TRANSDISCIPLINARY, MIXED METHODS, SYSTEMS RESEARCH ON FARMER FOCUSED DECISION-MAKING FOR CONSERVATION AGRICULTURE IMPLEMENTATION

A Thesis

by

LISA AKINYEMI

Submitted to the College of Graduate Studies of
Tarleton State University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Chair of Committee:	Barbara C. Bellows Ph.D.
Committee Members:	Edward Osei Ph.D.
	James P. Muir Ph.D.
	Benjamin L. Turner Ph.D.
Head of Department:	Ryan Morgan Ph.D.
Dean, College of Graduate Studies:	Barry D. Lambert, Ph.D.

May 2020

Major Subject: Environmental Science

Acknowledgements

This thesis would not have been accomplishable without the participation of producers in 17 counties whose time and dedication to conservation agriculture are greatly appreciated. The Southern Sustainable Agriculture Research and Education Grant was influential in this research as well as my selection of a Master's program. Special thanks to Texas Institute for Applied Environmental Science Staff, Noble Research Institute Staff, Harvey Kahlden with Natural Resources Conservation Service in Karnes County, and many others who helped guide the research development. Two undergraduate research assistants, Diana Dinh-Andrus and Izaria Ferguson helped with the mixed methods coordination and analysis.

I would also like to thank each one of the committee members for their individual expertise and assistance in improving my communication and writing skills. In addition, Dr. Barbara C. Bellows wrote the grant, actively recruited me, and continuously encouraged me. Dr. Bellows had the largest part in the transformation from an undergraduate level of thinking I knew what it takes to performing at a graduate level.

Scholarships involved in the graduate education include the Davidson Presidential Scholarship, Dick Smith College of Science and Technology, and Bob Hallmark. Credit is also due to the Tarleton State University's Permaculture Garden Volunteers, Texas A&M AgriLife Stephenville Staff, Dr. Ali Saleh, and Tarleton State University Travel Grants, and the Department of Chemistry, Geosciences, and Physics. Prior to my graduate studies, the Texas A&M University-Kingsville's Undergraduate Research and McNair's Scholar Program staff were influential in getting me to this point. Thank you.

Abstract

Akinyemi, Lisa, Transdisciplinary, mixed methods, systems research on farmer focused decision-making for conservation agriculture implementation. MASTER OF SCIENCE (Environmental Science), May 2020., 101 pp., 6 tables, 18 figures, bibliography, 107 titles.

Ecosystem services such as water quality are improved with Conservation Agriculture System (CAS) implementation. CAS consist of multiple conservation practices intentionally utilized to provide combined results over consecutive years based on soil health principles. Soil health principles guide agriculture producer decision-making in selecting multiple conservation practices to maintain organic matter cover over soil, keep a root in the ground year-round, minimize soil disturbance, include plant species diversity, and incorporate livestock for additional biodiversity. While conservation agriculture, decision-making, farmer-first and bottom-up research has been conducted for over 40 years, additional resources currently exist to assist in conservation implementation improvements. With additional resources for conservation implementation, additional pressure exists to include heterogeneous groups of agriculture producers in research related to targeting finances. While the USDA Census does have some information available for assessing conservation agriculture decision-making trends, there is more information needed in transdisciplinary research that can be achieved by selectively interviewing CAS producers. This thesis uses geographical information systems to estimate trends in the USDA Census (CHAPTER I), scheduled phone interviews at the producers convenience (CHAPTER II), a stakeholder analysis adapted to accommodate varying participation from multiple CAS stakeholder representatives (CHAPTER II), the Nutrient Tracking Tool, benefit-cost analysis, and

Farm Economic Model for indicative estimates of differentiated productions in the Texas-Oklahoma region (CHAPTER III), and preliminary system dynamic methods. Understanding of interconnected factors that affect agriculture producer's on-farm decision making has both on-farm and off farm potential impacts. Improving support personnel understanding of producer decision-making can lead to improved funding effectiveness. Then funding effectiveness can improve CAS implementation rates, which can make positive impacts on water quality and other ecosystem service benefits.

Nomenclature

CAS	Conservation Agriculture Systems
NTT	Nutrient Tracking Tool
FEM	Farm Economic Model
$MtCO_2$	Mega Tons Carbon Dioxide
NRCS	Natural Resources Conservation Service
USDA	United States Department of Agriculture

TABLE OF CONTENTS

LIST OF GRAPHICS

TABLE

FIGURE

CHAPTER I

INTRODUCTION

Anthropogenic behavior, specifically social and policy changes, increase at the cost of natural resource sustainability (Raudsepp-Hearne et al. 2010). Suggested changes toward sustainability have been contested since the original Limits to Growth by Meadows et al. (1972). In Conversation Earth (2018), Dennis Meadows stated "right now, the global economy and global population is so far beyond sustainable levels, the goal is not to slow down, but get back down… Rather than striving for proactive prevention of future issues, we need to be looking at the crises that are going to occur in the future and understand what we need to do now in order to have the knowledge, the people, general public awareness required to make really radical changes when the time is ripe…" Natural resources need to be preserved proactively (Meadows et al. 1972; Raudsepp-Hearne et al. 2010; Conversation Earth 2018) and the agricultural industry is an economic activity closely associated with environmental protection (Kristensen et al. 2016).

In general, agriculture operations can either cause non-point source pollution to air, water, and land or conservation agriculture productions can systematically work with nature and potentially mitigate pollution. Many organizations are interested in improving conservation agriculture system (CAS) implementation, but there are disconnects in numerous technical and financial assistance programs that need to be addressed for continued improvement to occur at regional levels (Knight and Reed 2019; Mehan and Carpenter 2019; Prokopy 2019).

One region with historical challenges and current needs for CAS implementation improvement is Texas and Oklahoma, USA. Air pollution has been a repetitive problem since the late 1930's due to heavy tillage practices (Eagan 2001; Hansen and Libecap 2004). The underlying reason for agricultural nutrients contaminating surface and ground water supplies is water runoff, leaching, and soil erosion (Pimental et al. 1998). Both nitrogen (N) and phosphorous (P) are responsible for eutrophication (Environmental Protection Agency Staff 1974), toxic algal blooms in fresh water, hypoxia (Turner and Rabalais. 2003), oxygen depleting algal decay in salt water, and algae-based bio-diesel production in otherwise potable water (Baird and Cann p. 308 2012). In addition to algal blooms, nitrates leach through depleted soil and contaminate ground water, causing anthropogenic health concerns such as respiratory problems in babies, non-Hodgkin's lymphoma, and bladder cancer (Baird and Cann 2012 p. 156).

Regionally contaminated hydrologic regions include the Texas Gulf Coast (Parsons Staff 2019; Emirhuseyinoglu and Ryan 2020), and the Ogallala Aquifer (Gilley et al. 1982). Three hydrologic regions encompass Texas and Oklahoma including the Arkansas-White-Red hydrologic region, Texas-Gulf hydrologic region, and the Rio Grande hydrologic region (Rebich et al. 2011). Non-point source pollutants flow from various productions through these three hydrologic regions into the Gulf of Mexico, which affect the fishing industry. In addition to water and air pollution, the Texas and Oklahoma region also has unreliable climate conditions for agricultural production including semi-arid climates with more frequent rainfall extremes due to climate change.

Cropping and livestock systems in semi-arid conditions, such as the Texas and Oklahoma Panhandles, typically rely on irrigation (Allen et al. 2007). However, climate change and water efficient fixes that led to increased demands have previously stressed water supplies (Allen et al. 2007). Crop selection based on months of water availability is one recommendation for handling expected summer rainfall decreases in the El Reno, Oklahoma area (Zhang and Nearing 2005) and managing crop and livestock combined rotations of *Gossypium hirsutum* L. (cotton), forage, and beef *Bos taurus* L. (cattle) is another recommendation (Allen et al. 2007). Winter cover crops economically improve no-till *G. hirsutum* in the Texas Rolling High Plains with precipitation variability due to climate change (DeLaune et al. 2020). Due to this regional rainfall variability, (Sun et al. 2018; DeLaune et al. 2020), organizations need additional research to identify reliable, locally adapted practices for improving conservation agriculture system (CAS) implementation.

In the past 80 years, conservation agriculture factors (Ciriacy-Wantrup 1947; Stubbs 2020) affecting decision-making regarding the use of these practices (Steinbeck 1939; Schmolke et al. 2010) have been widely studied. Some studies have used theoretical perspectives and interdisciplinary methods to reveal ethical decision-making trends among agriculture producers and the environmental implications of those trends (Dunn et al. 2010; Turner et al. 2017). Other, regional, case studies demonstrated advantageous development policies and procedures that aid producers in conservation agriculture decision-making (Bawden 1991; Johnstone et al. 2018; Ducks Unlimited Staff n.d.). Many of these studies focused on the ecological effects and economic advantages provided by conservation agricultural practices, such as efficient use of N and P and reducing water erosion of sediment (Saleh et al. 2015; Gassman et al. 2009). Multiple factors have been studied to assess the environmental and ecological performance of agricultural production systems at various scales including farm (Gosnell 2011) and industry (Friedrich et al. 2017), national (Glenk et al. 2017), and global (Lal 2015).

Environmental modeling is a useful approach with many computer programs available, which have been used by various organizations needing to simulate effectiveness of specific CAS management decisions (Fisher et al. 2017). One of these computer programs is the Nutrient Tracking Tool (NTT), which is used by Old Woman Creek Pay-for-Performance Program in Ohio (Fisher et al. 2017) and the Maryland Water Quality Nutrient Trading Policy (Maryland Department of Agriculture and Environment Staff n.d.). Advantages of NTT are cost, familiarity, a user-friendly interface, and preprogrammed data for weather and soil through the United States Department of Agriculture (USDA) Web Soil Survey and National Weather Data (National Oceanic and Atmospheric Administration) (USDA Office of Environmental Markets n.d.; National Center for Water Quality Research Staff. n.d.).

Decision-Making Research is Another Aspect of Improved Knowledge Needed for CAS Implementation. Conservation agriculture decision-making studies typically focus on analyses of external factors (Prokopy et al. 2008; Carlisle 2016) and less on the process between the farm gate and the kitchen table (Tilman and Clark 2014; Kristensen et al. 2016) and material-energy flow (Forrester 1968; Li et al. 2012). Conservation agriculture decision-making involves policies and procedures implemented by various branches of the USDA derived from provisional funding in the US Agriculture Improvement Act of 2018 or predecessor documents (US Congress 2018; Harrigan and Chaney 2019). Other aspects of agriculture decision-making include ecology, economics, environmental factors, land tenure, and human behavior (Carlisle 2016). A "systems thinking" perspective, also known as complexity science, can be used to comprehensively evaluate relevant factors of conservation agriculture decision-making (Walters et al. 2016; Turner et al. 2017).

Conservation agriculture decision-making occurs at multiple levels, initial implementation, continued implementation for consecutive seasons, and additional adaptations (Prokopy et al. 2008; Hand and Nickerson 2009; Carlisle 2016). Initial implementation is the stage of decision-making where one or more conservation practices are substituted for conventional practices on various portions of land, like cover crops added instead of bare ground between seasons on a practice field. Continued implementation is a seasonal choice that often depends on regional conditions and economics, while additional adaptation occurs with more determined mindset and critical assessment of long-term economic benefits. CAS consist of multiple conservation practices over consecutive years. According to Jay Forrester (1968), the founder of system dynamics and professor at Massachusetts Institute of Technology., the word "decision" is used here to mean "the control of an action stream." The technical definition for decisions will be used in conjunction with decision-making research where one or more people have control of action streams, domino effects, snowball effects, or any other type of intentional and unintentional outcomes from those decisions.

Key "decisions" of conservation agriculture at all implementation stages include management practices that maintain vegetative soil cover, minimize soil disruption, maintain living roots in the soil throughout the year, and enhance plant and animal biodiversity in the field (Fuhrer and Bott n.d.). These "decisions" work together through a soil community, or soil food web (Phillips 2020), which ideally improve ecosystem services such as local water quality (Mehan and Carpenter 2019; Prokopy 2019). Implementation of multiple practices are expected to have better results in combination than individually (Hand and Nickerson 2009). If ecosystem services, such as local water quality, continue to suffer as a result of agriculture and related socio-economic practices, then anthropogenic wellbeing and vitality will continue to decline (Meadows et al. 1972; Raudsepp-Hearne et al. 2010; Tilman and Clark 2014). In Forrester's words (1968) "there should be bridging articles to show how system concepts can be applied in the functional areas and to management policy."

Because the key "decisions" in agriculture are made at the agriculture production level by producers, developing research processes around their professional knowledge can bridge gaps in conservation agriculture decision-making. While system dynamics were initially designed for technical industries such as factories, these processes have also been adopted for use in agriculture and ecology (Turner et al. 2016). The integrated nature of agriculture is much more regionally diverse than industrial systems due to climate, soil types, weather, and other specific production requirements. We suggest developing processes for regional dynamics rather than larger or smaller scale simulation models. Combining ecological and economic modeling to system dynamics modeling helps include detailed factors that would normally be excluded from a system dynamics model, provides information on trends within the region, and provides positive and negative economic and environmental numbers per operation modeled.

This study is not representative of all agriculture productions, or all conservation agriculture productions, but does provide diverse information within the Texas-Oklahoma region to develop system dynamics-based processes to better understand conservation agriculture decision-making processes. Like Walters et al. (2016), "In doing so, we hope to encourage a dynamic systems-based paradigm shift in agricultural systems analysis."

Organizations Working with the Natural Resource Conservation Service to Improve Conservation Agriculture Implementation with Technical Information and Funding Assistance. The Natural Resources Conservation Service (NRCS) has developed, cost-shared, and assisted agriculture producers in implementing 170 conservation practices in various locations nationally. One popular funding method still approved for use in most areas is the Environmental Quality Incentives Program (EQIP) that assists producers with implementing conservation practices to support existing CAS. Various non-profit organizations and business marketing campaigns are approved to supplement NRCS with technical information and funding assistance including Noble Research Institute in Ardmore, Oklahoma; Miller Coors in Tarrant County (Littlefield 2013), Texas; No-Till Farmers, Texas Organic Farmer's and Gardener's Association (TOFGA), National Center Appropriate Technology (NCAT), and Holistic Outreach Practical Education (HOPE) for Small Farmer Sustainability. Additionally, there are two pilot programs for ecosystem service markets in or near the Texas-Oklahoma region including Ecosystem Marketplace Consortium (Knight and Reed 2019) and Indigo Ag (personal communication with Elizabeth Combs, representative, on January 28th, 2020).

Data and Modelling Methods and Descriptions for Ecosystem Problem Understanding Prior to Sustainable Action Planning. According to Forrester (1968), "it is the task of the scientist to develop constructs and techniques of observation and measurement adequate to characterize the properties of any given life space at any given time and to state the laws governing changes of these properties." Research undertaken for this thesis was designed to provide adequate measurement inputs into a systems dynamic model with the objective of understanding and observing, from the producers' perspectives, factors that motivate and inhibit the initial, continual, and supplemental implementation of CAS. This thesis provides the preliminary stages in the development of a system dynamics modeling process. These preliminary stages include data gathering through oral interviews with farmers and farm support personnel, data analysis processes, and causal loop diagrams, recognition of archetypes or common problem structures within various systems and seeing the big picture to form a systems hypothesis. Methods used to accomplish data collection include geographical information system analysis of USDA Census information, scheduled phone interviews at 22 producers' convenience, Nutrient Tracking Tool management option simulations for impact analysis on watersheds, Farm Economic Model analysis for assessing producer economic options, and cost-benefit analysis for assessing managers' economic perspectives favoring conservation agriculture productions.

Materials and Methods

Geographical information system (GIS) analyses of USDA Census information was combined with research observations, and literature reviews to describe the amount of conservation agriculture practice implementation as a percent of total farms per county in the Texas-Oklahoma region of the USA. GIS system ArcMap 10.6 was used to produce county maps. Microsoft Excel was used to calculate relationships among components of the census information.

The USDA Census information used include year 2017, chapter 1, table 1, row 1 (https://www.nass.usda.gov/Publications/AgCensus/2017), which is the total agriculture productions; chapter 2, table 41, for conservation easements, no-till, reduced tillage, and cover crops; and chapter 2, table 43, for alley cropping and rotational grazing (NASS Staff 2019a). The provided numbers were summed and used as conservation agriculture percentages of total productions per county. The total numbers of conservation practices and agriculture productions for Texas and Oklahoma combined were also compared to the national data. Rates were calculated from the 2017 and 2012 data.

The USDA Census information GIS county maps for various crops (NASS Staff 2019b) were then compared to the hectares insured per crop type (RMA Staff 2017) for decision-making comparisons in Texas. Interviews with 22 agriculture producers from 14 Texas and 3 Oklahoma counties were conducted over the phone at the producer's convenience between April 2019 and January 2020. During the same time period, support personnel were also interviewed in person, over the phone, or at conferences to gain additional perspectives on new information. Specific numbers of productions, which continuously use multiple conservation practices per county, were requested from the NRCS, but confidentiality protocol prohibited obtaining additional information.

