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Agriculture and the Environment: Exploring the Adoption of Sustainable Farming Practices in the US

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Résumé

Cette étude vise à examiner l'impact de la sécheresse et des programmes d'aide financière gouvernementaux sur l'adoption de pratiques agricoles durables aux États-Unis. Plus précisément, l'étude analyse l'adoption du travail de conservation du sol, des cultures de couverture, des systèmes de drainage, du pâturage tournant, des systèmes de cultures intercalaires, et du sylvopastoralisme en utilisant des données du Recensement de l'Agriculture du Département de l'Agriculture des États-Unis (USDA). Les résultats montrent que les deux facteurs ont un impact significatif sur l'adoption de pratiques durables, avec certaines pratiques étant moins réalisables en période d'extrême sécheresse. De plus, des paiements moyens élevés provenant des programmes fédéraux de conservation encouragent l'adoption de pratiques de restauration du sol, tandis que des paiements moyens élevés provenant d'autres programmes fédéraux, principalement des programmes d'aide en cas de catastrophe, ont découragé l'adoption de pratiques réduisant la productivité ou qui génèrent des bénéfices à long terme.

Mots clés : pratiques agricoles durables, adoption, sécheresse, aide financière gouvernementale, Moindres Carrés Ordinaires (MCO), régression linéaire, données de panel.

Méthodes de recherche : L'étude utilise un modèle de régression linéaire pour analyser l'impact des conditions de sécheresse et des programmes d'aide financière gouvernementaux sur l'adoption de pratiques agricoles durables. D'autres variables de contrôle incluses dans le modèle sont l'intensité de production agricole, le type de production agricole, le régime foncier, le modèle d'entreprise, la taille de l'exploitation, l'utilisation de l'irrigation, l'année et le niveau d'adoption de la pratique auparavant. Les coefficients ont été estimés à l'aide de la méthode des moindres carrés ordinaires (MCO).

Abstract

This study aims to examine the impact of drought and government financial aid programs on the adoption of sustainable agricultural practices in the United States. Specifically, the study analyzes the adoption of conservational tillage, cover crops, drainage systems, rotational grazing, alley cropping, and silvopasture using data from the United States Department of Agriculture (USDA)'s Census of Agriculture. The results show that both factors have a significant impact on the adoption of sustainable practices, with some practices being less feasible during severe drought conditions. Additionally, higher average payments from federal conservation programs encouraged the adoption of soil-restoring practices, while higher payments from other federal programs, mainly disaster aid programs, discouraged the adoption of productivity-reducing or long-term benefit-generating practices.

Keywords: sustainable agricultural practices, adoption, drought, government financial aid, pooled Ordinary Least Squares (OLS), linear regression model, panel data.

Research methods: The study uses a linear regression model to analyze drought conditions and government financial aid programs' impact on the adoption of sustainable agricultural practices. Other control variables included in the model are farm production intensity, production type, farmland ownership tenure, farm business model, farm size, irrigation usage, year, and past adoption level of the practice. The coefficients were estimated using the pooled Ordinary Least Squares (OLS) method.

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List of abbreviations

Abbreviation	Description
APGVT_FED	average payments per operation from any other federal government programs
APGVT_FEDC	average payment per operation received from federal government conservation programs
APGVT_LOCAL	average payments received per operation from local government programs
CPI	consumer price index
MRG	managed rotational grazing
PC.CTCTN	percentage of farms having practiced minimum tillage on their cropland
PC.ADN	percentage of farms using artificial ditches on their operation
PC.BEEF	percentage of beef cattle ranching and farms in the county
PC.CAN	percentage of farms having used alley cropping or silvopasture on their operation
PC.CATTLE	percentage of cattle feedlots farms in the county
PC.CCN	percentage of farms having used cover crops on their cropland
PC.CORP_F	percentage of family corporate farms in the county
PC.CORP_NF	percentage of non-family corporate farms in the county
PC.CTNTN	percentage of farms having practiced no-till on their cropland
PC.D0	percentage of area county with abnormally dry conditions
PC.D1	percentage of area county in moderate drought
PC.D2	percentage of area county in severe drought
PC.D3	percentage of area county in extreme drought
PC.D4	percentage of area county in exceptional drought
PC.DTN	percentage of farms using tile drainage on their operation
PC.FAM	percentage of family and individual farms in the county
PC.FRUIT	percentage of fruit and tree nut farms in the county
PC.GN	percentage of farms having used rotational grazing on their pastureland
PC.GRAIN	percentage of oilseed and grain farms in the county
PC.INST	percentage of institution, research, reservation, and other farms in the county
PC.LA	percentage of large acreage farms in the county
PC.LS	percentage of large farms in the county
PC.MA	percentage of micro acreage farms in the county
PC.MIDA	percentage of medium acreage farms in the county
PC.MIDS	percentage of midsize farms in the county
PC.MILK	percentage of milking dairy cattle operations in the county
PC.MS	percentage of micro-farms in the county
PC.ND	percentage of area county with no drought
PC.OWN	percentage of farms with full ownership of farmland in the county
PC.PARTNER	percentage of partnership farms in the county
PC.SA	percentage of small acreage farms in the county
PC.SHEEP	percentage of sheep and goat farms in the county
PC.SS	percentage of small farms in the county
PC.VEG	percentage of vegetable and melon farms in the county
TCROP	total value of crops produced in the year
TPD	total amount produced in the year

List of acronyms

Acronym	Full Form
ARMS	Agricultural Resource Management Survey
CBO	Congressional Budget Office
CFRA	Center for Rural Affairs
CHR & R	County Health Rankings & Roadmaps
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSP	Conservation Security Program
EESI	Environmental and Energy Study Institute
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FSA	Farm Service Agency
FWP	Farmable Wetlands Program
GLCI	Grazing Lands Conservation Initiative
GRP	Grasslands Reserve Program
NAC	National Agroforestry Center
NAICS	North American Industry Classification System
NAP	Non-insured Crop Disaster Assistance Program
NASS	National Agricultural Statistics Service
NCEI	National Centers for Environmental Information
NDMC	National Drought Mitigation Center
NIDIS	National Integrated Drought Information System
NIFA	National Institute of Food and Agriculture
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NSAC	National Sustainable Agriculture Coalition
OLS	Ordinary Least Squares
SARE	Sustainable Agriculture Research and Education
US	United States
USD	United States Dollar
USDA	United States Department of Agriculture
USDM	U.S. Drought Monitor
WRP	Wetlands Reserve Program

Preface

The primary objective of this research is to examine how drought conditions and government financial aid programs affect the adoption of sustainable agricultural practices in the United States. The study focuses on six sustainable practices: conventional tillage, cover crops, drainage systems, rotational grazing, alley cropping, and silvopasture. To the best of my knowledge, there has been no prior study that has used the United States Department of Agriculture's (USDA) Census of Agriculture data to examine the adoption of sustainable agricultural practices. By investigating the effects of drought conditions and government aid programs, this study aims to offer a more thorough comprehension of how these variables impact the adoption of sustainable agricultural practices. Additionally, our study attempts to fill the gap identified in Ding, Schoengold & Tadesse's (2009) research by exploring the relationship between government disaster payments and the adoption of sustainable practices.

The linear regression model is estimated using the pooled Ordinary Least Squares (OLS) method for practices observed more than once. This assumes that the unobserved individual-specific effects are not correlated with the observed explanatory variables over time. However, the findings of this study are limited due to the use of county-level data and other variables averaged at the state level. Furthermore, the study only establishes a correlation between drought conditions, government program payments, and conservation practice adoption rates but does not establish causality.

The Census of Agriculture data used in this thesis was obtained from the United States Department of Agriculture (USDA) and is publicly available. However, this study was conducted independently and not endorsed or certified by the USDA.

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Introduction

As climate change increases extreme weather events and water scarcity, crop and livestock production face rising risks and costs. To address drought problems in the short term, farmers have several options, including crop insurance, efficient irrigation systems, and drought-tolerant seeds. One long-term solution is to adopt sustainable agricultural practices such as conservation tillage and cover crops scientifically proven to enhance soil moisture-holding capacity while being economically viable. Despite government efforts to encourage adoption, rates still fall short. By investing in sustainable practices, the government can reduce the rising cost of disaster assistance programs (Wallander, Marshall, & Aillery, 2017; Klimas & Weersink, 2006; Bogdan and Kulshreshtha, 2021).

The aim of this study is to analyze the impact of drought conditions and government financial aid programs on the adoption of sustainable agricultural practices. Specifically, the study aims to investigate the adoption of the following sustainable practices: conservational tillage, cover crops, drainage systems, rotational grazing, alley cropping, and silvopasture. The analysis uses data from the United States Department of Agriculture's (USDA) Census of Agriculture, consisting of observations at the county and state levels. Due to confidentiality restrictions, farm-level observations and some specific county-level information were not available. To the best of my knowledge, no earlier study has used this census data to analyze the adoption of sustainable agricultural practices. The census is conducted once every five years and has been collecting data on some of these practices since 2007. Thus, the use of rotational grazing is observed in three periods, while alley cropping and silvopasture are observed in two periods, and conservational tillage, cover crops, and drainage systems are observed in one period.

Most previous studies have focused on adoption levels in specific regions and specific types of farming during a single period, which may not fully capture the dynamic nature of adoption behaviour. Some of the previous studies also relied on survey data, most survey respondents are generally early adopters which can bias the results. With the recent frequent occurrence of extreme weather events, there has been increased awareness of the benefits of sustainable practices in recent years, leading to more programs and incentives for farms to encourage adoption. By examining the impact of both drought and government assistance programs, this study aims to provide a more comprehensive understanding of how these factors influence the adoption of sustainable agricultural practices. Our study also tries to answer how government disaster payments can affect the adoption of sustainable practices which is a gap identified in Ding, Schoengold & Tadesse (2009).

Overall, our analysis demonstrates that both drought conditions and government program payments can significantly impact the adoption of conservational tillage, cover crops, drainage systems, rotational grazing, alley cropping, and silvopasture. The results suggest that some practices may be less feasible during periods of severe drought, as evidenced by lower adoption rates in these regions. However, alley cropping and silvopasture were attractive options for farmers facing production loss since they can supply additional revenue streams during drought conditions. Higher payments from federal conservation programs were found to encourage the adoption of soil-restoring practices, such as conservation tillage and rotational grazing. Conversely, higher payments from other federal programs, mainly disaster aid programs, discouraged the adoption of productivity-reducing or long-term benefit-generating practices. Our study employs the Ordinary Least Squares (OLS) approach, which assumes the absence of multicollinearity and omitted variables.

The research thesis is organized into several sections. The first part outlines the sustainable practices studied, as well as drought conditions, policy changes, and federal financial aid programs from 2007 to 2017. The second part provides an overview of previous studies related to the adoption of sustainable agricultural practices and the impact of various economic and demographic factors, including drought and government aid programs, on adoption decisions. In the first chapter, we introduce and explain the data used in this analysis. The second chapter presents the empirical methodology, and main variables of interest such as drought level, local and federal government payments, farm production, farm size, location, and farm business model. The third chapter presents the results and discusses the findings. Finally, the article concludes by summarizing the main findings, discussing the limitations of the study, and providing recommendations for future research in this area.

Sustainable Agricultural Practices

Rotational grazing and silvopasture are practices used by livestock farmers while alley cropping, conservation tillage, cover crops, tile and artificial ditch drainage are practices mainly used on crop farms.

Conservation (Minimum or No) Tillage Practices

Conservation tillage is a term used for both minimum (or reduced) and no (or zero) tillage. The minimum tillage method leaves more than 30% of the previous crop's residue on the soil surface by not completely turning over the topsoil. Zero-tillage adopters do not turn over their soil after harvest, leaving all the previous crop's residue.

Both practices require buying new equipment and added labour and chemical inputs. The on-farm benefits of using these practices are apparent in the short and long term. In the short term, they reduce the labour used for tilling soil. There is often a cost increase due to the rise in chemical inputs used, but studies have shown that no-tillage farming uses less energy (in the form of diesel fuel and gasoline) compared to conventional tillage, despite requiring more fertilizer and pesticide application. Machinery used for tilling the soil accounts for approximately 11% of total direct farm energy use in conventional tillage, while the energy used for the additional application of fertilizer and pesticides in no-till practices only accounts for 0.7% and 0.8%, respectively. In the long run, conservation tillage practices improving profit margins by increasing yields, increase soil moisture, conserve topsoil, and reduce the effects of wind and water erosion on soil health. These allow the soil to sequester more carbon and increase soil organic matter.

Both practices eliminate the need for summer fallow, leaving an empty field in between crop production to preserve soil moisture every few years, which would be essential in dryland areas where there is not enough precipitation during the crop growing season to produce a crop, as it allows water to be stored in the soil. Additionally, fields that rely on irrigation systems for moisture may not require the use of both practices. Some farms opt not to adopt conservation tillage since some crops, such as sorghum, perform better under conventional tillage (Davey, 2006; Nadella, Deaton, Lawley & Weersink, 2014; Deaton, Lawley & Nadella, 2018; Uri, 1998).

Cover crops

Cover crops are grasses or legumes that serve as soil cover in between cash crop planting. They can be harvested for forage, human consumption, or integrated into the soil. They are either undersown in a field where the main crops are growing or planted after the main crop is harvested. Cover crops help improve soil health, prevent soil erosion, and reduce nitrogen leaching. Legume cover crops can fix nitrogen more effectively in the soil, which increases the productivity of the following crop that will be seeded. The total acreage of cover crops has increased almost five times from 2008 to 2013. In 2011, cover crops were used on 1.7 percent of cropland in the United States, this rate varied greatly by region (Shirriff, Kc & Berg, 2022; Nadella et al., 2014; Hindsley, 2002; Environmental and Energy Study Institute [EESI], 2017).

The median cost of cover crops in 2012 was 37 USD per acre. Cover crops can take anywhere from one to five years to generate a positive net profit, depending on the reason they are being used. For instance, if cover crops are used for grazing or to combat herbicide-resistant weeds during drought conditions, they can generate a net positive return or break even in the first year. If they are used to facilitate the transition from conventional tillage to no-till, they can also generate a positive net return or break even in the first year. When cover crops are used to address soil compaction or low soil fertility, which are both issues that can limit yield, they can generate a positive net return or break even by the second year. Finally, if cover crops are used for no specific purpose during regular rainfall seasons, they will take an average of three years to break even and up to five years to yield a profit (Sustainable Agriculture Research and Education [SARE], 2019). Given that cover crops generate social benefits and can take a few years to yield a positive net return, it is worth considering subsidizing cover crop seeds for a short period. Motta, Wayne Reeves, Burmester & Feng (2007) and Claassen, Bowman, McFadden, Smith & Wallander (2018) found farms that employ conservation tillage, cover cropping, and crop rotation for several years can enhance soil health and maximize crop yields.

Drainage systems

Agricultural drainage removes excess water from the soil and can be done through surface or subsurface methods. Artificial ditch drainage is surface drainage while tile drainage is subsurface that uses materials like clay, concrete, or plastic pipes. Drainage systems were considered sustainable agricultural practices because of their potential to improve soil health and increase profitability by reducing labour and fuel costs or creating opportunities to grow high-value crops that might not be viable in wet conditions.

However, drainage systems can create nutrient run-offs and increased streamflow that can cause flooding if not installed properly in some cases. While some still consider them sustainable, the USDA has not provided financial assistance for drainage systems since 2000. Compared to other practices, farmland owners do not need to reinstall tile drainage or create ditches every year. These systems can remain functional for many years with small maintenance (Fleming and Fraser, 2001; USDA Natural Resources Conservation Service [NRCS], 2001; Oborne & Neudoerffer, 2010).

Rotational grazing

Rotational grazing is also known as controlled grazing, management-intensive grazing, or managed rotational grazing (MRG). Rotational grazing involves the frequent movement of livestock through one part of the farm's total pastureland called a paddock. This frequent movement allows plants to rest and regrow to grazing height while livestock grazes another paddock. In most states, lands are not grazed between November and April, except in the Delta and Southeast regions. The length of the grazing period and rest period are dependent on land and forage yield. Livestock commonly used for rotational grazing include cattle, sheep, and goats, among others. This practice helps farms adapt to extreme weather events, such as drought, increased temperatures, and extreme precipitation. During drought, the additional plant residue cover from MRG allows for faster recovery of vegetation once moisture returns. Ranchers can generally expect increased land health with rotational grazing systems but not really an increase in profitability.

The cost and societal benefit of using this practice is limited but the USDA provide cost-share programs to assist farmers in purchasing the necessary materials for fencing. There is also non-financial aid to ranchers who do not apply for financial assistance, which includes sharing research findings and providing technical support for prescribed grazing (USDA NRCS, 2009; USDA Northwest Climate Hub, 0000; USDA NRCS, 2019; Becker, Kreuter, Atkinson & Teague, 2017).

In 2007, 13% of dairy producers on average used MRG across Maryland, Pennsylvania, New York, and Vermont. This rate varied across the regions due to differences in forage productivity (Winsten, Kerchner, Richardson, Lichau & Hyman, 2010). The adoption rate of this practice among cattle operations in the US decreased from 40% in 2007 to 32% in 2012, and to 30% in 2017 (Whitt and Wallander, 2022).

Alley cropping and silvopasture practices

Alley cropping is a sustainable agricultural practice that involves planting annual or perennial crops between tree rows. The perennial crop provides continuous annual income, while the tree matures. This practice helps farmers diversify their revenue streams. As a result, it reduces risks associated with lower yields from primary crops. It also helps retain soil moisture by reducing water loss through evaporation, thanks to the cover crop that is grown between the trees or shrubs (USDA National Agroforestry Center [NAC], n.d.).

Silvopasture is a sustainable agroforestry practice that involves integrating grazing forage production in between tree production. This system can provide annual income through the grazing of animals while the tree crop matures. Some trees can also provide additional feed such as acorns and honey locust pods. Grazing can be seen as an additional revenue stream while the tree crop matures. This practice helps increase wildlife diversity and improve water quality from fewer run-offs. Livestock commonly used for grazing in this practice include cattle, sheep, and goats. Rotational grazing could be a good addition to this practice, it would minimize the young tree stems damage from the weight of livestock that grazes the silvopasture (USDA NAC, n.d.).

Both practices have initial upfront costs, but tangible benefits become evident in the first year.

