (Donofrio, et al. 2020). In addition, mixed reports and skepticism on the general effectiveness of these projects has hindered producer confidence about entering into contracts as part of a carbon sequestration program or market (Dinterman 2022). These complications reflect a few of the continued concerns from producers and agricultural parties regarding agricultural carbon credit contracts, which has the capacity to ultimately leave producers disregarding this option altogether.

1.2. Purpose Statement and Objectives

The purpose of this thesis is to quantify the willingness of farmers and ranchers within the Southern Great Plains to enter into agricultural carbon credit contracts on grasslands. To fulfil the purpose of this thesis, serval objectives were undertaken. These include:

1. A thorough examination of the current state of carbon credit markets and their history.
2. The development and administration of a stated choice experiment to quantify the willingness of farmers and ranchers in the Southern Great Plains to adopt a grassland carbon credit contract.; and
3. Examination of optimal contract attributes for agricultural producers to adopt these contracts on their operations.

Chapter 2 - Background

Carbon markets are a relatively new market concept that operate to financially incentivize individuals, businesses, and governments to reduce their carbon footprint. Historically, these markets have been met with varying levels of challenges that have caused several initiatives to ultimately fail. However, with the impending impacts from and continued action to mitigate further climate change – voluntary carbon markets have continued to gain momentum in recent years. This section will address the background that led to the development of various carbon markets – both active and discontinued.

2.1 Growing Global Carbon Awareness

Discussions pertaining to the reduction of global greenhouse gas (GHG) emissions for the benefit of the environment date back to as early as the 1950's within the scientific community (Zillman 2009). However, it was not until 1979 that the first international climate conference, the World Climate Conference, was held to formally address the issue of anthropogenic changes to our climate (Zillman 2009). One of the most notable conclusions of this conference was the growing sentiment that nations needed to work together to further improve their knowledge of the changing climate and to discuss potential solutions to the associated problems (Zillman 2009). To this, awareness of the potential threats of climate change began to develop and gain momentum throughout the 1980s and 1990s. Climate change was again formally addressed at The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992. This conference brought together leaders of 179 nations to further discuss the topic (Jackson 2007). One of the most significant results of the UNCED was the signing of the United Nation Framework Convention on Climate Change (UNFCCC) by 166 nations. The UNFCCC would later prove to be paramount to the agreement known as the Kyoto Protocol of 1997 (Britannica 2023).

2.2 Global Climate Agreements

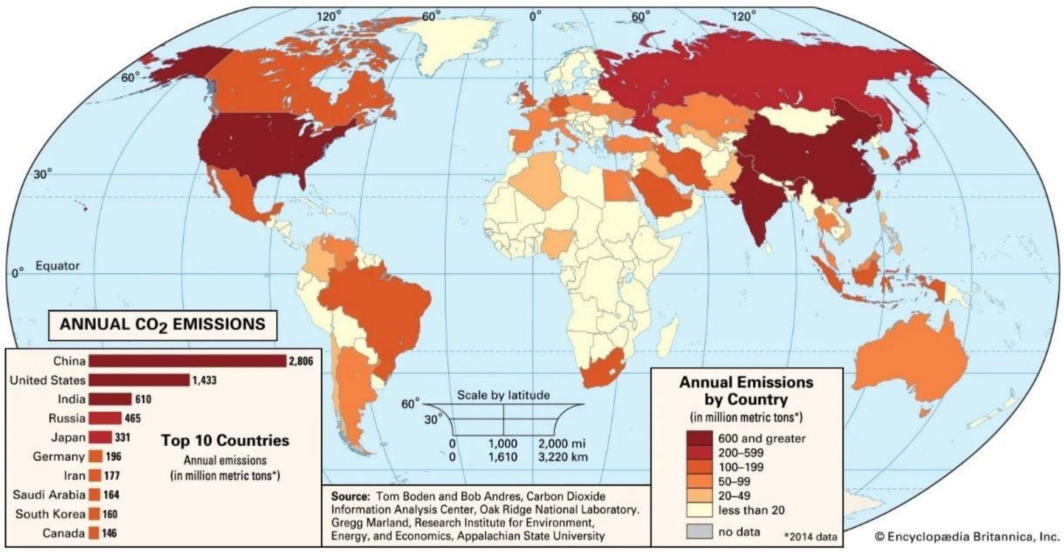
The Kyoto Protocol was developed by the United Nations Framework Convention on Climate Change (UNFCCC) in an effort to slow global warming, by working with 160 parties to reduce greenhouse gas emissions on a world-wide scale (Breidenich, et al. 1998). The greenhouse gases that the protocol worked to reduce included carbon dioxide, nitrous oxide, methane, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulfur hexafluoride. The protocol largely put the financial burden to reduce emissions on developed nations, as it was believed at the time that they were most at fault for the majority of carbon emissions. This legally binding climate treaty would ultimately become international law in February of 2005 with an intention to require developed countries to reduce their emissions by an average of 5 percent in order to lower greenhouse gas levels to levels measured in 1990. Reductions would be achieved during the commitment period from 2008 to 2012. The Kyoto Protocol would also establish the first formal system to monitor countries' progress toward these goals (Breidenich, et al. 1998).

While the Kyoto Protocol established the first primary international agreement to develop a standard for reducing global greenhouse gas emissions and being the first credible system to create a formalized international market for carbon credits, it contained flaws that damaged the effectiveness of its intended mission (Helm 2012). Perhaps the foremost problem that the protocol failed to address was the fact that developing nations are much more dependent on coal and oil for an energy source than most developed nations (Figure 2.1). Both China and India in 2020 accounted for 35% of the world's total carbon emissions – whilst the UK, France and Germany combined represent only 4% of the world's total carbon emissions (CFI Team, 2023). In the Kyoto Protocol, China and India were tagged as two of the non-Annex I countries in the treaty and were thus exempted from any reduction requirements. Additionally, the United States, the world's second largest greenhouse gas emitter, did not ratify the protocol - making another significant emitter unbound to the requirements of the treaty.

Several key trends ultimately developed that led to the de-escalation of the Kyoto Protocol. First, it was discovered that without any actual method to force states to set and work towards achievable emission reduction goals, efforts on behalf of other states were deemed essentially ineffective. Additionally, the lack of a leadership commitment from developed countries led to a reluctancy to engage in effective emission reduction commitments by other member countries. Finally, profit maximizing motives of firms and countries were at times opposed to emission reduction efforts, which exposed weaknesses in the market mechanism utilized in the Kyoto Protocol (Gupta 2010).

Figure 2.1 World Map Showing Countries with Largest Annual Carbon Dioxide Emissions

By courtesy of Encyclopædia Britannica, Inc., copyright 2005; used with permission.
Source Gathered: (Britannica, 2022)



In lieu of the weakened confidence in the effectiveness of the Kyoto Protocol, negotiations continued to reemerge pertaining to the future of limiting greenhouse gas emissions post-Kyoto. In 2011, the 17th Conference of the Parties in Durban, South Africa, directly acknowledged this by agreeing to construct a new legally binding treaty. Additionally, the conference stressed that by 2015 a new legal climate treaty would be drafted that would effectively include top carbon emitters that were not following or bound by the Kyoto Protocol (including China, India and the United States). This new treaty would later be known as the Paris Climate Accord, which actively works withs the European Union Emission Trading Program (EU ETS). The Paris Climate Accord was ultimately signed by all 196 signatories of the United Nations Framework Convention on Climate Change, replacing the Kyoto Protocol (Bodansky 2016).

It is worth noting that the efforts of the Kyoto Protocol were not entirely in vain. This can be observed as carbon markets, in terms of both volume and market level, currently serve as the largest class of environmental trading markets in the world by a significant margin (Newell, et al. 2014). Furthermore, the Kyoto Protocol put into place a framework for several future carbon markets that are still active to this day. Thus, the benefits of the original framework are still being reaped in multiple ways. At the very least, the Kyoto Protocol initiated a sentiment of widespread interest in carbon markets and led to the development of several climate exchanges.

2.3 Carbon Markets and Carbon Credits

The unique nature of the negative externalities that surround GHG emissions is paramount in understanding the growing demand for emission reductions. Unlike the negative externalities of most industrial economic occurrences, the emissions of GHGs have proven to be distinct, as their consequences have essentially the exact same properties across the globe regardless of where they were originally emitted (Newell, et al. 2014). For instance, the temperature increase that is a result of excessive carbon emissions will be equally absorbed across the world irrespective of the original location of the emissions. Additionally, GHGs tend to be long-lived in their pollution nature - meaning that once they are omitted, GHGs can stay in the atmosphere for prolonged periods of time, ranging from decades to centuries (Evironmental Protection Agency 2023). The dangerous potential consequences of climate change (flooding, sea level rise, drought, and heatwaves) have continued to catch widespread attention across the globe and has caused prolonged requests for large emissions reductions in the public and private sectors alike. In 2019, an estimable 7.6 million individuals from 185 countries participated in a Global Climate Strike urging world leaders to take urgent action in addressing climate change (Martiskainen, et al. 2020).

A major result of the calls for a sustainable future can be found in the lofty goals of both state and national governments. For instance, in 2021 the European Commission adopted numerous legislative proposals describing its intentions of the European Union to be climate neutral by 2050 (European Commission n.d.). Similarly, Assembly Bill 32, or the California Global Warming Solutions Act of 2006, required California to return to 1990 levels of GHG emissions by 2020 (California Air Resources Board 2015). In 2020, China's President Xi Jinping announced at the United Nations General Assembly that China will aim to obtain carbon neutrality before 2060 (McGrath 2020). Amongst many sustainable goals made public in the last decade, notable carbon reduction pledges in the private sector include General Motors planning to make global products and operations carbon neutral by 2040 (Jones 2021) and Delta Airlines committing to net-zero carbon emissions by 2050 (DeLuca 2021).

One of the primary goals of a carbon market is to shift the liability and responsibility of these negative environmental consequences onto the main players that are actively emitting greenhouse gases. Ideally, when both producers and consumers hold some responsibility to pay for the carbon that they are emitting, there will continue to be an economic incentive for both parties to work towards reducing their emissions and simultaneously invest in sustainable products (improved energy efficiency, low-carbon technologies, etc.) (Newell, et al. 2014). The price of carbon, ideally, should equal the "social cost" that is manifests (Morris 2022), meaning that if one ton of carbon is figured to cost the public $30, then the emitter should have to pay

$30 to omit that ton. However, determining, or even estimating, the price of carbon has proven to be an extremely difficult task as the societal impacts of climate change are perpetually growing (Aldy and Stavins 2011). For this reason, policymakers often resort to setting prices for carbon at a level that they hope will prove to be effective in incentivizing emitters to adopt practices that are consistent with reducing their emissions (Newell, et al. 2014).