Results and Discussion

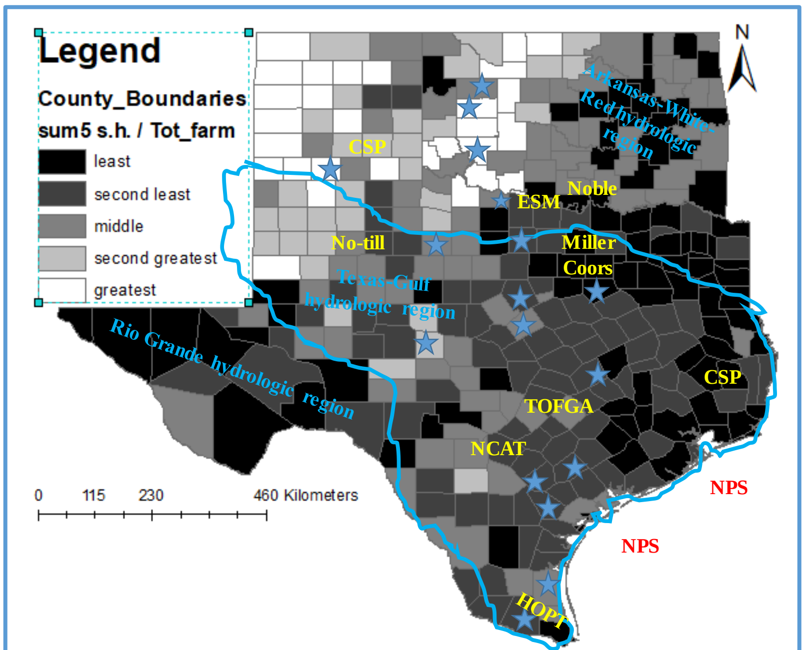
Nationally, CAS is implemented at an annual rate of 1.1% while the Texas-Oklahoma region is experiencing -0.8% overall CAS implementation for the six agriculture practices measured in the USDA Census conservation easements, no-till, reduced tillage, and cover crops; alley cropping and rotational grazing (NASS Staff 2019a). These five practices are conservation easements, no-till, reduced tillage, cover crops, and rotational grazing. Looking at each practice separately shows regional implementations of cover crops are improving while other practices are staying the same or moving out of operation. Conservation practice implementation is only one aspect of the numerous choices agriculture production managers make. The USDA Census Summary for Texas and Oklahoma shows a 97% family owned trend regionally (NASS Staff 2019a). The national annual rate of productions leaving agriculture is 0.6% and the regional annual rate is 0.1%. These rates show the Texas- Oklahoma region producers are more likely to maintain conventional practices on agriculture land than either removing land from agriculture or implement CAS compared to producers on a national scale. These rates help USDA and other organizations estimate total effectiveness of CAS implementation in their area (personal communication with Jimmy Emmons, regional coordinator for Farm Production and Agriculture Conservation on June 14th, 2019), but they do not specify if the practices are implemented continuously, which productions implement multiple conservation practices, or whether productions implement conservation practices such as contour farming or planting pollinator plant buffers that are not included in the USDA Census calculations of conservation practices.

Table 1.1
USDA Census data comparison for total conservation practices and total production.

USDA Census Data	**2017**	**2012**	**(2017-2012)/ 5 operation/yr**	**Annual Rate**
Conservation Practices (US)	***945,856***	898,596	9,452	1.1%
Conservation Practices (TX&OK)	***84,088***	87,502	-683	-0.8%
Agriculture Productions (US)	***2,042,220***	2,109,303	-13,417	-0.6%
Agriculture Productions (TX&OK)	***326,947***	329,054	-421	-0.1%

By mapping the USDA Census data for the percent of six total conservation practices per total agriculture productions in each regional county, researchers can see an overview of how CAS implementation varies across counties (figure 1.1) (NASS Staff 2019a). While this map is based on somewhat limited data, it does summarize interview participation areas, hydrologic regions flowing into the Gulf of Mexico, and various programs and organizations involved in CAS implementation. This big picture concept shows an interconnectedness between on-farm choices, support personnel and government policy decisions, and economic industries relying on various ecosystem service benefit

Figure 1.1
Geographic Information System map of 5 conservation practices measured by the USDA Census



NPS = Non point source pollution
CSP = Region preferred for Conservation Stewardship Program
ESM = Pilot region for Ecosystem Marketplace Consortium
= County of one or more interview participants
= Hydrologic region division within Texas and Oklahoma
Sum 5 s.h. / Tot_farm = (conservation easements + cover crops + rotational grazing + no-till + reduced tillage) / Total Farm Productions

According to Jaimie Foster Ph.D. (personal communication on June 2018), implementation of specific conservation practices that comprise CAS appears to be related to areas where NRCS and other organizations have promoted and prioritized each practice. Conservation Stewardship Program (CSP), which is still available in select locations, is used as a representative of CAS-related NRCS priorities. The Ecosystem Marketplace Consortium has a pilot environmental credit trading program near the Texas-Oklahoma border while Indigo Ag has a carbon credit program in Kansas.

Through discussions with 89 support personnel and interviews with 22 agriculture producers, we observed clear trends that lined up with many outreach programs from the Texas-Oklahoma region including: NRCS regional conservationists Harvey Kahlden in Kennedy, Texas; Will Brock in Frederick, Oklahoma; Noble research foundation in Ardmore, Oklahoma; Holistic Outreach Practical Education for Small Farmer Sustainability in Harlingen, TX; the Texas Organic Farmers and Gardner's Association in San Angelo, TX; the National Center for Appropriate Technology in San Antonio, TX; the Miller Coors Watershed Project in Tarrant County, TX; and No-Till Farmers Organization that holds an annual conference near Lubbock, Texas. The Ecosystem Marketplace Consortium has a pilot environmental credit trading program near the Texas-Oklahoma border while Indigo Ag has a carbon credit program in Kansas.

In one phone interview, a producer suggested crop insurance is a limiting factor for agriculture decision-making. Crop insurance limits crop selection by county and cover crop growing cycles (Harrigan and Charney 2019). The USDA Census provides a summary by state for various crops (figure 1.2) (NASS Staff 2019b). There is a trend between counties with reported yield and hectares insured for each crop type including

Zea mays L., *G. hirsutum*, *Sorghum bicolor* L., and *Triticum aestivum* L. (figure 1.3). For example, *G. hirsutum* yield is reported in 91 counties and has the highest hectares insured.

Figure 1.2
Geographical Information System maps of county crops

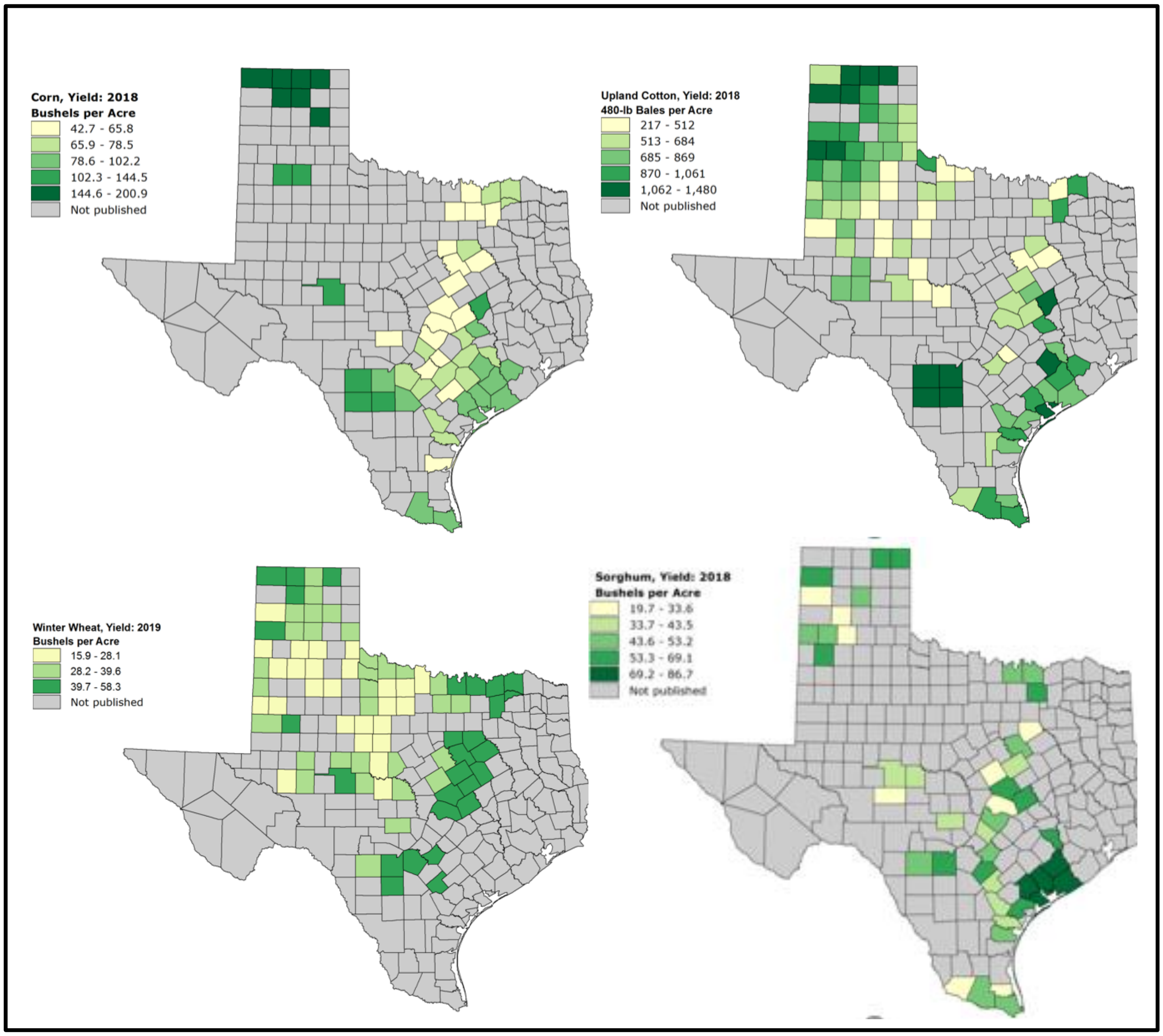
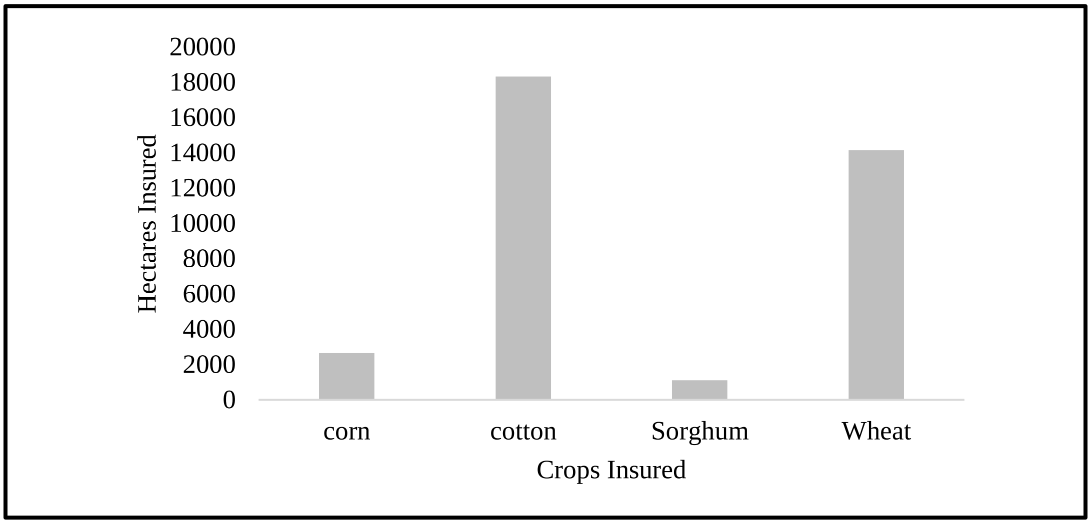


Figure 1.3
Table of hectares insured per crop including *Z. mays*, *G. hirsutum*, *S. bicolor*, and *T. aestivum* (RMA Staff 2019).



The trend between crops selected per county and crops insured per county affects which crops can be rotated, the rotation timing, cover crop implementation within the crop rotation timing, and whether livestock can be used to mow or terminate the crop. The most common crop selection and insurance related decision interview participants described was *S. bicolor* vs. *Z. mays*. *S. bicolor* is more drought tolerant, less susceptible to hogs, and stays green longer, which provides more organic matter after harvest. However, *Z. Mays* is more insurable and typically more profitable due to ethanol production for gasoline additives.

Cover crop are promoted through NRCS and have not been a hindrance to crop insurance in some areas, but the opposite exists in other areas due to confusing wording, previous subcommittee recommendations, and other reasons (Harrigan and Charney 2019). Cover crops are relatively new to Texas, possibly as a result of the changing demand (Groff 2019) and concerns with cover crop competition for soil moisture in arid areas of the state (personal communication with Jimmy Emmons on June 24th, 2019).

According to a national cover crop survey, 63% of non-cover crop producers were concerned about the crop insurance rules while only 18% of cover crop users expressed perceived or actual crop insurance rule interpretations against cover crops (Conservation Technology Information Center Staff 2017). The Agriculture Improvement Act of 2018 did address cover crop interpretation concerns (Harrigan and Charney 2019). However, the crop insurance is specifically for the cash crop. According to one farmer in the South Rolling Hills, cover crops in that area are still considered double crops. Therefore, the risk of attempting to fix N with cover crops must be assumed solely by the producers unless they are lucky enough to qualify for EQIP or other funding. Additionally, the crop insurance premium calculations are based on risk, but do not account for over ten years of conservation practices (personal communication with Jim Johnson of Noble Research on August 15th, 2019).

Summary and Conclusion

In Conversation Earth (2018), Dennis Meadows, lead author of Limits to Growth (1972), stated "… we need … to understand what we need to do now in order to have the knowledge, the people, general public awareness required to make really radical changes when the time is ripe…" In the Texas-Oklahoma region, implementation rates for the sum of five measured conservation practices are declining overall, although cover crop rates are improving (NASS Staff 2019a). Three hydrologic regions encompass Texas and Oklahoma (Rebich et al. 2011). Non-point source pollutants flow from various productions through these three hydrologic regions into the Gulf of Mexico. The sustainability of ecosystem service benefits, such as water quality depend, in large part on improved CAS implementation.

Conservation agriculture practices, which cover soil, minimize soil disruption, maintain living roots in the soil throughout the year, and enhance plant and animal biodiversity in the field (Fuhrer and Bott n.d.) are actively managed for both agriculture production and ecosystem service functionality. The implementation of CAS occurs initially as conventional methods are transitioned, seasonally as management practices are selected and maintained, and supplementary as additional conservation practices are adapted (Prokopy et al. 2008). Improving the socio-economic system affecting conservation agriculture decision-making is crucial both for enhancing the environmental sustainability of farm operations and off-farm ecosystem services. For CAS implementation improvement, disconnects among various components of technical and financial assistance need to be addressed at the regionally and local levels (Knight and Reed 2019; Mehan and Carpenter 2019; Prokopy 2019). For example, the Risk Management Agency (RMA) that oversees crop insurance regulations limits cover crops in semi-arid conditions while the NRCS actively promotes cover crops in the same areas (personal communication with Jimmy Emmons on June 24th, 2019). Both the RMA and NRCS are divisions of the USDA and actions appear to be taken to coordinate the various departments within the past year such as coordinating both the NRCS and the RMA under a new division Farmer Production and Agriculture Conservation typically referred to as FPAC (personal communication with Jimmy Emmons January 27th, 2020). Mixed messages to producers about financial decisions cause stress and potentially limit conservation practice implementation.

The Texas-Oklahoma region of the USA was selected to supplement transdisciplinary research and a pilot program known as the Ecosystem Marketplace Consortium that is providing CAS producers along the Texas and Oklahoma border with various environmental credits. This study uses mixed methods including conversational interviews, environmental modeling, economic analyses, and preliminary systemic modelling. The interview process resulted in raising critical questions and identifying critical interactions that can be examined in more detail in follow-up studies.

A “systems thinking” perspective is used throughout this thesis to comprehensively evaluate relevant factors of conservation agriculture decision-making. Many external factors also affect conservation agriculture decision-making. Methods in four separate chapters are designed to give estimates that can be used in further model development research, instead of definitive answers. A bottom-up, systems thinking approach based on producers’ knowledge, perceptions, and experience, evaluated using mixed methods provides an integrated perspective that may guide policy makers, researchers, and educators as they seek to enhance producer implementation of conservation agricultural practices.

CHAPTER II

STAKE HOLDER ANALYSIS COMPARED WITH META DATA

Agriculture producers in the Texas-Oklahoma region of the USA are a minority group who manage approximately 80% of the land area and are pressured by social, economic, and environmental factors outside of their individual control (US Census Staff 2010; NASS Staff 2019a). In the past decade, generational and economic shifts led to agriculture land sales for many non-agriculture purposes (Nickerson et al. 2012). Some agriculture producers have been able to withstand social and economic pressure and adapt with the help of scientific developments in order to prepare for global population growth, rising cost of inputs, and declining natural resources within the next 30 harvests (Hill and Kaiser 2019). However, many of the scientific advances may not be the best practices for conserving the environment (Raudsepp-Hearne et al. 2010; Glenk et al. 2017) and other scientific options openly admit there are trade-offs involved such as groundwater pollution vs. surface water pollution (Gilley et al. 1982).

Conservation agriculture systems (CAS) are based on soil health principles including keeping the soil covered, minimizing soil disruption, maintaining living roots in the soil throughout the year, and enhancing biodiversity in the field (Fuhrer and Bott n.d.). CAS is made up of multiple conservation practices including no-till farming, planting cover crops between cash crop seasons, rotational grazing for plant diversity improvement, and maintaining pollinator habitats to promote beneficial insect populations. Combining practices effectively and monitoring progress enhance ecosystem services more than any individual practice alone (Hand and Nickerson 2009). The NRCS has established, funded, and provided technical assistance for approximately 170 various conservation practices, which are implemented throughout the USA. Other organizations aid the NRCS with match money to further support CAS implementation (personal communication with Adam Carpenter, American Water Works Association, August 13th, 2019). Disconnects between support personnel agenda and agriculture producer conservation decision-making need addressed on a regional level for improved rates of CAS implementation.

Regional Level Match Money Programs Learn from Mistakes of Previous Programs. Human lives depend on water quality and the National Water Quality Initiative has established adaptable protocol for trading point source and non-point source Total Maximum Daily Limits between industrial polluters with and conservation agriculture producers for cost effective compliance options (Prokopy 2019). These protocols have been adopted by 14 states (Troutman 2014). However, the Environmental Protection Agency has not met the enforcement expectations these protocols depend on (Johnstone et al. 2018).

The Chesapeake Bay Business for the Bay program is an example of positive outcomes of the National Water Quality Initiative and can serve as a role model for community support of CAS. Using the Environmental Protection Agency's eco-labeling program, Business for the Bay has provided match money and volunteer base to aid with various CAS implementation such as riparian buffers, rotational water systems and fencing to limit agriculture nutrients from entering streams. When businesses participate effectively, they are rewarded with the use of Chesapeake Bay's eco-label. Consumers supporting the Chesapeake Bay program are encouraged to look for the eco-label and limit their individual pollution. Thus, a sense of community and shared accomplishment replaces the typical agribusiness economic framework.