Finally, the conservation practices mentioned above yield multiple benefits that improve the surrounding environment of farms. For example, they reduce soil erosion and promote long-term carbon sequestration. Additionally, the adoption of conservation practices often demands substantial initial investments, which can discourage farmers from implementing them. The USDA offers financial aid programs to overcome these hurdles. The payments compensate farmers for the social benefits, help them cover the initial investment costs and help them recognize the long-term benefits.

Drought from 2012 to 2017 in the US

The US experienced an unprecedented drought in 2012 which was the worst drought since 1988. The northern plains and heartland regions had really hot temperatures and lacked rain during the growing season. This severely reduced corn, soybeans, and winter wheat yields. In 2012, about 20% of the country faced more than moderate drought and 35% was under severe drought. Only 3.8% of the country was in more than moderate drought in 2017. That year had both wet and dry extremes in various parts of the country and during different months. The first five months of the year were abnormally wet, filling up water reservoirs, while the rest of the year was abnormally dry, leading to large wildfires due to below-normal precipitation and elevated temperatures. The lack of spring precipitation led to lower forage production for grazing, forcing ranchers to sell their cattle earlier than usual. Producers also harvested grain crops as forage to feed their livestock. The US Northern Plains were severely impacted, particularly during the critical cropping months, resulting in $2.6 billion in agricultural losses. In 2007, temperatures increased, but not to the same extent as in 2012. Although pasture conditions were poor in July 2007 due to dry weather, they improved in most counties after September (Folger, 2017; NOAA National Centers for Environmental Information [NCEI], 2013, 2009; NOAA National Integrated Drought Information System [NIDIS], 2019).

Policy Changes from 2007 to 2017 in the US

The Farm Bills[1] dictate federal regulations that are enforced by agencies like the USDA Natural Resources Conservation Service (NRCS) and USDA Environmental Protection Agency (EPA) at both the national, state, and county levels. These regulations set overall policies, programs, and budgets.

The 2002 Farm Bill increased funding for the Environmental Quality Incentives Program (EQIP). It also created the Conservation Security Program (CSP) which paid producers to adopt or maintain specific conservation practices and the Grazing Lands Conservation Initiative (GLCI) program which provided funding, technical assistance, peer-to-peer learning, or training to implement grazing systems. The GLCI was cut in the 2008 Farm Bill. The 2008 Farm Bill added more funding for the conservation programs such as CSP, EQIP, Grasslands Reserve Program (GRP), and Wetlands Reserve Program (WRP). The 2014 Farm Bill included increased funding for programs that contained agroforestry such as the EQIP, CSP, and Conservation Reserve Program (CRP). The 2018 Farm Bill amended some conservation programs. In 2021, a new program called the Pandemic Cover Crop Program was introduced, offering insurance premium discounts for the use of cover crops. The definition of cover crops was revised so that its adoption does not impact a farm's insurance coverage. All of these federal conservation programs remain accessible to all farms across the US, but certain programs vary to cater to local conditions and needs. For instance, the funding allocated to the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) is subject to regional differences (USDA NAC, 2016; Harris, Lubben, Novak, and Sanders, 2008; USDA Economic Research Service [ERS], 2002; Westcott, Young, and Price, 2002; Harris, 2023; USDA Economic Research

[1] 2002, 2008, 2014, and 2018 Farm Bill acts were active in 2007, 2012, 2017, and 2021, respectively.

Service [ERS], 2023; USDA Economic Research Service [ERS], 2023; Congressional Research Service, 2023).

Government Financial and Technical Assistance Programs Offered Across the US

Federal government programs cover a wide range of activities, including protecting drinking water resources, restoring forests and wetlands, and improving the environment. The USDA offers several land retirements programs, including CRP, the Conservation Reserve Enhancement Program (CREP), WRP, and the Farmable Wetlands Program (FWP). Furthermore, the USDA provides financial assistance for the adoption of conservation practices through programs such as EQIP and CSP. In case of a disaster, the Non-insured Crop Disaster Assistance Program (NAP) aids non-insured farms. Producers can enroll at any time throughout the year in the conservation programs. However, for programs like EQIP, CSP, and NAP, participants are required to request funding on a yearly basis by a specific deadline. Participants in these programs receive payments to cover costs that have been or will be incurred in the given year. All of these programs operate within budget limitations specified in the Farm Bill.

The CRP has been in existence since 1985. Under this program, landowners can voluntarily retire highly erodible areas in exchange for rental payments. They must commit to leaving the land out of production for a period of 10 to 15 years. The enrollment process for the CRP involves two main mechanisms: the general signup and the first-come, first-served system in certain regions only. During the general signup process, all applicants are assigned an Environmental Benefits Index (EBI) score, which indicates the level of environmental challenges present on their land. Additionally, candidates submit bids for the rental price they would like to receive in exchange for retiring their land. The amounts are capped around the average cash rent of farmland in the county. These mechanisms ensure that priority is given to areas facing higher environmental challenges. Apart from the rental payments, they can also receive additional payments to implement certain conservation practices, such as planting native grasses and trees or vegetative cover crops and not tilling the land (Ferris and Siikamäki, 2009; Cramton, Hellerstein, Higgins, Iovanna, López-Vargas, & Wallander, 2021).

Land enrolled under the CRP program could be approved for haying or grazing in cases of emergencies when forage production dropped by at least 40 percent. The 2014 Farm Bill established the CRP Grasslands program, which offers farmers annual payments of up to 75 percent of their land's grazing value. Through this program, farms can practice common grazing techniques such as rotational grazing on their enrolled land. Additionally, the program provides cost-sharing assistance for necessary equipment, such as up to 50 percent coverage available for cross-fencing equipment. While most of the land under CRP is temporarily conserved to grasslands, there is an alternative option that is less utilized which is to convert the cropland to permanent forest land that can be used for silvopasture. This approach is potentially more sustainable (Davis and Gordon, 2020).

The CREP is a more intensive version of the CRP that provides higher rental payments and additional eligible conservation practices for lands that are at a higher risk of environmental degradation (USDA, 2015; Commodity Credit Corporation, 2003; Stroman & Kreuter, 2016; USDA Farm Service Agency [FSA]; n. d.; Whitt and Wallander, 2022).

The WRP, renamed Wetland Reserve Easements Program, was first introduced in the 1990 Farm Bill. This voluntary program provides financial and technical assistance to private landowners for converting marginal agricultural land into wildlife wetlands habitats and maintaining wetland buffers. Participants can practice rotational grazing on enrolled land after submitting a compatible use agreement. Another wetland restoration program is the FWP. Under this, landowners can voluntarily retire farmed wetlands and receive assistance to plant vegetative cover. Plant cover includes partially submerged plants or specific trees (USDA FSA, n.d.; USDA FSA, 2018; USDA FSA, 2013).

In both CRP and WRP conservation programs, there is a restriction that limits land enrollment to a maximum of 25 percent of the total farmable land in any given county.

The EQIP provides financial support for the implementation of new conservation practices, which cover less than 75% of installation costs. The coverage varies by region. Under EQIP, payments are made after the costs have been incurred: participants proposed conservation practices implementation plans which are reviewed and approved for reimbursement for one-year. In some cases, advance payment options are available where participants receive payment before costs are incurred, but they must ensure that the funded project is implemented within 90 days. This program offers grants to help farmers adopt conservation practices, such as cover crops, conservation tillage, rotational grazing, alley cropping and silvopasture (Center for Rural Affairs [CFRA], n. d.).

For farms and ranches already using conservation practices, such as cover crops, conservation tillage, alley cropping and silvopasture, the CSP offers payments to implement improved versions of the practices. CSP contracts span a duration of five years. Participants receive yearly payments for maintaining existing integrated conservation practices or for adding additional practices to their operations.

The NAP provides financial assistance to uninsurable crop producers affected by natural disasters, such as low yields, loss of inventory, or prevented planting. Loss compensations are capped for each applicant. It covers certain uninsurable cover crops, such as alfalfa, alfalfa mixture, native grass rangeland, and other forage loss that are intended for grazing. (National Sustainable Agriculture Coalition [NSAC], 2022, USDA FSA, 2020).

Literature review

This section presents a review of US studies (Gould, Saupe & Klemme, 1989; Soule, Tegene & Wiebe, 2000; Hindsley, 2002; Lambert, Sullivan, Claassen & Foreman, 2007; Ding, Schoengold & Tadesse, 2009) and Canadian studies (Davey, 2006; Nadella et al, 2014) on the adoption of sustainable practices. All of the studies were limited to specific regions or specific farm production in the country. Except for Nadella et al. (2014), which used more recent data, all studies were based on data collected before 2010. The main objective of this review is to identify the control variables that significantly affect the adoption rates and summarize the impact each demographic and economic variable had on adoption in past studies. Most of the reviewed studies used individual-level data collected from farms. Ding, Schoengold & Tadesse (2009) was the only one that used county-level data.

Hindsley (2002) and Nadella et al. (2014) used voluntary surveys that tend to have a higher response rate from early adopters than non-adopters. Early adopters, also known as market innovators, can deal with greater levels of uncertainty due to exposure to various information sources and higher participation in community activities (Padel, 2001; Dunn, Ulrich-Schad, Prokopy, Myers, Watts & Scanlon, 2016).

Finally, after reviewing 40 articles, Baumgart-Getz, Prokopy and Floress (2012) found that the type of variable included in the model affected the results; when age or education were measured as continuous variables, they had a significant and negative impact on adoption, while when they were measured as binary or ordinal variables, they had an insignificantly positive impact.

Farm Location

Some studies control for regulations by including farm location indicators such as regions, provinces, or states. In Hindsley (2002), the Neuse River in North Carolina was divided into three regions, with the lower region experiencing more water quality problems. The results indicated that while the geographical location of farms significantly impacted the adoption of grasses or legumes, it did not significantly affect the adoption of conservation tillage, cover crops, and controlled tile drainage.[2] On the contrary, Soule et al. (2000) found that farms located in North Carolina, South Carolina, and Kentucky were more likely to use conservation tillage than farms in other regions. In a Canadian study, Davey (2006), found that farms located in provinces with a

[2] Farms located in the lower region were significantly less likely to adopt grasses or legumes in rotation compared to those in the higher region.

prominent fuel industry and irrigation use had a significantly lower likelihood of adopting conservation tillage.

Some studies also use location indicators as a proxy for regional climate conditions like temperature, precipitation, soil, and topography. However, most studies prefer to control for these factors using separate indicators that better capture the effect of local environmental issues. Regional drought level indicators can also control for all of these factors. Wallander, Aillery, Hellerstein and Hand (2013) found that farms in higher drought-prone regions were more likely to enroll in CRP. Therefore, land in severe drought is often left out of production and would adopt fewer practices.

Regional Climate

Certain practices, such as conservation tillage, are more effective at warmer temperatures to prevent crops from drying up during droughts. However, farms with cooler soil or weather may not adopt conservation tillage as it can reduce soil temperature and adversely affect production. Uri (1998) and Soule et al. (2000) found that an increase in temperature did not significantly affect the probability of adopting conservation tillage. In contrast, Davey (2006) found that higher maximum temperatures in certain months of the growing season significantly increased the probability of adopting conservation tillage.

Some practices are more effective in low-precipitation weather, such as conservation tillage that increases moisture in the soil. Previous research has controlled for precipitation by including a total precipitation variable for each month of the growing season or the total precipitation in the year. Soule et al. (2000) found that fields with more precipitation did not significantly affect the probability of adopting conservational tillage but were significantly more likely to adopt practices profitable over the medium-term[3] since these practices are used to mitigate excess water issues. On the contrary, Davey (2006) found that the probability of adopting conservation tillage decreased as total precipitation in certain months of the growing season increased. Surprisingly, Uri (1998) found that an increase in the average rainfall increased the likelihood of adopting no-till. Additionally, Ding, Schoengold and Tadesse (2009) found that the adoption of conservation tillage was not significantly impacted by historical wet conditions, whereas dry conditions have a significant positive effect.

Soil productivity can affect the effectiveness of sustainable practices, so studies often include control variables for soil characteristics like erosion and salinity, as well as texture and type (Nadella et al., 2014; Davey, 2006; Uri, 1998). Certain soils, such as brown soil type or sandy soil texture, are prone to water shortage and are well-suited for conservation tillage. Meanwhile, clay soils can have excess moisture, making them ideal

[3] Including contour farming, strip cropping, and grassed waterways.

for cover crops. Most studies (Uri, 1998, Nadella et al., 2014; Ding, Schoengold & Tadesse, 2009) found that farmers with lower productivity soils were significantly more likely to use conservation tillage, but surprisingly Gould et al. (1989) and Davey (2006) did find that farms with higher productivity soils were significantly less likely to adopt minimum tillage technology. At last, in Nadella et al. (2014), soil productivity had no significant effect on cover crop adoption.

The topography of a field, including higher slopes, can worsen issues with water run-off and soil erosion. Conservation tillage can help reduce water run-off erosion problems on hilly land. Uri (1998) and Nadella et al. (2014) found that farms with higher-sloped land were significantly more likely to adopt conservation tillage. This variable was not significant to the adopting cover crops.

Government Financial and Technical Assistance

Farmers often make decisions on farming practices based on profit-maximizing behaviour and financial constraints. However, high adoption costs of sustainable practices may lead to a reluctance to address environmental issues unless there is a direct financial benefit. Studies have shown that farmers who receive government payments have a more positive perception of sustainable practices (Prokopy, Floress, Klotthor-Weinkauf & Baumgart-Getz, 2008; Hindsley, 2002). Financial assistance programs can help alleviate the financial burden of adopting new practices. They can be cost-effective if the benefits extend beyond individual farms and positively impact the broader community. Studies (Hindsley, 2002; Cooper, 2003; Singer, Nusser & Alf, 2007) found that receiving financial assistance increased the likelihood of cover crop usage, conservation tillage, grasses or legumes in rotation, and controlled tile drainage. This variable was insignificant for cover crops in rotation or permanent vegetative cover use (Hindsley, 2002; Dunn et al., 2016).

Sustainable practices can be complex and have negative impacts if not implemented correctly, which can discourage farmers during the learning period (Davey, 2006; Pindyck and Rubinfeld, 2001). Information and professional groups can provide crucial guidance and technical support. Access to quality information, financial capacity, and being connected to local networks have the biggest impact on adoption according to Baumgart-Getz et al. (2012). Lambert et al. (2007) and Davey (2006) found that the probability of adopting conservation tillage increases if extension services or research farms were nearby.

Farms in the US have access to various financial and technical assistance programs, several of which were listed in the introduction section.

Farm Production Type

Sustainable practices adopted by farms depend on their production system, with crop and livestock farms adopting different practices. Cover crops are more useful in between vegetable production cycles or underseeded with grain crops since they fix more nitrogen. Conservation tillage may not be suitable after thick residue-producing crops, and summer fallow or irrigation may be preferable. However, irrigation may not be possible during extreme droughts due to evaporating water reserves (Nadella et al., 2014; Stewart & Thapa, 2016; Davey, 2006).

In Nadella et al. (2014), conservation tillage and cover crop adoption significantly decreased in corn and soybean farms while several other studies including Uri (1998), Soule et al. (2000), Lambert et al. (2007), and Ding, Schoengold and Tadesse (2009) found that grain production significantly increased the probability of adopting conservational tillage.

Soule et al. (2000) found that higher proportions of soybean production decreased the likelihood of cover crop use and adoption of profitable practices over the medium-term. Nadella et al. (2014) also found that higher proportions of winter wheat production significantly increased the probability of cover crop use. Farms with a higher percentage of total farm sales from livestock were significantly more likely to use grasses or legumes in rotation and controlled tile drainage according to Hindsley (2002), but livestock sales were an insignificant determinant for conservation tillage and cover crops adoption.

At last, Davey (2006) found that practicing summer fallow on the operation did not significantly affect the adoption of conservation tillage.

Farmland Tenure

Sustainable practices can have immediate or long-term benefits, but renters tend to adopt fewer long-term practices such as conservation tillage, since they have no incentive to improve the land they do not own, especially if the rental agreement is for the short-term. Profit-maximizing firms will only rent additional acres if it is financially feasible, as long as the marginal revenue generated from the additional land is equal to the marginal cost of operating that land. Thus, renters may already be highly productive, making them unlikely to change production methods.

Lee and Stewart (1983), Soule et al. (2000) and Davey (2006) found that farms with owned plots were less likely to adopt conservational tillage compared to those with some rented farmland. In contrast, Lambert et al. (2007), Nadella (2014) and Deaton et al. (2018) observed that tenure status did not significantly affect the use of conservation tillage.

Deaton et al. (2018) found that producers were less likely to adopt cover crops on rented acres, even the ones who had long-term rental agreements. On the contrary, Nadella (2014) found that the use of cover crops increased by 8.3% on a rented plot than owned plot. However, when the rented variable was divided into long-term or short-term agreements, farms expecting to rent for less than or up to 5 years significantly decreased cover crops use.

Farm Size

Farm size has been used as a measure of capital or economy of scale. Large-scale farms have greater gross farm sales which might mean more capital available to be invested in sustainable practices (Baumgart-Getz et al., 2012). Certain farm equipment comes in one size, they can spread their capital cost and use their equipment more efficiently. Meanwhile, small-scale farms are usually those operated as side businesses or by retirees.

Larger farms were significantly more likely to adopt conservation tillage, as found by Soule et al. (2000), Hindsley (2002), and Nadella et al. (2014). Hindsley (2002) also found that larger farms were significantly more likely to use various sustainable practices, including cover crops in rotation, grasses or legumes in rotation, controlled tile drainage, and permanent vegetative cover. However, Soule et al. (2000) found that larger farms were less likely to adopt practices that did not offer economies of scale advantages.

To account for the possibility of large farms adopting sustainable practices at different rates than smaller farms, Hindsley (2002) included farm size squared as a control variable. He found that farm acres squared had a significant negative effect on the use of conservation tillage, cover crops in rotation, grasses or legumes in rotation, controlled tile drainage, and permanent vegetative cover. The negative coefficient suggests that as the size of the farm increases, the marginal rate of adoption decreases.

In some studies, farm income indicators are used interchangeably with farm size and land tenure since farm income is highly correlated with both. In general, larger farms tend to have greater income, sales, assets, and higher-valued crop production. A higher net income can mean more capital for investing in sustainable practice adoption or increased borrowing capacity. Some studies (Lambert et al., 2007; Davey, 2006) found that farm income or gross farm sales significantly increased the likelihood of adopting conservation tillage. Hindsley (2002) found that higher-income farms had a significant positive effect on the use of cover crops and controlled tile drainage while having an insignificant effect on the adoption of conservation tillage, grasses or legumes in rotation, and permanent vegetative cover.