There are several different marketing methods that have been utilized to determine a price that accounts for the demand for carbon credits. Some of the most popular emission reduction methods that set a price for carbon reductions include reductions versus a historic baseline (such as the Kyoto Protocol); reductions against a business-as-usual baseline (percent reduction versus projected 2030 emissions); or utilizing a carbon tax (Newell, et al. 2014). As previously observed, the European Union and the State of California have implemented lofty emissions reductions targets; interestingly, both governments have utilized a unique program that uses a reduction verses historic baseline and acts as a market for carbon credits: a Cap-and-Trade Program.

In essence, the goal of the cap-and-trade system is rooted in the idea that the government is not specifically enforcing how emissions (pollution) are to be reduced – rather, it focuses on merely setting a cap on the total emissions allowed. Thus, the cap-and-trade market system works in a way that the government sets the maximum amount of emissions allowed in an industry (the “cap”) and allows the marketplace the liberty to dictate how best to react to the changing limits (the “trade”). Under the jurisdiction of the Cap-and-Trade system, a carbon allowance is synonymous with a carbon credit. The permitted allowances, or credits, are distributed to polluting businesses either through an auction or free allocation (Environmental

Defense Fund 2023). Ideally, one allowance is the equivalent of one ton of emissions. As time goes on, the standard number of allowances that are permitted, or the cap, decreases which, hypothetically, causes the amount of total pollution emitted to also decrease (Environmental Defense Fund 2023).

Businesses involved in the cap-and-trade system have several ways to react to the lowering of the cap, which is what the “demand” for allowances is rooted in. With the ongoing decreasing number of permitted credits, and the coinciding increase in their price, businesses in the long term have a strong incentive to invest in clean technology and reduce their overall emissions. Additionally, there is another incentive to reduce emissions as businesses are allowed to trade their excess credits at the market price – which can act as another stream of revenue for sustainable business operations. If businesses go over the level of emissions that are permitted to them, they are either subject to a tax or are forced to purchase credits from the companies that have excess allowances. Another option that businesses are allowed to pursue is simply “banking” their excess credits for either future use or to be held as an investment asset. Ultimately, one of the main ambitions of the cap-and-trade system is to let the market dictate the demand and price of carbon in order to foster market innovation and investments in sustainable business practices (Center for Climate and Energy Solutions 2023).

2.4 Carbon Offsets

It is critical to acknowledge that carbon credits and carbon offsets, though they are often referred to as interchangeable, are not the same thing. Carbon credits are allotted to businesses in a cap-and-trade market and act as permitted emission allowances in the form of one ton of carbon per credit. Carbon offsets, on the other hand, fund projects that lower emissions from the environment or are actively removing emissions from the global environment altogether (Peterby 2023). Offsets, like credits, also represent one metric ton of carbon dioxide or equivalent (Blinch 2023). Given the market demand for carbon emission reductions, there are several opportunities to supply the necessary credits that enable businesses to meet their permitted emission allowances. A key aspect of the carbon credit market is the carbon offset market and the number of non-agricultural businesses that are actively participating in the market (D. Aiken 2021).

Another distinction that needs to be made when observing carbon offsets are their trading limitations. Unlike a carbon credit that is actively traded in a cap-and-trade market system, the carbon emission is primarily traded in what is called a voluntary market. In short, a voluntary market is a market that facilitates the efforts of business and organizations that are working towards carbon reductions or neutrality to be connected with those who have the ability to offset emissions. The market is referred to as “voluntary” as there is no technical governing body enforcing the reduction or offset in emissions – the suppliers and buyers of these offsets are doing so entirely on a voluntary basis (Lawrence 2021). Hypothetically, carbon offsets work as an interim method for businesses to declare carbon neutrality as they progressively work to reduce carbon emissions in their own operation and supply chain. While the market is voluntary, it has proven to be extremely lucrative with a total traded value of $1.4 billion in 2021 – indicating both a growing supply and demand for carbon offsets (The World Bank n.d.).

Without an overseeing regulatory body that validates a reduction in emissions, such as what is in play with compliance markets (a market established by a government or entity that oversees the supply and trading of credits), it can be difficult for a voluntary market to verify an offset. Currently, there are four major standards that uphold a standard for the market: Verra's Verified Carbon Standard, the Gold Standard, Climate Action Reserve, and the American Carbon Registry (Lawrence 2021). The purpose of these four standards is to ensure that consumer confidence exists in the credit that is being purchased has truthfully done what it claims – offset one ton of carbon dioxide.

The methods in which carbon offsets can be generated and supplied to the market are both extensive and diverse. Carbon offsets can be divided into one of two categories – mechanical or natural offsets. Activities such as reforestation, developing or conserving grasslands, or altering farming practices that promote carbon sequestration all represent natural offsets. Mechanical offsets include investments in renewable energy - such as wind turbines, solar panels, and even partaking in carbon capture technology (Ollendyke 2023). Each of the four previously listed standards verify offset projects for both mechanical and natural offsets. Some of the most common projects these four standards pursue include international development, exercising land use changes, altering industrial processes, and utilizing carbon capture and storage (CCS) technologies (Ollendyke 2023). An example of a land and water management change would be the Verra's (Verified Carbon Standard) Adjusted Water

Management in Rice Cultivation in Hongan County, China (project 3754). In this example, Verra took on a 13,194-hectare project to alter flood management practices so to mitigate methane emissions from anaerobic decomposition from the overflooding or rice fields – with an expected annual average of GHG emission reductions of 58,111 tCO_2e/year (Verra 2022).

Another prime example of a carbon offset project could entail a rancher entering into a contract with the company *Grassroots Carbon* to preserve or enhance their grasslands as a carbon sink (Nickel 2022). Before the project is issued any credits, however, it must first meet the rigorous standards designed by a verifying party. An example of this would be the Texas-based nonprofit BCarbon, which specializes in the conversion of carbon dioxide to soil organic carbon and makes initial soil measurements and then five-year incremental measurements of the soil to record, verify, and document that increases in soil organic carbon were achieved (Nickel 2022). This process continues for the duration of the contact. From there, an independent entity such as The Climate Action Reserve will convert the measurement into verified credits. Typically, one acre of grassland can produce anywhere from 0.67 to 7.1 credits of carbon (Mao, 2023). This supply of credits can then ultimately be sold to corporations that are looking to lessen or remove their carbon emission footprint in the voluntary marketplace.

2.5 Carbon Markets in the U.S.

Carbon markets in the U.S are diverse in their structural designs and have historically varied in their levels of success. Notable examples of these markets include the California Cap-and-Trade, Chicago Climate Exchange, and numerous voluntary market mechanisms. These markets will be analyzed in the following sections.

2.5.1. California Cap-and-Trade

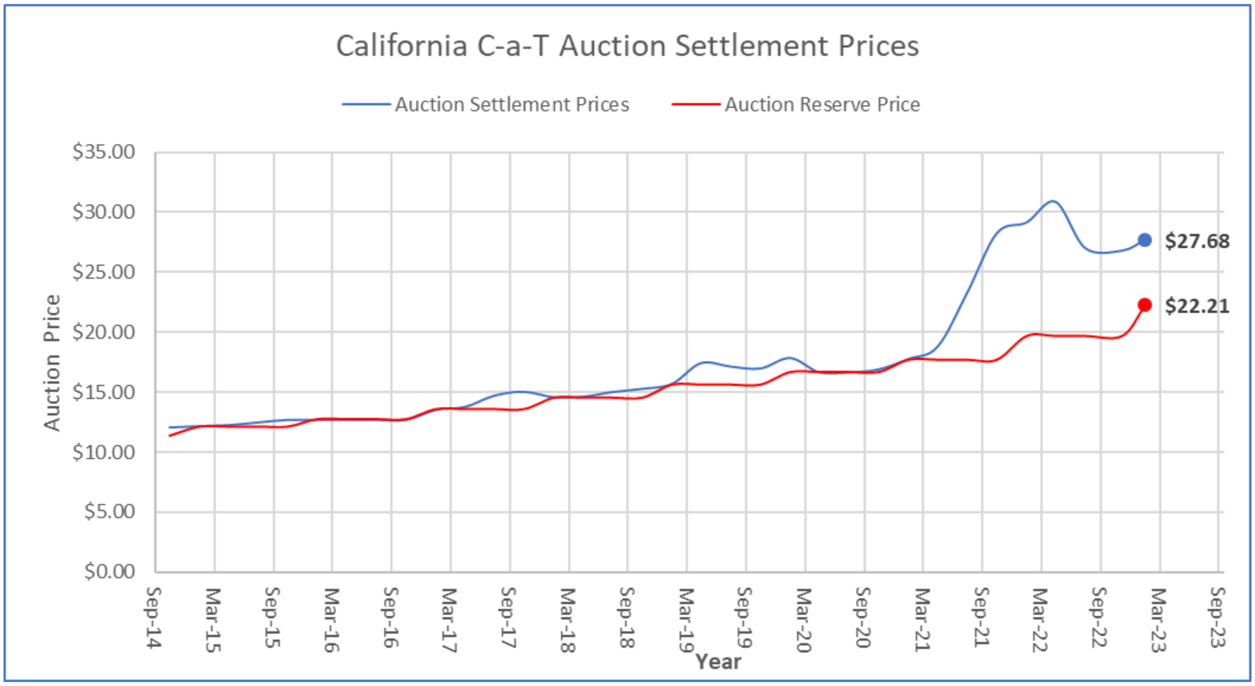
The California Cap-and-Trade program is the product of the passage of Assembly Bill 32, the California Global Warming Solutions Act of 2006. In reference to the Kyoto Protocol, the bill requires California to reduce its GHG emissions to that of 1990 levels by 2020. This significant reduction would be a 15% reduction from a "business as usual" approach (California Air Resources Board 2015). Given the growing sentiment for the state to reduce its emissions, a Cap-and-Trade market approach was adopted in 2013 to establish a price that would further incentivize long-term investment in cleaner energy. The limit or "cap" would be placed on emitters that release more than 25,000 MTCO2e per year, which amounts to about 450 entities, and accounts for a total of 85% of California's greenhouse gas emissions (California Air Resources Board 2023). An industry cap was set in 2013 to emission levels that were 2 percent below the emissions of 2012. Then, in order to meet the reduction goal by 2020, the cap declined by 2 percent in 2014 – and then declined again 3 percent each year from 2015 to 2020 (California Air Resources Board 2015).