Using environmental credit trading strategies instead of eco-labeling, two pilot programs are overcoming challenges discovered in the last two decades by various total maximum daily load and carbon credit trading programs. Indigo Ag has a pilot program in Kansas based on trading carbon dioxide equivalents (CO_{2e}), currently valued at approximately $15 per designated amount of CO_{2e}, or optimistically $74 per hectare (personal communication with Elizabeth Combs, with Indigo Ag, on January 28th, 2020).

The Ecosystem Services Markets Consortium has a pilot program in Texas and Oklahoma brokering payments for million metric ton (MMt) CO_{2e} as well as minimizing nitrogen (N) and phosphorus (P) water quality credits (Knight and Reed 2019). Using multiple payments, they hope to pay deserving ranchers more than $74 per hectare (personal communication with Chad Ellis, with Noble Research Institute, on August 14th, 2019). The demand scale is 5.2 billion dollars per 190 MMt CO_{2e}, 4.8 billion dollars per 1.58 billion pounds of N, and 3.8 billion dollars per 0.8 billion pounds of P (Knight and Reed 2019). Some of the improvements over predecessor programs include use of drones and simulation programs in verification processes (Fisher et al. 2017; personal communication with Chad Ellis, with Noble Research Institute, on August 14th, 2019; Yuan et al. 2019). These pilot programs are working towards becoming national programs soon, thereby stimulating more conversions of farms from conventional agriculture to CAS than to non-agriculture land uses.

With Additional Resources for Conservation Implementation, Additional Pressure Exists to Include Heterogeneous Groups of Agriculture Producers in Research Related to Targeting Finances (Mehan and Carpenter 2019; Knight and Reed 2019; personal communication with Elizabeth Combs from Indigo Ag on January 28th, 2020).

Multiple research methods are available for including agriculture producers in funding decisions or otherwise examining conservation agriculture decision-making. Mitchel et al. (2012), Smith et al. (2017) and Gramig and Widmar (2017) used quantitative methods to measure willingness to adopt conservation based on various funding programs as opposed to actual conservation practice adoption (Prokopy 2008; Hands and Nickerson 2009). Conservation Technology Information Center Staff (2017) conduct national cover crop surveys annually. These online surveys have separate scripts for cover crop and non-cover crop producers. The annual surveys do not measure continuous adoption of cover crops or other conservation practices, but they do provide quantitative data on cover crop decision-making for heterogeneous groups of national agriculture producers. A more common method than mail or internet surveys of agriculture producers is surveys of literature (Nelson et al. 2008; Ells and Soulis 2013; Carlisle 2016; Silva et al. 2018). Surveys of literature form a specific set of questions and use extensive literature reviews from a specified typed of journal articles or online databases.

All these research methods allow researchers to collect statistical representation of agriculture producers within a one-year time frame, from question formation to result analysis, and none of these methods encourage agriculture producers to voice unrequested knowledge. Statistical analyses are good for proving or disproving the researcher’s original assumptions, but agriculture producers who implement conservation practices have more knowledge to offer researchers than researchers would originally know to ask (Friedrichsen et al. 2018).

Systems research also provides tools for gathering professional knowledge of various stakeholder groups and analyzing that knowledge through various methods. Depending on the time frame, recorded focus group discussions in specific locations with diverse stakeholder group representatives is one systems data collection method (Sassenrath et al. 2010; Walters et al. 2016; Behzadifar et al. 2019). A drawback to focus group discussions is that building trust among various participants takes time and funding for multiple group meetings (Weeks et al. 2017). Without trust building exercise, authoritative assumptions are made. Authoritative assumptions in groups of diverse individuals can cause misinterpretations of each other's arguments (Pahl-Wostle 2007). Authoritative assumptions can also lead to a phenomenon known as group think where all the individuals take on the opinion of the highest assumed authority (Dweck 2006).

Another systems research tool for gathering professional knowledge is semi-structured or iterative interviews (Turner et al. 2014; Berariu et al. 2016). Iterative interviews start with careful selection of participants (Turner et al. 2014; Berariu et al. 2016), unlike statistical designs (Bandoni 2009). In addition to careful participant selection, choosing how many questions to ask involves choosing how in-depth and time consuming the study should be (Varvosky and Brugha 2000). Another choice to be made is whether to conduct the semi-structured interviews face-to-face, over the phone, or using technological meeting options and whether to include recording devices.

In addition to data collection methods, analyses methods are also essential. Choices considered include the Likert 4 and 5 point Scales (Brown 2000), the progressive farmer first analysis approach instead of scientist first analysis approach (Fredriechsen 2018), agent based analysis with separated questions for each stakeholder group and specialized coding comparisons (Zeaman 2019), and stakeholder analysis (Varvasovszky and Brugha 2000; Turner et al. 2014; Behzadifar et al. 2019). The stakeholder analysis was designed for integrated communication with various stakeholder group representatives within a system. The stakeholder analysis is a process of counting various factors and sub-factors mentioned repeatedly in the conversations with the aid of a coding method to connect various statements by using similarities within descriptions. For example, decreased use of pesticides might be described as pollination strips or other beneficial insect promoting methods because pesticides would not discriminate against non-beneficial insects. Potential biases to avoid include order selection (2019 thesis), scientist framed farm research (Fredriechson 2018), and computation of stakeholders by rank order (Pahl-Wostle 2016).

In this research study, phone interviews were conducted with 22 conservation agriculture producers in 14 Texas counties and 3 Oklahoma counties between the months of April 2019 and January 2020. Observations of discomfort and trust issues developed as the researcher requested to use a recording device, so careful notes were taken instead. In this study, both the farmer first analysis and the stakeholder analysis are used to evaluate the data collected from interviews, presentations, and publically available farm support information.

Materials and Methods

In this study, mixed-methods interviews and public-access data mining were conducted with two stakeholder groups 1) producers involved in conservation agriculture practices, and 2) agriculture support entity representatives. Texas and Oklahoma CAS producers with four or more years of experience using multiple conservation practices were this study’s primary focus. The aim of this study was to investigate experienced CAS producer opinions and agricultural supportive entities views on the impacts of external factors on regional adaptation of CAS. This study used stakeholder analyses framework from Turner et al. (2014), stakeholder and social network analyses from Behzadifar et al. (2019) and Varavosovszky and Brugha (2000), and farmer first analyses from Scoones et al. (2009). In Varavosovszky and Brugha (2000), specific instructions are given to select the depth of the interactions, or amount of questions, to fit the time frame available. In this study, the in-depth "analysis with detailed assessment of stakeholder interests, positions, networks, and influence" took nine months, April 2019 to January 2020, to provide other transdisciplinary research groups in the Texas and Oklahoma region a more comprehensive concept of the current CAS systematic condition.

Questionnaire. A quantitative and qualitative questionnaire guided semi-structured conversations with producers. The questionnaire was developed after researching agriculture decision-making, decision-making in general, conservation agriculture practices, and case studies (personnel communication with R. Hanagriff, Ph.D. February 12th 2018). There were originally 12 demographic questions, 9 environmental questions, 3 conservation training questions, and 18 questions dealing with economics, incentives, and funding policy specifics, with the remaining 5 questions dealing with land tenure, and 3 questions about other influences and messages to others (table 2.1; Appendix A-B). Both qualitative, specific categorical answers, and quantitative, open ended, responses were expected. Although the conversational design did not require the questions to be asked verbatim, the questions did provide a basis that typically guided the conversations. Notes were taken of each interview and the answers were entered into an excel database. Process documentation included measures taken to obtain interviews and related data, responsiveness to initial contact, length of interview, level of interest of participant, provided unprompted information, specific answers, and follow up correspondence (German and Stroud 2007: Schmolke et al. 2010).

Table 2.1
Questionnaire numbers with some example questions that were used in the analysis.

Demographics	What is/are the age groups of the primary operator(s)?
	What is/are the highest education level of the primary operator(s)?
	How many days are worked off farm by the (primary operator(s) and spouse(s))?
	What is the primary occupation of the primary operator(s)?
On Farm Environment/ Economics	Can you tell me about the production?
	What percentage of the land operated is leased to the decision-making operator?
	What conservation agriculture outreach programs have you learned from?
	What (environmental; economic; other) benefit/loss have you experienced as a result of this implementation?
Messages	Do you have any suggestions for communicating the value of conservation practices and ecosystem services to absentee landowners, consumers, and other producers?

Primary Producer Interviews. The primary focus of this research has been the 22 CAS producers within the Texas and Oklahoma region that provided 60 to 90 minutes of their time for in depth, conversational phone interviews. Primary participants represent multiple CAS productions in 14 Texas counties and 3 Oklahoma Counties. Texas counties are: Bee, Denton, Dewitt, Ellis, Erath, Hamilton, Haskell, Hidalgo, Karnes, Mason, Milam, Swisher, Wichita, and Willacy. The Oklahoma counties are Custer, Dewey, and Kiowa. The primary stakeholders were the most willing to schedule time and most likely to expand on topics approached in the questionnaire. Recruitment processes included 1) contacting producers involved in a soil health research project funded through the same SARE grant as this research,, 2) attending various Soil Water Conservation meetings, workshops, and their annual conference, 3) contacting Noble Research Institute's consultants, and 4) networking with producers locally. Most of the interviews were conducted over the phone at the producer's convenience. Unsuccessful recruitment included requesting contacts and estimates of qualified producers from various USDA NRCS offices due to confidentiality restrictions. This process took nine months (April 2019 to January 2020) to complete, although other research was ongoing during this time frame.

Secondary Producer and Support Personnel Interviews. Additionally, 20 other CAS producers either participating in conservation training programs or presenting at them, and 89 support personnel were interviewed for 30 minutes or less. The workshops and conferences attended during this process include: Texas Wheat Producers Workshop in Vernon, August 29th 2018; Texas Water Resources Workshop in Riesel on April 3rd 2019; the Southern Region Water Conference in College Station July 23-25 2019; the Soil Water Conservation Conference in Pittsburg Pennsylvania, on July 29th - 31st 2019; the Tri-Society Conference in San Antonio November 8th – 11th, 2019; a small soil health workshop at Roan Ranch near Fredericksburg December 14th 2019; and the No-Till on the Plains Conference in Wichita Kansas on January 23rd 2020. The workshops were attended to provide the researcher with opportunities to develop the important skill of professionally communicating with farmers, ranchers, and other agriculture producers. The research conferences provided the researcher with the opportunity to present the preliminary her research and reevaluate the research process prior to finalizing the results. Finally, the Roan Ranch and No-Till on the Plains Conferences were attended as additional efforts to gain farmer and support personnel insights during the interview time frame of April 2019 to January 2020.

Additional Information Sources. As an additional means of collecting producer and support personnel insights, published case studies, publicly accessed US agriculture related information, and an interdisciplinary literature review were also conducted. These include approximately 86 journal articles (i.e., not repeated in other categories), 35 publicly accessible data, 16 case studies, 6 books, and 2 producer surveys. These covered topics from individual producer's techniques (Ristow 2019) to national policy and funding approaches (US Congress 2018), with many various topics in between such as livestock enterprise budgets (Amosson 2011), ecosystem service markets (Knight and Reed 2019; Wilcox 2019; Ecosystem Marketplace Staff 2017). The additional information supplemented the interviews and allowed the researcher to compare information previously identified and various methods used.

Stakeholder Analysis. Primary and secondary interview data were separated by the type of agriculture production represented. Four stakeholder groups emerged, 20 support personnel, 11 combination farms and ranches, 7 row crop farms, and 4 other agriculture productions, and. The support personnel participant number was selected based on the largest sub-factor count instead of the total amount of support personnel due to other information also being provided. Most of the participants also had secondary productions that influenced some of the provided information. Secondary agriculture productions included: a feedlot, two meat packing plants, a full-time landlord, some occasional landlords, a crop insurance company, and various board memberships on conservation committees. The stakeholder analysis involved a count of various factors mentioned in the conversations by various stakeholder groups. These methods have been described in Varavasovszky and Brugha (2000), Turner et al. (2014), and Behzadifar et al. (2019). Appendices C-E provide examples of specific coding used to analyze which factors were mentioned more and therefore deemed more important. Due to designing the research to learn from producers and expand methods as we went, the initial questions may have skewed the stakeholder analysis count.

Table 2.2 lists identified sub-factors for each stakeholder group. Both solicited and unsolicited CAS producer information was analyzed first, and the support personnel information was evaluated second using the CAS producer sub-factors. Open coding was the process selected for categorizing various statements. For example, any mention of pollination improvements was taken to mean lower pesticides and water quality improvements were translated to chemical pesticide/ nutrient reductions (Appendix E).

In table 2.2, each of the four stakeholder groups received a count for each sub-factor chosen based on solicited and unsolicited interview responses. Both unsolicited and solicited sub-factors are listed, and combined totals are provided when information is similar. These sub-factor counts were divided by the number of participants for each group. This process also allowed inclusion of most of the unsolicited information and unevenly distributed information. The column labeled “graph” in Table 2.2 refers to information presented in Figure 2.2.

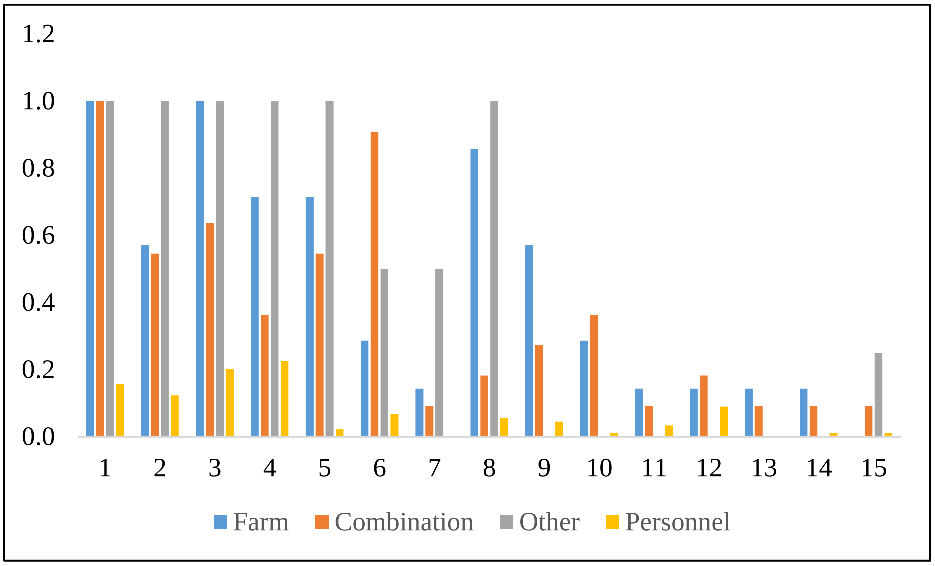
Table 2.2
Stakeholder analysis listing the number of times each sub-factor is mentioned in interviews.

Participants per Stakeholder Group Considered in Analysis			7	11	4	89
Unsolicited Sub-factor	**Solicited Sub-factor**	**Graph**	**Farm**	**Combination**	**Other**	**Personnel**
Erosion, Environmental Limitations, Hogs	Increase in Soil Health	1	1.0	1.0	1.0	0.2
On Farm Economics	Increase of Diversity & Quality	2	0.6	0.5	1.0	0.1
Cover Crops and Livestock	Increase in Biodiversity	3	1.0	0.6	1.0	0.2
General Environmental Concerns	Decrease in Chemical Pesticides & Nutrients	4	0.7	0.4	1.0	0.2
Local Knowledge & Community Support		5	0.7	0.5	1.0	0.0
	Educators, Researchers, Sustainable NGO's	6	0.3	0.9	0.5	0.1
Pay Back, Break Even	Responses to question 33 ranged 0-10 years.	7	0.1	0.1	0.5	0.0
Yield Same or Better	Commodity Yield Increase	8	0.9	0.2	1.0	0.1
Cover Crops & Hemp Experimentation	Hands on Adaptation & Learning	9	0.6	0.3	0.0	0.0
Belief in Self & Determination		10	0.3	0.4	0.0	0.0
Support to Community with any Government Funding		11	0.1	0.1	0.0	0.0
Pilot Projects		12	0.1	0.2	0.0	0.1
Living off the Land		13	0.1	0.1	0.0	0.0
Water Infiltration		14	0.1	0.1	0.0	0.0
Flexible contracts		15	0.0	0.1	0.3	0.0

Results and Discussion

Solicited and unsolicited information were then combined using table 2.2 and graphed in figure 2.1 for an overview of sub-factors based on the number of times mentioned per participant interviewed. The ten sub-factors that were most mentioned overall by agriculture producers were erosion, environmental limitations, hogs; on farm economics; cover crops and livestock; general environmental concerns; local knowledge and community support; learning from specific educators, researchers, and sustainable NGO's that have previously earned the producers respect; payback and break even periods ranging from same season to ten years depending on amount of investment and personal preferences or operational needs; relationship based land tenure, which includes family, friends, family of friends, and respect built relationships; yield same or better as opposed to decreased yield due to conservation implementation; and flexible contracts, especially for other types of agriculture. Research processes allowing each CAS agriculture producer to volunteer their time at their convenience and have their shared knowledge count both individually and as a group representative is vastly different than other types of research requesting feedback on a scientific opinion.