Corporation Type

Corporate farms, usually larger with more income, can invest in newer technologies for sustainable practices, has more tax incentives for buying new equipment, have limited liability protection during bankruptcy and have fewer capital constraints than family farms. Davey (2006) found that corporate-operated farms were 1.92% more likely to adopt minimum tillage technology compared to farms structured as partnerships or sole proprietorships.

Off-farm residing producers typically have custom operators, spend less time making decisions and have other revenue streams, while those who reside on-farm may attend more local project presentations. Davey (2006) found that a producer residing on the farm is significantly less likely to adopt conservation tillage practices than one residing off-farm. Lambert et al. (2007) found that off-farm income and total household income have no significant effect on a producer's probability of adopting practices including conservation tillage. A custom operator runs several farms at one time, which allows them to learn and apply the latest technology. Uri (1998) found that single owner versus farm partnership has no effect on the decision to adopt conservation tillage.

Time

It typically takes several years from when an innovative technology is first introduced on the market to the point where most producers adopt it. This delay is often due to farms waiting for the technology to improve over time. A previous study found that it takes an average of 9.04 years for the average firm to adopt a technology from the time it becomes available (Doraszelski, 2004; Feder and Umali, 1993). Since all the practices mentioned in this paper first gained attention in the US somewhere between the 1970s and 1990s, factors that were found to be significant in the initial phases of adoption, such as farm size, credit, land tenure, and the operator's level of education or age, maybe insignificant today. In Davey (2006), the coefficients of year dummy variables were positive but not significant.

Other Individual Farmer Characteristic

Previous older studies examined the impact of other factors such as age, education level, and environmental concerns on adoption.

Age was often used in models as a proxy for environmental awareness or risk aversion, but recent studies refute the assumption that younger farmers are more aware of benefits (Ervin and Ervin, 1982; Litchtenber, 2001). Another argument is that older producers nearing retirement may be less inclined to adopt practices with long-term benefits or high risks, but a succession plan or the desire to increase land value before selling the farm can mitigate this barrier. Some studies found that older producers are significantly more likely to adopt conservation tillage or practices profitable over the medium-term (Lapar and Pandey, 1999; Soule et al, 2000), while other studies found that younger and higher-educated producers are less likely to adopt soil practices (Forster and Stem, 1979; Baron, 1981; Ervin, 1981; Norris and Batie, 1987; Feder and Umali, 1993; Jensen, Lambert, Clark, Holt, English, Larson, Yu & Hellwinckel, 2015). Finally, some studies (Westra and Olson, 1997; Uri, 1998) found age not to be significant to conservation tillage adoption.

Education was included in the model as a positive measure of individual capacity. Higher-educated producers can process information quickly, weigh the pros and cons of practices, and identify environmental concerns. Except for Soule et al. (2000), who found that college education significantly increased the probability of adopting conservation tillage, education is usually insignificant since new farming knowledge is usually shared by nearby producers. Thus, it is important to distinguish education from extension training programs designed to share information about specific sustainable agriculture practices.

Individual environmental concerns have been found to have an impact on the adoption of sustainable practices. According to Hindsley (2002), regulation perspectives have a significant effect on adoption. Producers who disagreed with the idea of farms paying higher fines for polluting the Neuse River or believed that people would do the right thing for the river without government regulations had a significantly lower probability of adopting controlled tile drainage, while those with greater knowledge of water pollution were more likely to adopt legumes in rotation and those who perceived poor water quality in their communities were less likely to adopt grasses or legumes in rotation. Furthermore, Gould et al. (1989) and Soule et al. (2000) found that land quality plays a significant role in the adoption of conservation tillage. According to these authors, producers whose lands experienced soil erosion were significantly more likely to adopt practices which reduce soil erosion, such as conservation tillage and medium-term management strategies.

Chapter 1
Data

Data

The main data in this paper is the 2017, 2012 and 2007 Census of Agriculture.[4] These are conducted by the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS). The Census of Agriculture is conducted once every five years. The questionnaires were distributed by mail to farm and ranch operators in December 2017. It collected data for the 2017 calendar year, the same for the 2012 and 2007 censuses. It looks at several farm characteristics including land use and ownership, production practices, income, and expenditures.[5] County and state-level aggregate data are publicly available on the NASS's website.[6] Data is comparable between 2017, 2012 and 2007 for the variable used in this paper. The results of the 2021 Census of Agriculture were not publicly available at the time of this study.

Only information on farm demographics, socio-economic characteristics and rotational grazing practice was available in the 2007 Census of Agriculture. All other practices were only available in the 2012 and 2017 Census of Agriculture.

County and state-level drought intensity indicators from 2007 to 2017 were obtained from the U.S. Drought Monitor (USDM)'s website.[7] The drought index is taken at the midpoint of each of the four seasons (on the 15th of February, May, August, and November).

To create the dataset using R, the relevant variables from the USDA Census of Agriculture dataset were transformed from long to wide format, with observations listed by location (state, region, and county) at different time periods. Then, the drought index values were merged with the Census dataset. Finally, the final dataset had 9252 observations where 3078 counties were observed each year.

All monetary values were adjusted for inflation. The payments received by operations from state and local government agricultural programs, federal conservation programs, and other federal government programs in 2012 and 2007 were converted to their 2017 values using the consumer price index (CPI). Similarly, the cost of cover crop seeds and other monetary values in the database were also adjusted for inflation using the CPI

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[4] Complete data available at www.nass.usda.gov/AgCensus
[5] https://www.nass.usda.gov/AgCensus/FAQ/2017/
[6] https://quickstats.nass.usda.gov/api/
[7] https://droughtmonitor.unl.edu/DmData/DataDownload/ComprehensiveStatistics.aspx

values for the years 2007, 2012, and 2017 in the US, which were 207.3, 229.6, and 245.1, respectively (Federal Reserve Bank of Minneapolis, n. d.).

Description of the Data

According to USDA, the Census of Agriculture surveys all the farms or ranches in rural or urban areas with $1000 or more of agricultural products produced or sold during the census year. Farmland enrolled in the following land retirement programs CRP, WRP, FWP, or CREP is considered part of the total number of acres operated if they meet the conditions of being a census farm with $1000 or more in sales.

The total number of operated acres includes cropland, permanent pasture and rangeland, woodland, and all other lands in farms. All other lands in farms include land in farmsteads, homes, buildings, livestock facilities, ponds, roads, and wastelands.

Cropland refers to all acres suitable for crop production without additional improvements. This category is divided into cropland pasture and grazing, cropland harvested, cropland on which crops failed or were abandoned, cropland in summer fallow, and idle cropland. Cropland harvested includes land on which crops were harvested at least once. If two or more crops were harvested, it was counted only once. Cropland in summer fallow refers to land that is uncropped in the current year but will be harvested in the following years. Summer fallows are used to control weeds and accumulate moisture before grains are planted. This practice is optional in some areas, but it is a requirement for crop production in the drier cropland areas of the West. Idle cropland is left idle or used for cover crops that are not harvested or grazed. Some cropland remains idle each year for various physical and economic reasons. Pasture and grazing cropland are distinct from permanent pasture as it is capable of being used for crop production.

Woodlands and forestlands consist of tree canopies, shrubs, and forbs. Permanent pasture and rangeland are primarily used for livestock and wildlife production. It should be noted that the term "pastureland" encompasses permanent pasture and rangeland, along with woodland pastured, and other pasture and grazing land that includes cropland pasture and grazing (USDA. Economic Research Service., 2019; USDA. Natural Resources Conservation Service, n. d.).

Different denominators were used to calculate the percentage of farms that adopted specific agricultural practices in the census. The denominator depended on the type of land on which the practice could be adopted on. For example, the percentage of farms using rotational grazing was calculated as the total number of farms with pastureland acres using this practice divided by the total number of farms with pastureland acres in the county. This is because livestock farms without pastureland could not adopt this practice.

On the other hand, questions in the census related to cover crops and conservation tillage were limited to the number of cropland acres on which each practice. Hence, the percentage of farms using these practices was calculated as the total number of farms with cropland acres using the practice divided by the total number of farms with cropland acres in the county. Cover crops adopted on acres under a CRP agreement are not included in the total number of acres on which cover crops were adopted.

Similarly, questions related to alley cropping and silvopasture, artificial ditch and tile drainage generally asked how many acres of each practice were adopted. Therefore, the percentage of farms adopting these practices was calculated as the total number of farms with acres operated using each practice divided by the total number of farms with acres operated in the county. Additionally, percentage variables related to farm demographics and socio-economic characteristics were also created using the total number of farms with operated acres in the county. To assess the adoption of drainage systems, the census only asks whether any acres were drained by tiles or artificially drained by ditches in 2017, and it did not collect information on when those systems were first installed on the farmland. This means that farms with already installed and fully functional drainage systems in 2017 may not have additional costs associated with their usage.

Two counties in the dataset, Hudson, New Jersey in 2012 and Bronx, New York in 2017, did not have farms. Also, 23 counties did not have any pastureland, and 8 did not have any cropland in 2012 and 2017. As a result, they have not been considered in the regression model since the practices studied could not be adopted in those counties.

Descriptive Statistics

Sustainable Agricultural Practices

Rotational grazing was observed at all three periods, while alley cropping and silvopasture were observed at two periods. Cover crops, minimum tillage, no-till, conservation easement, artificial ditch drainage, and tile drainage practices were all observed at one period at the county level and twice at the state level.

From 2012 to 2017, there was a decrease in the percentage of farms that adopted MRG, which went from 22.3% to 21.4% (Figures 3 and 4 in the Appendix). The percentage of farms that practiced alley cropping and silvopasture increased from 0.13% to 1.51%, used cover crops increased from 8.6% to 10.4%, used minimum tillage increased from 12.6% to 14.7%, practiced no-till increased from 17.9% to 18.9%, had artificial ditch drainage increased from 10.3% to 10.4% and had tile drainage increased from 10.3% to 10.7% (Figures 5 to 14 in the Appendix).

Table 1: Summary Statistics of the Adoption Rate of Sustainable Practices in 2017 Across Counties

Practices	Min	1st Q	Median	3rd Q	Max	Mean
Rotational Grazing	0	0.17	0.21	0.25	1	0.21
Alley Cropping and Silvopasture	0	0.01	0.01	0.02	0.25	0.02
Cover Crops	0	0.06	0.09	0.13	0.67	0.10
Minimum tillage	0	0.04	0.09	0.21	0.59	0.13
No-till	0	0.07	0.13	0.26	0.78	0.18
Artificial Ditch Drainage	0	0.04	0.08	0.14	0.82	0.11
Tile Drainage	0	0.01	0.02	0.09	0.75	0.09

Note: This table presents the distribution of the percentage of each sustainable practice adopted in 2017 across counties, including the minimum value, the first quartile, the median, the third quartile, the maximum value, and the mean. The adoption rate ranges from 0 to 1, where 0 means no farms in the county adopted the practice and 1 means all farms did. The minimum and maximum values represent the lowest and highest county adoption rates, respectively.

The first quartile (1^{st} Q.) represents the adoption rate at which 25% of counties fall below, while the median (50th percentile) is the value that divides all counties in half according to their adoption rate. The third quartile (3^{rd} Q.) represents the adoption rate at which 75% of counties fall below.

The mean is the average adoption rate of all observations in 2017.

Although the adoption rate of MRG decreased over the years, it remains one of the more commonly adopted conservation practices. In contrast, silvopasture and alley cropping are not widely used.

Region: state or SARE-NASS region

For the practices that were observed in more than one period, 50 dummy variables for each state were included to control for regional characteristics. For the rest, a combination of the Sustainable Agriculture Research and Education (SARE) and National Agricultural Statistics Service (NASS) regions were included to control for regional characteristics. SARE is a program that supports research and education in sustainable agriculture practices. SARE offers grants and programs to researchers, farmers, and educators to promote sustainable agriculture practices. The research results are shared with farmers to help them implement sustainable practices on their farms. SARE operates in four regions: North Central, South, Northeast, and Western regions (Figure 1 in the Appendix). Each region is responsible for organizing activities and funding projects that are tailored to the unique needs of the region and its local communities. This approach ensures that the projects and programs are effective in addressing the challenges faced by farmers and communities in that region. This program was created by USDA's National Institute of Food and Agriculture (NIFA). NASS regions are classified based on the local climate and agricultural production. There are a total of 12 NASS regions, including Mountain, Northeastern, Eastern Mountain Southern, Great Lakes, Upper Midwest, Heartland, Delta, Northern Plains, Southern Plains, Northwest, and Pacific Region (Figure 2 in the Appendix). These regions have some overlap with the SARE regions, except for West Virginia, which falls under the Northeast SARE region. The Northeast SARE region was divided into two:

Eastern Mountain and Northeastern NASS regions (NIFA & USDA, 2021; NSAC, 2021; USDA NASS, 2023).

The state of Maryland is taken as a reference group. Farms in this state have high adoption rates of sustainable practices compared to some of the other states. Maryland's largest commercial industry is agriculture, which has led to the implementation of various programs and policies aimed at promoting sustainable agriculture. For example, the state provides cost-share programs to farmers for the installation of cover crops and supports network creation such as the Maryland Grazers Network which promotes rotational grazing. Maryland is in the Northeast-Northeastern SARE-NASS region. This is taken as a reference group (Montgomery County Government, n.d.; USDA ERS, 2016).

Drought levels in each county

The National Drought Mitigation Center (NDMC) created the USDM map that assigns a level of drought for each region in the county based on its climate, soil conditions, and other factors such as the amount of water available in streams, lakes, and soils. The total area of the county is divided into the percentage of land area affected by drought conditions, which are classified into six groups: PC.ND, representing the percentage of area county with no drought; PC.D0, indicating abnormally dry conditions in the area that could potentially lead to drought; followed by PC.D1, PC.D2, PC.D3, and PC.D4 representing areas in moderate, severe, extreme, and exceptional drought, respectively. Areas classified as "abnormally dry" are not currently experiencing drought, but they are either in the process of going into drought or coming out of it. This short-term dryness can extend the harvest time and negatively affect the quality of the harvest. In some areas, there may be a few water deficits when coming out of a moderate drought. Areas classified as "moderate drought" are experiencing some crop and pasture damage due to a few water shortage problems. In these areas, voluntary water-use restrictions are often requested to conserve water resources. In areas with severe to exceptional droughts, the farm’s bottom line is affected. In those areas, it is inconvenient for farms to adopt certain conservation practices that increase the farm's water needs. Areas classified as "severe drought" are impacted by drought, with likely crop or pasture losses and common water shortages. Water restrictions are often imposed in these areas to manage scarce water resources. Areas classified as "extreme drought" are experiencing major crop or pasture losses and widespread water shortages, so it is hard to meet demand. Areas classified as "exceptional drought" are experiencing exceptional and widespread crop or pasture losses, and shortages of water in reservoirs, streams, and wells. Exceptional drought areas are more likely to be retired into a conservation easement program such as CRP (U.S. Drought Monitor [USDM], n.d., 2021).

Due to the particular drought conditions in 2017 and 2012, mentioned previously, the indexes used in this study are calculated by averaging the percentage on the midpoint of each of the four seasons (i.e., January-March, April-June, July-September, and October-December), for each group.

Table 2: Summary Statistics for 2017 Drought Level Indicators

Area in Drought	Min	1st Q	Median	3rd Q	Max	Mean
No Drought (%)	0	0.56	0.75	1	1	0.75
Drought Level 0 (%)	0	0	0.12	0.25	0.89	0.16
Drought Level 1 (%)	0	0	0	0.12	0.99	0.07
Drought Level 2 (%)	0	0	0	0	0.48	0.02
Drought Level 3 (%)	0	0	0	0	0.43	0.01
Drought Level 4 (%)	0	0	0	0	0.22	0.001

Note: This table presents the distribution of the percentage of area under each drought level in 2017 across counties, including the minimum value, the first quartile, the median, the third quartile, the maximum value, and the mean. The area in drought ranges from 0 to 1, where 0 indicates no area in the county experienced that level of drought and 1 indicates that the entire county was affected by that level of drought. The minimum and maximum values represent the county with the lowest and highest, respectively, areas under each drought level.

As mentioned previously, drought levels were higher in 2012. In 2012, only 49.76% of the county area in half of the counties was drought-free, while in 2017, 75% of the county area in half of the counties was free of drought, as shown in Table 2. Also, in 2012, certain counties in the South and Southern regions had the highest percentage (53% to 75%) of their surface area in exceptional drought. In contrast, in 2017, it was some counties in the West and Mountain regions had a portion (0.005% to 22%) of their surface area in exceptional drought.

Government programs payments in each state

Most farm programs are given by the federal government, but some states and counties have their specific programs.

Payments received from federal government conservation programs include those received under the CRP, CREP, WRP, and FWP. Only information on annual rental payments was available, the financial assistance payments received by farms for adopting conservation practices are not part of this amount. Payments received from any other federal government programs include those made under the livestock programs, disaster and market loss programs, NAP, EQIP, CSP, and any other federal programs. (Perdue, Bartuska, and Hamer, 2017; Vilsack, Woteki, and Clark, 2012; Conner, Jen, and Bosecker, 2007). Livestock programs support various aspects of livestock production, including breeding, feeding, and marketing. All these payments exclude insurance payments.

Due to confidential criteria, some of the total payments made to farms were hidden at the county level, and thus, average payments per operation program at the state level were used in this study. The study includes average payments received per operation from local government programs (APGVT_LOCAL), average payments per operation from any other federal government programs (APGVT_FED), and average payment per operation received from federal government conservation programs (APGVT_FEDC). To verify if it is appropriate to use the average instead of the total amount paid, the correlation between the total amount paid and the number of farms receiving the payments was examined to see if an increase in the number of farms increases the total amount. A strong positive correlation was observed between the total amount paid and the number of farms receiving the payments.[8] Also, there was no negative correlation between the average amount paid and the number of farms receiving the payments, indicating that the average amount is not substantially affected by the total number of farms. The correlation was nearly zero.[9]

Table 3: State Average Government Programs Payments Received in 2017

Avg. Payment	Min	Median	Max	Mean
From Local Government Programs	694	6224	17767	6559
From Other Federal Programs	4163	12584	40312	14293
From Conservation Federal Programs	0	4837	23417	6531

Note: All payment values were rescaled by dividing by 1,000.
This table presents the distribution of the state average government programs payments in 2017, including the minimum value, the median, the maximum value, and the mean.