The California Air Resources Board (CARB) works to create the number of allowances, or credits, that are equal to the allowable number of permissible emissions. The entities that are participating must then purchase these allowances through a quarterly auction. Thus, if a company needs to emit above its restriction, it must go to the auction and bid against other entities to purchase the limited number of allowances. Additionally, the market implements a floor (reserve) price to ensure a strong price signal that will incentivize needed reductions in emissions (California Air Resources Board 2023).

Figure 2.1.2 analyzes data gathered from the California Air and Resources Board website. Essentially, this table communicates the steady increase in prices throughout the span of the California Cap-and-Trade program (2014-present). Settlement prices were rather stagnant for the first five years and rarely exceeded the reserve price by a marginal amount. During the lockdown periods prompted by COVID-19, auction settlement prices lost much of their acquired momentum and fell back to the reserve (floor) price. Intuitively, this makes sense, as many large businesses were likely to reduce their operations due to reduced demand, smaller workforces, and other COVD-19 related effects. Interestingly, around the first quarter of 2021, prices rapidly increased and drastically exceeded their floor price by margins as high as 60% in quarter four of 2021. Ultimately, this trend reveals a strong demand for allowances that is both resilient and growing. This could largely be a result of the industry preparing to meet the long-term goals that California has pledged in the future (climate neutrality by 2050), and that businesses are investing in credits to hold as assets that will gain value in the future (Storrow 2022).

Figure 2.2 California C-a-T Auction Settlement Prices.

Source: (California Air and Resources Board, 2023)



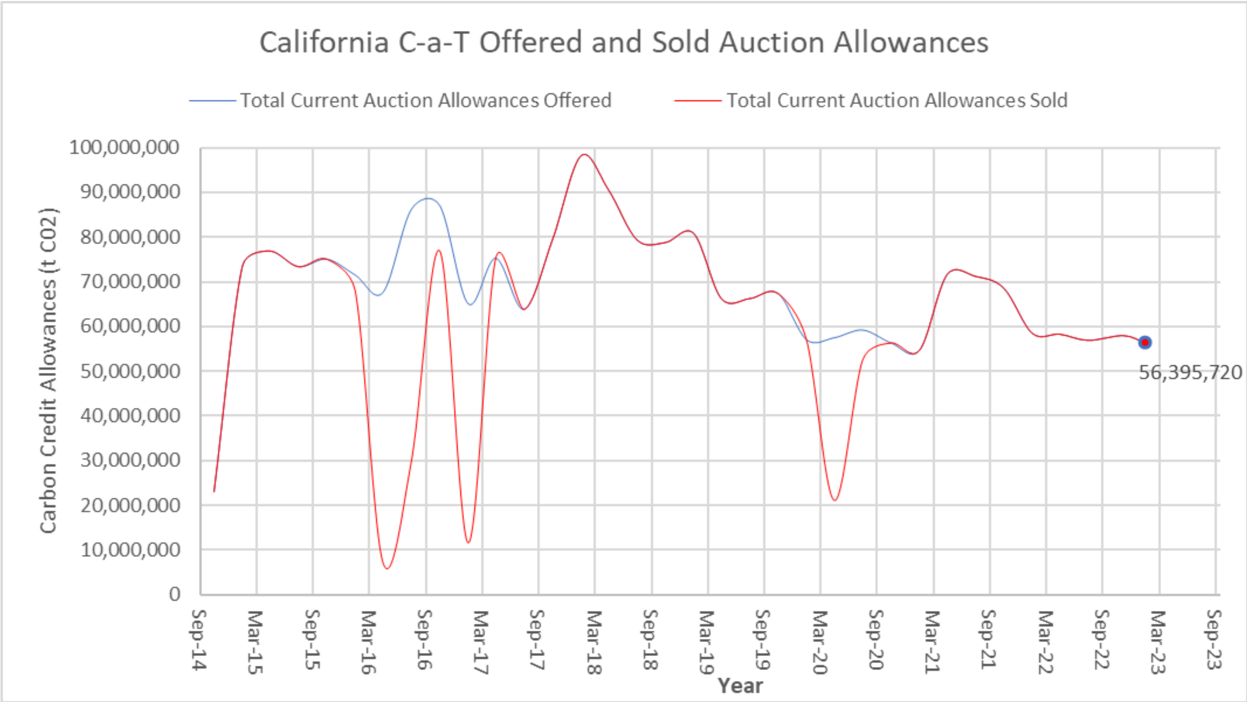
The California cap-and-trade market allows carbon offsets to play a role in the program. The California Air Resources Board, on page 2 of their page *Cap-and-Trade Program: Frequently Asked Question*, defines these offsets as "real, quantifiable, enforceable, permanent, additional, and verified reductions of GHGs generated from projects in economic sectors – like forestry or agriculture – that are not covered by the Cap-and-Trade Program" (California Air Resources Board 2023). These offsets credits can work within the parameters of a regulatory market – not exclusively a voluntary market. Thus, businesses in the cap-and-trade market can purchase offsets from producers and count that towards their reduction obligations. While the CARB only allows these credits to work towards only 8% of their compliance obligations, this does leave room for more investment opportunities within the carbon credit marketplace (California Air Resources Board 2023).

Figure 2.2 shows total current auction allowances offered and sold throughout the quarterly auctions in the CARB from 2014 to present. This reveals the amount of carbon allowances that CARB allowed for sale through the auction against what was purchased by the industry. The graph displays more volatility than the settlement and reserve prices. The way that the number of allowances is determined is based on a quartile budget derived from the cap-and-trade's yearly budget – this number can also be added to by unsold allowances from undersubscribed auctions in prior quarters and can return to the market after two consecutive auctions have resulted in a settlement price above the reserve price (Coleman, 2023).

The data in Figure 2.2 reveals the number of allowances sold almost always matches the allowances offered with the exceptions of the auction that took place in 2016 – 2017 and the first half of 2020. Similar to the fall in auction settlement prices, the total current auction allowances sold through the 2020 auctions decreased as the COVID-19 lockdowns drastically decreased capacity and production for many businesses in California, resulting in less allowances needed than what was being offered at that time.

Figure 2.3: California C-a-T Offered and Sold Auction Allowances

Source: (California Air and Resources Board, 2023)



As the California cap-and-trade auction approaches its tenth year of commission, it has been met with both praise and criticism. The auction generates financial proceeds that are then redistributed to state projects that support various environmental goals through the Greenhouse Gas Reduction Fund (Office of Governor Gavin Newsom 2022). In fact, as of June 2022 the Greenhouse Gas Reduction Fund was valued at over $20 billion of total capital in California (Morgenstern and Adler 2022). Aside from the financial benefits, these programs have helped California achieve its goal of a 13% reduction in GHG emissions (to that of their 1990 emission levels) four years early – meeting the goal in 2016 opposed to 2020 (Pfeifer-Rosenblum 2020)

However, recent studies have also suggested that a cap-and-trade market system actually has the propensity to increase local pollution levels and result in negative externalities for those that are geographically close to the facilities involved in the market (Common Dreams 2019). While the idea of a cap-and-trade is to reduce overall industry emissions on both the individual and aggregate level, the offset caveat has the tendency for companies to increase their local pollution given that they make the proper investments to offset these emissions (Song 2019). For example, when utilizing the CalEnviroScreen, an interactive dashboard designed by the California Office of Environmental Health Hazard Assessment (OEHHA) to analyze the latest data on geographic pollution levels in California, it was found that those most affected by the increased pollution levels are demographics primarily consisting of “disadvantaged communities” (Pfeifer-Rosenblum 2020). Furthermore, studies of a similar nature have been conducted in other regions of the United States that partake in smaller cap-and-trade markets and have yielded similar results (Common Dreams 2019). With the public attention being drawn to this issue, there has continued to be pressure placed on government to provide legislation to direct more financial support from the Greenhouse Reduction Fund to projects that are designed to benefit “disadvantaged communities” in California (California Office of Environmental Health Hazard Assessment 2022).

2.5.2 Chicago Climate Exchange

While the United States decided to opt out of the Kyoto Protocol, several prominent individuals still believed there was a significant demand within the country for a carbon market to develop. In 2003, Dr. Richard Sandor founded the Chicago Climate Exchange (CCX) (Radio

Finance 2023). Perhaps one of the largest appeals of the Chicago Climate Exchange was rooted in its market-based approach in cutting greenhouse gas emissions. The Chicago Climate Exchange was the world's first voluntary, legally binding greenhouse gas trading program for emission offset projects in the U.S (University of Nebraska Extension 2009). The voluntary market approach allowed both public and private institutions to join in committing to reducing their greenhouse gas emissions. This was made possible through the buying and selling of the Carbon Financial Instrument (CFI) - which equated to the right of emitting the equivalent of 100 metric tons of carbon. The market gained notable traction from 2007 – 2009 as it oversaw 43% of the voluntary carbon market transactions in the international marketplace (Sabbaghi and Sabbaghi 2017).

The Chicago Climate Exchange also included the option for offset trading. This was utilized through the hierarchy of membership within the exchange that delegated different tasks to members based on their respective categories. The membership levels included: members, associate members, participant members, and exchange participants. Members were entities that generated and emitted greenhouse gases through their business, including energy production, manufacturing and travel. Associate members, while not generating greenhouse gases, were tasked with offsetting all of their indirect emissions. Participant members were composed of offset providers and aggregators. These projects would work to offset emissions by developing projects that would store and eliminate emissions. In doing so, these projects could also create offsets that could be traded on the exchange. Finally, exchange participants consisted of companies or entities that did not have a greenhouse gas emissions reduction goal but had the option to purchase offsets (known as Carbon Financial Instruments) in order to retire the project contracts (Trimarchi n.d.).

The Chicago Climate Exchange thrived for a period, but it ultimately had several critical flaws that forced it to end trading in 2010. Notably, factors that contributed to this failure included a surplus of CFI allowances in conjunction with a weak demand – which ultimately led to the rapid decrease in CFI trading prices. This was largely a result of offset project developers being free to generate CFIs through their project, making any need to purchase a CFI of little value. For this reason, CFIs had the unrestricted ability to rapidly grow in number while facing a fixed demand (Groneworld 2011). Another dilemma that hindered the flourishing of the CCX was the failure of notable climate change legislation in 2010, causing further interest to dwindle for market participation (Rudolf 2010).