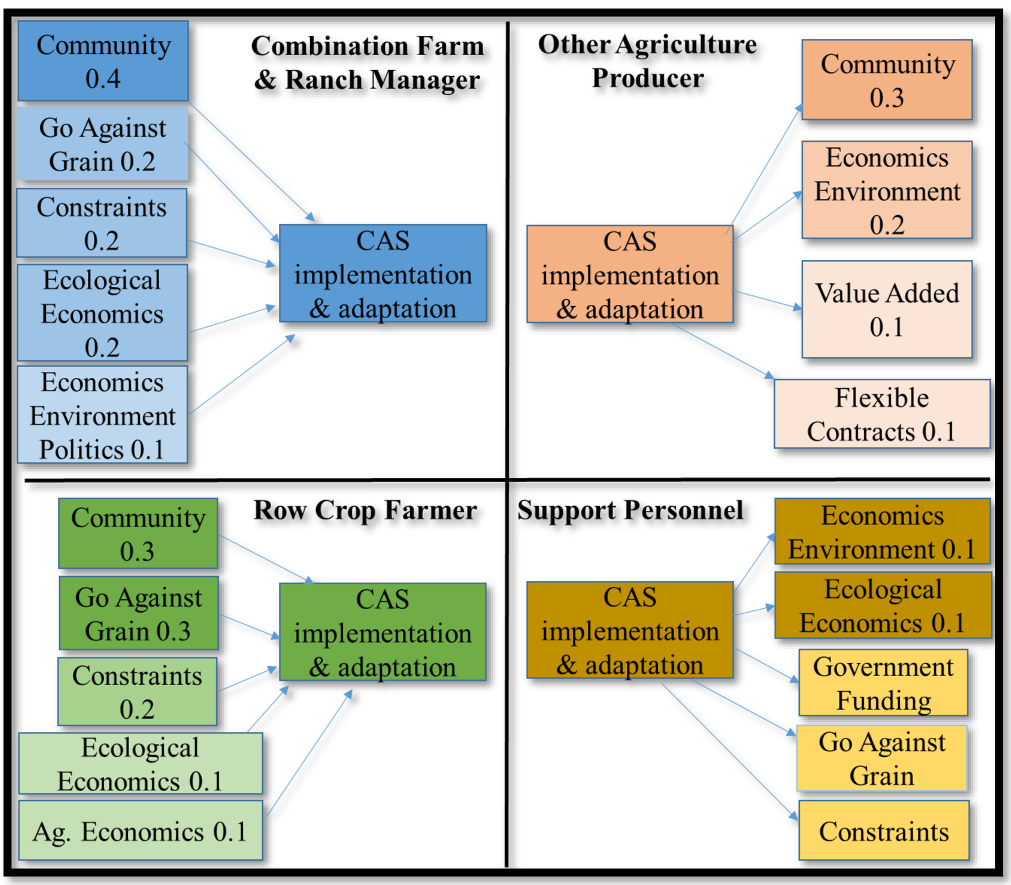
Figure 2.1
Solicited and unsolicited sub-factors mentioned per participant interviewed



Variety in each of the CAS producer stakeholder groups was observed from farm size to production type. Other types of agriculture is a stakeholder group with four participants, which include smaller operations (i.e., less than 200 hectares each), 2 dairies, 1 vegetable farm, and a 1 ranch, and 2 organic certifications. While this process allowed the smallest stakeholder group to have an opinion evaluated among the other stakeholder groups, other research processes would have excluded these opinions. The stakeholder group with row crop farmers ranged from 32 to 4,040 hectares each with 2 or more crops rotated per farm. Combination farm and ranches ranged from a startup operation on 94 hectares of inherited land to approximately 3400 hectares of land that is 70% leased.

Unsolicited information and support personnel information was separated into factors of importance for a visual portrayal of observed differences (figure 2.2). The factor community includes the sub-factors: local knowledge/support from community, and tenure based on relationships, support to community with any government funding, and living off the land. Community was the most important factor with various sub-factors for each agriculture production group. However, only part of the sub-factor including government support was mentioned by support personnel. The most outspoken group of agriculture producers was the combination farm and ranch managers. Some of the combination farm and ranch managers regularly participate in political advising groups, the Ecosystem Marketplace Consortium, and the Miller Coors and NRCS water cleanup project in the watershed area serving Tarrant County. One farmer was more concerned about specific crop limitations for his region while other agriculture producers were more concerned with managing overall risk.

Figure 2.2
Stakeholder analysis comparison of main factors for combination farm and ranchers, farmers, other agriculture producers, and support personnel.



Summary and Conclusions

Anthropogenic vitality depends on ecosystem services such as water quality, air quality, food, and fiber. As multiple conservation practices systematically work together, ecosystem services are improved. CAS decisions are made for initial implementation, seasonal continuation, and additional adaptation by agriculture producers, a minority group in the US, yet they manage approximately 40% of the land nationally. Economic solutions are emerging to value ecosystem services as more than commodities and externalities including the National Water Quality Initiative, the Ecosystem Services Market Consortium, and Indigo Ag's carbon market pilot program (Knight and Reed 2019; Prokopy 2019; Wilcox 2019).

Processes that evaluate CAS producer professional insights are needed for targeting funds efficiently (Mehan and Carpenter 2019). This study focused on primary stakeholder interviews, secondary support personnel interviews, and documented processes of research expansion to verify professional opinions when applicable. Economics was only 40% of the total factors considered by producers during CAS decision making. Other factors identified by the stakeholder analysis and discussed include environment, economics, conservation training, external funding, generational land and skills, equipment, attitudes, positive and negative social interactions, and land tenure strategies. The priority among factors and sub-factors varies among stakeholder groups and affects the way they relate to each other. Combination farm and ranchers with diversified enterprises are able to hire labor and therefore get off the farm at various times of the year, which influenced their ability to have a voice at the table and therefore technical assistance and funding options that suite their needs.

Specialty productions struggle with the amount of research required to find funding suitable to their needs and need a voice at the state and region table, not just the local universities and small conservation groups in specific counties. In order to include farmer voices more and not just combination farm and ranch managers, interviews need conducted at the agriculture producer's convenience and data analyses need to account for unsolicited information provided through professional knowledge.

Researchers, politicians, and consumers should care about the farmers because the on-farm decision-making affects 80% of the Texas farmland (http://data.txlandtrends.org/Trends/Statewide), is largely made off farm, in places like the grocery store, crop insurance policy meetings, and even the voting booths. Empowering agriculture producers to speak up **at their convenience**, or not providing those opportunities, will affect the future of grain, cotton, vegetables, and dairy products as well as water quality, air quality (Hill 2019), and the coastal areas of the Gulf of Mexico (Parsons Staff 2019). Decisions involving fertilizers and chemicals have lasting legacies on multiple generations.

CHAPTER III

MEASURING ECONOMIC AND ENVIRONMENTAL IMPACTS ON TWO AGRICULTURE PRODUCTIONS IN TEXAS-OKLAHOMA REGION, USA.

Nitrogen (N) and phosphorus (P) are vital to agriculture production and phytoremediation of contaminated soils. However, in the wrong amounts, these nutrients toxify the water supply. Soil erosion averages 13 tons per hectare in US on cropland with bare soils (Pimental et al. 1998). The off-farm financial damage estimates for the national health and property due to soil erosion is $10 billion per year (Pimental et al. 1995), which would be approximately $16.4 billion in 2018. The national cost of the nutrients that leach from the fields was $20 billion per year (Pimental et al. 1995), or $32.8 billion in 2018. Using this estimate for current on-farm economics, nutrient losses cost an average $16,060 per year per production (NASS Staff 2019). In addition, global climate change has caused billions of dollars in crop insurance claims and increased agriculture related water quality concerns (Farm Support Agency Staff n.d.). Implementation of conservation agriculture systems is a preventative measure in the process of source water protection (Mehan and Carpenter 2019).

Tillage practices influence the size and location of soil aggregates since these practices disrupt the growth of fine plant roots and mycorrhizae, which are the primary stabilizers of soil aggregates (Six and Paustian 2014; Lal 2015). Individual aggregates represent ecological niches for microbial colonization based on C availability and soil type (Triverdi et al. 2015). Aggregates and soil organic matter, enhanced through use of cover crops, can reduce soil erosion, promote water infiltration, and minimize nutrient leaching and runoff.

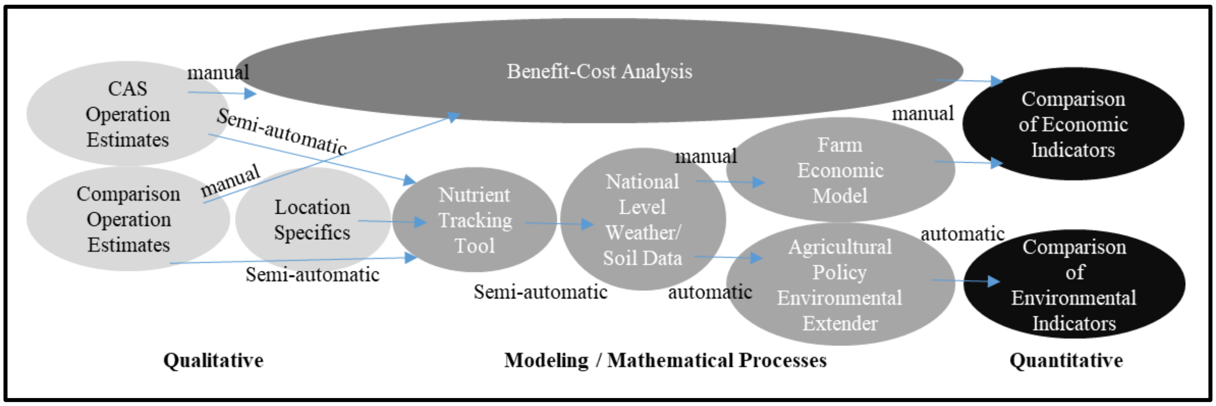
The Nutrient Tracking Tool (NTT), the Farm Economic Model, and benefit-cost analyses are environmental and economic tools that can be used to estimate the impacts of farm management practices. The NTT-Research Edition is a free simulation with preprogrammed data for weather, soils, and management specifics that can be adjusted as needed (https://ntt-re.tiaer.tarleton.edu/welcomes/new?locale=en) (Saleh et al. 2015; Moriasi et al. 2016). This tool incorporates the USDA NRCS Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) to provide soil and land management practice data and National Weather Data (National Oceanic and atmospheric administration). It is used to simulate transport of N, P, and sediment erosion into surface water as well as deep percolation into ground water.

The benefit cost analysis designed by Gordon (2013) and used by Bodell (2019), and Brandt (2019) had benefits calculated on one side of a T chart and costs calculated on the other. The costs are then subtracted from the benefits for the practice or system estimates. Cost-benefit analyses assessments focus on changes in costs rather than changes in net income for a business operation.

The Farm Economic Model is a whole farm model that simulates the economic impacts of various scenarios on agricultural operations (Osei et al., 2000a) based on estimates enterprise budget information (Gassman et al. 2009). Input components include crop operations, ownership and characteristics of structures, facilities and equipment, financing terms, land areas and uses.

These three assessment methods provide related but discretely different types of information about farm productions. Interconnected relationships among the data collection, simulation modeling, and analysis components of these three tools are illustrated in figure 3.1. Estimates obtained from the integrated outputs from these tools can be used to answer the research questions: "How effective are various CAS in providing ecosystem services?" "How do on-farm benefits and costs from CAS compare with off-farm benefits and costs from CAS?", and "How effective are available measurements to quantifiably estimate factors such as environmental risks and uncertainty and economic costs and benefits?"

Figure 3.1
Connections among various methods based on Gassman et al. (2009), Gordon (2013), and Saleh et al. (2015).



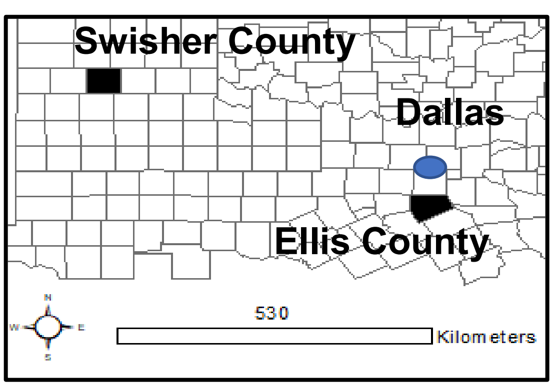
Case studies are often used in farmer decision-making research to illustrate the complex conditions, processes, and interactions that influence farmers' decisions (e.g. Feola et al. 2015; Osmond et al. 2015; Cielo et al. 2014). Expanding assessments of farmer decision-making to include descriptions of farm operations, environmental conditions, producer perceptions, farm economics, and impacts on ecosystem services can provide a more tangible understanding of these interactions.

We understand the interviewed CAS producers described in Chapter II are more experienced than a representative sample of regional agriculture producers would be and that there are numerous computer models to choose from for these estimates. The diversity of producers experienced in the use of CAS provided field tested and honest feedback that helped researchers understand what is really at stake when agriculture producers make seasonal decisions to the benefit or detriment of regional, national, and international consumers of both products and externalities. These insights provide the basis for integrating environmental and economic assessments with case study analyses.

Materials and Methods

Survey methods described in CHAPTER II were used to determine farm productions used in this study. Data from ten of the 22 producers interviewed was used to conduct NTT to assess environmental impacts of farming practices. The producers were selected for diversity of CAS in various regional climates and soil types rather than representation of a population of agriculture producers. Seven productions were analyzed using cost-benefit analyses, and three were analyzed using the Farm Economic Model. Two farm productions, one located in Swisher County, TX and the other located in Ellis County, TX were then used to develop case studies highlighting the critical, interconnected factors affecting farmer decision-making regarding CAS (figure 3.2). Both case studies were assessed by all the methods described here as well as the methods in other CHAPTERS.

Figure 3.2
Geographical Information System map identifying Swisher and Ellis counties.



The producers in Swisher and Ellis counties primarily farm by themselves and have similar age and ethnic demographics. They both operate medium-sized family owned productions that are less than 800 hectares plus additional 66-70% of their operations as leased land. Both producers see themselves as risk takers and go to field days in their area as well as research conservation methods online.

Swisher County, Texas has unassessed watersheds and polluted watersheds (Environmental Protection Agency Staff 2012). The Ogallala Aquifer in the Southern Great Plains has been polluted with nitrates and pesticides from irrigation runoff (Gilley et al. 1982). The suggested solutions included irrigating below crops needs (p. 132), reducing tillage (p. 150), using furrows (p. 62-73), and precision timing and application amounts of fertilizer and pesticides (p. 140). Trade-offs between ground water and surface water were anticipated (p. 140). Warnings were given to policy makers that the recommendations would be economically feasible for some operations and not for others. While the Gilley et al. (1982) scientific information is outdated, it has been well diffused in the Texas Panhandle (Rogers 1991).

The Swisher County producer rotates *G. hirsutum* (cotton) and *S. bicolor* (sorghum) on approximately 1800 hectares with no-till and organic residue. “Cover crops” do not keep a root in the ground year-round and are only selectively used when the land fertility makes it worth taking out of production. Since only a small section is covered only part of the year, cover crops were not included in the simulated scenario. The majority, 84%, of the production is dryland. The producer receives below average government incentives with above average costs that are typical for the size of production operated. This producer feels restricted from leasing more land, skeptical about giving up control for funding contracts, and wonders if the methods described in the soil health field days and online information will work in Swisher County. Initially, no-till was only applied to a small field and produced a sorry crop that was blessed with hail damage. The following year, the producer used genetically modified *G. hirsutum* (cotton) seed to assist the no-till production and converted the whole farm. These practices have been used for over twenty years and all the recommendations from Gilley et al. (1982) mentioned above are exceeded. No updated government information was found for the Swisher County area, although No-Till Farmer did have Texas Panhandle case studies (Crummett 2016). An additional $28-35 per hectare with flexible contracts would help the participant apply cover crops.

The Ellis county production has both *B. taurus* (cattle) and crops kept on separate acreage and rotated separately. This distinction is important, because other productions joined crops and livestock in the winter seasons, but this producer did not want to increase terrace repair costs or to repair unnecessary ruts in the field. The interview covered mostly cropping practices and as a result, so did the NTT and benefit-cost analysis. However, additional online information was available on the livestock enterprise and was used in the FEM calculations. The producer offered to provide detailed information from precision agriculture data, but the same methods as the Swisher county production were chosen instead. The crops rotated include *Z. mays* (corn), *G. hirsutum* (cotton), *T. aestivum* (wheat) when the price is worth it, and *Helianthus annuus* L. (sunflowers). *Cannabis sativa* (hemp) is a serious consideration for the upcoming seasons. The diverse crop rotations that are flexible around droughts, contracts, and crop insurance on Vertisol (blackland) soil characteristically found in Texas. Additionally, cover crops have been included for three to four years to keep a root in the ground throughout most of the year. Cover crop species were trial and error and environmentally provide benefits, however they have not provided the desired return on investment of $2 per invested $1 even with the help of the Miller Coors program (Littlefield 2013) and some fertilizer reductions. Radishes have impacted the cash crop and are no longer used as a cover crop because they get stuck in the Vertisol. Both herbicides and winter kill are used to terminate cover crops as necessary. Both no-till and strip till are used depending on contract specifications. Strip till is the preference with the reasoning that there is less damage to the soil than ruts caused by planting and harvesting in muddy conditions.

Nutrient Tracking Tool Analysis. While other studies deliberately limit the number of productions to one or two (Saleh et al. 2015; Moriasi et al. 2016), this study examined 10 different productions. These 10 productions included 4 combination farms and ranches in Texas and Oklahoma, five Texas farms, and one dairy. NTT was used to estimate N, P, and sediment losses from fields based on farm management practices. From these 10 productions, two productions were selected for case studies based on extreme differences and availability of environmental as well as economic decision-making information.

Due to the number of productions on each farm, simulation specifics are only presented for the most prevalent CAS production and its baseline comparison of the two case studies. The area of interest, management practices, and other specifics were simulated with the information provided in NTT to closely emulate he practices described in the case study introduction as opposed to uploading our own research data.

Benefit-Cost Analysis. The 7 analyses of Texas productions include 4 combination farm and ranch, 2 panhandle farms, and a farm in the Rio Grande Valley. Information from the interviews were used to determine costs incurred and cost savings due to CAS practices. Changes in net income were then calculated on a per hectare basis. This study focuses on the analysis for each case study described in the introduction and the other producer information provided the researchers with comparative information.

Farm Economic Model Analysis. We conducted a farm economic analysis on three productions, a no-till wheat (*T. aestivum)* and cotton (*G. hirsutum)* rotation crop farm in the Texas Panhandle, a farm and ranch combination in Ellis County, TX, and a dairy in Hamilton County, TX, and their conventional counterparts. The two case studies were the focus of this study and the dairy production was used as comparative information. The methods are described in Osei et al. (1995) for dairy farms, Gassman et al. (2009) for use in APEX to compare $/acre with environmental indicators, and Osei and Jaffri (2016) for estimating climate change impacts. As seen if figure 3.1, FEM uses information from NTT for weather and soil specifics and we manually entered NTT data and the various scenario specifics for CAS and non-CAS.