The Northeast Northeastern regions had the highest average payments from local government programs in both 2017 and 2012 (Figure 15 in the Appendix). However, for at least half of the states, the average payments from local government programs decreased from 2012 to 2017. In contrast, the average payments from federal government programs increased during the same period.

Farms production intensity in each state

Due to confidential criteria, some of the total production values were hidden at the county level thus the state level was used in this study. The production intensity is measured by the total amount produced (TPD) in the year. It is divided into crop (TCROP) and livestock production.

Table 4: Total State Production in 2017

Production Intensity	Min	Median	Max	Mean
Total Crop (%)	0.03	3.73	33.35	5.20
Total Production (%)	0.06	9.34	45.15	11.33

Note: All three totals were rescaled by dividing by 1,000,000,000.

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[8] The correlation between the number of farms receiving the payments and the total amount received per operation from local government programs, payments per operation from any other federal government programs, and payment per operation received from federal government conservation programs is 0.7193444, 0.8668294, and 0.7193444, respectively.

[9] The correlation between the number of farms receiving the payments and the average amount received per operation from local government programs, payments per operation from any other federal government programs, and payment per operation received from federal government conservation programs is 0.017963357, 0.00169002, and 0.04295002, respectively.

This table presents the distribution of the total production value in 2017 at the state level, including the minimum value, the median, the maximum value, and the mean.

In 2017 and 2012, Texas and Iowa had the highest-valued animal production, while California, Iowa, and Illinois had the highest-valued crop production. For at least 80% of the states, the total crop production decreased from 2012 to 2017, while the total livestock production increased.

Farm production type in each county

The census data on farm production were collected and categorized using the North American Industry Classification System (NAICS) codes. oilseed and grain operations are classified under code 1111, vegetable and melon operations under code 11121, fruit and tree nut operations under code 1113, sheep, and goat farms under code 1124, milking dairy cattle operations under code 112120, beef cattle ranching and farms under code 112111, and cattle feedlots farms under code 112112. These categories are not mutually exclusive. To provide an overview of the farms' production in the county, the percentage of farms is reported for each of these categories: oilseed and grain farms (PC.GRAIN), vegetable and melon farms (PC.VEG), fruit and tree nut farms (PC.FRUIT), sheep and goat farms (PC.SHEEP), milking dairy cattle operations (PC.MILK), beef cattle ranching and farms (PC.BEEF), and cattle feedlots farms (PC.CATTLE).

The U.S. is the largest producer of livestock products. In 2016, the U.S. produced 17% of the world's chicken and cattle meat and 15% of global milk production. The U.S. mostly grows corn and soybeans which are oilseeds and grains crops. Corn is mainly grown in the Corn Belt region, while soybeans are primarily grown in the Midwestern states (Mekonnen, Neale, Ray, Erickson & Hoekstra, 2019; Government of Alberta, 2023).

Table 5: Summary Statistics for Farm Production Type in 2017

Farm Production	Min	1st Q	Median	3rd Q	Max	Mean
Beef Farm (%)	0	0.14	0.28	0.44	1	0.30
Grain Farm (%)	0	0.007	0.05	0.28	0.86	0.16
Sheep Farm (%)	0	0.02	0.03	0.054	0.57	0.042
Fruit Farm (%)	0	0.004	0.01	0.03	0.91	0.04
Vegetable Farm (%)	0	0.004	0.01	0.03	1	0.03
Milk Farm (%)	0	0	0.003	0.01	0.37	0.01
Cattle Farm (%)	0	0	0.002	0.008	0.18	0.006

Note: This table presents the distribution of the percentage of farms that produces each commodity in 2017 across counties, including the minimum value, the first quartile, the median, the third quartile, the maximum value, and the mean. The percentage of farms in the county producing the specified commodities ranges from 0 to 1, where 0 indicates no farm in the county produces the specified commodity and 1 indicates that all farms in the county produce it. The minimum and maximum values represent the county with the lowest and highest percentage of farms producing the commodity, respectively.

Beef cattle ranching and farming are primarily concentrated in specific regions. In fact, Table 4 shows that half of all counties had at least 28.04% of their total farm and ranch production dedicated to beef cattle. From 2012 to 2017, half of the counties experienced a decrease in the number of oilseed and grain producers as well as milk and dairy cattle operations. In 2012 and 2017, Illinois and Iowa were found to have the highest percentage of farms producing oilseeds and grains, while Alaska had the highest percentage of farms producing vegetables and melons. In California and Hawaii, the highest percentage of farms produced fruits and nuts. Finally, Texas and Oklahoma had the highest percentage of farms classified as beef cattle farms and ranches.

Farm tenure in each county

The percentage of farms with full ownership of farmland (PC.OWN) in the county. A farm is considered to have full ownership if it operates on land that it owns outright. If a farm operates on land that it owns outright plus land that it rents from others, it is considered to have partial ownership and is not included in the percentage. A farm that owns acres and rents them out to others is not considered part of their total acres operated but is instead considered as someone else's rented or leased land.

Table 6: Farmland Ownership Tenure

Land Tenure	Min	1st Q	Median	3rd Q	Max	Mean
Full Ownership (%)	0	0.61	0.70	0.76	1	0.68
Partial Ownership (%)	0	0.18	0.24	0.30	0.75	0.25
Entirely Rented (%)	0	0.04	0.06	0.09	0.87	0.07

Note: This table presents the distribution of the percentage of farms under each tenure in 2017 across counties, including the minimum value, the first quartile, the median, the third quartile, the maximum value, and the mean. The percentage of farms in the county under the land tenure ranges from 0 to 1. For example, for full ownership land in the first row, 0 indicates no farm in the county owns all the land it operates and 1 indicates that all farms in the county own all the land they operate. The minimum and maximum values represent the county with the lowest and highest percentage of farms under each tenure, respectively.

Most farms in each county have full ownership of their farmland, as shown in Table 5. Only the percentage of farms with full ownership is controlled for in the adoption models since conservation practices increase the value of the land owned, which can incentivize farmers to adopt.

Business type in each county

Percentage of family corporate farms (PC.CORP_F), non-family corporate farms (PC.CORP_NF), family and individual farms (PC.FAM), institution, research, reservation, and other farms (PC.INST) and partnership farms (PC.PARTNER) in the county.

A family corporate farm is a separate legal entity owned by shareholders who are often family members. They tend to be large-income farms. In contrast, family or individual farms are typically medium-sized. Both types of farms may have a clear succession plan in place and may be incentivized to adopt conservation practices that improve the value of their farmland.

A farm partnership involves two or more individuals sharing ownership, providing access to additional resources and expertise, as well as cost-sharing opportunities for adopting new practices.

Institution farms are typically owned and operated by organizations like universities, government agencies, or non-profit organizations. These farms are often utilized for research, education, or public service purposes. Due to their non-profit nature, they may be more open to experimenting with new practices that might not be financially feasible.

Table 7: Farm Business Model Type in 2017

Farm Type	Min	1st Q	Median	3rd Q	Max	Mean
Family Business (%)	0	0.80	0.86	0.90	1	0.84
Family Corporation (%)	0	0.03	0.05	0.08	0.57	0.058
Non-family Corporation (%)	0	0	0.004	0.009	0.33	0.007
Institution (%)	0	0.01	0.02	0.03	1	0.02
Partnership (%)	0	0.04	0.06	0.09	0.53	0.07

Note: This table presents the distribution of the percentage of farms under each business model in 2017 across counties, including the minimum value, the first quartile, the median, the third quartile, the maximum value, and the mean. The percentage of farms in under a business model ranges from 0 to 1. For example, for family farms in the first row, 0 indicates no farm in the county is a family farm and 1 indicates that all farms in the county are family farms. The minimum and maximum values represent the county with the lowest and highest percentage of farms under each business model, respectively.

Table 6 shows that, in 2017, family farms accounted for 86% of all farms in the United States. Although this business model may have fewer tax incentives for adopting conservation practices, family farms can benefit from healthier soil by implementing such practices on land they own. The percentage of family and individual farms is taken as the reference group.

Farm size groups in each county

The percentage of farms with different acreage operated in the county is broken down into categories of 1 to 9.9 (PC.FS01N), 10 to 49.9 (PC.FS02N), 50 to 69.9 (PC.FS03N), 70 to 99.9 (PC.FS04N), 100 to 139 (PC.FS05N), 140 to 179 (PC.FS06N), 180 to 219 (PC.FS07N), 220 to 259 (PC.FS08N), 260 to 499 (PC.FS09N), 500 to 999 (PC.FS10N), 1000 to 1999 (PC.FS11N), and 2000 or more (PC.FS12N) acres operated. The percentage of farms with different harvested acreage ranges in the county is broken down into categories of 1 to 9.9 (PC.HS01N), 10 to 19.9 (PC.HS02N), 20 to 29.9 (PC.HS03N), 30 to 49.9 (PC.HS04N), 50 to 99.9 (PC.HS05N), 100 to 199 (PC.HS06N), 200 to 499 (PC.HS07N), 500 to 999 (PC.HS08N), and 1000 or more (PC.HS09N) acres harvested.[10]

Farms that operated on 10 acres or fewer were uncommon, accounting for only one-sixth of all farms in 2007. Among these farms, only 17% reported sales exceeding $10,000. The majority of farms that generated sales between $10,000 and $500,000 primarily produced high-value crops, such as floriculture, tree nurseries, and fruits and vegetables. Farms that reported sales exceeding $500,000 generally raised livestock in confinement. In the U.S., the midpoint cropland acreage was 1105 and 1234 acres in 2007 and 2012, respectively (James, Korb and Hoppe, 2013; James and Hoppe, 2017; Newton, 2014).

[10] To reduce the number of groups, the number of acres operated, and acres harvested categories were combined based on their correlation. Farms operating on 10 or fewer acres are referred to as micro acreage farms (MA), while those operating between 10 and 999 acres, 1000 and 1999 acres, and 2000 or more acres are classified as small (SA), medium (MIDA), and large (LA) acreage farms, respectively. Similarly, farms that harvested from 10 or less acres, 10 and 499 acres, 500 and 999 acres, and 1000 or more acres are referred to as micro (MS), small (SS), midsize (MIDS), and large (LS) farms, respectively. Micro farms are taken as a reference group.

Chapter 2
Empirical Model

The objective of this study is to investigate how different regional and economic characteristics can influence the overall adoption rate of various sustainable agricultural practices in each county, including rotational grazing, alley cropping and silvopasture, artificial ditch drainage, tile drainage, cover crops, minimum tillage, and no-tillage practices.

The empirical model used in this study is a linear regression model. The explanatory variables selected for the model based on the literature review are regional drought levels, average government program payments, farm production intensity, production type, farmland ownership tenure, farm business model, farm size, irrigation usage, year, and past adoption level of the practice. Some explanatory variables were excluded from certain models depending on their relevance to the adoption of the given practice and data availability, as previously mentioned. Note that all acronyms used in the equations below can be found in the table of acronyms for reference.

Rotational Grazing and Alley Cropping and Silvopasture Practices Adoption Model

The practices of rotational grazing and silvopasture are conservation practices adopted by livestock farms on permanent pasture or cropland. Therefore, the type of livestock and crop production was included in Equation (1), and the production intensity was measured by the total value of crops and livestock produced in the state. We estimate the linear regression model, Equation (1), using the pooled OLS method, since we have panel datasets with two time periods. It is assumed that the unobserved individual-specific effects are not correlated with the observed explanatory variables over time.

$$PC.GN_{t,i} \text{ or } PC.CAN_{t,i} =$$

$$\beta_0 + \beta_1 PC.D0_{t,i} + \beta_2 PC.D1_{t,i} + \beta_3 PC.D2_{t,i} + \beta_4 PC.D3_{t,i} + \beta_5 PC.D4_{t,i} + \beta_6 TPD_{t,s} + \beta_7 PC.GRAIN_{t,i} + \beta_8 PC.VEG_{t,i} + \beta_9 PC.FRUIT_{t,i} + \beta_{10} PC.SHEEP_{t,i} + \beta_{11} PC.MILK_{t,i} + \beta_{12} PC.BEEF_{t,i} + \beta_{13} PC.CATTLE_{t,i} + \beta_{14} PC.OWN_{t,i} + \beta_{15} PC.SA_{t,i} + \beta_{16} PC.MIDA_{t,i} + \beta_{17} PC.LA_{t,i} + \beta_{18} PC.CORP\ F_{t,i} + \beta_{19} PC.CORP\ NF_{t,i} + \beta_{20} PC.INST_{t,i} + \beta_{21} PC.PARTNER_{t,i} + \beta_{22} APGVT\ LOCAL_{t,s} + \beta_{23} APGVT\ FED_{t,s} + \beta_{24} APGVT\ FEDC_{t,s} + \beta_{25} YEAR_t + \beta_{26\ to\ 76} State_i + \varepsilon_{t,i,s},$$

$$with\ t = year,\ i = county\ and\ s = state$$

(1)

where $PC.GN_{t,i}$ is the percentage of farms that have used rotational grazing on their pastureland, $PC.CAN_{t,i}$ is the percentage of farms that have implemented alley cropping or silvopasture practices on their operation and the error terms are identically and independently distributed. The percentage of area in the county with no drought ($PC.ND_{t,i}$), the percentage of micro acreage farms in the county ($PC.MA_{t,i}$), the percentage of family and individual farms in the county ($PC.FAM_{t,i}$), the year 2017 and the state of Maryland were taken as reference groups.

Artificial Ditch and Tile Drainage Practices Adoption Model

Artificial ditch or tile drainage are drainage systems adopted by crop producers. Thus, only the type of crop production was included in Equation (2), and the production intensity was measured by the total value of crops produced in the state. We used the OLS method to estimate the linear regression model, Equation (2), as we have data for only one period. It assumes that there is no correlation between the error terms and the independent variables.

$$PC.ADN_i \ or \ PC.DTN_i \ =$$

$$\beta_0 + \beta_1 PC.D0_i + \beta_2 PC.D1_i + \beta_3 PC.D2_i + \beta_4 PC.D3_i + \beta_5 PC.D4_i + \beta_6 TCROP_s + \beta_7 PC.GRAIN_i + \beta_8 PC.VEG_i + \beta_9 PC.FRUIT_i + \beta_{10} PC.OWN_i + \beta_{11} PC.SA_i + \beta_{12} PC.MIDA_i + \beta_{13} PC.LA_i + \beta_{14} PC.CORP\ F_i + \beta_{15} PC.CORP\ NF_i + \beta_{16} PC.INSTT_i + \beta_{17} PC.PARTNER_i + \beta_{18} APGVT\ LOCAL_s + \beta_{19} APGVT\ FED_s + \beta_{20} APGVT\ FEDC_s + \beta_{21} Adoption\ level\ in\ 2012_s + \beta_{22\ to\ 35} SARE\ and\ NASS\ Region_i + \varepsilon_{i,s},$$

$$with\ i = county\ and\ s = state \qquad (2)$$

where $PC.ADN_i$ is the percentage of farms using artificial ditches on their operation and $PC.DTN_i$ is the percentage of farms using tile drainage on their operation and the error terms are identically and independently distributed. The percentage of area in the county with no drought ($PC.ND_i$), the percentage of micro-farms in the county ($PC.MS_i$), the percentage of family and individual farms in the county ($PC.FAM_i$), and the Northeast and Northeastern SARE-NASS region were taken as reference groups.

Cover Crops, Minimum Tillage, and No Tillage Adoption Model

Cover crops, minimum tillage, and no-till are used by crop producers. Therefore, only the type of crop production was included in Equation (3), and the production intensity was measured by the total value of crops produced in the state. Instead of grouping farms by size based on area operated, indicators based on acres harvested were included in the model. We used the OLS method to estimate the linear regression model, Equation (3). It assumes that there is no correlation between the error terms and the independent variables.

$$PC.CCN_i,\ PC.CTCTN_i\ or\ PC.CTNTN_i\ =$$

$$\beta_0 + \beta_1 PC.D0_i + \beta_2 PC.D1_i + \beta_3 PC.D2_i + \beta_4 PC.D3_i + \beta_5 PC.D4_i + \beta_6 TCROP_s + \beta_7 PC.GRAIN_i + \beta_8 PC.VEG_i + \beta_9 PC.FRUIT_i + \beta_{10} PC.OWN_i + \beta_{11} PC.SA_i + \beta_{12} PC.MIDA_i + \beta_{13} PC.LA_i + \beta_{14} PC.IRRN_i + \beta_{15} PC.CORP\ F_i + \beta_{16} PC.CORP\ NF_i + \beta_{17} PC.INST_i + \beta_{18} PC.PARTNER_i + \beta_{19} APGVT\ LOCAL_s + \beta_{20} APGVT\ FED_s + \beta_{21} APGVT\ FEDC_s + \beta_{22} Adoption\ level\ in\ 2012_s + \beta_{22\ to\ 35} SARE\ and\ NASS\ Region_i + \ \varepsilon_{i,s},$$

$$with\ i = county\ and\ s = state \tag{3}$$

where $PC.CCN_i$ is the percentage of farms having used cover crops on their cropland, $PC.CTCTN_i$ is the percentage of farms having practiced minimum tillage on their cropland and $PC.CTNTN_i$ is the percentage of farms having practiced no-till on their cropland. The percentage of area county with no drought ($PC.ND_i$), the percentage of micro-farms in the county ($PC.MS_i$), the percentage of family and individual farms in the county ($PC.FAM_i$), and the Northeast and Northeastern SARE-NASS region were taken as reference groups.

Chapter 3
Results and Discussion

The coefficient estimates of the regression models are in Table 8, 9 and 10.