2.6 Carbon Offset Contracts and Potential on Grasslands in the U.S.

The emphasis in sequestering carbon to mitigate climate change has historically been focused on forested ecosystems. It is commonly understood that forests are prolific at absorbing and storing carbon within their trunks, biomass and leaves (Kerlin, Grasslands More Reliable Carbon Sink Than Trees 2018). However, due to the high-risk of a complete loss of carbon storage in the event of a forest fire, focus is continuing to shift towards grasslands as a more robust carbon storage mechanism (Dass, Houlton, et al., Grasslands may be more reliable carbon sinks than forests in California 2018). Grasslands, with deep extensive root systems, have the potential to hold carbon in the soil even in the event of a grassland fire.

Another promising aspect of grasslands is found in their sheer magnitude on the Earth's surface. Across the globe, habitat's deemed grasslands cover over 50% of the land surface on the planet and thus provide a potential massive sink to feasibly store and sequester carbon (Fagione, Parton and Ahlering 2016). It must be observed that alongside the growing global population, the demand for food and energy is also increasing. To this, landowners are economically incentivized to convert their rangelands from idle grasslands to a means of producing commodities that are in high demand (crops, oil, animal production, etc.). For this reason, nearly 70% of all Earth's grasslands have transitioned into agricultural production (Foley, et al. 2011). Similarly, estimates in North America indicate that nearly 70% of grasslands across the Great Plains have also been converted from their historic native grasslands (Samson, Knopf and Ostlie 2004). As farmers are economically incentivized to utilize their land for agricultural production, the carbon storage capacity of the soil will inevitably decrease as it is converted to other land uses (plowed, mined, grazed, etc.).

With rising commodity prices and reduced governmental funding, grassland preservation programs such as the Conservation Reserve Program (CRP) have also dwindled in acreage enrollment. The Conservation Reserve Program is administered by the Farm Service Agency (FSA) and works with farmers to voluntarily remove environmentally sensitive land from agricultural production in exchange for yearly rental payments (U.S. Department of Agriculture 2023). CRP reached its peak enrollment of 37 million acres in 2007 (Fagione, Parton and Ahlering 2016). In 2021, CRP enrollment was reported to be 20.8 million acres – a decrease of nearly 17 million acres from 2007 (U.S. Department of Agriculture 2021). It is reasonable to conclude that notable economic incentives must take place for grasslands to be preserved. A grassland carbon offset marketplace may be a valuable alternative. To enter a grassland carbon credit contract, landowners contract an aggregator to whom they can sell their offsets to (Adams and Jones n.d.). These contracts typically specify the actions that the landowner must take to reduce their emissions, hand over the rights of the carbon to the aggregator, standardize how the revenue from the offsets sales will be split between the landowner and aggregator, and establish how many years the landowner must uphold the change in their practices (Adams and Jones n.d.).

The general effectiveness of grassland carbon credit contracts in sequestering carbon emissions is a highly studied topic. Marissa Ahlering, Joseph Fargione, and William Parton (2016) addressed this question to a region of threatened grasslands in the northern Great Plains in North Dakoata. This study effectively applied the Avoided Conversion of Grasslands and Shrublands v.1.0 (ACoGS) methodology from the American Carbon Registry to study the quantity of emissions that could be reduced from protecting this land. The research team found that protecting a mere 10% of 2.1 million hectares in the area with the highest emissions would reduce carbon emissions by 11.7 million tons of CO2 over a 20-year period – avoiding a potential social cost of $430 million worth of carbon emissions (Fagione, Parton and Ahlering 2016).

Furthermore, recent research supports that grasslands have the capacity to act as a more robust carbon sink than forests (Dass, Houlton, et al., Grasslands May Be More Reliable Carbon Sinks than Forests in California 2018). This is a result of a grasslands' extensive root system that can continue to sequester carbon in the soil even in the event of the grass being decimated – including the events of grassland fires or livestock grazing (Kerlin, Grasslands More

Reliable Carbon Sink Than Trees 2018). Conversely, a forest largely relies on storing and sequestering carbon within its biomass and leaves, which, given the event of a forest fire, the formerly stored carbon will be released into the atmosphere. The ability for grasslands to serve as a more reliable carbon sink than forests is also expected to increase as the effects of climate change are expected to compound – thus causing the likelihood of forest fires to increase (Kerlin, Grasslands More Reliable Carbon Sink Than Trees 2018). In continuation with this research, the ability to graze livestock while simultaneously being enrolled in a carbon contract is a necessary and realistic valuation as, hypothetically, livestock grazing may not be as detrimental to the carbon sequestration and storage due to grasslands extensive root systems, with most of the biomass below ground.

Grassland carbon contracts thus hold a massive amount of potential in sequestering carbon from the Earth's atmosphere and can hold further secondary benefits for producers with enhanced grassland soil health. Contracts stipulations between landowners and aggregators tend to vary greatly in relation to income, length of contract, restricted practices, and various other details (J. D. Aiken, Ag Carbon Credit Contract Checklist 2021). For this reason, the current state of carbon markets has left many producers hesitant in entering grassland carbon contracts.

2.7 Competing Enterprises for Grassland Management

2.7.1 Pasture Rental

A common source of income for landowners in the Southern Plains is to rent their pasture to livestock producers. These cash rental rates are typically reported on an annual basis per acre by USDA through surveys, which are administered to determine the annual pasture cash rent that was paid in a given year. Pasture rental rates have the propensity to greatly vary across a given state due to a number of factors. Some of the major contributing factors of varying rental include forage quality, size of pasture, and water ability (Farm Progress 2011). From the years 2011 – 2020 Average Gross Cash Rent ($ per Acre) for dryland pasture has increased. For instance, the Kansas average gross cash rent in 2011 started at $16.00 per acre and increased to $19.50 in 2020 (Sahs 2021). As of 2022, pasture cash rent in Kansas averaged $21 per acre – which was $1.00 higher than 2021 (Bounds 2022)

2.7.2 Conservation Reserve Program (CRP)

The Conservation Reserve Program was signed into law through the Food Security Act of 1985 with two main objectives: reducing soil erosion on cropland and lowering the excess of surplus grain (U.S. Department of Agriculture 2020). Since its passage, the program has proven to be widely popular and successful for the nearly four decades that it has been in operation. As of May 2023, The United States had about 23 million acres enrolled in CRP contracts (U.S. Department of Agriculture 2023). In 2023, Kansas had 1,830,987 acres enrolled with the average CRP rental rate being $41.57 per acre (U.S. Department of Agriculture 2023). CRP contracts that producers enroll in range in length from 10 to 15 years.

A component of the CRP program is the Grasslands Conservation Reserve Program, which helps landowners maintain their grasslands and pastures and maintains the land as a grazing area. The Grasslands CRP program has also proven to be widely successful with more than 3.1 million acres enrolled in 2022 – which was a 22% increase from the previous year. One of the main motivations of the Grasslands Conservation Reserve Program is to allow producers and landowners to carry on with their grazing practices (haying, mowing, or harvesting seed) whilst preserving the nation's grasslands (U.S. Department of Agriculture 2023). The program also serves the dual purpose of actively sequestering carbon within the soil, while mitigating the risks of wildfire. Kansas Grassland Rental Rates proved to be substantially lower than regular CRP rates with an average of $18.92 per acre (U.S. Department of Agriculture 2023).

Chapter 3 - Data and Methods

To assess the willingness of producers to adopt a grassland carbon credit contract, a survey was conducted that included a stated choice experiment to examine producers' willingness to enter into a grassland carbon credit contract. The study region included producers in Kansas, Colorado, Oklahoma, New Mexico and Texas which are states that compose the Southern Great Plains of the United States. To assess the acquired data, logistic regression models were developed and utilized to elicit the producer's valuation of each unique contract attribute.

3.1 Study Region

The study region for this project is the Southern Great Plains of the United States, which includes Kansas, eastern Colorado, Oklahoma, Texas and eastern New Mexico. These five states have a combined total of over 271 million acres in agricultural production, with 61 million acres devoted to grazing pasturelands (USDA-NASS 2023). Livestock production is one of the primary enterprises across the region, with cattle inventories totaling 27,350,000 head in January 2023 (USDA-NASS, 2022). The region accounts for nearly 31% of all cattle in the United States' inventory (United States Department of Agriculture 2023). Primary cash crops produced in this region include the production of corn, soybeans, sorghum, hay, cotton and wheat (2022 State Agriculture Overview, NASS).

Within the study region, a total of 8,705,458 acres are enrolled in the Conservation Reserve Program as of October 2023 (United States Department of Agriculture 2023). Colorado has the largest acre enrollment at 2,796,024 acres followed by Texas with 2,165,330 acres (U.S.

Department of Agriculture 2023). Kansas has 1,975,677 acres enrolled in CRP followed by Oklahoma with 669,382 acres enrolled (U.S. Department of Agriculture 2023). In total, this region equates to 32% of all CRP acreage. As of 2023, there were 58,277 CRP contracts across the region, with Kansas having the most contracts at 28,195 (approximately 48% of contracts in this region) followed by Texas with 13,463 contracts. The average annual rental payments in this region are $27.27 per acre. The highest annual rental payments were in Kansas at $39.25 per acre, followed by Texas at $33.72 per acre (United States Department of Agriculture 2023).

3.2 Conceptual Model

Following Roe et al. (2004), we assume that producers will enter into a grassland carbon credit contract if it maximizes their expected utility. They will choose a contract with a level of attributes that maximizes their utility or will choose not to enter into a contract. Conceptually, let producer *j*'s expected utility for contract *i* be given by:

$$U_{ij} = U\left(R_{ij}, C_{ij}, G_{ij}, L_{ij}\right)$$

where R_{ij} refers to the returns per acre under contract *i for* producer *j*; C_i denotes the variation in the payment level per acre for contract *i* for producer *j*; G_i is the option to graze livestock on grassland under contract *i* for producer *j*; and L_i is the contract length in years for producer *j*. All these attributes were found to be statistically significant contract attributes in the literature that examine contractual arrangements with farmers (e.g. (Roe, Sporleder and Belleville 2004)).

The expected marginal utility for each contract attribute is the partial derivative of utility or marginal utility with respect to a given attribute. The expected marginal utility for returns under the contract or contract payment per acre is dU_{ij}/ dR_{ij}. Economic theory suggests that average annual payment per acre will positively affect the adoption rate of the contract as producers are assumed to want to maximize profit or wealth, increasing the value added to their operations and land. The marginal utility for the variance in contract payment can be written as dU_{ij}/ dC_{ij}. A higher variance may be expected to negatively affect a producer's willingness to enter into a contract. This is rooted in the assumption that producers will be relatively risk-averse about entering into new contracts, especially in new markets. Li et. al (2016) observed travel times with ranges for arrival to capture time variability and concluded that travelers would be willing to pay for less variance in their arrival time. The marginal utility of having the ability to graze livestock on the land under the contract is given by dU_{ij}/ dG_{ij}. The ability to graze livestock is expected to have a positive impact on whether producers elect to enter into a contract. Typically, producers will work to maximize the amount of value they can extract from their land, and the ability to both generate revenue from carbon credits and cattle production would act as a substantial incentive for producers. Finally, the marginal utility of the length of the contract can be expressed as dU_{ij}/ dL_{ij}. The length of the contract is expected to negatively impact a producer's willingness to enter into a carbon contract - as farmers may be more hesitant to lock their land into a longer-term contract, potentially reducing flexibility with what can be done with the land. Furthermore, previous literature suggests that novel contracts become less preferable as their length requirements increase (Roe, Sporleder and Belleville 2004). However, given we are focusing on marginal crop land, it could be possible that the contract's length may have a positive marginal impact.