Results

The two case studies discussed in the introduction were productions in Swisher County and Ellis County. Using these case studies further in the economic results and detailed ecological results were only provided for those two productions. While multiple scenarios were simulated per production, the primary scenario, which was described under CAS, evens out the information provided in both interviews and the results from the NTT analysis.

The benefit-cost analysis displayed in table 3.1 describes the primary scenario for Ellis County under cost option a. The secondary scenario, cost option b uses the additional interview information provided for Ellis County, which happened to be the most enthusiastic and detailed interview. Using the primary scenario, the Ellis County saves approximately $21 more per hectare, which is the most reasonable comparison and uses the assumption that had other producers shared the same details, the higher savings may have also been comparative.

Table 3.1
Benefit-cost analysis for the Ellis County and Swisher County Case Studies

Ellis County Case Study without Bos taurus L.				Swisher County Case Study			
Decrease in Cost		**Increase in Cost**		**Decrease in Cost**		**Increase in Cost**	
Item	**total $**	**Item**	**total $**	**Item**	**total $**	**Item**	**total $**
AVC	182,568	Equipment	(42,857)	80% AVC	159,525	pesticides	-22,500
Fertilizer 1	70,298	Cover crop	(257,500)	90% Equipment	89,550	Learning 1***	-2,222
Water	211,150	Learning 1***	(2,222)	25% Time	22,500	Learning 2***	-818
Soil Replacement	11,588	Learning 2***	(2,454)	84% Water	120,960	Opportunity Cost	-247,402
Terrace Repair	10,300	Learning 3 ***	(1,465)			Soil Replacement	10,125
Fertilizer 2	736,450	Climate and soil	(231,750)			Field repare	9,000
Total Decrease Cost option a	**485,903**	**Total Increase Cost option a**	**(306,498)**	**Total Decreased Cost**	**392,535**	**Total Increased Co**	**-272,942**
Cost option b	**1,222,353**	**Cost option b**	**(538,248)**				
Annual change in net income option a			**179,404**	**Annual change in net income**			**119,593**
Annual change in net income per hectare			**87.09**	**Annual change in net income per hectare**			**$66.00**
2060 crop hectares 70% leased 100% dryland				1800 total hectares 66% leased 84% dryland			

AVC is average variable cost (i.e., unspecified) *** is references (Bodell 2019; Brandt 2019; Ristow 2019)
(Bodell 2019; Brandt 2019; Ristow 2019)

The NTT results (table 3.2) list both Ellis and Swisher production details for total N, subsurface N (Swisher only), Total P, Total sediment, and deep percolation. The subsurface N estimate provides a Nitrate in groundwater comparison between the *G. hirsutum* and crop rotation in Swisher County. Unlike the recommendation provided by Gilley et al. (1982), the simulated scenario favors conventional practices to no-till and crop rotation without cover crops. Cover crop addition of any type planted between cash crops would change the scenario, but existing assumptions of water competition prevent this implementation. The column on the readers far right for each production shows the expectations and lists whether they are met or unmet. While both producers validated their beliefs and actions with scientific research, Swisher County is not meeting the water quality standards in the simulation while Ellis County is. This provides evidence that research recommendations (Gilley et al. 1982), diffusion of science (Rogers 1995), and conservation practice implementation estimated in the USDA census do not necessarily prevent erosion or nutrient depletion with ground and surface water goals due to imperfect and/or contradictory information. No estimates were done to determine if wind erosion was limited with no-till. Glenk et al. (2017) did list field experiments with similar results for consecutive years. With field tested experiments showing similar results in semi-arid areas, the simulation was trusted for indicative numbers.

Table 3.2
NTT Outputs for Swisher and Ellis County Case Studies

Swisher County	*G. hirsutum* continuous	*S. bicolor* & *G. hirsutum*		(Negative)
Description	Losses	Losses	Change	Expectation
Total N (kg/ha)	4.2	12.1	8.1	unmet
Total P (kg/ha)	0.2	0.5	0.3	unmet
Total Sediment (kg/ha)	224.2	224.2	0	unmet
Ellis County	*Z. mays* continuous	Precision CAS		
Total N (kg/ha)	15.3	1.1	-14.2	met
Total P (kg/ha)	.8	.1	-.7	met
Total Sediment (kg/ha)	441.3	27.5	-413.3	Met

Farm Economic Model Analysis. We conducted a farm economic analysis on three productions, a no-till wheat (*T. aestivum)* and cotton (*G. hirsutum)* rotation crop farm in the Texas Panhandle, a farm and ranch combination in Ellis County, TX, and a dairy in

Hamilton County, TX, and their conventional counterparts (table 3.3). The methods are described in Osei et al. (1995) for dairy farms, Gassman et al. (2009) for use in APEX to compare $/acre with environmental indicators, and Osei and Jaffri (2016) for estimating climate change impacts. As seen if figure 3.1, FEM uses information from NTT for weather and soil specifics and manually enters NTT data and the various scenario specifics for CAS and non-CAS. The FEM does have a larger than expected learning curve and the analyses had to be conducted by Dr. Osei. Dr. Osei applies a 5% penalty for CAS management of all crops. The following studies provided crop, livestock, fertilizer, and irrigation specifics:

- TX high plains crop and livestock budget (Amosson 2011; Becker et al. 2017)
- Annual wheat (*T. aestivum*) review (Hundle 2017; NASS STAFF 2017).
- Fertilizer price prediction for 2015 and 2030 (Tenkorang 2006)
- Agriculture water estimates (Wichelns 2010)

Table 3.3
Farm Economic Model of case studies in Ellis and Swisher counties.

Ellis County Case Study with *Bos taurus* L.				Swisher County Case Study			
Description	Baseline	CAS	Improved	Description	Baseline	CAS	Improved
kg/ha	*Z. mays* & *B. taurus*	Rotation & B. taurus	Y/N	kg/ha	*G. hirsutum*	Rotation	Y/N
Sales	$2,490,247	$2,361,469	N	Sales	$2,226,623	$2,115,291	N
Revenue	$4,282,598	$4,153,819	N	Revenue	$2,226,623	$2,115,291	N
Total Cost	$3,643,065	$3,392,469	Y	Total Cost	$1,717,766	$1,623,053	Y
Net Profit	$639,532	$761,350	Y	Net Profit	$508,856	$492,238	N
Results for no-till include a 5% yield penalty based on data for corn, but applied to all other crops							

The NTT results were combined with all 10 the productions in a way that shows gaps between the baseline or conventional practices and the CAS management. The gaps specifically for N and P (figure 3.3a), sediment (figure 3.3b), surface flow, and deep percolation (figure 3.4) are presented graphically per production with the county name provided. The most ecologically effective scenario using all five soil health practices in multiple ways was Custer County, Oklahoma. However, Ellis County, Texas was selected over Custer County, Oklahoma for the case study due to the amount economic information available and both productions using the five soil health principals at least once per year. Contrastingly, the least effective was Swisher County, Texas with only two soil health practices used. Use of simulations, such as presented here, can help stimulate critical communication and develop trust between producers and support personnel, potentially preventing costly mistakes while providing producers with alternatives for field experimentation when data already exists. Continuously adapting modeling programs to include updated information such as *Helianthus annuus* L. (sunflowers). and multi species cover crops is another suggestion for research.

Figure 3.3
Nutrient Tracking Tool Analysis for N, P, and Sediment comparisons.

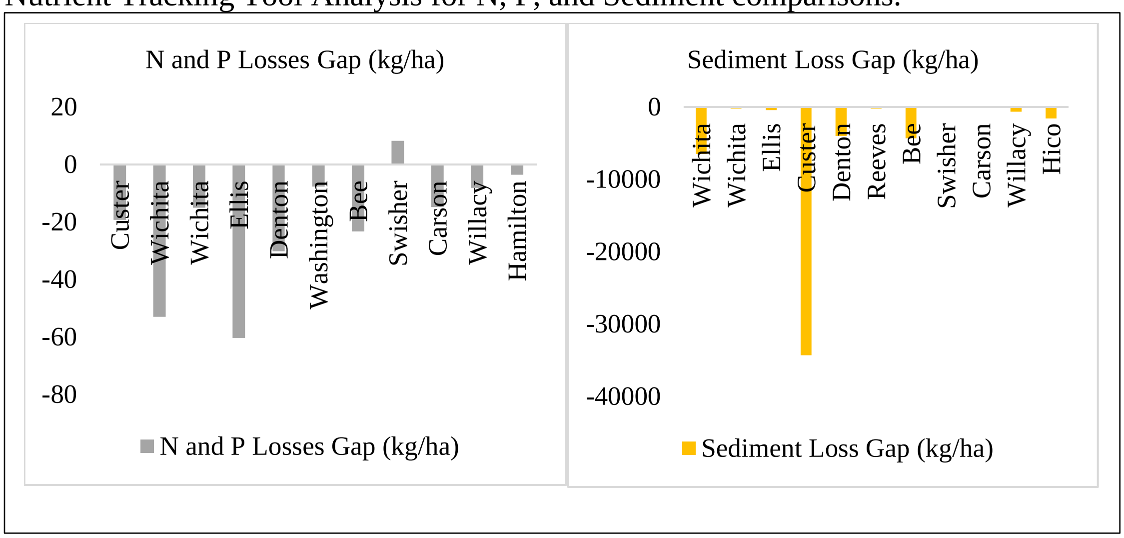
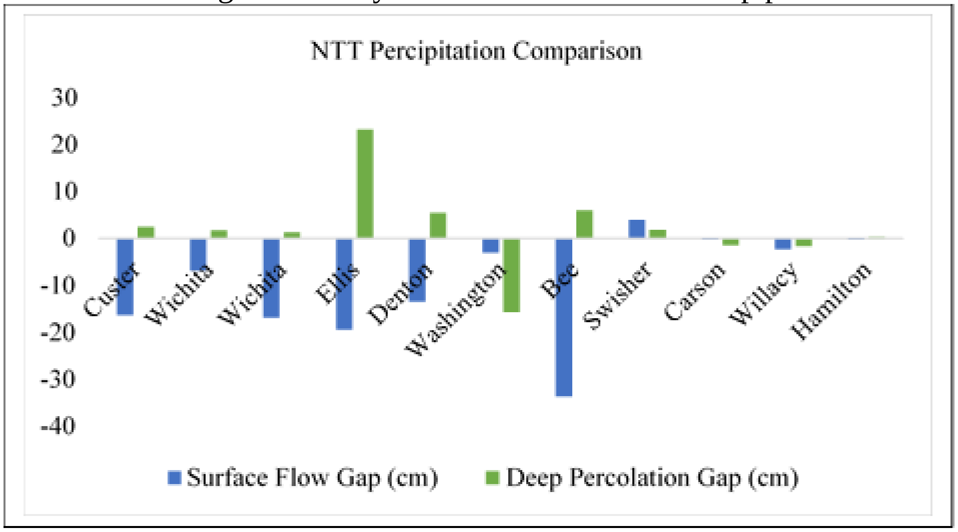


Figure 3.4
Nutrient Tracking Tool Analysis for surface flow and deep percolation comparisons.



Discussion

Economics and environmental considerations are interconnected (Pimental 1998). As N and P increase in costs due to supply and demand, the water quality typically decreases due to runoff. Improving the nutrient application therefore prevents runoff and allows the water cleanup projects to handle existing pollution instead of overcoming additional pollution too (Baird and Cann 2012). Chapter I discusses framing messages to producers with beneficial outcomes not only to the production, but also to the community. As support personnel understand more about the interconnectedness of economics and the environment, these messages become clearer.

This study uses ecological and economic modeling programs and analyses for indicative numbers based primarily on two case studies and secondarily on ten of the 22 productions interviewed in Chapter II. The case studies in Chapter III were selected for both economic and environmental information and differences in challenging ecoregions within the Texas-Oklahoma region of the USA. Both case studies were also early interview participants, which allowed more time for more analyses. Choices were made to use interview information, online information, and conservation training estimates found in literature instead of visiting the productions and collecting more specific on-farm data. The alternative option would have incurred additional traveling expenses and was unnecessary for indicative numbers but would have been more favorable if rigorous estimates were needed. These indicative numbers were designed to go into a system dynamic model. Chapter IV discusses the preliminary systems thinking results and the construct needed to include the indicative numbers in the modeling processes. In the benefit-cost analysis, choices were made to focus on the interview information that would even the playing field rather than the detailed information available on one production over the other. Basically, by using value added marketing, any available funding for on-farm conservation and precision agriculture implementation, and aggressive economic investment strategies the Ellis County producer lowered costs an average of $21 per hectare or $60,000 per production with a difference of 260 hectares in production sizes. This strategy also helped with the total net income between the baseline and the CAS production despite a CAS management penalty accounted for.

In addition to indicative numbers, differences in personalities and business strategies were also observed. In Swisher County, the producer felt limited from renting based on no-till and crop rotation practices. The producer felt limited from the five soil health principles by water quantity concerns promoted in the Ogallala Aquifer area (Gilley 1982; Reedy and Scanlon 2016). The producer also felt limited by available funding and the control battles over who decides what the funds should be used for on the land. A later interview with a different producer in the same area showed the land tenure and cover crop concerns could be a difference of mental models, while the funding concerns were similar although this study found online resources suggesting NRCS funds are actually available in that area. This may be due to the NRCS Conservationist's priority projects in that area.

The producer in Ellis County had a very aggressive business strategy and a high-risk personality. The expectation of a return on investment to be $2 for every $1 invested within three to four years was the highest expected return on investment. Additionally, the producer rated his economic and environmental decision making in an 80:20 ratio. The ratio was then used in the interview process as an example and it was the highest ratio on the economic side of any participants. This producer was also the first one to suggest crop insurance affects decision making, which was confirmed in literature and by multiple research agencies and other participants (CTIC Stafff 2017; personal communication with Jim Johnson at Noble Research Institute and Dr. Scott Cook). Chapter I includes information about crop insurance premiums, benefits, policies, interpretations, and claims and how these factors relate to on-farm decision making.

Summary and Conclusion

Ecologic and economic simulations provide indicative insights that can shape support personnel programs, which affects CAS implemntation and target selection of earmarked funding for water quality improvements (Mehan and Carpenter 2019). Because so much can go wrong in real world CAS over space and time, the 22 Texas and Oklahoma-region interviews were used to select 10 ecological assessments and 2 case studies with economic information incorporated. These assessments and case studies were compared to literature based on similar climates to better understand how economics and environment are interconnectedly involved in CAS implementation decision-making at initial, seasonal, and additional adaptation stages (Prokopy 2008; Carlisle 2016).

Support personnel make suggestions based on local and next best regional research anf farming information (Gilley et al. 1982; Smith et al. 2020). These suggestions, when applied to on-farm CAS implementation, become part of lasting legacies nutrients have on the watersheds (Parsons Staff 2019). Simply stated, no-till and crop rotations are not sufficient CAS for the purpose of ground water nitrate reduction, surface water nutrient and sediment reductions, and general erosion control. More research needs conducted in the Texas and Oklahoma Panhandle on implementing cover crops affectively, because ignoring them entirely involves health risks of farmers and society as a whole (Baird and Cann 2012). Once sound localized research is conducted, ethical diffusion is necessary for health risk reduction (Rogers 1995).

CHAPTER IV

SYSTEMS THINKING ARCHETYPES FOR ENHANCE PRODUCER – SUPPORT PERSONNEL COMMUNICATION

"Cheap food or clean water, take your pick" (anonymous). Consumers, policy makers, nutrient manufacturers, and support personnel play a large role in CAS decision making or the lack thereof. CAS benefit society and producers who use them efficiently, consecutively, and with continual adaptation (Prokopy 2008). Soil health principles guide effective CAS decision making (Fuhrer and Bott n.d.). With live roots in the ground year -round, photosynthesis continuously occurs (biology), as well as C sequestration (Six and Paustian 2014; Lal 2015), and erosion control (Pimentel 1995). Biodiversity, soil organic matter, minimal soil disturbance, soil cover, and livestock inclusion are components of soil health decisions made by producers (Fuhrer and Bott n.d.). Plants, animals, and even symbiotic microbial activity (Hatfield 2005; Phillips 2020) then systematically act on those decisions (Forrester 1968). According to Hatfield (2005 p. 3), assessments of systematic processes involving decisions include key sustainability indicators including biological, socio-economic, nutrient balance, and water use.

Without agriculture productions providing ecosystem service benefits to society, unsustainable economic activity will continue to surpass limits to growth (Conversation Earth 2018; Meadows et al. 1972). Improvement of CAS implementation in the next 30 harvests is a sustainable option for impacting climate change (Hill and Kaiser 2019). However, CAS implementation occurs in the Texas-Oklahoma region at a rate of "chopping down trees…with an axe" (personal communication with Jimmy Emmons on June 24th, 2019).

One way to accomplish these sustainability goals is taking time to listen to CAS producers' concerns (Mehan and Carpenter 2019) as a vital part of bottom-up research (Edelenbos et al. 2017), economic policy making (Ploeg and Rezai 2019), and targeting available funding (Mehan and Carpenter 2019). Major benefits of CAS for producers are reduced variable input costs, ability to reduce fixed costs through equipment sales, and long-term financial goal achievement including additional funding opportunities during periods of loan unavailability (Ristow 2019). Major benefits of CAS to society are erosion control (Pimentel 1995), water quality improvement (Prokopy 2019), and human health and wellbeing improvements over time (Baird and Cann 2015). Even though CAS can greatly minimize overall risk, especially over the long term, it presents substantial challenges in administering the complex trade-offs of each individual agriculture operation. Examples of these challenges include managing for biodiversity by lowering a systematic dependency on excess fertilizers and pesticides (Glenk et al. 2017), selecting scale and equipment to match adaptations needed and producers' risk tolerance (Ploeg and Rezai 2019), and in some cases, waiting for land succession completion from one generation to the next (Gosnell 2011).