Table 8: Regression Model Coefficients for Adoption of Rotational Grazing, Alley Cropping, and Silvopasture Practices

Variables	Rotational Grazing Adoption (%)	Alley Cropping and Silvopasture Adoption (%)
Constant	0.1989 (***)	0.0144 (***)
Pct Abnormally Dry	0.0109 (***)	0 ()
Pct Moderate Drought	0.0083 (*)	0.0038 (***)
Pct Severe Drought	0.0001 ()	0.0068 (***)
Pct Extreme Drought	-0.0162 (**)	0.0083 (***)
Pct Exceptional Drought	-0.0179 (**)	0.0077 (***)
TPD st	-0.0025 (***)	0.0022 (***)
Pct Oilseed and Grain Farms	-0.0171 (*)	-0.0121 (***)
Pct Vegetable and Melon Farms	0.0829 (***)	0.0496 (***)
Pct Fruit and Tree Nut Farms	-0.0113 ()	0.0073 (**)
Pct Sheep and Goat Farms	0.1846 (***)	0.0177 (***)
Pct Milking Dairy Cattle Operations	-0.0409 ()	-0.0114 (*)
Pct Beef Cattle Ranching and Farms	0.1613 (***)	-0.003 (*)
Pct Cattle Feedlots Farms	0.056 ()	-0.032 (*)
Pct Owned	0.0315 (***)	0.0042 (*)
Pct Small Acreage Farms	0.0406 (***)	0.015 (***)
Pct Medium Acreage Farms	0.0241 ()	0.0147 (**)
Pct Large Acreage Farms	0.0302 (**)	-0.0024 ()
Pct Family Corporation	0.065 (***)	-0.0008 ()
Pct Non-Family Corporation	-0.0137 ()	-0.0201 ()
Pct Institution	0.0745 (**)	-0.0002 ()
Pct Partnership	0.1064 (***)	0.0063 ()
Avg Pmt State and Local Gvt st	0.0004 ()	0.0002 ()
Avg Pmt Fed Other Gvt st	-0.0014 (***)	-0.0005 (***)
Avg Pmt Fed Cons Gvt st	0.0022 (***)	-0.0008 (***)
Year = 2012	0.0123 (***)	-0.0225 (***)
Year = 2007	0.0551 (***)	x
State Dummies?	Yes	Yes
N	*9213*	*6164*
Multiple R-squared	*0.4077*	*0.4331*
Adjusted R-squared	*0.4028*	*0.4262*
P-value	*< 2.2e-16*	*< 2.2e-16*

*Significance level: 0.01 '***' 0.05 '**' 0.1 '*'*

Notes: This table reports the estimation of the coefficients from Equation (1). The dependent variable is the percentage of farms that have used rotational grazing on their pastureland in the first model and the percentage of farms that have implemented alley cropping or silvopasture practices on their operation in the second model. The percentage of area in the county with no drought, the percentage of micro acreage farms in the county, the percentage of family and individual farms in the county, the year 2017 and the state of Maryland were taken as reference groups.

Table 9: Regression Model Coefficients for Adoption of Artificial Ditch and Tile Drainage

Variables	**Artificial Ditch Drainage Usage (%)**	**. (%)**
Constant	0.0921 (***)	0.2088 (***)
Pct Abnormally Dry	-0.0212 (**)	-0.0182 (*)
Pct Moderate Drought	-0.0548 (***)	-0.0159 ()
Pct Severe Drought	-0.043 (*)	0.023 ()
Pct Extreme Drought	0.0546 ()	0.0645 ()
Pct Exceptional Drought	-0.3513 (**)	-0.3295 (**)
TCROP st	-0.0036 (***)	-0.0025 (***)
Pct Oilseed and Grain Farms	0.19 (***)	0.3464 (***)
Pct Vegetable and Melon Farms	0.0245 ()	-0.1589 (***)
Pct Fruit and Tree Nut Farms	0.0725 (***)	0.0451 (*)
Pct Owned	-0.0837 (***)	-0.1968 (***)
Pct Small Acreage Farms	-0.0667 (***)	-0.0733 (***)
Pct Medium Acreage Farms	-0.0676 ()	-0.1485 (***)
Pct Large Acreage Farms	-0.1665 (***)	-0.2368 (***)
Pct Family Corporation	0.1228 (***)	0.0234 ()
Pct Non-Family Corporation	-0.0942 ()	-0.1831 ()
Pct Institution	-0.272 (***)	-0.1242 (**)
Pct Partnership	0.2013 (***)	-0.1655 (***)
Avg Pmt State and Local Gvt st	-0.0004 ()	0.0016 (*)
Avg Pmt Fed Other Gvt st	0.0006 ()	0 ()
Avg Pmt Fed Cons Gvt st	0.0032 (***)	0.005 (***)
State's Usage Level in 2012	0.8839 (***)	0.6708 (***)
SARE-NASS Region Dummies?	Yes	Yes
N	*3083*	*3083*
Multiple R-squared	*0.3939*	*0.7258*
Adjusted R-squared	*0.3873*	*0.7228*
P-value	*< 2.2e-16*	*< 2.2e-16*

*Significance level: 0.01 '***' 0.05 '**' 0.1 '*'*

Notes: This table reports the estimation of the coefficients from Equation (2). The dependent variable is the percentage of farms using artificial ditches on their operation in the first model and the percentage of farms using tile drainage on their operation in the second model. The percentage of area in the county with no drought, the percentage of micro-farms in the county, the percentage of family and individual farms in the county, and the Northeast and Northeastern SARE-NASS region were taken as reference groups.

Table 10: Regression Model Coefficients for Adoption of Cover Crops, Minimum Tillage, and No-Till

Variables	**Cover crops Adoption (%)**	**Minimum tillage Adoption (%)**	**No-till Adoption (%)**
Constant	0.0762 (***)	0.1269 (***)	0.1232 (***)
Pct Abnormally Dry	0.036 (***)	-0.007 ()	0.0473 (***)
Pct Moderate Drought	-0.0115 ()	-0.0014 ()	0.0055 ()
Pct Severe Drought	-0.0335 (**)	-0.0937 (***)	0.1053 (***)
Pct Extreme Drought	-0.0531 ()	-0.0744 (**)	0.2089 (***)
Pct Exceptional Drought	-0.1815 (*)	-0.0527 ()	0.0549 ()
TCROP st	-0.0014 (***)	-0.0008 (*)	-0.0037 (***)
Pct Oilseed and Grain Farms	0.0074 ()	0.2879 (***)	0.4162 (***)
Pct Vegetable and Melon Farms	0.2229 (***)	0.1085 (***)	0.1285 (***)
Pct Fruit and Tree Nut Farms	0.0687 (***)	0.0025 ()	0.0079 ()
Pct Owned	-0.0566 (***)	-0.093 (***)	-0.1019 (***)
Pct Small Farms	-0.0382 (***)	-0.0055 ()	-0.046 (***)
Pct Midsize Farms	0.139 (***)	0.3719 (***)	0.0614 ()
Pct Large Farms	-0.0346 (**)	0.1444 (***)	-0.0582 (**)
Pct Irrigation System	x	0.0724 (***)	-0.0445 (***)
Pct Family Corporation	-0.0207 ()	-0.0237 ()	0.0398 ()
Pct Non-Family Corporation	-0.1769 (**)	-0.0258 ()	0.0092 ()
Pct Institution	0.0427 ()	-0.0151 ()	-0.03 ()
Pct Partnership	0.0713 (**)	0.0005 ()	0.0737 ()
Avg Pmt State and Local Gvt st	0.0067 ()	-0.0016 (**)	0.0027 (***)
Avg Pmt Fed Other Gvt st	0.0095 (***)	-0.0003 ()	-0.0015 (***)
Avg Pmt Fed Cons Gvt st	0.0014 (**)	0.0011 (*)	0.0041 (***)
State's Adoption Level in 2012	0.7522 (***)	0.2859 ()	0.6337 (***)
SARE-NASS Region Dummies?	Yes	Yes	Yes
N	*3080*	*3080*	*3080*
Multiple R-squared	*0.3882*	*0.7937*	*0.6658*
Adjusted R-squared	*0.3816*	*0.7914*	*0.6621*
P-value	*< 2.2e-16*	*< 2.2e-16*	*< 2.2e-16*

*Significance level: 0.01 '***' 0.05 '**' 0.1 '*'*

Notes: Notes: This table reports the estimation of the coefficients from Equation (3). The dependent variable is the percentage of farms having used cover crops on their cropland in the first model, the percentage of farms having practiced minimum tillage on their cropland in the second model, and the percentage of farms having practiced no-till on their cropland in the third model. The percentage of area in the county with no drought, the percentage of micro-farms in the county, the percentage of family and individual farms in the county, and the Northeast and Northeastern SARE-NASS regions were taken as reference groups.

Drought Levels in Each County

Tables 8 and 10 show that counties with higher abnormally dry areas had significantly higher adoption rates of rotational grazing and cover crops compared to those with higher no-drought areas (PC.ND). On the contrary, counties with higher severe drought areas had significantly lower adoption rates of cover crops compared to counties with more no drought areas. Similarly, counties with higher extreme or exceptional drought areas had significantly lower adoption rates of rotational grazing and cover crops compared to those with higher no-drought levels. Rotational grazing involves moving livestock to different paddocks which allows for the forage to recover and regenerate. This technique can aid farms in adapting to moderate drought conditions. However, in drought conditions that exceed extreme levels, even rotational grazing becomes ineffective since the pasture yields are severely affected in the paddocks currently used for grazing. High drought conditions can dry up pastureland to the point that farms are not able to feed their livestock due to food shortages. Hay shortage forces farms to find alternative feed or sell off their livestock. Cover crops are agricultural practices that involve cultivating additional crops alongside or after primary crops to mitigate soil erosion and improve the soil's ecosystem. However, during severe drought periods, cover crops can also increase the demand for water or compete with cash crops for water.

Surprisingly, in Table 8, counties with higher levels of moderate, severe, extreme, or exceptional drought areas had significantly higher adoption rates of alley cropping and silvopasture adoption compared to counties with more no-drought areas (PC.ND). In alley cropping, annual or perennial crops are grown between rows of trees, which can minimize water loss from evaporation. The additional crops can aid in diversifying farm production and generating additional revenue streams in the short term. Grazing can be viewed as an added revenue stream while the tree crop matures. Similarly, silvopasture entails cultivating grazing forage production between tree production, which can also offer annual income while the tree crop matures and reduce water erosion. In both practices, the additional crops typically do not compete with trees for water as their roots are deep, and trees use water from deep in the ground. Thus, this practice is feasible in higher-drought areas. Alley crops and silvopasture can serve as alternative feed when there are not enough pasture yields (NOAA, 2018).

Table 10 shows that counties with higher percentages of abnormally dry, severe, or extreme drought areas had significantly greater adoption rates of no-till practices compared to counties with no drought (PC.ND). This finding explains why counties with higher percentages of severe or extreme drought areas had significantly lower adoption rates of minimum tillage relative to counties with no drought. During severe or extreme drought conditions, farms substitute minimum tillage with no-till practices, which can conserve more soil moisture. Furthermore, the lands in these areas are often unsuitable for crop or pasture production. When such lands are retired into a conservation agreement, it is normal for no-till practices to be implemented on them. Past studies analyzed the adoption of conservation tillage, the combination of no-till and minimum tillage. Similarly, Davey (2006), Nadella et al. (2014), and Uri (1998) found that conservation tillage adoption increased during drought conditions, characterized by higher temperatures, lower precipitation, or higher sloped land. However, Uri (1998) also found that the adoption of no-till practices was more likely during higher average rainfall.

In Table 9, counties with higher levels of drought areas significantly used lower rates of drainage practices compared to counties with no drought area (PC.ND). Artificial ditch drainage and tile drainage practices are designed to manage excess water. This practice is less needed in areas experiencing drought, as excess water may be less of an issue. Soule et al. (2000) also found that in fields with no drought and higher precipitation, farmers were significantly more likely to adopt practices aimed at mitigating excess water issues.

Overall, drought conditions can have a significant impact on the adoption rates of farms' conservation practices. Some conservation practices may be less feasible in a drought area.

Government Program Payments in Each State

Most farms in US are eligible to receive payments from different government programs. Government payments are divided in three categories: state and local government agricultural programs payments, federal government payments received under conservation programs and federal government payments received under other programs. All these programs were explained in detail earlier.

Table 10 shows that counties in states with higher average payments per operation from state and local government agricultural programs (Avg Pmt State and Local Gvt st) adopted significantly more no-till, but less minimum tillage. The coefficient for this variable was not found to be significant for the adoption of the other practices. This lack of significance may be because many of the funding opportunities for these practices are provided by the federal government rather than state and local governments. While local governments may provide financial assistance for the adoption of conservation practices, they are more likely to assist through knowledge transfer groups or local networks. Some states, like Minnesota, have established programs to offer resources to support the adoption of minimum tillage practices, while other states, such as Pennsylvania and Colorado, have facilitated the formation of networks to exchange ideas and promoting the implementation of no-till farming (CHR & R, n.d.).

Tables 8 to 10 show that counties in states with higher average payments per operation from federal conservation programs (Avg Pmt Fed Cons Gvt st) showed significantly higher adoption rates of soil-restoring practices such as rotational grazing, cover crops, conservation tillage, and drainage practices. These programs aim to retire lands that are considered damaging to neighbouring land and biodiversity, especially in areas with extreme climate conditions. Only the average annual rental payments received by farms in the state are considered by this variable. However, farms enrolled in the federal conservation programs, CRP, WRP, and FWP, can also receive financial assistance to adopt certain conservational practices. For example, they can adopt vegetative cover crops and practice no-till on their retired land. Land enrolled in conservation programs can also receive subsidized cover crop seeds. Some states with higher cover crop adoption spent, on average, lower amount on cover crop seeds compared to states with cover crop lower adoption (Figure 9 in the Appendix). Farms enrolled in the CRP-Grasslands program can use their retired land for common grazing practices and receive upfront cost subsidies such as for cross-fencing. In addition, farms enrolled in the WRP program can also adopt rotational grazing on their enrolled wetland. This variable was not significant for silvopasture adoption. Although cropland under CRP can be converted to permanent forest land for silvopasture, it is still an unpopular option. While federal conservation programs do not provide financial assistance for drainage systems, the adoption of these systems in conservation areas may be higher because they can be particularly beneficial in addressing excess water issues near wetland conservation areas.

The total payment per operation from other federal government programs is the sum of unexpected loss compensation payments under programs like the NAP and financial assistance for the adoption of certain conservation practices under programs like the EQIP and CSP. The Congressional Budget Office (CBO) baseline provides projected estimates of federal spending on mandatory programs under the 2008 farm bill (Monke, 2013). The financial baseline budget for NAP is lower than that of EQIP and CSP, but it is bigger for direct payments. Since disaster payments are greater than conservation assistance payments, according to the budget forecast, disaster payments will have a greater impact. The value of this variable increases if major unexpected losses occurred in a state. Since farms in states with high unexpected losses would likely stick to conventional practices instead, states that receive higher average payments per operation from other federal government programs would adopt fewer conservation practices. This explains why the observations suggest that counties in states that receive higher average payments per operation from other federal government programs (Avg Pmt Fed Other Gvt st) had significantly lower adoption of rotational grazing, no-till, alley cropping and silvopasture, but a significant positive correlation with cover crop adoption (Tables 8 and 10). Another possible explanation for this negative correlation is that these farms may prioritize short-term profits over long-term environmental benefits. Cover crops, before 2018, were not insurable crops, but certain losses were covered under NAP.

Financial assistance can play a critical role in the adoption of sustainable practices as some practices can have high upfront and maintenance costs and may only provide social benefits or tangible benefits to the farm in the long term.

These programs that offer financial incentives, such as payments or subsidies, may also offer technical assistance on how to implement them effectively and raise more awareness about the benefits of sustainable practices.

In past studies, the type of financial assistance payments given was not distinguished. Nevertheless, Hindsley (2002) found similar results where farms receiving financial assistance for sustainable practice adoption were significantly more likely to use conservation tillage, grasses or legumes in rotation, and controlled tile drainage. However, this variable was found to be insignificant for cover crops. Additionally, studies by Lambert et al. (2007) and Davey (2006) found that farmers who had access to information were more likely to adopt conservation tillage practices.

Farms Production Intensity in Each State

In Table 8, counties in states with higher levels of crop and animal production (TPD st) had significantly lower adoption rates of rotational practices. Rotational grazing involves using only a portion of the pastureland at any given time, which decreases the amount of available grazing area. This practice is most suitable for farms with lower livestock density or higher pastureland. States with higher production might also use their cropland pasture to produce cash crops instead of using it for grazing while using intensive livestock feeding production (USDA Climate Hubs, n. d.).

On the contrary, in Table 8, counties in states that have higher levels of crop and animal production (TPD st) had significantly adopted more alley cropping and silvopasture practices. These practices allow farmers to maintain their current production levels and increase their crop and pasture production by adding additional crops in unused areas. Farms can diversify their production and generate additional income without having to decrease their current production levels. Alley cropping adds additional crop production on ongoing tree production fields, and silvopasture adds crops in forest areas that were previously bare.

Tables 9 and 10 show that counties in states with higher levels of crop production intensity (TCROP st) had significantly lower adoption rates of cover crops, conservation tillage, tile drainage, and artificial ditch drainage. Counties in states with higher levels of production may be less inclined to adopt sustainable practices if these practices can hinder ongoing production. Cover crops can result in improved yields in the long term, but they may compete for resources such as water and nutrients, potentially hindering the growth of the primary crop when cover crops are inter-seeded with the primary crop. This explains why cover crops were less used in more productive states. Certain types of cover crops are planted after the main cash crop and harvested but most are not harvested, instead, they would be incorporated into the soil. In the short term, these are just seen as additional costs. Conservation tillage practices often require more time and resources and may result in a lower yield in the short term. Therefore, farms with higher levels of production may be less inclined to practice conservation tillage. Also, farms in highly productive states may operate on land that does not face excess water issues; thus, they might use less of these drainage systems.

Farm Production Type in Each County

The oilseed and grains category includes oilseeds used to produce oil, soybeans, dry peas, beans, wheat, corn, and other related crops. These are considered cash crops. Table 8 shows that counties with a higher percentage of oilseed and grain farms adopted significantly lower rates of rotational or alley cropping and silvopasture practices, as expected. Farms producing grains tend to only focus on the intense production of cash crops.

On the contrary, Tables 9 and 10 show that counties with a higher percentage of oilseed and grain farms had significantly higher rates of conservation tillage, artificial ditch drainage or tile drainage practices. This could be because these practices improve the efficiency of cash crop production rather than diversifying crop production. For example, the use of conservation tillage can improve cash crops yields in the long term while increasing profit in the short term from less fuel and machinery used on fields. Tile drainage and artificial ditch drainage can also help manage water and improve drainage, which can be especially important for crops like oilseeds and grains that require well-drained soils (NIR-For-Food, n. d.).