3.3 Survey and Choice Experiments

3.3.1 Survey Design and Administration

Primary data for this study was collected through a mail survey titled *Wildfire and Conservation Across the Ranching and Farming Agricultural Landscape.* The survey was mailed to agricultural producers in the Southern Great Plains and administered following the Dillman method (Dillman, Smyth and Christian 2014). The survey was mailed to producers in two waves, with the first wave sent the first week of June and second wave the second week of July. A postcard reminder was sent one week after the first mailing to remind recipients to complete the survey. The survey asked a series of questions concerning wildfire data perceptions, experiences, and mitigation practices; CRP enrollment, re-enrollment and management; land management and conservation practices; a stated choice exercise on willingness to enroll marginal and CRP lands into a carbon credit program; farm characteristics; and farmer demographics.

A total of 4,000 surveys went out by mail to agricultural producers and landowners across the study region. An additional 17 surveys were completed at a county fair as a small convenience sample in Ford County. This brought the total sample size to 4,017 surveys. A total of 55 of the surveys were mailed back or returned uncompleted due to being returned from sender (e.g. bad mailing address) (8); being deceased (25); no longer farming or ranching (20); or fully retired (2). We received 466 surveys back with usable responses. This gave a response rate of approximately 11.8%. In comparison to other mail-in survey initiatives, this response rate was relatively high as the Direct Marketing Association's 2023 Response Rate Report revealed that direct mail typically averages a response rate of 2.7%-4.4% (Boughey 2023).

Additionally, in the paper *Challenges in Recruiting U.S. Farmers for Policy-Relevant Economic Field Experiments* the necessary incentives to increase response rates with agricultural producers are explored. In this paper, their two experiments yielded response rates of only 2% from their survey they sent out to producers (Weigel, et al. 2020).

Reasons for failing to complete and mail back the survey are diverse as agricultural producers tend to be largely seasonal in their workload with peak “busy” months being in Spring and Fall; however, many producers may have been traveling, working on miscellaneous farm projects or had various other preoccupations. Given incomplete responses to the stated choice and demographic questions, 295 surveys were usable for analysis of the stated choice experiment for this study. Many producers did not have land enrolled in CRP or may have not viewed themselves as having extensive marginal land and then skipped the stated choice questions because they believed that is may not apply to them.

3.3.2 Representatives of the Sample

Based upon all respondents that responded to the survey, the average age of a producer was 67 years, which is slightly higher than the 2022 United States Census of Agriculture’s report of 59 years for this region of study (NASS USDA 2024). The numbers reported in the 2022 United States Census of Agriculture were adjusted to account only for farms larger than 220 acres so to exclude hobby or part-time farming operations. Additionally, respondents to the survey were 85% male and 15% female – while the census reported producers in this region to be split 65% male and 35% female. Finally, of the farmers and ranchers responding to the survey 89% identified as white and 8% and identified as Spanish, Hispanic or Latino, with the remaining 3% as other ethnicities. These percentages were somewhat different from the Agricultural Census. The Census reported producers in this region to be 91% white and 5% Spanish, Hispanic or Latino. 58% of producers indicated they had a college degree, but this is not directly reported in the Ag Census (NASS USDA 2024).

The average farm/ranch size of farmers responding to the survey was 3,411 acres with the average crop acreage being 972 acres. According to the 2022 Census, the average size of a farm in this region was 2,114 acres. Farmer and rancher respondents also had an average of 129 acres of land enrolled in CRP per year on average over the past 10 years. This number was lower than the average farm CRP acreage for this region reported in the Census, which was 398 acres (but this is not a 10-year average, but a snapshot in time). Land for pasture and grazing purposes averaged about 3,212 acres per operation for survey respondents, while land for pasture and grazing in the Census averaged 1,406 acres per operation. The average number of cow-calf pairs per farm was 146 pairs; which compared to the 2022 Census, is below the average cattle inventory per farm for this region of 302 pairs. Producers also reported that approximately 52% of total gross values of sales came from crop production and 57% came from livestock production, but neither metric was reported on in the Census. All these statistics with those from the Agricultural Census in 2022 are reported in Table 3.1. Results from this study should be interpreted with these comparisons in mind.

Table 3.1 Representatives of Survey Respondents

Characteristics	Census (2022)	Survey
Average Age	59	67
Gender:		
Percentage of Males	65%	85%
Percentage of Females	35%	15%
Race		
Percentage White	91%	89%
Percentage Hispanic	5%	8%
Acreage		
Total	2,114	3,412
Crop	771	972
CRP	398	129
Pasture	1,406	3,212
Cow-calf pairs	302	146

3.3.3 Grassland Carbon Credit Program Stated Choice Experiment

For this study, of particular interest was a stated choice experiment assessing the willingness of producers and landowners to enter into a grassland carbon credit contract as a potential alternative to the Conservation Reserve Program or other current land management option on marginal agricultural land. A discrete choice experiment can reveal an individual's preferences about hypothetical markets that may not be fully established yet, such as carbon markets. The goal of the discrete choice experiment designed here was to estimate the importance (e.g. willingness to accept) of different contract attributes and quantify an individual's willingness to enter into a grassland carbon credit contract. Economic theory assumes that a rational producer will conduct themselves in a manner that will maximize their utility, assuming utility is an increasing function of the returns or profits from the contract. If a producer decides to enter into a contract, it should be their utility maximizing option.

Survey participants were asked to consider three independent choice scenarios that had them decide if they would enter into a hypothetical grassland carbon credit contract with differing attributes. The contracts were composed of four attributes: (1) average annual payment per acre, (2) year-to-year payment variations, (3) the ability to graze livestock and (4) the length of the contract. The attributes and levels are summarized in Table 3.2.

Table 3.2 Stated Choice Experiment Contract Attributes, Definitions and Levels

Attribute	Definition	Levels
Average Annual Payment per Acre	The average payment a producer would receive for each acre enrolled in the contract	\$10, \$30, \$50, \$70, \$90, \$110
Year-to-Year Variation	The percentage amount that the payment levels could vary year-to-year	0%, 10%, 30%, 50%
Allowed to Graze Livestock	The ability to simultaneously graze livestock while enrolled in a grassland carbon contract	Yes, No
Contract Length	The length of the land's contractual enrollment	10, 20

Under a given contract, a producer would be responsible for undertaking specific land management practices for 10 or 20 years that would generate carbon credits. In turn, a hypothetical agribusiness would financially compensate the producer while retaining the rights to aggregate, manage and establish the credits.

The first attribute under the contract is the annual payment per acre, which is based on market prices for carbon credits using the California Cap-and-Trade carbon credit market to establish payment levels. The attribute levels for the average annual payments per acre were

$10, $30, $50, $70, $90 and $110. These payment amounts were based on historic prices from the California Cap-and-Trade's quarterly auction settlement prices. Starting in November 2014, the lowest auction price was $12.10 per ton - and the auction price peaked in May 2022 at $30.85 per ton (California Air Resources Board 2024). The average price from these auctions was $17.49 per ton. Per Jordan Mao, an Analytical Associate from The Climate Action Reserve, the range of credits generated from one acre of grassland spans from 0.67 to 7.1 per acre. On average, we assumed grasslands have the potential to generate approximately 2.4 credits per acre (Climate Action Reserve 2023). When multiplying this across the average, minimum and maximum prices in the market, farmers can expect a median return of $41.60 per acre with a minimum of $28.78 per acre and maximum of $73.38 per acre per acre from grasslands carbon credits in the market, respectively (Table 3.3). Attribute levels were chosen to cover the range from $30 to $70, with higher and lower values to add in more extreme values for additional variation in the attribute levels.

Table 3.3 Carbon Credit Generation per Acre of Grassland

	Credits / Acre		Average Credit
	0.67	7.1	2.3785
Maximum	$20.67	$219.04	$73.38 / Acre
Minimum	$8.11	$85.91	$28.78 / Acre
Average Payment	$11.72	$124.19	$41.60 / Acre

Payment per acre variance was the second attribute. The levels for this attribute were set at 0%, 10%, 30%, and 50%. The payment variance was included to capture the dynamic nature of carbon credit prices within the carbon credit marketplace. The standard deviation for the entire California Cap-and-Trade's prices for the period 2014-2023 was $6.54 per ton. The first half of the period (2014 – 2018) had a standard deviation of $1.15 per ton and the second half (2019 – 2023) had a standard deviation of $5.49 per ton. We utilized these standard deviations overall and, in each period, to derive the payment variation attribute. For example, based on the standard deviation for each sub period, 95 percent of the time during the first period (2014-2018) the carbon price was within plus or minus approximately $2.30 per ton from the average price of $13.50, while in the second period (2019-2023) the carbon price was within plus or minus approximately $11 per ton from the average price of $21.48. During the first period then prices varied up to approximately 17% from the mean, while during the second period they varied by as much as 51% from the mean. These percentages were rounded down to 10% and 50%, and we added an intermediate value of 30% to give three levels of possible variation. Additionally, we included one variance level of 0% to signify that the displayed price in the survey was guaranteed for the producer. This was to assess the influence of the other three levels on a fixed, guaranteed price.

The third attribute, livestock grazing, was presented as a binary "Yes" or "No" option for each contract. The ability to graze livestock on the grassland acreage under contract serves as a way for producers to diversify their investment and have more value generated from their land. With grasslands having deep, extensive root systems that store carbon in the soil, disturbances to the grass biomass (such as grazing) may not significantly affect the sequestration potential

(Kerlin, Grasslands More Reliable Carbon Sink Than Trees 2018). The attribute of contract length for every option was either 10 or 20 years. The time frame of 10 to 20 years was determined to establish permanence in sequestering carbon into the soil (J. D. Aiken, Ag Carbon Credits 2021).

Farmers were presented with three grassland carbon credit contract options and asked to indicate if they would be willing to enter into each hypothetical option by selecting Yes or No. An example question is provided in Figure 3.1.