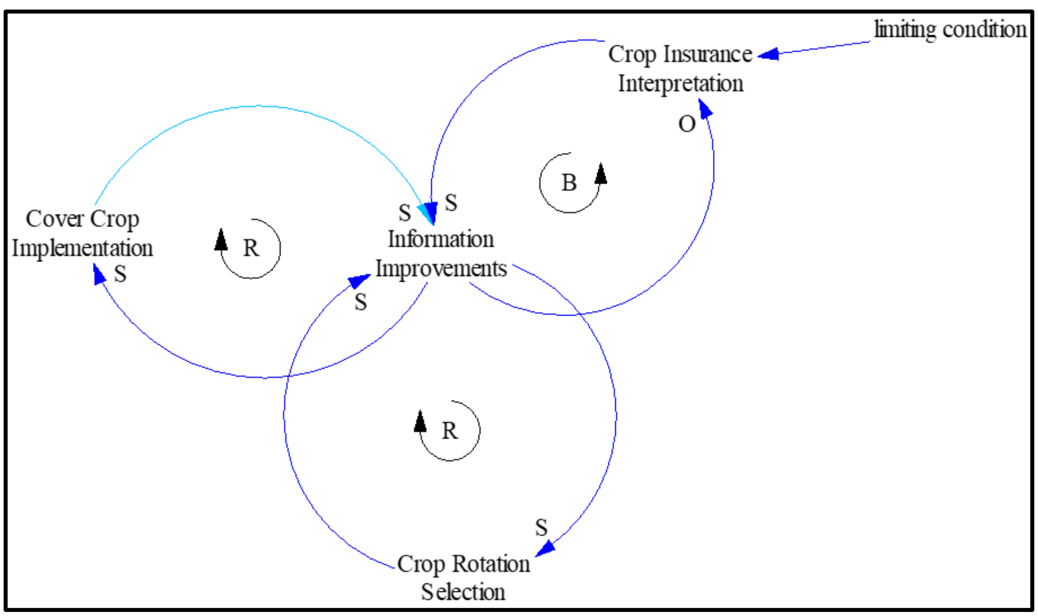
CAS contain a multitude of diverse components, interacting non-linearly and dynamically in both space and time (Wu and Marceau 2002), with the likely threats of neighboring production managers' ignorance and climate change influencing financial outcomes (Hansen and Libecap 2004). As Wu and David (2002) point out, "an obvious challenge in modelling complex ecological systems is… to integrate the rigor of reductionism with the comprehensiveness of holism. This study was designed to use ecological and economic modeling and attain indicative assessments rather than rigorous reductionism. Assessments from Chapter III can be used in a system dynamics model once the construct is complete and tested accurately. The preliminary systems thinking approach provided in this chapter includes archetypes found in multiple dynamic interactions (Senge 1990). Systems archetypes are tools with established definitions and warning signs that are used for constructing consistent explanations about dominant feedback processes, clarifying and assessing mental models about those systems, and identifying leverage points in the system available for effective change. Mental models are perceptions, goals and values, and beliefs that affect data selection processes.

Application of the Systems Approach. A systems thinking approach uses various sets of available tools including behavior-over time graphs, causal loop diagrams, and simulation models to map and explore dynamic complexity of decisions in both the socio-economic sense (Ells and Solis 2013) and the complexity science logic (Forrester 1968). Systems thinking tools, known as archetypes, include descriptions, warning signs, and various scenarios these common dynamic feedback process problems occur (Senge 1990). This study uses system archetypes to assess potential reinforcing problems and solutions involving stakeholder group representatives. The selected symbols include S for same relationships, O for opposite relationships, R for reinforcing processes, and B for balancing processes. Same relationships are directly connected variables that increase or decrease together, such as water quality and human health. Opposite relationships are directly connected variables where one increases as the other decreases, such as pesticide use and pests. Reinforcing processes have exponential growth or decay graphs over time associated with them while balancing processes are associated with oscillating graphs over time. For example, lily pads in a nutrient rich pond can grow exponentially unless there is a removal process to balance the lily pad growth.

Crop Insurance Limits to Growth (figure 4.1). Both cover crops and crop rotations are implemented at growing rates in the Texas-Oklahoma region of the USA. The growth is largely from farmer to farmer training (personal communication with Jimmy Emmons, FPAC district director, on June 24th 2019). This training process is a reinforcing feedback process with potential for exponential growth or decay (Senge 1990). However, producers are being told by NRCS to plant cover crops and specific crops for climatic reasons, while the RMA restricts cover crops, inter-seeding, and double cropping which all provide roots in the ground year-round (CTIC 2017). Sometimes these restrictions are due to interpretations (Harrigan and Charney 2019). The Agriculture Improvement Act of 2019 attempts to clarify these interpretations, but still restricts practices interpreted as interceding and double cropping (US Congress Staff 2018). The crop insurance restrictions are balancing feedback processes that have potential to reverse the growth cycles and turn them into decay processes (Senge 1990 p. 390). Crop share leases, outdated science prominently diffused in an area, and insufficient determination during initial attempts are additional limits to growth observed in this thesis research.

Chapter III used ecological and economic analyses to arrive at indicative numbers for use in system dynamics models once the modeling construct is completed. These numbers were primarily provided by the two case studies, Swisher County and Ellis County. The change in cost on a per hectare basis of $21 or a per operation basis of $60,000 difference between applying five soil health principles and two soil health principles. The total net income gaps between Swisher County's baseline scenario and CAS scenario was approximately $16000 in favor of conventional methods including continuous *G. hirsutum* planting (cotton), mainly because a no-till penalty of 5% was added to the income estimates. Alternatively, the Ellis County scenario had an increase in total net income from the baseline scenario due in part to close records of cost differences, added value marketing, Miller Coors program participation, and other specifics offered. The Miller Coors program participation was estimated using the NTT data and the water quality pricing provided by the Ecosystem Marketplace Consortium (Knight and Reed 2019) and is approximately $70 total for 2060 hectares. As the producer says, its only change to them and does not cover the amount of cover crop seed spent, but it is a drop in the bucket.

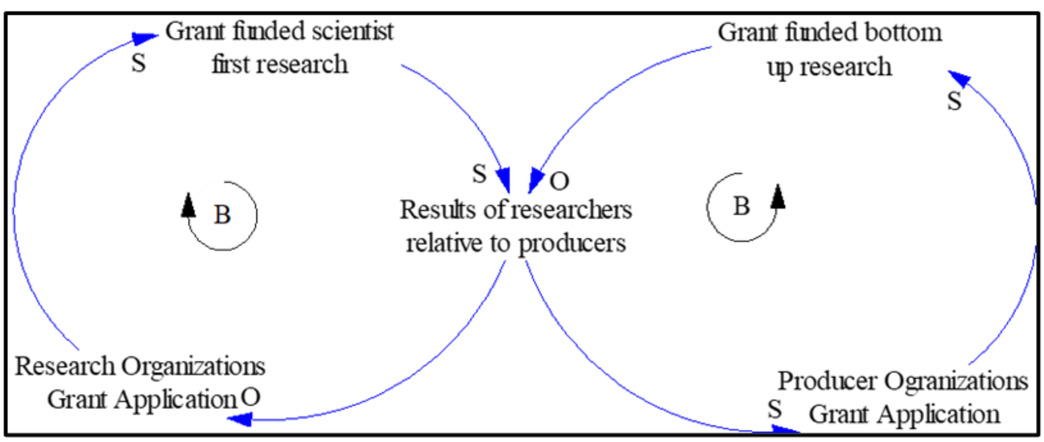
Figure 4.1
Limits to growth with a balancing feedback process and two



Grant Application Escalation (Senge 1990) (figure 4.2) . Both researcher and producer organizations apply for Conservation Innovation Grants and other related grants (NRCS STAFF). When agriculture producers perceive universities and other research organizations as gaining funding "when we are the ones with results" they increase their grant application efforts and reduce their participation in other research projects. Research organizations that are funded by grants systematically apply for additional grants. Each failed attempt is improved upon and each successful attempt is learned from. When scientists use on-farm research to validate a hypothesis instead of putting the farmer first with a bottom up perspective, cycles of mistrust and aggression continue to fuel two or more balancing feedback processes (Senge 1990). Warning signs from producers include the following statements:

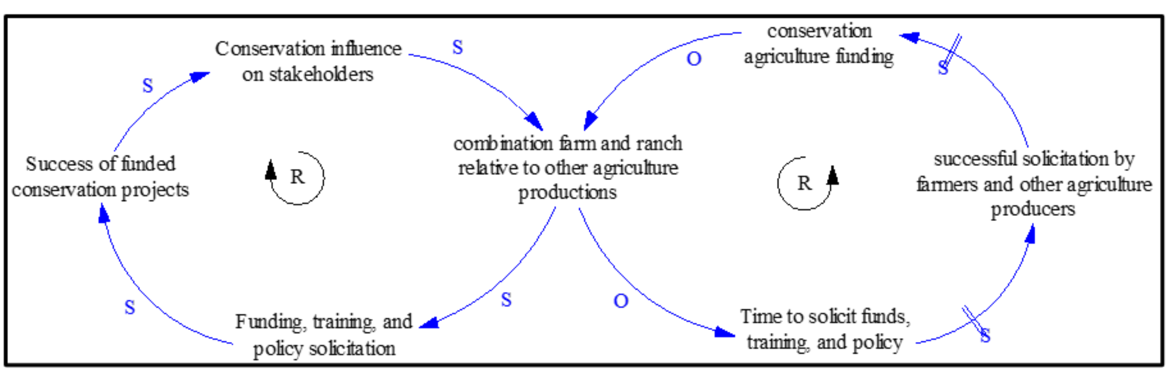
- "Finding the right fit, doing the research, making the crops work, and finding compatible funding options feels like a post grad course."
- "We want to hire a professional to come up with a plan on what to do…Supportive resources are under-staffed and underfunded. The system is not working that well."
- "Universities get research grants when we are the ones with results."

Figure 4.2
Escalation of grant funding with two balancing feedback processes.



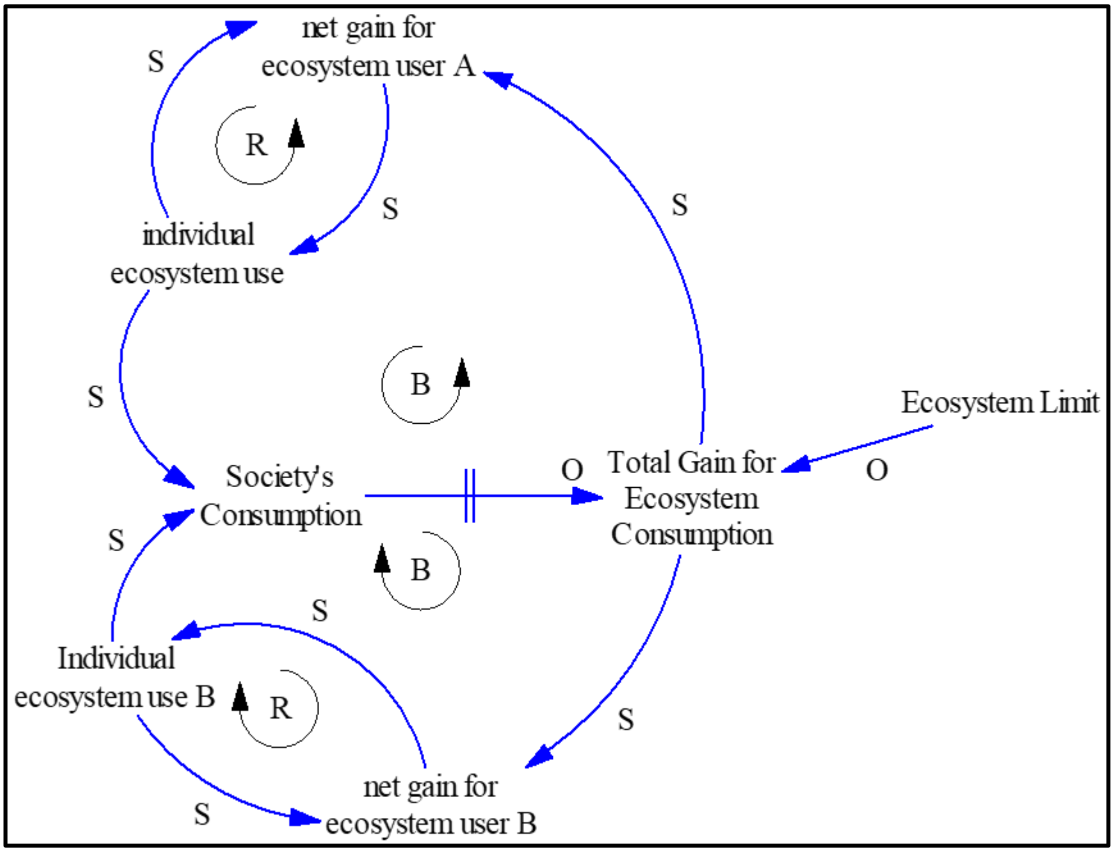
Success to the Successful (figure 4.3). By participating in politics and pilot funding projects, combination farm and ranch managers help shape funding, conservation training, consumer education, and political advising. There is potential for success to the successful to become a systematic process (Senge 1990; Wayland et al. 2018). The success to the successful diagram describes two agents competing for the same scarce resource. This structure includes two reinforcing processes that oppose each other. The systematic favoring of combination farm and ranchers would automatically exclude the specific sub-factors the row crop farmers and other agriculture productions value differently. Additionally, support personnel need to view training, technical assistance, and funding including government funding through the eyes of the community, and how the community perspective affects individual producers. Building confidence in the producers to go against the grain and be willing to adapt local and regional practices also needs to be included more by support personnel. Ecological economics became a separate factor and includes input reductions, water infiltration increases, pilot programs with water and carbon trading options, and achieving the same or greater yield without the input reducing practices, as indicated in the Chapter III.results. Appendix D includes specific suggestions to consumers, other producers, and landowners.

Figure 4.3
Success to the successful



General Tragedy of the Commons (Senge 1990 p. 397)(figure 4.4) Anthropogenic activity can be looked at on an individual basis. People in society consume limited natural resources such as water quality, water quantity, air quality, and other ecosystem services without regard for society as a whole, but solely to meet the individual's needs. When this happens initially, rewards are high, such as plentiful water quality to dilute an individual pollution incident. Eventually, returns diminish, and efforts intensify. The resource, such as water quality is at risk of becoming significantly polluted. For early warning signs of water quality include increased rates for drinking water (Hatfield 2005 p. 3), boiling water notices (South Ellis County Water Supply Corporation. 2020), and do not swim or fish signs posted (Hatfield 2005 p. 184). However, water quality concerns have already increased to include indicators involving detriments human health (Baird and Cann 2012), fishing and tourism industry lows (Smith et al. 2020), and dead pets (Karacostas 2019). The producers in Northern Texas and Oklahoma typically identify plowing with air quality after the Dust Bowl of the 1930's due to awareness raised and changes recommended (Eagan 2001). However, the same awareness has not been raised for water quality concerns and many agriculture producers have not had that "aha moment" (personal communication with Jimmy Emmons on June 24th, 2019).

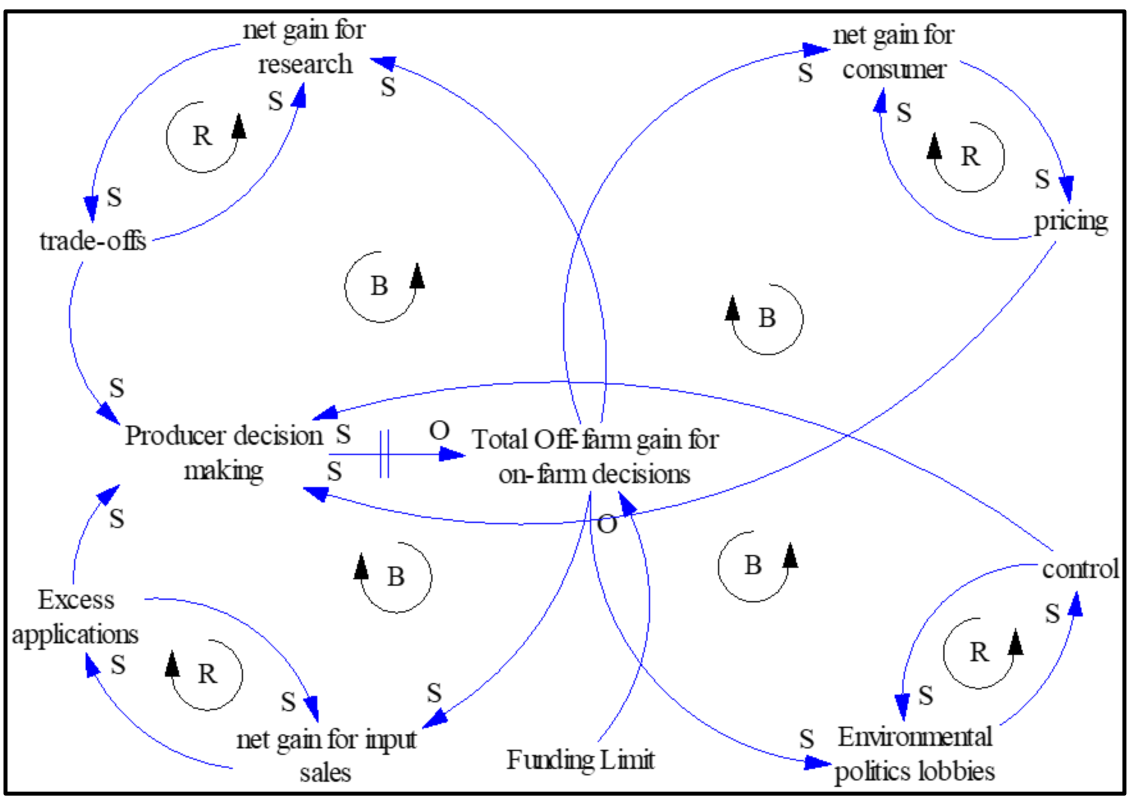
Figure 4.4
Tragedy of the commons of natural resources with multiple feedback processes.