Tables 8 and 10 show that counties with a higher percentage of vegetable and melon farms had significantly higher adoption of rotational grazing, alley cropping and silvopasture, cover crop use and conservation tillage. Vegetable crops need less water, fertilizer, and pesticide inputs than oilseed crops, and are typically grown in rotation, different crops grown each year on the field. Some grazed crops, alley crops, and cover crops are legume crops. Since some vegetable crops require fewer chemical inputs to maintain their yield and quality than oilseed and grain crops, it is generally easier to transition from intensive tillage to conservation tillage on vegetable or melon production plots. On the contrary, Table 9 shows that counties with a higher percentage of vegetable and melon farms had significantly lower use of tile drainage practices. This result is unexcepted since tile drainage systems are designed to improve drainage in poorly drained soils, and vegetables could benefit from them. The lower adoption could be due to vegetable farms already operating on well-drained soil that cannot be used for grains (Government of Alberta, 2014).

Tables 8 to 10 show that counties with a higher percentage of fruit and tree nut farms significantly adopted more alley cropping and silvopasture, cover crop, artificial ditch drainage, and tile drainage practices. Fruits and nuts are usually grown on tree farms. They are typically perennials, crops that often require several years before they start production that can be harvested over multiple years. This means they have larger upfront investments and a longer wait for returns. Alley cropping, silvopasture, and cover crops can provide additional benefits to the ongoing fruit and nut trees, such as increased profitability from additional crops that can be grazed or harvested annually, and enhanced soil health in the long run. Fruit fields can benefit from artificial ditch drainage and tile drainage practices since their roots are sensitive to excess moisture.

Table 8 shows that counties with a higher percentage of sheep and goat farms had significantly higher rates of rotational grazing, alley cropping, and silvopasture practices adopted. Grazing animals like sheep and goats require access to fresh forage, which can be provided by these practices. Rotational grazing is better than intensive grazing. Alley cropping can provide shade and shelter for grazing animals from the sun. The same reasoning applies to why counties with a higher percentage of beef cattle ranching and farms also had higher adoption rates of rotational grazing.

Table 8 also lots shows that counties with a higher percentage of milking dairy cattle operations, beef cattle ranching and farms, and cattle feedlots farms adopted significantly lower rates of alley cropping and silvopasture practices. This may be because these operations often rely heavily on intensive confinement feeding practices, which prioritize maximizing production and efficiency over ecological and animal welfare. These operations may require copious amounts of land just for infrastructure, permanent pasture, and rangeland. They might have limited cropland for alley cropping.

Previous studies have reported mixed effects on the adoption of conservation tillage and cover crops in crop production, particularly in oilseed grain farming, as well as in livestock production.

Farm Tenure Ownership Rates in Each County

Tables 8 to 10 show that counties with a higher percentage of farms with full farmland ownership (Pct Owned) had adopted significantly more rotational grazing, alley cropping and silvopasture but significantly lower rates of cover crops, conservation tillage, and drainage systems. Full ownership of the land provides greater control and flexibility over land use decisions. Farms with full ownership may be more willing to implement practices that may take longer to show benefits, as they can reap the rewards in the long term. Conservation tillage and cover crops require less capital investment; thus, they can be more easily implemented on rented or leased land. Since the census inquired whether any acres were drained by tiles or artificially drained by ditches in 2017, farms that had already installed pipes and ditches in previous years may not face any cost barriers in using drainage these systems apart from their maintenance cost. Renters may be willing to pay a higher price for farmland that already has a drainage system installed.

Business Type in Each County

Tables 8 and 9 show counties with a higher percentage of family corporation farms significantly used more rotational grazing and artificial ditch drainage than counties with a higher percentage of family farms. Most farms in the US are family farms. They might have fewer resources than corporation or partnership farms.

In Table 10, counties with a higher percentage of non-family corporation farms adopted significantly lower rates of cover crops than counties with a higher percentage of family farms (PC.FAM). Non-family corporations may be more focused on maximizing short-term profits and may not prioritize sustainable farming practices.

Tables 8 to 10 show that counties with a higher percentage of farm partnerships had adopted significantly more rotational grazing and cover crops but used fewer drainage systems than counties with a higher percentage of family farms. Partnerships farms have more experts in their decision-making process along with more resources.

Tables 8 and 10 show that counties with a higher percentage of institutional or other farms adopted more rotational grazing but used fewer drainage practices than counties with a higher percentage of family farms. Institutional farms generally test out new practices or improve existing ones. All the practices studied in this research have been known by farmers since the seventies. Although rotational grazing has been popular since the 90s, its adoption has declined over the years. Research farms may be studying why that is the case. Drainage systems were more popular in the late 19th century. They were used to increase land productivity.

Farm Size Groups in Each County

Tables 8 and 9 show that counties with a higher percentage of farms that operate more acres than micro-farms had greater adoption rates of rotational grazing, alley cropping, and silvopasture practices, but lower use of tile or artificial ditch drainage than counties with a higher percentage of micro-farms. This is because these practices are more easily implemented on larger acreage farms, which have more land to diversify their production. Drainage practices have increasing marginal upfront and maintenance costs since they need additional resources per acre such as additional pipes and labour. They may be more cost-effective for smaller farms.

Table 10 shows that counties with a higher percentage of medium farms adopted significantly higher rates of cover crops than counties with a higher percentage of farms with micro-farms while counties with a higher percentage of small or large acreage farms adopted significantly lower rates of cover crops than the reference group. Cover crops have increasing marginal costs since they require additional resources per acre added such as additional seeds, labour, and chemical inputs but larger farms have more acres to diversify their crop production.

Table 10 shows that counties with a higher percentage of medium or large farms adopted significantly higher rates of minimum tillage than counties with a higher percentage of micro-farms while counties with a higher percentage of small or large farms adopted significantly lower rates of no-till than the reference group. Although conservation tillage requires additional agrochemical inputs with spending on fuel and labour for application, the benefits of not tilling the soil decrease fuel and labour cost for tillage. The decrease in costs can outweigh the increase in costs. This might not be the case for no-till. Also, conservation tillage involves investing in new machines, and there can be an economy of scale associated with spreading equipment costs over more acres. However, the benefit is limited to a certain number of acres, after which more equipment must be purchased.

The adoption of these sustainable practices is influenced by the total area that can be farmed due to their optimal marginal cost and economies of scale. In other words, at a certain level of farm acres, input marginal costs are minimized. Certain agricultural practices may be more cost-effective for medium or large farms than for small ones.

Irrigation Adoption in Each County

Table 10 shows that counties with a higher percentage of farms with irrigation systems (Pct Irrigation System) adopted significantly more minimum tillage, but significantly less no-till. Farms equipped with irrigation systems may not need to use conservation tillage to mitigate the impact of dry soil on crop production. No-till involves leaving all previous crop residue on farmland that may not be necessary on farms with irrigation systems installed. Instead, minimum tillage, which leaves at least 30% of previous crop residue, can still be effective in mitigating dry soil problems without increasing the pest issues.

Dynamics of Adoption Rates

From 2007 to 2012 and 2017, there was a significant decrease in the overall adoption rate of rotational grazing practices in the counties. The elimination of the GLCI program in the 2008 Farm Bill could explain this decreasing trend in MRG practice adoption since 2007. The GLCI program offered financial assistance with straightforward payments for the adoption of rotational grazing or silvopasture. While alternative programs exist today, they are not as adequate as GLCI for funding the adoption of MRG. For example, the EQIP provides funding for grazing management practices. However, the funding amount differs across states to account for regional considerations and payments can only be received once the practice is successfully adopted. While transitioning to MRG requires significant upfront costs for equipment such as electric fencing, water systems, or farm-specific grazing plans designed by experts. It may also be partly due to the increase in extreme drought conditions throughout the years, rendering pastureland ungrazeable, causing farmers to resort to other options. Further research is needed to understand the reasons behind this trend. Recently, USDA launched another survey, the 2018 Agricultural Resource Management Survey (ARMS) to understand why rotational grazing is becoming less popular. However, counties with higher adoption in the past had higher adoption in 2017.[11] On the contrary, there was a significant increase in the overall alley cropping and silvopasture adoption rate from 2012 to 2017, as indicated by the negative coefficient of the 2012 dummy variable in table 8.

Tables 9 and 10 show that counties in states with higher adoption rates in 2012 of cover crops, conservation tillage, artificial ditch drainage practices, or tile drainage practices also had higher adoption rates in 2017. These results suggest that farmers in a particular state are more likely to continue using a practice once they adopt it. This may be due to the increased knowledge gained from adopting the practice in the past.

[11] The correlation between the percentage of farms having adopted rotational grazing in 2017 and in 2012 is 0.6074.

The multiple R-squared values indicate that approximately 40.27% of the variation in rotational grazing, 43.31% in alley cropping and silvopasture, 38.82% in cover crop, 39.39% in artificial ditch drainage, 72.58% in tile drainage, 79.37% in minimum tillage, and 66.58% in no-till can be attributed to the independent variables included in their respective models. There may still be additional factors not accounted for in the models that influence the adoption of these practices. However, for the estimates to be unbiased in the OLS approach, the assumptions that the independent variables are not strongly correlated and that there are no omitted variables must be respected.

To obtain unbiased estimates, it is essential to account for all relevant variables and ensure that there are no omitted variables in the analysis. For example, it is important to ensure that the allocation of funding budget limits for financial assistance programs to states is done randomly, so as not to introduce bias into the estimates. Government financial aid payments are classified into three categories based on their source: state and local government, federal conservation programs, and other federal programs. Most conservation programs have consistent spending limits per state, regardless of the drought level in the area. Other federal non-insured disaster programs primarily address livestock and forage losses resulting from natural disasters or disease outbreaks. However, the offerings from state and local governments program may be correlated with drought conditions.

Furthermore, it is important that independent variables are not strongly correlated. Farms in drought areas are more inclined to participate in conservation and disaster aid programs. However, it is worth noting that the compensation provided to farms in regions experiencing extreme drought is lower compared to areas without drought. Additionally, it is important to recognize that most disaster aid programs primarily offer compensation for losses of non-insured livestock or crop caused by diseases.

Conclusion

Our analysis demonstrates that both drought conditions and government program payments can have a significant impact on the adoption of conservational tillage, cover crops, drainage systems, rotational grazing, alley cropping, and silvopasture. The results suggest that some practices may be less feasible during periods of extreme drought, as evidenced by lower adoption rates in these regions. However, in the case of alley cropping and silvopasture, they can supply additional revenue streams during drought conditions, potentially making them more attractive options for farmers facing production loss. Previous studies that controlled for regional climate conditions by using a continuous variable instead of a categorical one failed to consider that farmland in regions with extreme climate might not be farmed. Farms located in dry to moderate drought regions tended to adopt more soil moisture conservation practices, while those located in regions with extreme drought conditions adopted fewer such practices. This may be because the land in such regions is not suitable for crop or forage production and may instead be retired into a conservation program.

Higher average payments from federal conservation programs were found to encourage the adoption of soil-restoring practices, such as conservation tillage and rotational grazing, but higher average payments from other federal programs, mainly disaster aid programs, had the opposite effect, they discouraged the adoption of productivity-reducing or long-term benefit-generating practices. However, higher average payments from other federal programs encouraged the adoption of cover crops since they were not insurable prior to 2018 but covered under certain disaster aid programs.

As hypothesized by Ding, Schoengold and Tadesse (2009), disaster payments had a similar effect to insurance coverage on the adoption of no-till practices. Ding, Schoengold and Tadesse (2009) found that insured cropland had a negative impact on no-till adoption. This can be due to farms being compensated for any production loss from drought or the adoption of no-till might affect their insurance coverage. However, insurance coverage was not considered in this study due to data limitations. Also, almost all farms[12] in the US are insured (USDA ERS, 2023).

Study Limitations

While this study offers valuable insights into the impact of drought conditions and government program payments on the adoption of conservation practices at the county level, there are limitations to using county-level observations. The study relied on overall observations at the county level, such as the percentage of the county affected by

[12] From 2007 to 2017, approximately 80% to 90% of farms in the US were insured.

drought. Farms are often located in specific regions within a county with specific levels of drought severity. Thus, using farm-level observations would likely provide more accurate results, as it would allow for a more detailed analysis of the specific factors that influence farmers' adoption decisions.

The study only examines the relationship between drought conditions, government program payments, and conservation practice adoption rates, but it does not establish causality. To obtain unbiased estimates, it is important to minimize strong correlations between drought conditions and government program payments, as well as to mitigate the potential influences from omitted variables that could affect the observed associations. Another limitation of this study is that the average program payments per operation at the state level were used due to confidential criteria. However, this approach may not account for the variation in payments across counties within a state, and the resulting averages may not be as precise as the total payments.

Finally, using one-period data limits the ability to draw conclusions about the long-term adoption trends of those practices. Changes in environmental conditions or policy changes over time could impact the validity of the findings. Adding the 2021 Census data could also provide more accurate results and help to control for time-varying trends.

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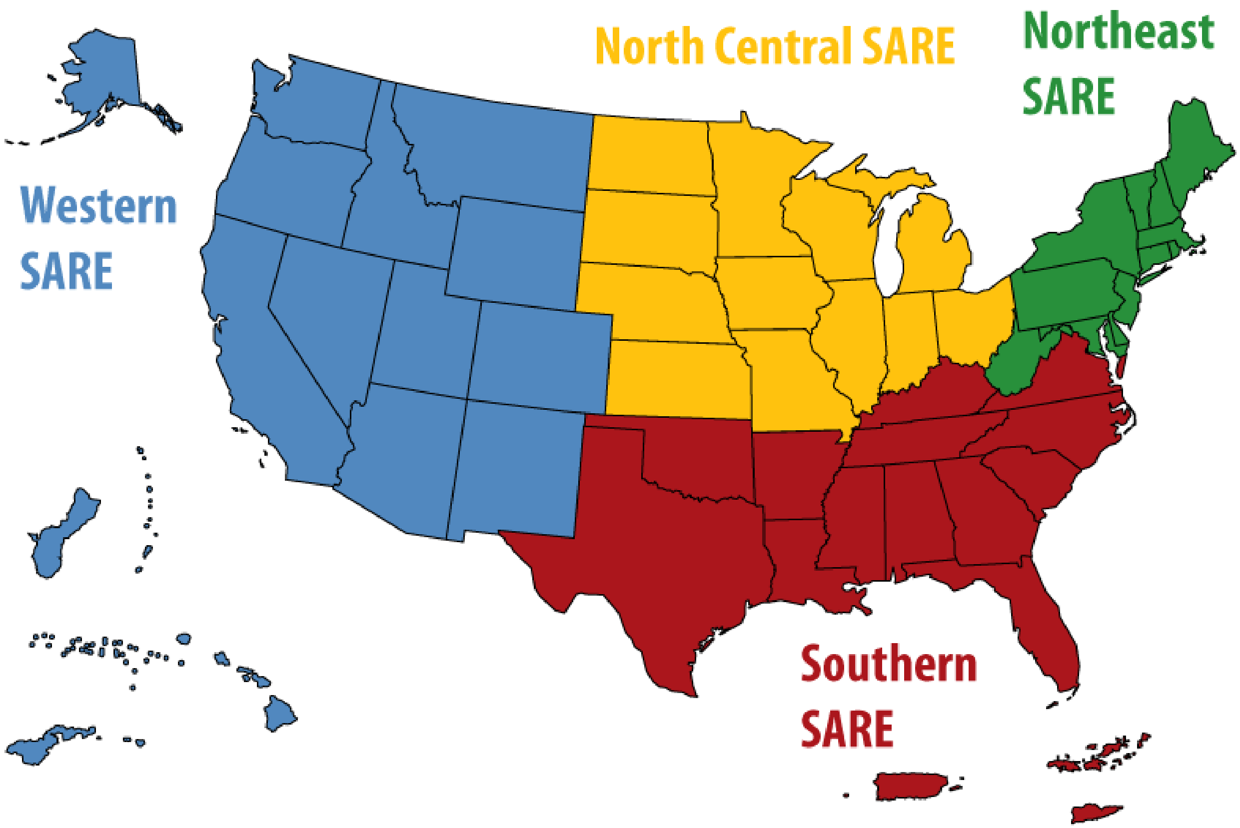
Appendix

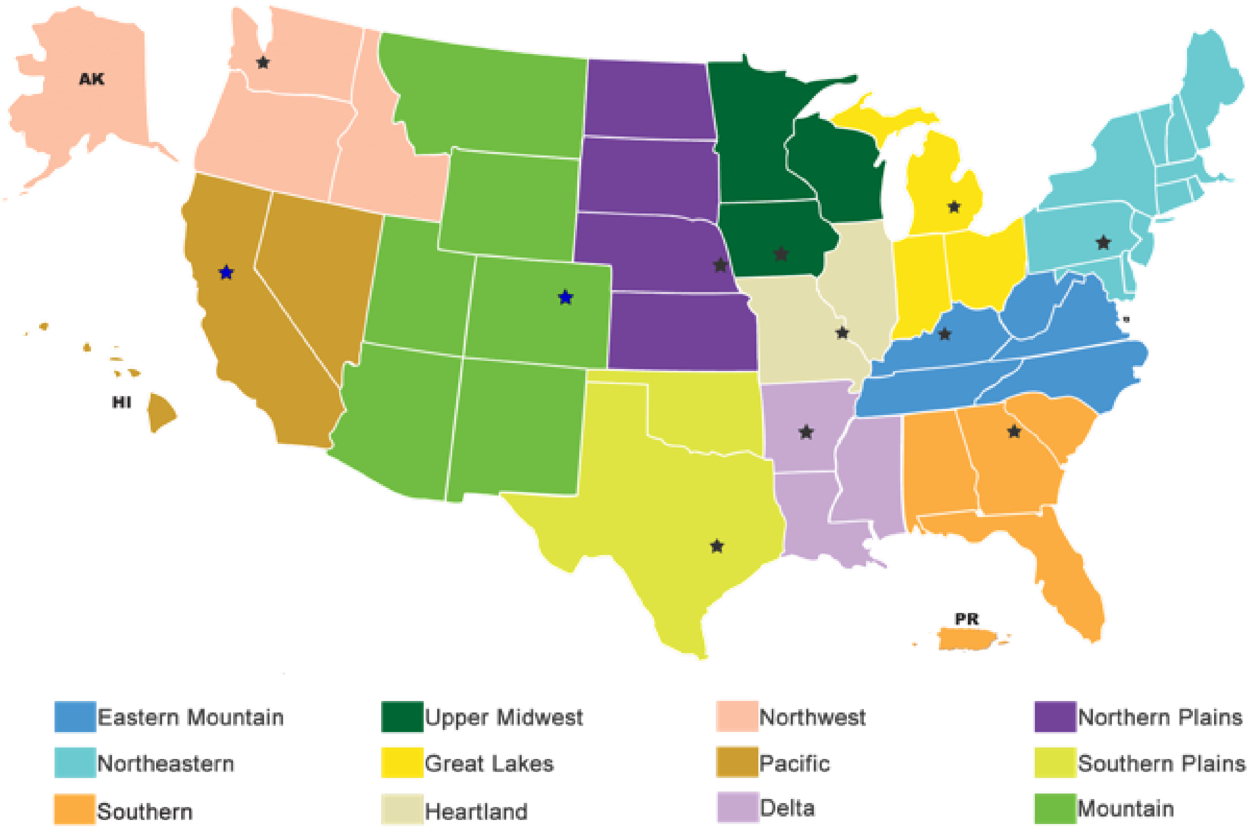
SARE and NASS Regions

Figure 1: SARE Regions



Source: SARE (sare.org)