Figure 4.1 Survey Question Displaying Contract Attributes

		Option 1	Option 2	Option 3
Contract Attributes	Average Annual Payment per Acre	$30	$110	$30
	Year-to-Year Variation	30% ($21 to $39)	50% ($55 to $165)	50% ($15 to $45)
	Allowed to Graze Livestock	Yes	Yes	No
	Contract Length	20	10	10
Would you be willing to adopt this contract?		☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No

In the choice experiment, we utilized the binary "Yes" or "No" format for assessing each option to maintain incentive compatibility. Furthermore, we maintained incentive compatibility by stating "*Your average annual payment per acre under the contract would be based on the market rate for carbon credits and all producers with contracts in your area would receive the same rate*" – which decouples the payment level from an individual producer's decisions, making the price exogenous (Czajkowski, et al. 2017).

In a survey asking abstract questions, there will always be some degree of hypothetical bias active. In order to best mitigate this, we utilized a statement to reinforce the consequentiality of their choices. This can best be observed in the last sentence of the second paragraph of our question stating that, "*This question will help to determine the viability of a carbon market in your local area for land management and conservation*." By including this final statement, producers are explicitly reminded that their response may play a part in dictating whether an alternative cash flow opportunity, in the form of a carbon market, may be considered in their local area. For this reason, if a producer had a reasonable expectation that they may be interested in exploring a carbon contract within their operation in the future, they were incentivized to answer in accordance with their best economic reasoning.

The text provided in the survey to each respondent is given below:

> *Several private agribusiness firms are exploring a private market version of the CRP. This would give you the option to sign a 10- to 20-year contract to manage the land in a specified way with a private agribusiness firm that would monitor and certify management practices under a contract annually. The land could not be simultaneously enrolled in the CRP. Land management practices under the contract could include maintaining grasslands, restoring native grasslands, and enhancing wildlife habitat.*
>
> *You would earn carbon credits for undertaking these land management practices, which you would be paid for through the agribusiness firm who would aggregate, manage, and establish the carbon credits earned from your operation. Your average annual payment per acre under the contract would be based on the market rate for carbon credits and all producers with contracts in your area would receive the same rate. However, the annual payment per acre would vary by a given percentage each year due to carbon market dynamics. For example, if the annual payment for a given year is $50 and the variation in the market is 20%, then the actual payment received each year could vary between $40 and $60. The current market rate for carbon credits is currently uncertain due to limited carbon markets in your area. This question will help to determine the viability of a carbon market in your local area for land management and conservation.*
>
> *You are being asked to consider three different contract options. For each contract you are provided the average annual payment level per acre for the contract, the amount by which that annual payment level may vary from year to year during the life of the contract, whether grazing of livestock is allowed on the land, and the contract length. Please indicate if you would be willing to consider each contract option presented below by marking "Yes" or "No" for each option.*

Following Bergtold et. al (2014), a fractional factorial design from a 6x4x2x2 full factorial experimental was utilized. Given this was a mail survey, it was deemed that a fractional factorial design with smaller blocks of questions was more practical than a more complicated design. The fractional factorial was designed to identify main effects and bilinear interactions between attribute levels. An optimal fractional factorial design was determined using PROC OPTEX in SAS. The D-Efficiency, a measure of how efficiently experimental data can be used to estimate model parameters, yielded a score of 91.7%. This resulted in 60 choice sets that were blocked into groups of three, which resulted in 20 versions of the choice experiment for the survey. From there, each survey and corresponding block was randomly assigned to a survey recipient.

3.4 Empirical Model

To estimate the influence of the different attributes on the willingness of a producer to enter int a grassland conservation contract, we analyzed the stated choice experiment data using a conditional logistic regression model. A conditional logistic regression model is a discrete choice statistical model used to measure the relationship between multiple independent variables and a discrete dependent variable. The model is specified following using random utility theory. We observe that producer *j* will enter into contract *i* if it maximizes utility, given by:

$$U_{ij} = V_{ij}\left(R_{ij}, C_{ij}, G_{ij}, L_{ij}\right) + \varepsilon_{ij}$$

where*:*

$$V_{ij} = \beta_0 + \beta_1 R_{ij} + \beta_2 C_{ij} + \beta_3 G_{ij} + \beta_4 L_{ij}$$

In this model, as is convention in much of the stated choice literature, we assume linearity in the attributes and parameters.

It is not possible to directly measure a consumer's given utility based on their actions, instead we can only observe their decision-making processes, a binary outcome. That is, we observe:

$$Y_{ij} = \begin{cases} 1 \ \ if \ U_{ij} > 0 \text{ (enters into a contract)} \\ \qquad\qquad 0 \ Otherwise \end{cases}$$

This signifies that if the producer adopts the contract, their utility will increase above zero. This can be assumed, as utility is invariant to linear affine transformations. Using probabilistic math, we can restate this decision using the probabilistic equation (Greene, 2011):

$$P\left(Y_{ij} = 1 \middle| X_{ij}\right) = P\left(U_{ij} \geq 0 \middle| X_{ij}\right)$$

That is, the probability of an agent accepting a contract (Y_{ij} = 1), given its attributes (X_{ij}), is equal to the probability that the utility of the individual will increase from accepting the contract ($U_{ij} \geq$ 0). Put another way, we could observe that this would also equal the probability that the indirect utility of the contract in addition to all other factors not accounted for in the model (ε_{ij}) will be greater than zero given the contract's attributes. In which case, the probability equation can be equivalently stated as:

$$P\left(V_{ij} + \varepsilon_{ij} \geq 0 \middle| X_{ij}\right)$$

This last equation can be rewritten as:

$$P\left(\varepsilon_{ij} \geq \ -V_{ij} \middle| X_{ij}\right) = P\left(\varepsilon_{ij} \leq V_{ij} \middle| X_{ij}\right).$$

The last inequality follows from assuming the underlying conditional density function for the probability equation is symmetric. We obtain an estimable model by assuming a functional form for the underlying density function (Greene, 2011).

Assuming that ε_i is distributed Logistic:

$$F(V_{ij}) = \left[1 +_{exp}\{-V_{ij}\}\right]^{-1}$$

We then obtain a regression model where Y_{ij}, a binary variable, represents the dependent variable, $\left[1 +_{exp}\{-V_{ij}\}\right]^{-1}$ is the equation for the conditional mean, and w_{ij} represents a mean zero error term for the unexplained variation in Y_{ij}. Finally, the regression model can then be written as:

$$Y_{ij} = \left[1 +_{exp}\{-V_{ij}\}\right]^{-1} + w_{ij},$$

where V_{ij} was defined as earlier (Greene, 2011).

Discrete choice models examining stated choice experiments often are used to find what a producer or respondent would be willing-to-accept (WTA) for an individual attribute on the margin. An example of this would include: what would a producer be willing to accept to have the ability to graze livestock within their contract? A producer's willingness to accept for a single unit change in a contract is equal to:

$$WTA_a = \frac{\beta_a}{\beta_1},$$

where β_a signifies the coefficient of the given attribute being assessed (such as variance) and β_1 is the coefficient of the payment attribute (Greene, 2011). The WTA provides us a measure of producers' preference for the different contract attributes (Bergtold, Shanoyan, et al. 2017). For example, if the WTA for variance elicited was $2.50 per acre, then we can interpret this as the producer is willing to accept $2.50 additional per acre for a 1% increase in the change of variance. Additionally, if the WTA for the option to graze was -$25.5 per acre, then the producer is willing to forgo $25.50 of payment per acre to retain the ability to graze livestock.

The delta method is used to estimate asymptotic standard errors for each of the WTA measures. The delta method is a statistical technique to approximate the distribution of a function of a random variable (Greene, Econometric Analysis 1993).

The linear functional form of the utility function assumes the marginal utility or response to a change in variance is constant. In fact, the responses to the variance attribute (*C*) may be nonlinear. To examine this, we treated the variance variable (*C*) as discrete, reformulating the systematic part of utility as: $V_{ij} = \beta_0 + \beta_1 R_{ij} + \beta_2 C_{ij}^{10} + \beta_3 C_{ij}^{30} + \beta_4 C_{ij}^{50} + \beta_5 G_{ij} + \beta_6 L_{ij}$, where each variate C_{ij}^{k} is binary variable for k = 10, 30, 50. The coefficient or marginal utility estimated for C_{ij}^{k} for k = 10, 30, 50 is relative to a stated guaranteed price (*k* = 0). This approach provides a way to assess a nonlinear response as a piece-wise linear approximation.

Next, as with many stated choice studies in the literature, there could possibly be unobserved heterogeneity within the sample population that we were surveying. Unobserved heterogeneity arises due to the existence of unmeasured preferences or differences between study participants that are not directly accounted for within the model. Potential sources of unobserved heterogeneity could arise from views and beliefs about the environment, culture, worldviews, amongst others. Not modeling or correcting for the unobserved heterogeneity could lead to biased estimates (Greene, 2011). For this reason, we consider a mixed logit model that can capture such unobserved heterogeneity. The underlying random utility model for farmer or rancher *i* is given by: $U_{ij} = \beta_0 + \beta_{1i} R_{ij} + \beta_{2i} C_{ij} + \beta_{3i} G_{ij} + \beta_{4i} L_{ij} + e_{ij}$. It is assumed that $\beta_{kij} = b_k + \sigma_k \omega_i$ where $\omega_i \sim N(0, \sigma_k)$ for k = 0,1,2,3,4. Here, $b_k$is the mean of the associated parameter distribution and σ_k is the standard deviation of the distribution

(Greene, 2011). We estimate the mixed logit model assuming all the parameters are random following a normal distribution and that the parameters are independent of each other. We estimate models for when variance enters the random utility function linearly as a continuous variable (C_{ij}) and as levels (C_{ij}^{k}).

All econometric models were estimated using NLOGIT (Greene, Econometric Analysis 1993). We estimated standard conditional logistic regressions for each model specification with the payment variance attribute treated as continuous and discrete, as well as mixed logit models for each specification. For the mixed logit models we used 1000 Halton Draws, the David-Fletcher-Powell algorithm for model estimation and set the termination criteria for the gradient at 1E-6.

Chapter 4 - Results

The results for the mixed random parameter logit models estimated, including the option of the variance attribute entering as a continuous variables and as binary variables representing the three variance levels, are presented in Tables 4.1 and 4.2. Overall, the results from this study extend the literature on the potential for a grassland carbon credit marketplace. Results reveal the effect of contract design and associated attributes on farmer's willingness to enter into a grassland carbon credit contract. In addition, the results highlight the willingness to accept for each attribute, revealing the importance of these attributes from the perspective of the farmer or rancher.