Producer Decision-Making Tragedy of the Commons. The system of conservation agriculture system implementation in the Texas-Oklahoma region of the USA and possibly elsewhere currently works where each stakeholder group has individual goals as opposed to unified goals. Researchers, consumers, policymakers, and salesman each have individual gains to achieve from on-farm producer decision-making. The NRCS has 170 conservation practices that are promoted differently in different areas. Cover crops is one of those conservation practices and has been promoted through EQIP and CSP, but not equally in all locations. In addition, some locations have researchers such as AgriLife, that recommend no-till without cover crops due to low moisture availability while similar areas nearby have success with cover crops despite low moisture availability. Figure 4.7

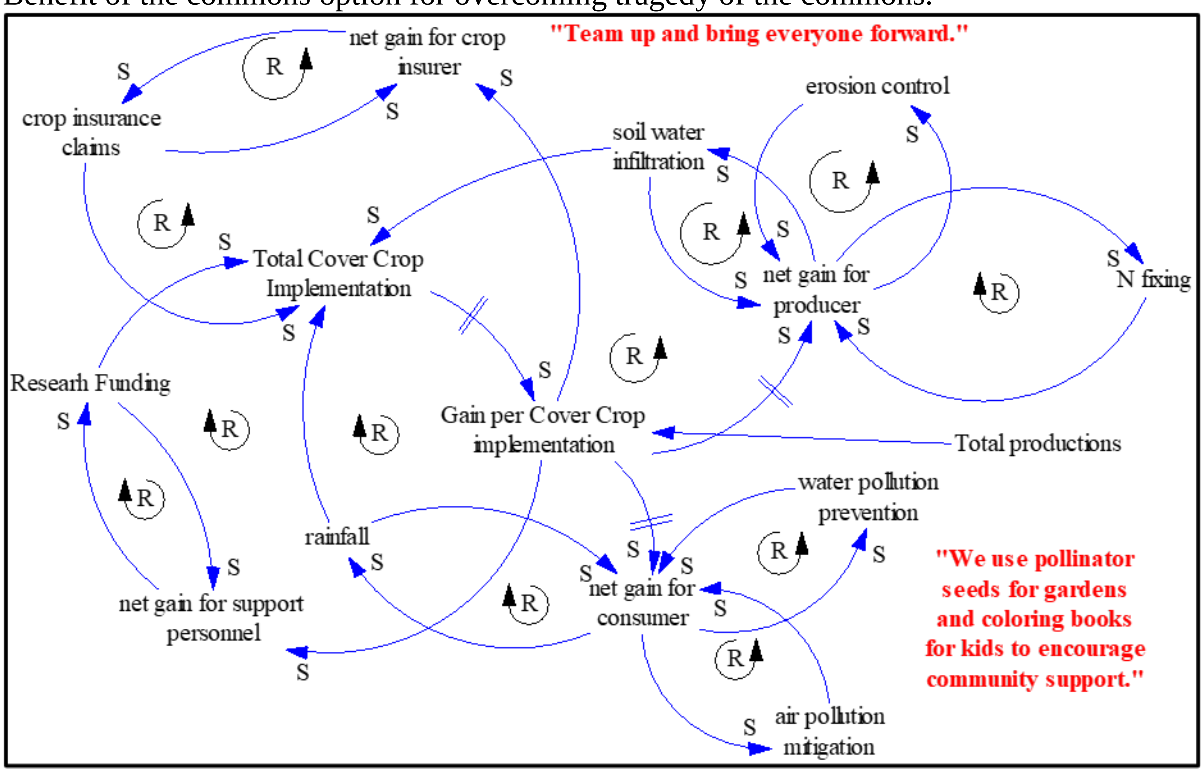
goes into more detail on the mental models while figure 4.5 goes into detail about the pressure placed on producer decisions. In the interviews, the most common response asked about mixed messages producers receive was the suggestion to select the information based on the producer's goals and expect differences of opinions. Figure 4.5 illustrates a tragedy of the commons where multiple stakeholder groups compete for the producer's decision, such as AgriLife saying don't use cover crop mixes and "snake oil" salesmen saying do use cover crop mixes. Each have individual goals and benefit from persuading the producer. One sign that a salesman is profiting from the sales is the newness of the vehicle driven.

Figure 4.5
Tragedy of the commons over producer decision making influencers.



Benefits of the Commons (figure 6). Unlike the tragedy of the commons archetype, there is potential gain for everyone involved in cover crop implementation. Stakeholder groups each have individual needs that can be achieved by working together to encourage cover crop implementation. Initial rewards will typically be delayed, but returns will increase exponentially. The resource limitation is simply the number of productions available to implement cover crops and keep photosynthesizing plants rooted year-round. Figure 4.6 depicts four stakeholder group representatives clockwise: a crop insurer, a producer, a consumer, and a researcher. Each stakeholder group representative has net gain for cover crop implementation. Crop insurance claims indirectly influenced by soil water infiltration, erosion control, N fixing, water pollution prevention, air pollution mitigation, rainfall increase, and research funding. As total cover crop implementation increases, so does the gain per cover crop implementation.

Figure 4.6
Benefit of the commons option for overcoming tragedy of the commons.



Discussion

In the crop insurance limits to growth several options are available for leverage identified by various interview participants. The premiums currently do not account for more than ten years of affective CAS management with documented results (personal communication with Jim Johnson, consultant at NOBLE Research Institute). Premiums are theoretically designed to penalize high risk productions and award low risk productions and with a more effective reward system, there would be more incentive to lower risk with affective CAS. The crop selection could be more realistic for the climate changing environment and allow both sorghum and corn instead of one or the other at preferred rates. Cover crop interpretations are changing to allow crop insurance of cash crops to continue as long as the cover crops are terminated within specifications. While this progress is good, more can be done to account for other termination options, inter-seeding procedures, and livestock integration methods. Additionally, cover crops could also be insured, and limit risks associated with insufficient organic matter production. At the present time, they fall under double cropping procedures and are essentially uninsured.

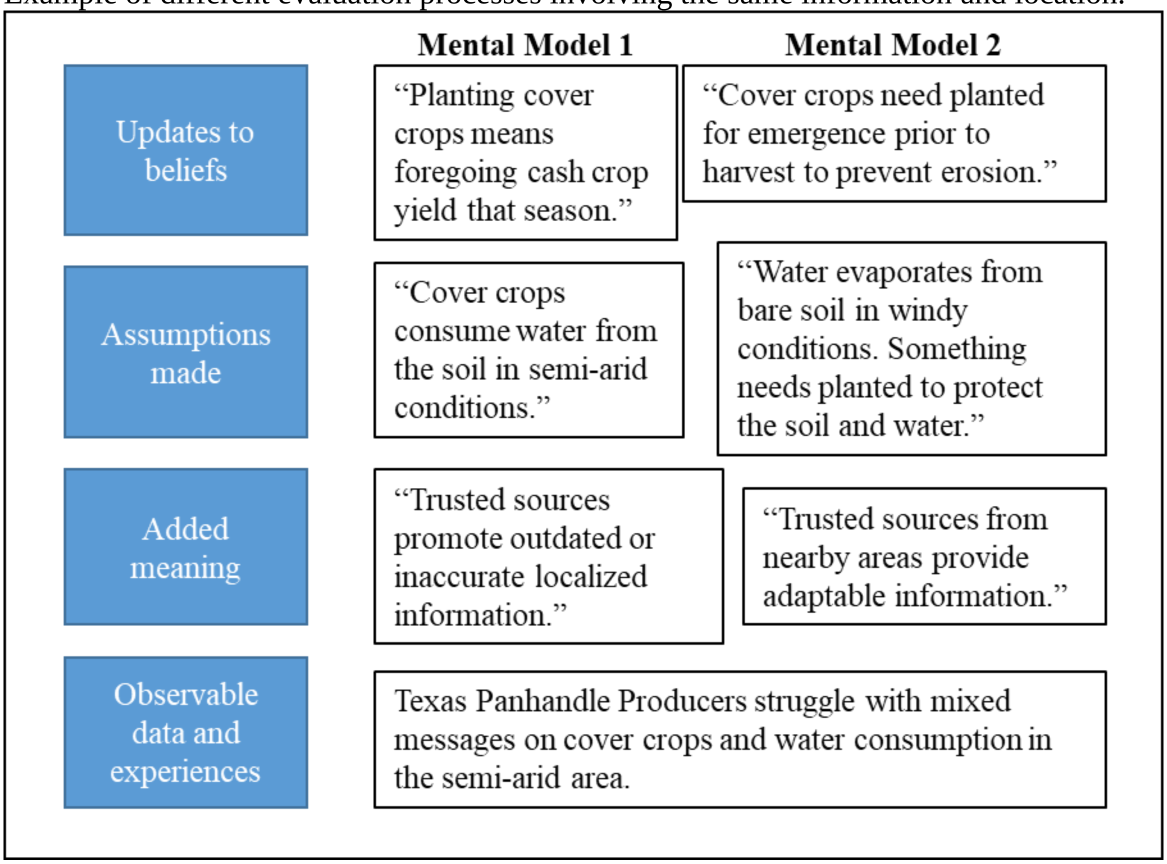
In the grant application escalation, more needs to be done to build trusting relationships and eliminate competition. Universities and research agencies incorporate grant writing into assigned duties. Including non-profit organizations, producer groups, and other CAS implementation stakeholder groups into the requested funding is an option for leveraging cooperation instead of competition.

The success to the successful archetype shows feedback processes involved in targeting producer groups based on the researcher's convenience or the policymaker's schedules. While more diversity in crops and products typically means more time flexibility and expertise, this is not always the case. Producers able to hire enough help and leave the productions at others convenience do not represent a diverse group of agriculture productions. Including phone and potentially online interviews at the producers' convenience allows more diverse groups of agriculture producers to have a voice at the table. Also, the most likely time for producers to leave the production in the Texas-Oklahoma region is December through March (Texas.gov Staff n.d.) and may change as climates change. This knowledge may help in designing research based on communicating directly with producers in a bottom up approach that depends on their expertise.

Multiple tragedy of the commons exist in the complex problem of CAS implementation in the Texas-Oklahoma region. Natural resources such as water quality, water quantity, air quality, and soil erosion affect and are affected by multiple segments of socioeconomics. Also, agriculture producer decision making has multiple stakeholder group representatives with multiple agendas competing for CAS producer decision benefits including product sales, research funding, and consumer product lines. This system combined with the reality that agriculture producers are a minority with influence over a majority of land causes pressure that can be alleviated by off-farm economic and political decision-making. Raising awareness of what decisions made economically and politically relieve that pressure needs done with a bottom up approach based on trusting relationships rather than authority (Pahl-Wostle 2007).

One localized example of dominant mental models that need addressed is the Texas Panhandle, a semi-arid area with promoted decreases in irrigation due to recharge limitations of the Oglala aquifer. The various CAS present in this area can be categorized based on whether roots are planted at least 11 months a year or if soil is bare between crop seasons. While one case study in Swisher County was evaluated in Chapter II, another mental model emerged in the same county during a later interview. These mental models lead to different actions and the process of evaluating the same information in the same county with differing results is shown in figure 4.7.

Figure 4.7
Example of different evaluation processes involving the same information and location.



Summary and Conclusion

One tool available to raise awareness economic and political influences that favor CAS implementation from a bottom-up approach is participatory system thinking workshops. Participatory systems thinking approaches are available to unite stakeholders and harness a combined energy toward a single goal (e.g., efficient team) vs. intentionally and unintentionally challenging each other (e.g., bumping into team members) (Senge, 1990). Experienced CAS producer perspectives should be a focus of systems thinking in agriculture, because they are uniquely personal-value based, affected by outside stimuli, and drive land-use changes (Chambers 1985; Turner et al. 2014). These land use changes not only occur as CAS innovators continue to adapt adequate research to their own productions, but also for more reluctant agriculture producers directly or indirectly learning from them (personal communication with Jimmy Emmons, FPAC district director, on June 24th 2019).

A comprehensive study conducted by Jimenez (2017) identified participatory involvement in watershed planning, effective outreach programs, and improved access to incentives for CAS as critical components of successful agricultural producer involvement in watershed trading programs. Additional research would comprehensively address these factors by bringing farmers, farm support personnel, landowners, potential ecosystem market development personnel, and other watershed stakeholders together to collaboratively identify effective CAS program implementation strengths, weaknesses, opportunities, and threats. These discussions may also lead to the implementation of ecosystem marketing programs that enhance farmer access to economic incentives.

Enhanced communication among watershed stakeholders leads to processes for addressing social, economic, and policy barriers to CAS adoption. The processes then enhance awareness among watershed stakeholders of potential ecosystem services markets, mechanisms for implementing these markets, and potential implementation delays due to differences in organizational structures and capabilities of involved stakeholders.

The scenario where crop insurance and support personnel get funding goals met without limiting the agriculture producers' ability to use affective CAS cannot happen on accident or without changing the current system. Researchers need to look beyond the data provided in the USDA Census to find problem areas with CAS implementation. Diffusion of scientific innovations depends largely on trust based relationships (Rogers 1

REFERENCES

Allen, V.G., M.T. Baker, E. Segarra, and C.P. Brown. 2007. Integrated irrigated crop-livestock systems in dry climates. American Science of Agronomy Journal 99:346-360, doi:10.2134/agronj2006.0148.Baird, C., and M. Cann. 2012. Environmental Chemistry. New York: W.H. Freeman Company. https://www.scirp.org/(S(lz5mqp453ed/snp55rrgjct55))/reference/ReferencesPapers.aspx?ReferenceID=2269302.

Amosson, S. 2011. Texas high plains: Texas crop and livestock enterprise budgets. Working paper, Amarillo, Texas, AgriLife Extension Texas A&M System. https://agecoext.tamu.edu/.

Baird, C., and M. Cann. 2012. Environmental Chemistry: 5th Edition. New York: W.H. Freeman Company.

Bandoni, M. 2009. A study of the relationship between dairy farmers' knowledge of the carbon credit market and their willingness to reduce greenhouse gas through offset programs. Master's thesis, Tarleton State University. Reference: UMI Number: 1478616.

Bawden, R.J. 1991. Systems Thinking and Practice in Agriculture. Keynote address, 85th Annual Meeting, American Dairy Science Association, Raleigh, NC, June 1990. Journal of Dairy Science, 74(7):2362–2373. https://doi.org/10.3168/jds.S0022-0302(91)78410-5.

Behzadifar, M., H.A. Gorji, A. Rezapour, A. Rezvanian, N.L. Bragazzi, and S. Vatankhah. 2019. Hepatitis C virus-related policy-making in Iran: a stakeholder and social network analysis. Health Research Policy and Systems 17(42):1-11, doi:10.1186/s12961-019-0442-1.

Berariu, R., C. Fikar, M. Gronalt, and P. Hirsch. 2015. Training decision-makers in flood response with system dynamics. Disaster Prevention and Management 25(2):118-136, DOI:10.1108/DPM-06-2015-0140.

Bodell, J. 2019. Soil health case study Ralf Sauter, Okuye Farms, CA. USDA and American Farmland Trust. https://farmland.org/project/quantifying-economic-and-environmental-benefits-of-soil-health/.

Brandt, B. 2019. Soil health case study: Eric Niemeyer, MadMax Farms, OH. USDA and American Farmland Trust. https://farmland.org/project/quantifying-economic-and-environmental-benefits-of-soil-health/.

Brown, J.D. 2000. Statustucs corner: Questions and answers about language testing statistics: What issues affect Likert-scale questionnaire formats? Shiken: JALT Testing & Evaluation SIG Newsletter, 4(1):27-30.

Carlisle, L. 2016. Factors Influencing Farmer Adoption of Soil Health Practices in the United States: A Narrative Review. Agroecology and Sustainable Food Systems,doi:10.1080/21683565.2016.1156596.

Ciriacy-Wantrup, S.V. 1947. Capital returns from soil-conservation practices. Journal of Farm Economics 29(4.2)1181-1196. https://www.jstor.org/stable/pdf/1232747.pdf?casa_token=du16AvBm7ZkAAAAA:OGXAuOdVprRqHHIQQkQ6syIj-

UnGdC7lsSgtyzZIWhtQIBbDUMVcjEcM2QlnAX1GPyrTAwbuBFEhf69_QBhfq2DCxFUBNLvatONR9ONQ6dxPtYz2MKc.

CTIC (Conservation Information Technology Information) Staff. 2017. Report of the 2016-17 National Cover Crop Survey. Joint publication of the Conservation Technology Information Center, the North Central Region Sustainable Agriculture Research and Education Program, and the American Seed Trade Association. West Lafayette, IN. https://www.ctic.org/files/2017CTIC_CoverCropReport-FINAL.pdf.

Conversation Earth Staff. 2018. Conversation earth-Dennis Meadows (#116). https://soundcloud.com/conversation-earth/limits-to-growth-dennis-meadows-116-encore.

Crummett, D. 2016. Committing to strip-till transforms high plains farm. Strip-Till farmer. https://www.striptillfarmer.com/articles/1951-committing-to-strip-till-transforms-high-plains-farm?v=preview.

DeLaune, P.B., P. Mubvumb, Y. Fan, and S. Bevers. 2020. Agronomic and economic impacts of cover crops in Texas rolling plains cotton. Agrosystems, Geosciences & Environment. https://doi.org/10.1002/agg2.20027.Ducks Unlimited Staff. n.d. Where Ducks Unlimited works: Delivering continental conservation for wetlands and waterfowl. https://www.ducks.org/conservation/where-ducks-unlimited-works/poe/home.

Dunn, B.H., J.S. Alexander, R.N. Gates, P.S. Johnson M.K. Beutler, M.A. Diersen, L.L. Janssen. 2010. Long-term production and profitability from grazing cattle in the northern mixed grass prairie. Rangeland Ecology & Management 63(2):233-242, doi:10.2111/REM-D-09-00042.1.

Ducks Unlimited Staff. n.d. Where Ducks Unlimited works: Delivering continental conservation for wetlands and waterfowl. https://www.ducks.org/conservation/where-ducks-unlimited-works/poe/home.

Dweck, C.S. 2006. Mindset: The new psychology of success. New York: Random House.

Eagan, T. 2001. The worst hard time: The untold story of those who survived the Great American Dust Bowl. Boston: Houghton Mifflin Company.