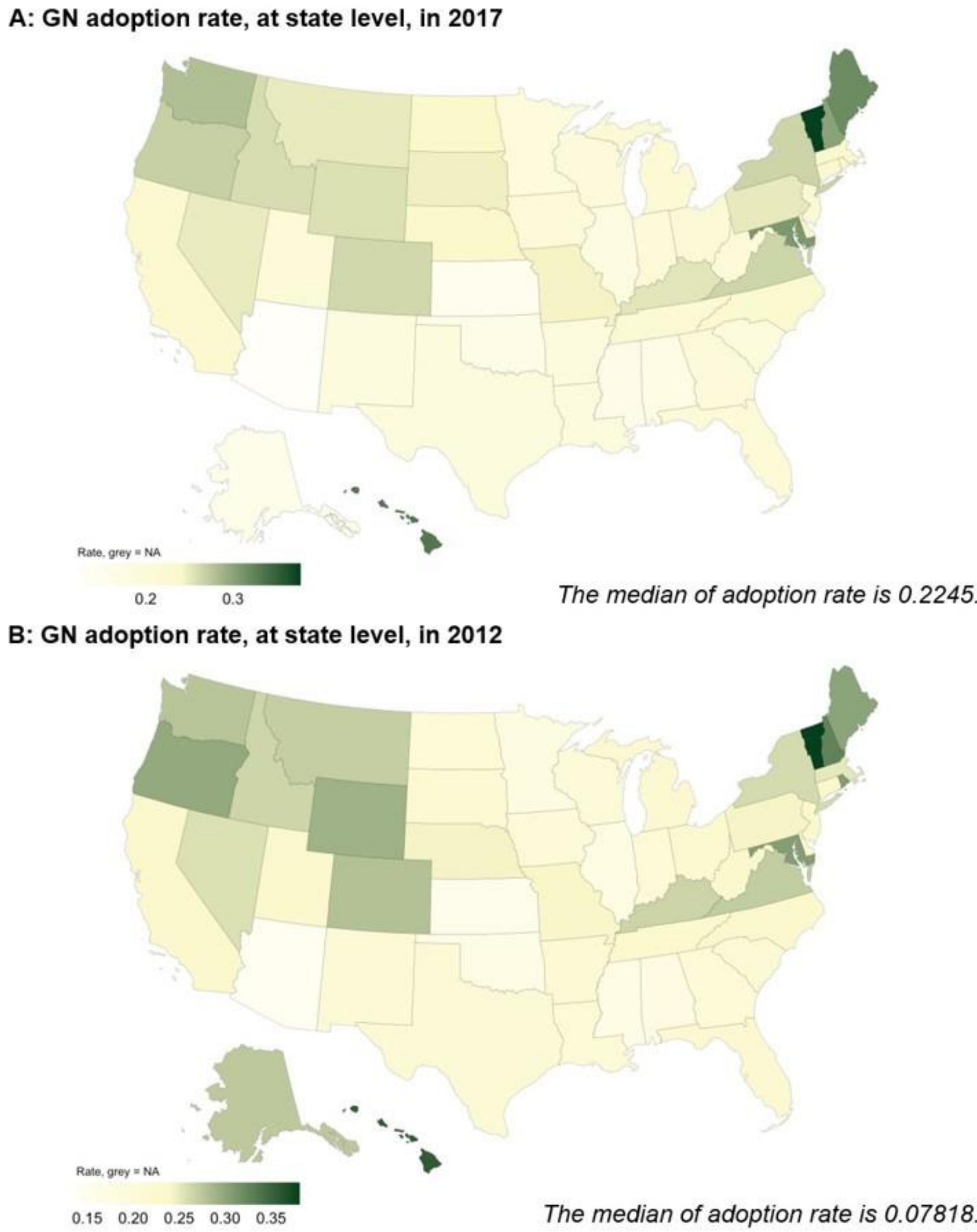
Figure 2: NASS Regional Offices Regions



Source: NASS (nass.usda.gov)

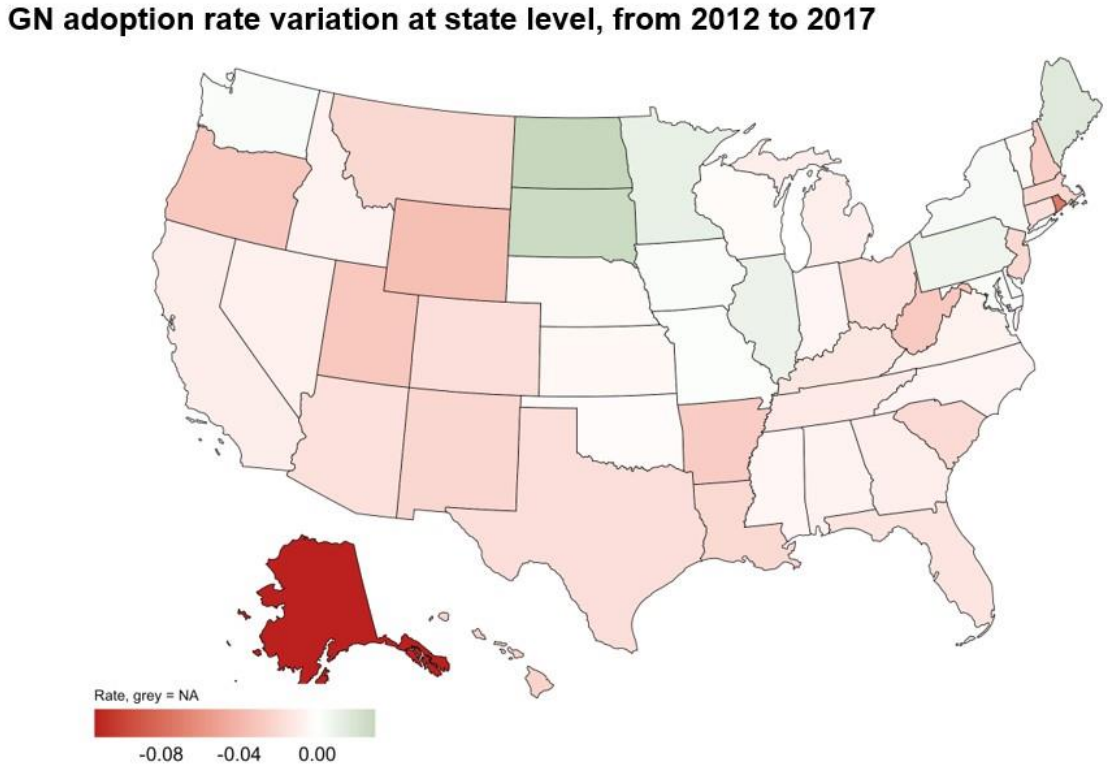
Sustainable Practices Adoption, at State Level, in 2012 and 2017

Figure 3: Rotational grazing adoption rate, at state level, in 2017 and 2012



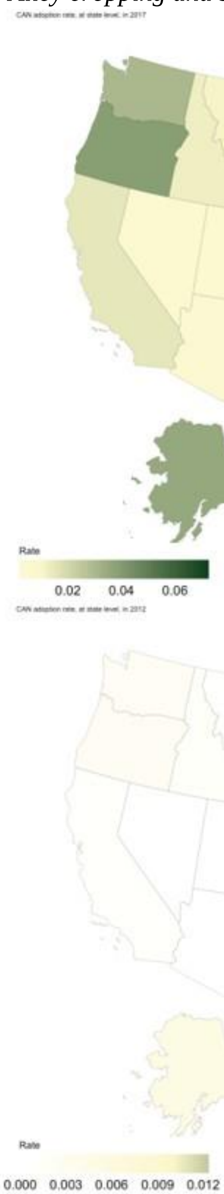
Source: Based on author's calculations

Figure 4: Rotational grazing adoption variation, at state level, from 2012 to 2017



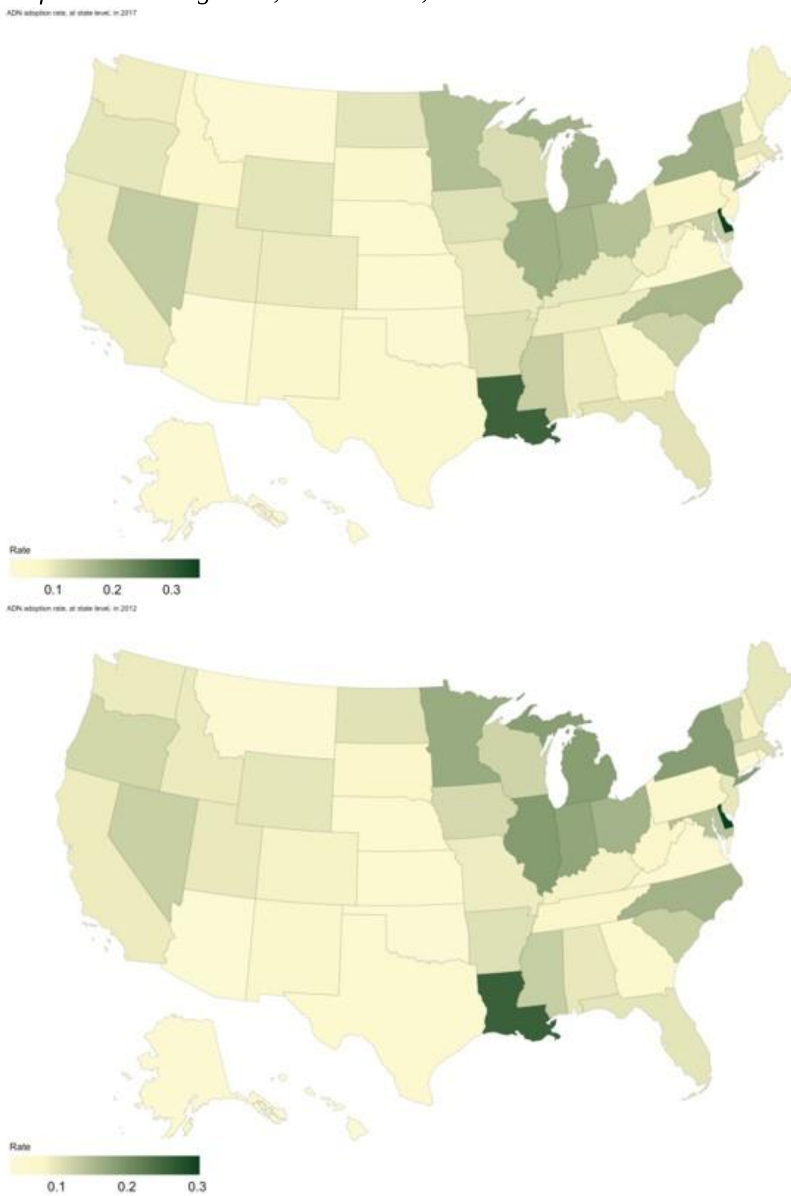
Source: Based on author's calculations

Figure 5: Alley cropping and silvopasture adoption rate, at state level, in 2017 and 2012



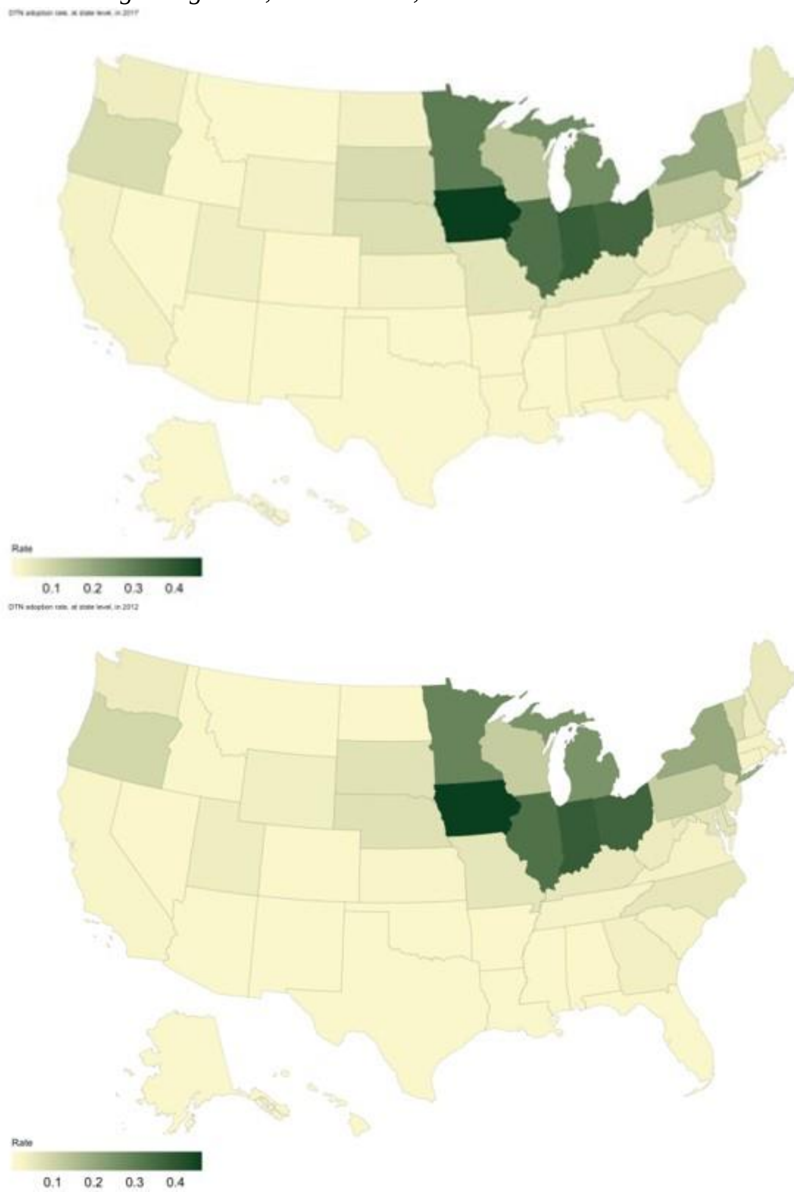
Source: Based on author's calculations

Figure 6: Artificial ditch usage rate, at state level, in 2017 and 2012



Source: Based on author's calculations

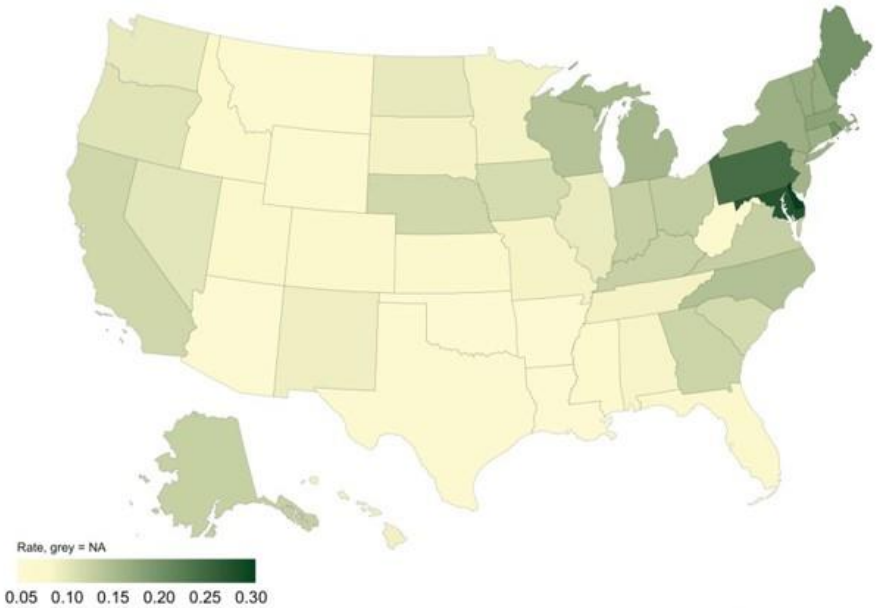
Figure 7: Tile drainage usage rate, at state level, in 2017 and 2012