The results for the base conditional logit models can be found in Tables A1 and A2 in the Appendix. Given the significance of the standard error deviation estimates for a number of random parameters in the mixed logit models, we choose to focus on the mixed logit models for the rest of the chapter.

The first mixed random parameter logit model where variance enters the utility function as a continuous variable is reported in Table 4.1. The McFadden Pseudo R^2 for the regression was 0.242 indicating a relatively good fit to the data. The payment per acre and grazing attributes both had p-values less than 0.01, revealing the statistical significance of both attributes. The payment variance and contract length attributes were not statistically significant, having p-values above 0.10. Payment had a positive coefficient (0.015), indicating that producers are more likely to enter into a contract with higher payments. Intuitively, this makes sound economic sense as producers are working to maximize their return to the land.

There was a negative coefficient for the variance attribute (-0.003). Producers' willingness to accept for a 1% increase in the variance is $0.15 per acre, but it was not statistically significant. The coefficient on the grazing attribute had a positive coefficient (1.08), indicating that producers would be more likely to adopt a contract that allowed for the option to graze. Furthermore, producers were willing to accept a payment that was $47.41 less per acre (in terms of lower payment received) for the option to graze livestock under a contract. With a a p-value of 0.0005, this metric was statistically significant. Finally, the coefficient for the contract length attribute is negative (-0.27) meaning that producers were less likely to adopt a contract if the contract length was longer. Producers are willing to forego $11.84 in payment per acre to have a shorter contract length of 10 years as opposed to 20 years. The standard error of the willingness to accept for contract length is 9.8 and the p-value is 0.23.

Table 4.1 Random Parameter Mixed Logit Model					
	Coefficient	Asymptotic Standard Error	P-Value for Z-Stat	Willingness to Accept Estimate (WTA)	Standard Error of WTA Estimate
Mean of Random Parameters					
Constant	-3.29***	0.46	0.00		
Payment	0.02***	0.005	0.00		
Variance	-0.003	0.007	0.63	$0.149	0.3
Graze	1.08***	0.24	0.00	-$47.41***	13.55
Length	-0.27	0.217	0.21	$11.84	9.8
Standard Deviation of Random Parameters					
Constant	1.37	0.45	3.04		
Payment	0.01	0.01	0.5		
Variance	0.03	0.01	1.73		
Graze	0.86	0.61	1.4		
Length	0.03	0.53	0.06		
Log Likelihood					-464.65
McFadden Pseudo R-Squared					0.242
Observations (*N*)					884

Notes: *****, **, and * indicate statistical significance at the 1%, 5% and 10% levels of significance, respectively.**

The second mixed random parameter logit model estimated (Table 4.2) included the levels of the payment variance attribute as binary variables to potentially capture if the effect of payment variance was nonlinear. The McFadden Pseudo R^2 for the mixed logit model estimated was 0.252. In this model, only the coefficients on the payment per acre and the option to graze attributes were statistically significant, having p-values below 0.05.

The payment variable had a positive coefficient (0.02), indicating that producers are more likely to adopt contracts with higher payments. The coefficient for a payment variance of 10% relative to a guaranteed payment (C10) was negative (-0.79). Producers needed a payment of $28.07 more per acre if the payment variance was 10% relative to a guaranteed payment. This indicates that a producer would have to be paid $28.07 to accept a contract with a payment variance level of 10%. The coefficient on a payment variance level of 30% relative to a guaranteed payment level (C30), was positive 0.27. Additionally, producers would be willing to accept a payment of $9.68 per acre less for a contract with a payment variance level of 30% relative to a guaranteed payment. The C50 variable, a payment variance of 50% relative to a guaranteed payment level had a negative coefficient (-0.68). Producers needed an extra payment of $24.22 per acre to have a variance level of 50% relative to a guaranteed payment level. Based on these metrics, producers were not interested in a 10% variance level, intrigued by a 30% variance level, and moderately open to a 50% variance level. This is, perhaps, a reflection of producer confidence and risk tolerance within this marketplace – meaning that producers are open to some price variance from a guaranteed level but do have a maximum and minimum risk tolerance. It is worth noting that all the coefficient estimates for the respective variance levels were not statistically significant as their p-values exceeded 0.05.

The coefficient for the option to graze attribute was positive (1.37) and producers were willing to accept a lower payment for this option of $48.52 per acre. Finally, the coefficient for contract length was negative (-0.36) and producers would be willing to forgo a payment of $12.79 per acre to have a shorter contract length of 10 years opposed to 20 years.

Table 4.2 Random Parameter Mixed Logit Model with Dummy Variables					
	Coefficient	Asymptotic Standard Error	P-Value for Z-Stat	Willingness to Accept Estimate (WTA)	Standard Error of WTA Estimate
Mean of Random Parameters					
Constant	-3.89***	0. **5**7	0.00		
Payment	0.02***	0.005	0.00		
Variance	--	--	--	--	
C10[a]	-0.79	0.56	0.16	$28.07	19.34
C30[a]	0.27	0.35	0.44	-$9.68	13.06
C50[a]	-0.68	0.52	0.19	$24.22	17.5
Graze	1.37***	0.29	0.00	-$48.52***	11.76
Length	-0.36	0.25	0.15	$12.79	8.92
Standard Deviation of Random Parameters					
Constant	1.74	0.41	0.00		
Payment	0.01	0.02	0.81		
Variance	--	--	--		
C10[a]	2.61	0.92	0.00		
C30[a]	1.06	0.93	0.25		
C50[a]	2.21	0.82	0.01		
Graze	0.13	1.39	0.93		
Length	0.16	0.94	0.86		
Log Likelihood					-457.86
McFadden Pseudo R-Squared					0.2527
Observations (*N*)					884

[a] Definition: C10, C30, C50 – The price variations of 10%, 30% and 50% from a guaranteed price, respectively.
***Notes*: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels of significance, respectively.**

Another point of interest is the distribution of the individual participants' willingness to accept for the various contract attributes. Following Greene (2011) individual parameter estimates can be obtained for each coefficient in the model using NLOGIT. From there, we can then estimate individual respondent's willingness to accept for a specific attribute. The summary statistics for the willingness to accept across individuals for specific attributes is presented in Table 4.3.

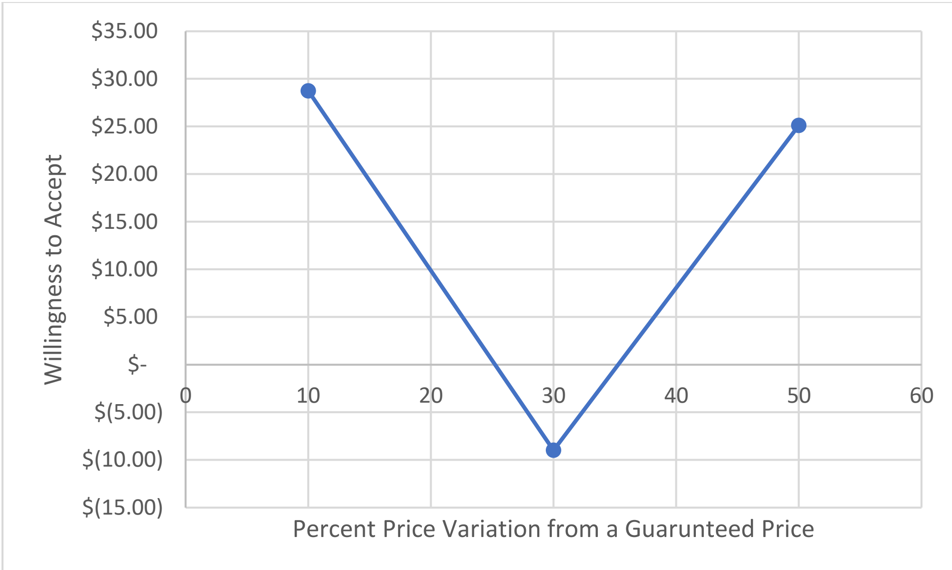
Table 4.3 Individual's Willingness to Accept for Different Contract Attributes ($ per acre).

	WTA for a 10% Payment Variance	WTA for a 30% Payment Variance	WTA for a 50% Payment Variance	WTA for the Option to Graze Livestock	WTA for Contract Length
Mean Across Respondents	28.75	-8.98	25.12	-$48.47	12.87
Minimum	-94.89	-42.11	-65.84	-$50.61	11.37
Maximum	104.28	70.25	159.16	-$44.24	16.3
Standard Deviation	38.45	10.51	30.96	$1.19	0.56
Observations (N)					289

[a] Definition: C10, C30, C50 – The willingness to accept for a price variation of 10%, 30% and 50% relative to a guaranteed payment level, respectively.
[b] Definition: WTA Grazing, WTA Contract Length – The willingness to accept for the ability to graze livestock and the willingness to accept for a 20-year contract over a 10-year contract.

Upon reviewing the WTA estimates in Table 4.3, one can assess the notable discrepancy in values for the willingness to accept across the payment variance levels of 10%, 30% and 50% relative to a guaranteed payment. The average willingness to accept across all individuals, for instance, for payment variance levels of 10%, 30% and 50% are $28.75, -$8.98, and $25.12, respectively. Essentially this reveals that on average, producers would need to be paid an additional $28.75 per acre for a year-to-year variation of 10% - and $25.12 per acre for a year-to-year variation of 50% relative to a guaranteed price. For a 30% variation level, however, producers would be willing to forgo $8.98 per acre to take on this variance level. These differences in valuation are visualized in Figure 4.1.

Figure 4.1 Individual's Willingness to Accept for Price Variation



Results may communicate that producers believe the upside potential of a 30% year-to-year variation level from a guaranteed price is a sort of "sweet spot" relative to no variation or variation of higher levels. Under this framework, it appears that producers value 30% variation as the utility maximizing option – and other variance levels are either too risky or not risky enough to elicit an adoption outside of an additional payment being made. For example, at a payment variance level of 10% with low payment levels, producers may not feel the variation is high enough to enter into a contract due to the lower probability of getting an increase in payment, while a 50% variation at lower payment levels may include too much risk of getting very low prices. The variation in payments would be directly tied to prices for carbon credits in the marketplace.

The nonlinear effect of the annual variation in payment levels can perhaps be understood through observing how individuals perceive a deviation from an original reference price. For instance, in the occasion that an individual is seeking to purchase bread at a grocery store, a small discount of 5% from its original price may not be enough of an economic incentive to elicit a response from the consumer. Conversely, a 95% discount in the original price of bread may alarm the consumer to think there is a latent flaw within the bread (expired, damaged, etc.) causing the consumer to also not purchase the bread. Finally, a medium discount of 45% may yield the most definite response as the consumer will likely perceive the bread to be an optimal deal between the discount in price and overall quality. Similarly, as producers are considering their three contract options, they may believe that a lower variation in payment levels may not be enough of an incentive to act upon, while a higher variation may possess a detrimental flaw within its structure – thus leading them to conclude that a middle variation level has the highest potential to benefit their farm operation.

The above example indicates there may be an interaction effect between payment level and payment variance. We examined the presence of such interaction terms as a robustness check. Interaction terms refer to variables that are multiplied together to capture the combined interaction between them on the outcome variable. The specific measurement of interest included the interactions between payment level and payment variance level. When included in the mixed logit model, mean coefficient estimates on the interaction term between payment level and payment variance levels of 10%, 30% and 50% were found not to be significantly different from zero. These results can be found in Table 4.4.

Table 4. 7 Mixed Logit Model Results with Price and Variance Dummy Interactions

	Coefficient	Asymptotic Standard Error	P-Value for Z-Stat	
Mean of Random Parameters				
Constant	-3.12***	0.75	0.00	
Payment	0.01	0.01	0.19	
Variance	--	--	--	
C10[a]	-0.39	0.86	0.65	
C30[a]	-0.85	1.05	0.41	
C50[a]	-1.4	1.36	0.30	
Graze	1.5***	0.36	0.00	
Length	-0.53	0.32	0.1	
PC10[b]	-0.003	0.014	0.82	
PC30[b]	0.02	0.015	0.19	
PC50[b]	0.01	0.017	0.54	
Standard Deviation of Random Parameters				
Constant	1.61***	0.54	0.00	
Payment	0.02**	0.01	0.05	
Variance	--	--	--	
C10[a]	0.31	1.88	0.87	
C30[a]	0.59	2.09	0.77	
C50[a]	0.85	2.37	0.72	
Graze	0.58	1.08	0.59	
Length	0.16	1.24	0.89	
PC10[b]	0.05**	0.02	0.02	
PC30[b]	0.02*	0.01	0.07	
PC50[b]	0.05**	0.02	0.03	
Log Likelihood				-452.62
McFadden Pseudo R-Squared				0.26
Observations (*N*)				884

[a] [Definition: C10, C30, C50 – The price variations of 10%, 30% and 50% from a guaranteed price, respectively]
[b] [Definition: PC10, PC30, PC50 – The coefficients on the price and 10%, 30% and 50% variance dummy interactions, respectively]
***Notes*: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels of significance, respectively.**

Chapter 5 - Discussion and Conclusions

The purpose of this thesis was to quantify the willingness of farmers and ranchers within the Southern Great Plains to enter into agricultural carbon contracts on marginal grasslands, including as an alternative to the Conservation Reserve Program. A discrete choice experiment was conducted as part of a mail-in survey to agricultural producers in Kansas, Colorado, Oklahoma, Texas, and New Mexico to examine this. The experiment developed a hypothetical contractual scenario to assess the willingness of agricultural producers to enter into a carbon credit grassland contract on their marginal grasslands or as an alternative to a CRP contract. Survey participants were asked to consider three independent choice scenarios with differing contract attributes. All choice scenarios were binary for incentive compatibility and a cheap talk and consequentiality script were included to reduce hypothetical bias. Contract options were composed of four attributes: (1) average annual payment per acre, (2) year-to-year payment variation, (3) ability to graze livestock, and (4) the length of the contract.

The findings of this paper indicate that producers in the Southern Great Plains strongly value the ability to retain the right to graze livestock on their marginal cropland when considering a grassland carbon credit contract. Largely, this is likely a result of their efforts to maximize returns and cash flow opportunities, as well as diversify risk within their operation. Secondly, payment levels are another important factor that shapes producers' considerations of entering into a contract.

Interestingly, the values of the willingness to accept (WTA) for the option to graze livestock, -$47.41 and -$48.52, are remarkably similar to the USDA-estimated county base values (CBVs) for Pasture, Rangeland and Forage (PRF) Insurance in the study region. CBVs, a publicly reported measure of the average economic value from grazing livestock on one acre of pasture or rangeland, are used as an estimate of expected revenue in setting PRF guarantees (USDA Risk Management Agency 2024). Selected CBVs from the study region can be found in Table A3 in the appendix. CBVs for Kansas in 2024 range from $52.30 in Brown County to $27.00 in Haskell County. Furthermore, recall that the willingness to accept the option to graze livestock within the contract is the amount of money the producer would be willing to forego to retain the ability to graze livestock while being enrolled in the grassland carbon contract.

While not directly statistically significant, producers preferred a shorter, 10-year contract, to a longer, 20-year contract. Year-to-year payment variation was not statistically significant but did provide some interesting insights. The results of the random parameter mixed logit model with dummy variables used for the payment variable levels indicated that producers had to be paid $28.07 per acre more if payment variance was 10% and $24.22 if payment variance was 50% relative to a guaranteed payment. However, a 30% variance level in payment relative to a guaranteed payment provided a “sweet spot” and was of higher interest to producers, where they would be willing to receive a lower payment of $9.68 per acre. This finding suggests producers have a threshold in which they are willing to bear risk for a grassland carbon credit contract.

The results of this research may be of primary interest to policymakers and agribusinesses interested in venturing into the grasslands carbon credit marketplace. Regarding carbon-interested agribusinesses, this study aids in understanding which attributes of a carbon credit contract producers value – and, perhaps more insightful, to what degree producers value these contract attributes. The paper analyzes producers’ valuation of livestock grazing, general risk assessment, sentiment towards payment levels, and preferred length of contracts. All these listed contract attributes should be considered when drafting a potential contract with producers. For instance, although the willingness to accept coefficients for payment levels and contract length were not statistically significant – they showed large variations in payment levels across producers and were high enough in magnitude to have economic significance worth noting from the perspective of an agribusiness. The results from our study indicate that the ability to graze livestock in particular is of importance to producers. Furthermore, agribusinesses may have limited financial budgets for a novel carbon program and having a study such as this could drastically expedite their work and save money within their research and development processes.

Next, policymakers at both the state and federal level could find this research beneficial as they work to formulate policies that develop the infrastructure to further implement a carbon credit marketplace within agriculture. In finding that producers highly value payment levels when deciding to enter into a contract, policymakers may find it beneficial to consider subsidies to help entice producers to enter into initial contracts in a new market and provide a guaranteed base-payment level for producers. Additionally, this potential subsidy may help policymakers to create further transparency for price revelation within the voluntary carbon market– in order to create extended legitimacy and boost confidence in the marketplace. In analyzing producer risk tolerance in year-to-year payment variation, policymakers may find it advantageous to reference this research in establishing a potential insurance program to help producers from downward price trends within the carbon marketplace. Finally, this study could help policymakers to develop continued pilot climate programs that work to meet the everchanging needs of agricultural producers – similar to the Partnership for Climate-Smart Commodities program (United States Department of Agriculture 2022).

Considerable limitations to this research project should be considered when discussing the results of this study. First, the size of the sample was constrained by the geographic scope of the producers and size of the survey sample obtained. Grasslands in the United States, extend beyond the states of Kansas, Oklahoma, Texas, Colorado and New Mexico - and producers within other regions could potentially elicit significant responses from those within this study's sample. Secondly, continued anti-renewable energy initiatives have been active throughout this region amongst agricultural producers and rural residents (Weise and Bhat 2025). It is possible that sentiments such as these could have affected the results of this study. Perhaps this limitation could be overcome by having respondents answer true / false questions on renewable energy to assess how accurate their knowledge of clean energy is.

There is room for continued future research as a similar survey could be replicated in other regions of the United States. Namely, the Northern Great Plains of Montana, Wyoming, North Dakota, South Dakota and Nebraska would provide valuable information about the willingness to adopt grassland carbon credit contracts in this region. Additionally, as the voluntary carbon market becomes more established, it would be worth researching how producer's valuation of the contract's attributes evolves. Finally, in this survey producers were not directly asked why they may have rejected the grassland carbon credit contract when selecting "No" to the contract due to space limitations. In total, there were 17 responses that marked "No" for each contract option. It would be advantageous to understand the various reasons that elicit a rejection of the contract on behalf of a producer.

The broader implications of this study include the general assessment of climate change sentiment in the Southern Great Plains region of the United States. This could prove to be useful for a multitude of reasons. Additionally, in the occurrence that this region would desire to establish a formal, top-down carbon market similar to the Chicago Climate Exchange, the information in this study would be of value. This work also advances research into producer's valuation of novel markets within agriculture – an occurrence that is likely to be repeated with time.

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Appendix

Table A1 Base Conditional Logit Model

	Coefficient	SE	T-Stat	P-Value
Const.	***-2.36	0.24	-9.83	0.000
Payment	***0.015	0.002	6.29	0.000
Variance	0.001	0.003	0.31	0.76
Graze	***0.83	0.16	5.18	0.000
Length	-0.14	0.15	-0.88	0.37
WTA				
Variance	-0.07	0.23	-0.31	0.76
Graze	***-55.38	13.62	-4.07	0.000
Length	9.19	10.55	0.87	0.38

***Notes*: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels of significance, respectively.**

Table A2 Base Conditional Logit Model with Payment Variance Levels Modeled as Dummy Variables

	Coefficient	SE	T-Stat	P-Value
Const.	***-2.41	0.26	-9.19	0.00
Payment	***0.015	0.002	6.28	0.00
Variance	--	--	--	--
C10[a]	-0.07	0.23	-0.3	0.76
C30[a]	0.26	0.22	1.18	0.24
C50[a]	0.05	0.23	0.21	0.83
Graze	***0.83	0.16	5.17	0.00
Length	-0.14	0.15	-0.88	0.38
WTA				
Variance	--	--	--	--
C10[a]	4.56	15.29	0.29	0.76
C30[a]	-17.18	14.99	-1.15	0.25
C50[a]	-3.18	15.14	-0.21	0.83
Graze	***-54.96	13.54	-4.06	0.00
Length	9.11	10.49	0.87	0.38

[a] Definition: C10, C30, C50 – The price variations of 10%, 30% and 50% from a guaranteed price, respectively.

***Notes*: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels of significance, respectively.**

Table A3 Ranges of County Base Revenue Values for Pasture, Rangeland and Forage Acreage

	Max.	Min.
Kansas	$52.30	$27.00
Colorado	$13.50	$9.80
Oklahoma	$37.40	$19.10
New Mexico	$11.50	$7.00
Texas	$27.20	$8.50

Source: (USDA Risk Management Agency 2024)