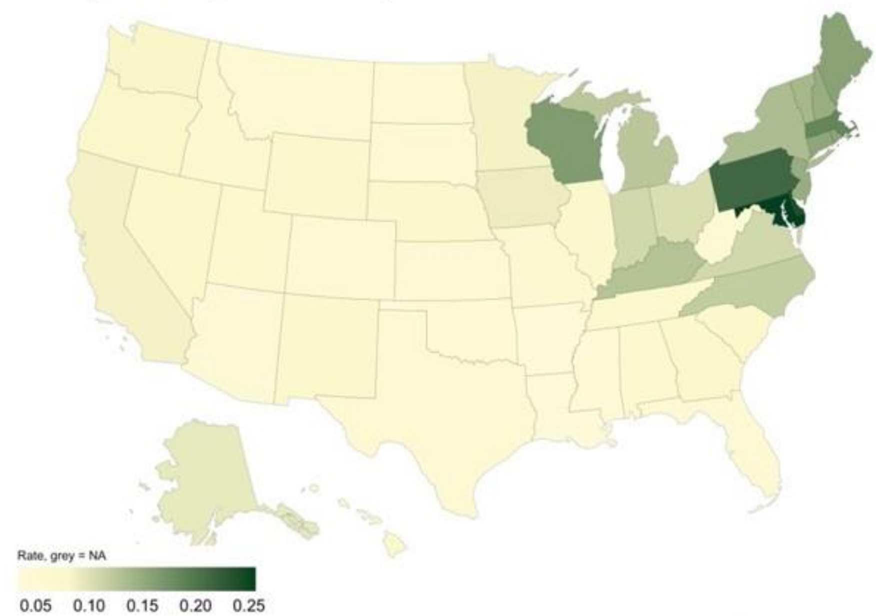
Source: Based on author's calculations

Figure 8: Cover crop adoption rate, at state level, in 2017 and 2012

A: CCN adoption rate, at state level, in 2017

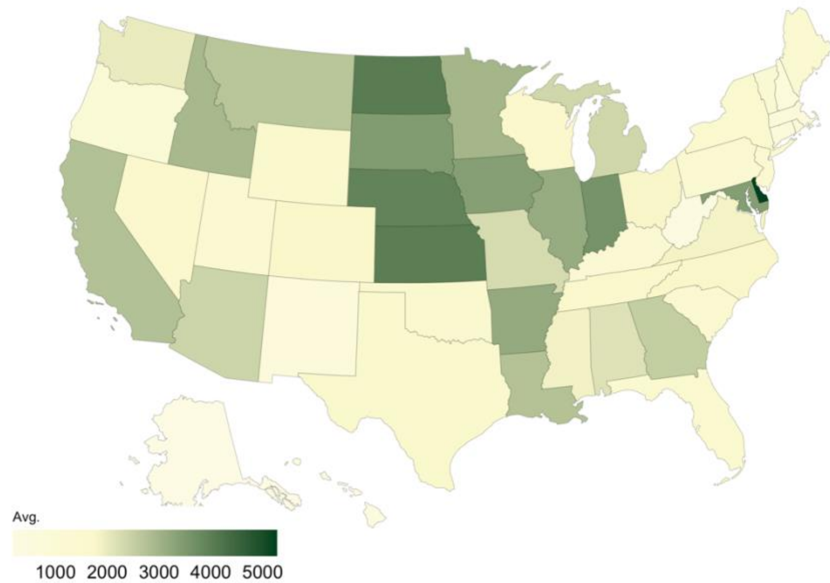


B: CCN adoption rate, at state level, in 2012



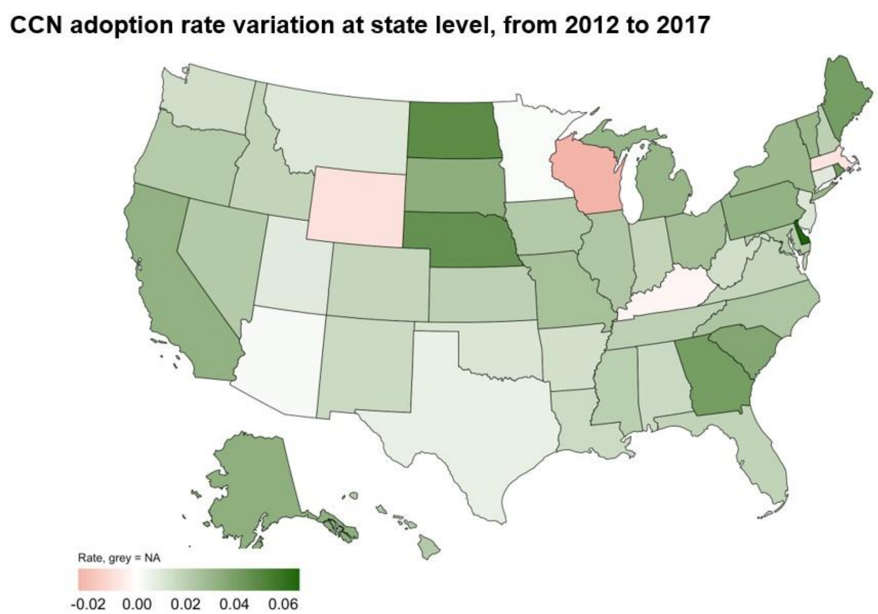
Source: Based on author's calculations

Figure 9: Average Cost of Cover Crop Seeds in 2017



Source: Based on author's calculations

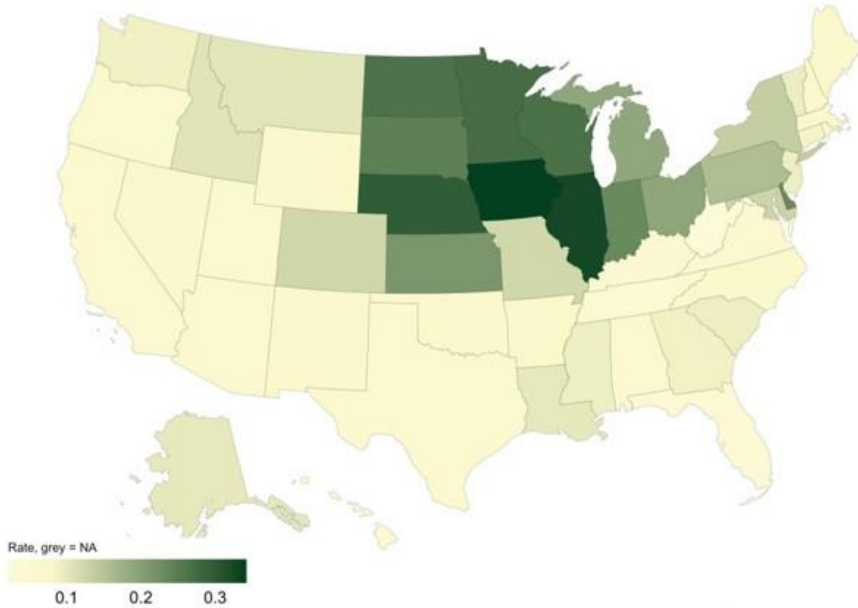
Figure 10: Cover crop adoption variation, at state level, from 2012 to 2017



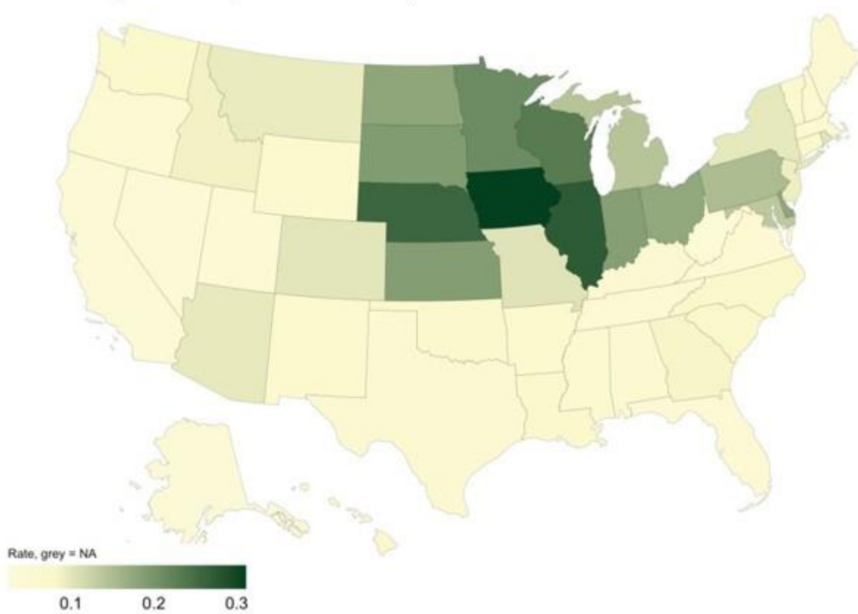
Source: Based on author's calculations

Figure 11: Minimum tillage adoption rate, at state level, in 2017 and 2012

A: CTCTN adoption rate, at state level, in 2017

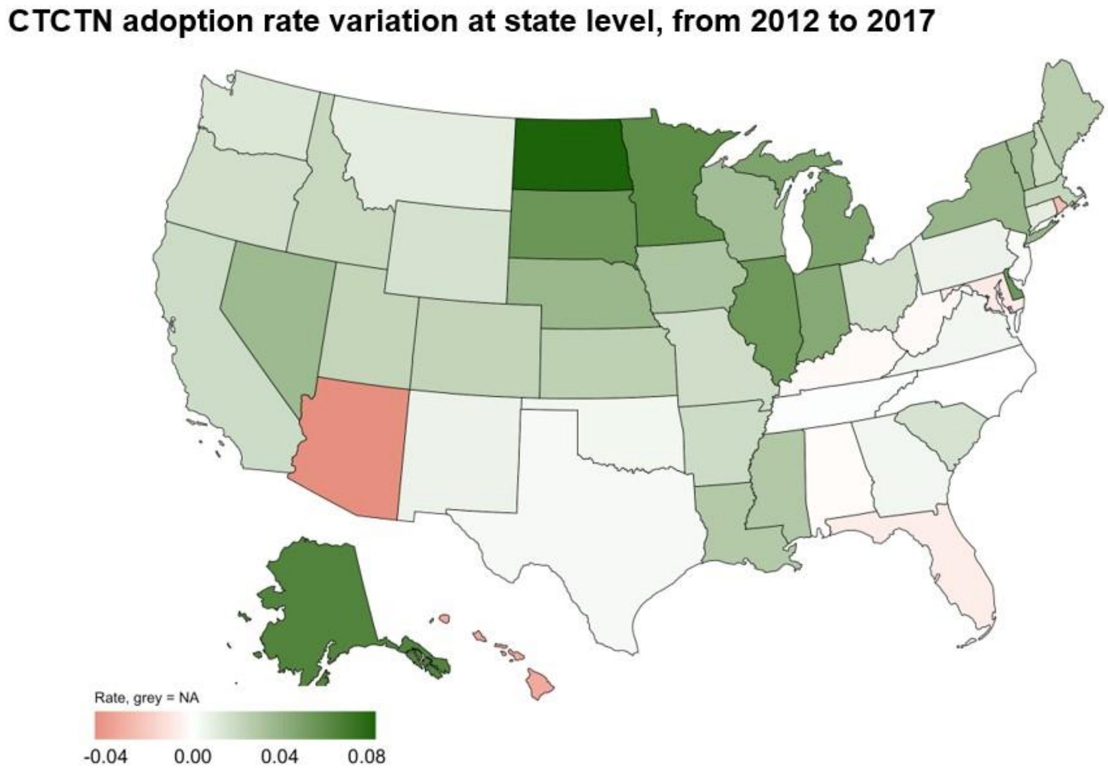


B: CTCTN adoption rate, at state level, in 2012



Source: Based on author's calculations

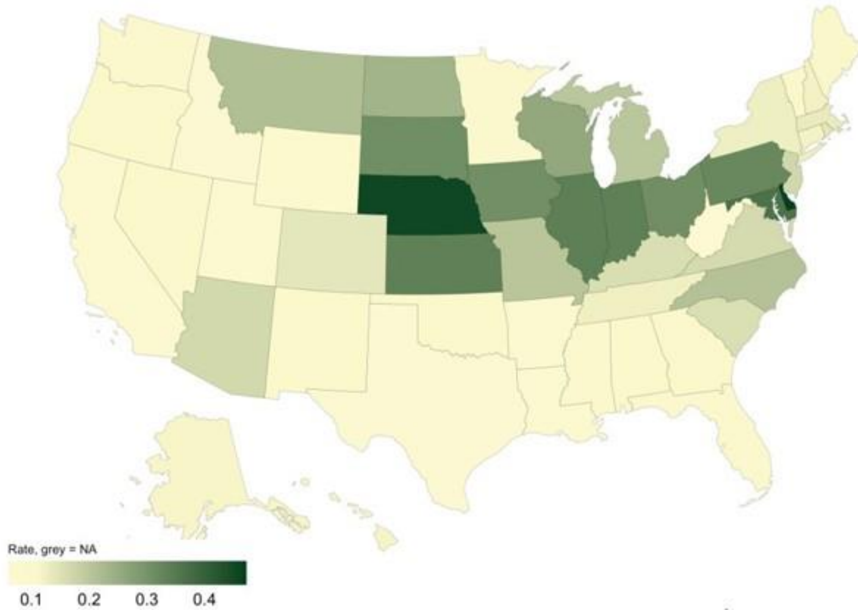
Figure 12: Minimum tillage adoption variation, at state level, from 2012 to 2017



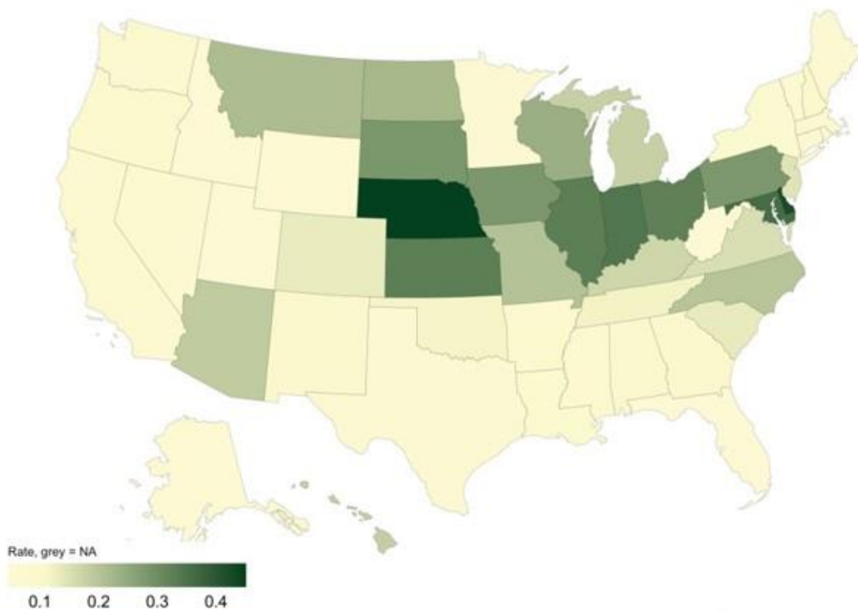
Source: Based on author's calculations

Figure 13: No-till adoption rate, at state level, in 2017 and 2012

A: CTNTN adoption rate, at state level, in 2017

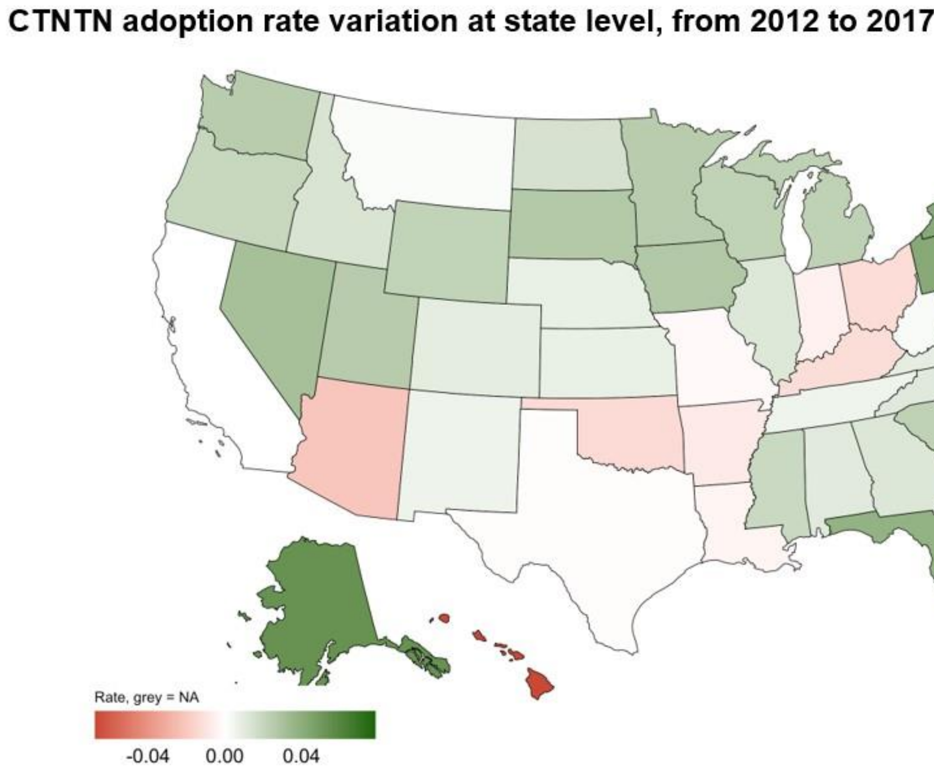


B: CTNTN adoption rate, at state level, in 2012



Source: Based on author's calculations

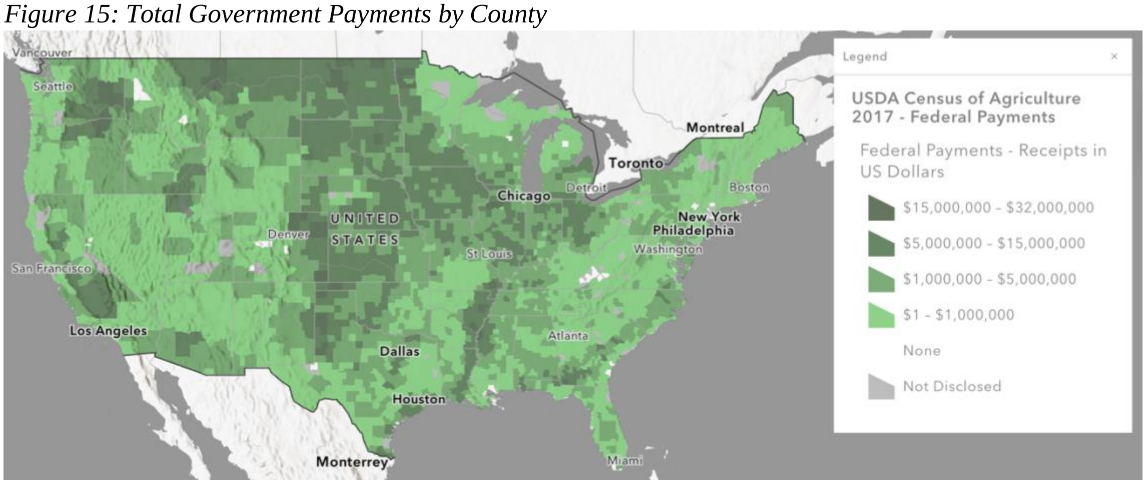
Figure 14: No-till adoption variation, at state level, from 2012 to 2017



Source: Based on author's calculations

Dependent Variables

Figure 15: Total Government Payments by County



Source: Web map created by juliah_esri on Living Atlas of the World