Ecosystem Marketplace Staff. 2017. Unlocking potential: State of the voluntary carbon markets 2017. Ecosystem Marketplace: A Forest Trends Initiative. https://www.forest-trends.org/wp-content/uploads/2017/07/doc_5591.pdf.

Edelenbos, J., A. Van Buuren, D. Roth, and M. Winnubst. 2017. Stakeholder initiatives in flood risk management: exploring the role and impact of bottom-up initiatives in three 'Room for the River' projects in the Netherlands. Journal of Environmental Planning and Management, 60(1):47-66, doi:10.1080/09640568.2016.1140025.

Ells, J.C., and Soulis, J., (2013). Do women farmland owners count in agricultural conservation? A review of research on women farmland owners in the United States. Soil and Water Conservation Society 68 (5) 121A-123A. doi:10.2489/jswc.68.5.121A.

Environmental Protection Agency Staff. 2012. TMDL Document for West Barnitz Creek Bacteria TMDL. https://ofmpub.epa.gov/waters10/attains-impaired-waters.tmdl-report?p-tmdl-id=42418.

Emirhuseyinoglu, G., and S. Ryan. 2020. Land use optimization for nutrient reduction under stochastic precipitation rates. Environmental Modelling and Software 123(104527):1-14. https://doi.org/10.1016/j.envsoft.2019.104527.

Farm Support Agency. Emergency Funding. Retrieved on 11/17/2019 https://www.fsa.usda.gov/programs-and-services/conservation-programs/emergency-conservation/index.

Fisher, K.A., J.R. Winsten, E. Spratt, R. Anderson, and R. Smith. 2017. Pay-for-Performance Conservation: A how-to guide. Delta Institute and Winrock International.

Forrester, J.W., 1968. Industrial Dynamics-After the first decade. Management Science 14(7):308-415. https://www.scribd.com/document/228973983/FORRESTER-1968-Industrial-Dynamics-After-the-First-Decade.

Friedrich, J., M. Ge, and A. Tankou. 2017. 6 Charts to Understand U.S. State Greenhouse Gas Emissions. World Resources Institute. August 10, 2017. https://www.wri.org/blog/2017/08/6-charts-understand-us-state-greenhouse-gas-emissions.

Friedrichsen, C.N., S.H. Daroub, M.C. Monroe, J.R. Stepp, and S.P. Wani. 2018. Mental Models of Soil Management for Food Security in Peri-Urban India. Urban Agriculture & Regional Food Systems 3:1-16, doi:10.2134/urbanag2017.08.0002.

Fuhrer, J.D and W.D. Bott. n.d. Soil health: Five principles of soil health. https://www.nrcs.usda.gov/wps/portal/nrcs/main/nd/soils/health/.

Gassman, P.W.; Osei, E.; Saleh, A.; Rodecap, J.; Norvell, S.; Williams, J. 2006. Alternative practices for sediment and nutrient loss control on livestock farms in northeast Iowa. Agriculture., Ecosystems. & Environment. 117, 135, doi: 10.1016/j.agee.2006.03.030.

German, L., and A. Stroud. 2007. A framework for the integration of diverse learning approaches: Operationalizing agricultural research and development (R&D) linkages in Eastern Africa. World Development 35(5):792-814, doi:10.1016j.worlddcv.2006.09.013.

Gilley, J.R., D.G. Watts, R.J. Supalla, M.S. Quinn, M. Twersky, F.W. Roeth, R.R. Lansford, and K.D. Frank. 1982. Strategies for reducing pollutants from irrigated lands in the Great Plains. Working paper, Robert S. Kerr Environmental Research Laboratory. Reference EPA 600/2-81-108.

Glenk, K., S. Shrestha, C.F. Topp, B. Sanchez, A. Iglesias, C. Dibari, and P. Merante. 2017. A farm level approach to explore farm gross margin effects of soil organic carbon management. Agricultural Systems 151:33-46, doi:10.1016/j.agsy.2016.11.002.

Gordon, H. 2013. Basic economic analysis using T-Charts. Working paper, United States Department of Agriculture Natural Resources Conservation Service Economics Technical Note No: TX-Econ-13-01. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1176611.pdf.

Gosnell, H., N. Robinson-Maness, and S. Charnley. 2011. Profiting from the sale of carbon offsets: A case study of the Trigg Ranch. Rangelands 33(5):25-29, doi:10.2111/1551-501X-33.5.25.

Gramig, B.M., and N.J. Widmar. 2017. Farmer preferences for agricultural soil carbon sequestration schemes. Applied Economic Perspectives and Policy 40(3):502-521, doi:10.1093/aepp/ppx041.

Groff, S. 2019. Do cover crops pay? Cover Crop Innovators. https://www.covercropinnovators.com/

Hand, M., and C. Nickerson. 2009. The role of cost-share rates and prices on the size of conservation investments in EQIP. Paper presentation at the Agricultural and Applied Economics Association's Annual Meeting, Milwaukee, WI, July 26-28, 2009. https://ageconsearch.umn.edu/record/49257/.

Hansen, Z.K. and G.D. Libecap. 2004. Small farms, externalities, and the Dust Bowl of the 1930s. Journal of Political Economy 112(3):665-694. https://www.jstor.org/stable/10.1086/383102.\

Harrigan, K. and A. Charney. 2019. Impact of 2018 Farm Bill provisions on soil health. Soil Health Institute and National Sustainable Agriculture Coalition. https://sustainableagriculture.net/wp-content/uploads/2019/09/FINAL-DIGITAL-Impact-of-2018-Farm-Bill-Provisions-on-Soil-Health.pdf.

Hatfield, J. 2005. The farmer's decision: balancing economic successful agriculture production with environmental quality. Soil Water Conservation Society.

Hill, J. and M. Kaiser 2019. 30 harvests: Creating the 2050 food systems for future generations. US Farmers and Ranchers Alliance Staff. https://usfarmersandranchers.org/30-harvests/.

Jimenez, A.Z., P. Ladron-de-Guevara-Porras, R. Prez-Ceballos, S. Diaz-Mondragon, R. Rosado-Solorzano. 2017. US-Mexico joint Gulf of Mexico large marine ecosystem based assessment and management: Experience in community involvement and mangrove wetland restoration in Terminos Lagoon, Mexico. Environmental Develoment 22:206-213. http://dx.doi.org/10.1016/j.envdev.2017.02.007.

Johnstone, C., C. Stephens, and T. Wolfe. 2018. Engaged communities. Chesapeake Bay Program and Businesses for the Bay: Webinar Series. https://businesses.allianceforthebay.org/event/2018-upcoming-free-lunch-learn-webinars/.

Karacostas, C. 2019. Toxic algae blooms that kill dogs are becoming more common. And climate change is making it wrse, scientists say. The Texas Tribune. November 14th. https://www.texastribune.org.

Knight, B., and D. Reed. 2019. Growing resilience in our nation's soil. Working paper, Ecosystem Services Markets Consortium. https://www.c-agg.org/wp-content/uploads/ESMC-Sacto_2019.pdf.

Kristensen, D.K., C. Kjeldsen, and M.H. Thorsoe. 2016. Enabling sustainable agro-food futures: Exploring fault lines and synergies between the integrated territorial paradigm, rural eco-economy, and circular economy. Journal of Agriculture Environmental Ethics 29:740-765, doi:10.1007/s10806-016-9632-9.

Lal, R. 2015. Sequestering carbon and increasing productivity by conservation agriculture. Journal of Soil and Water Conservation 70(3):54-62, doi:10.2489/jswc.70.3.55A.

Li, F.J., S.C. Dong, F. Li. 2012. A system dynamics model for analyzing the eco-agriculture system with policy recommendations. Ecological Modelling 227:34-45, doi:10.1016/j.ecolmodel.2011.12.005.

Littlefield, D. 2013. Charting new waters. USDA NRCS. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/tx/newsroom/stories/?cid=nrcseprd406463.

Maryland Department of Agriculture and Environment Staff. n.d. Maryland Water Quality Nutrient Trading Policy Statement. https://mde.maryland.gov/programs/Water/Documents/WQTAC/Nutrient-Trading-Policy-3-Pager-10-23-15(4).pdf.

Meadows, D.H., D.L. Meadows, J. Randers, W.W. Behrens III. 1972. The limits to growth: A report for The Club of Rome's project on the predicament of mankind. Washington, DC. Universe Books.

Mehan, T. and A. Carpenter. 2019. Bringing agriculture and drinking water utilities together for source water protection. Journal American Water Works Association 111(8):34-39. https://doi.org/10.1002/awwa.1340.

Mitchell, P.D., R.M., Rejesus, K.H., Coble, and T.O., Knight. 2012. Analyzing farmer participation intentions and county enrollment rates for the average Crop Revenue Election Program. Applied Economic Perspectives and Policy 34(4):615–636, doi:10.1093/aepp/pps038.

Moriasi, D., K.W. King, D.D. Bosch, D.L. Bjorneberg, S. Teet, J.A. Guzman, and M.R. Williams. 2016. Framework to parameterize and validate APEX to support deployment of the nutrient tracking tool. Agricultural Water Management 177:146-164. http://dx.doi.org/10.1016/j.agwat.2016.07.009.

NASS Staff. 2019a. Online Resources: Census Data Query Tool. Working paper, USDA National Agriculture Statistics Service, April 1. https://www.nass.usda.gov/Publications/AgCensus/2017/index.php.

NASS Staff. 2019b. Texas County Estimates. https://www.nass.usda.gov/Statistics_by_State/Texas/Publications/County_Estimats/ce_maps/ce_whea.php.

National Center for Water Quality Resources Staff n.d. Verification and enhancement of NRCS-USDA Nutrient Tracking Tool with a suite of best management practices. https://ncwqr.org/research/.

Nelson, E.S., Polasky, D., Lewis, A., Plantinga, E., Londorf, D., White, D., Bael, and J., Lawler. 2008. Efficiency of incentives to jointly increase carbon sequestration and species conservation on a landscape. IN Proceedings of the National Academy of Sciences, city, state dates publishers. 105(28):9471-9476, doi:10.1073/pnas.0706178105.

Nickerson, C., M. Morehart, T. Kuethe, J. Beckman, J. Ifft, and R. Williams. 2012. Trends in US farmland values and ownership. Working Paper, Lincoln, Publications from USDA-ARS / UNL Faculty 1598. https://digitalcommons.unl.edu/usdaarsfacpub/1598.

Osei, E., and S.H. Jafri. 2016. Climate Change impacts on agricultural production and farm incomes in Texas. Selected Paper prepared for presentation at the 2016

Agricultural & Applied Economics Association Annual Meeting, Boston, MA, July 31-August 2. https://ageconsearch.umn.edu/record/236053/.

Pahl-Wostle, C. 2007. The implications of complexity for integrated resources management. Science Direct: Environmental Modeling & Software 22 561-569.

Parsons Staff. 2019. Texas coastal waters: Nutrient reduction strategies report. Working Paper, Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, Texas General Land Office, U.S. Department of the Interior, National Oceanic and Atmospheric Administration, U.S. Department of Agriculture, U.S. Environmental Protection Agency. https://www.gulfspillrestoration.noaa.gov/sites/default/files/Task%205_FNLWatershed%20Assessment_August2019_FINAL.pdf.

Phillips, M. 2020. Biological alchemy: working with the soil food web to grow healthy crops. No-till on the Plains Advanced Concepts in Soil Health Symposium. Wichita, KS: Green Publishing.

Pimentel, D., C. Harvey, P. Resosudarmo, K. Sinclair, D. Kurtz, M. McNair, S. Crist, L. Spritz, L. Fitton, R. Saffouri, and R. Blair. 1995. Environmental and economic costs of soil erosion and conservation benefits. Science 267:1117–1123.

Pimentel, D. and N. Kounang. 1998. Ecology of soil erosion in ecosystems. Ecosystems 1:416-426.

Ploeg, F. and A. Rezai. 2019. Department of Economics discussion paper series: Stranded assets in the transition to a carbon-free economy. Oxford University, Oxford 894:1-31

Prokopy, L.S., K. Floress, D. Klothar-Weinkauf, and Baumgart-Getz. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. Journal of Soil and Water Conservation 63(5):300-311. https://doi.org/10.2489/jswc.63.5.300.

Prokopy, L. 2019. What is successful watershed management? An in-depth evaluation of the National Water Quality Initiative. Paper presented at the Soil and Water Conservation Society Annual Conference, Pittsburgh, PA, July 28-31, 2019. https://www.swcs.org/static/media/cms/19_AC_Final_Program_6B4BBCFB7062B.pdf.

Raudsepp-Hearne, C., G.D. Peterson, M. Tengo, E.M. Bennett, T. Holland, K. Benessaiah, G.K. MacDonald, and L. Pfeifer. 2010. Untangling the environmentalist's paradox: Why is human well-being increasing as ecosystem services degrade? BioScience 60(8):576-589, doi:10.1525/bio.2010.60.8.4.

Reedy, R.C. and B.R. Scanlon. 2016. Evaluation of Groundwater Nitrate Contamination in Major Aquifers in Texas. Final Contract Report prepared for Texas Commission on Environmental Quality. Austin, TX.

Ristow, A. 2019. Soil health case study: Jay Swede, Gary Swede Farm LLC, NY. USDA and American Farmland Trust. https:// farmland.org/soilhealthcasestudies.

RMA Staff. 2017. Texas Crop Insurance Spread Sheet. https://www3.rma.usda.gov/apps/sob/current_week/stcrop2017.pdf.

Rogers, E., 1995. Diffusion of innovations. New York: The Free Press.

Saleh, A., O. Gallego, and E. Osei. 2015. Evaluating Nutrient Tracking Tool and simulated conservation practices. Journal of Soil and Water Conservation 70(4):110-115, doi:10.2489/jswc.70.5.

Sassenrath, G.F., J.M. Halloran, D. Archer, R.L. Raper, J. Hendrickson, P. Vadas, and J. Hanson. 2010. Drivers impacting adoption of sustainable agriculture management practices and production systems of Northeast and Southeast United States. Journal of Sustainable Agriculture, 34:680-702, doi:10.10801/10440046.2010.493412.

Schmolke, A., P. Thorbek, D.L. DeAngelis, and V. Grimm. 2010. Ecological models supporting environmental decision-making: a strategy for the future. Trends in Ecology and Evolution 25:479-486, doi:10.1016/j.tree.2010.05.001.

Scoones, I., J. Thompson, and R. Chambers. 2009. Farmer first revisited: Innovation for agricultural research and development. Workshop Summary. Research Gate, doi:10.3362/9781780440156.

Silva, G., J., Fain, and B. Kittler. 2018. Pricing carbon in Oregon: Agricultural offset protocols. Leadership in conservation, thought, policy, and action. Portland, OR: Pinchot Institute for Conservation. http://www.pinchot.org/PDFs/CarbonPolicy_AOP.pdf.

Six, J., and K. Paustian 2014. Aggregate-associated soil organic matter as an ecosystem property and measurement tool. Soil Biology & Biochemistry 68:4-9, doi:10.1016/j.soilbio.2013.06.014.

Smith, D.R., R.D. Harmel, and R.L. Haney. 2020. Long-term agro-economic and environmental assessment of adaptive nutrient management on cropland fields with established structural conservation practices. Journal of Soil and Water Conservation 75(3):210-219.

Smith, K.A. 2014. For many small farmers, being certified ‘organic’ isn’t worth the trouble. CityLab. https://www.citylab.com/life/2014/08/for-many-small-farmers-being-certified-organic-isnt-worth-the-trouble/375968/.

South Ellis County Water Supply Corporation. 2020. Water quality report. https://secwater.com/water-quality-report.

Steinbeck, J. 1939. Grapes of wrath. The Euclid Ave. Cleveland: Temple Bulletin

Stubbs, M. 2020. FY2020 Appropriations for Agricultural Conservation. Congressional Research Service Staff. https://www.everycrsreport.com/files/20200121_R46011_f176c385870d0d71142ae0e248125f30f7982415.pdf.

Sun, A.Y., Y. Xia, T.G. Caldwell, and Z. Hao. 2018. Patterns of precipitation and soil moisture extremes in Texas, US: A complex network analysis. Advances in Water Resources 112:203-213. https://doi.org/10.1016/j.advwatres.2017.12.019.

Tenkorang, F. 2006. Projecting world fertilizer demand in 2015 and 2030. Thesis: Purdue University Graduate School.

Texas.gov Staff. n.d. Regional crops timeline. https://gov.texas.gov/film/page/crop_information.

Tilman, D., and M. Clark. 2014. Global diets link environmental sustainability and human health. Nature 515(7528):518-522. https://doi.org/10.1038/nature13959.

Troutman Sanders LLP Staff. 2014. National Water Quality Trading Alliance recently formed. Water World February 3, 2014.

https://www.waterworld.com/articles/2014/02/troutman-sanders-spearheads-national-water-quality-trading-alliance.html.

Turner, R.E., and N.N. Rabalais. 2003. Linking lands and water quality in the Mississippi River Basin for 200 years. BioScience 53(6):563-572.

Turner, B., M. Wuellner, T. Nichols, and R. Gates. 2014. Dueling land ethics: Uncovering agricultural stakeholder mental models to better understand recent land use conversion. Journal of Agriculture Environment Ethics 27:8310856, doi:10.1007/s10806-014-9494-y.

Turner, B.L., M. Wuellner, T. Nichols, R. Gates, L. Tedeschi, and Dunn, B. 2016. Development and evaluation of a system dynamics model for investigating agriculturally driven land transformation in the north central United States. Natural Resource Modeling 29(9):179-228, doi:10.1111/nrm.12087.

Turner, B.L., M. Wuellner, T. Nichols, R. Gates, L.O. Tedeschi, and B.H. Dunn. 2017. A systems approach to forecast agricultural land transformation and soil environmental risk from economic, policy, and cultural scenarios in the north central United States (2012-2062). International Journal of Agricultural Sustainability 15(2):102-123, doi: 10.1080/14735903.2017.1288029.

Trivedi, P., I.J. Rochester, C. Trivedi, J.D. Nostrand, J. Zhou, S. Karunaratne, I.C. Anderson, and B.K. Singh. 2015. Soil aggregate size mediates the impacts of cropping regimes on soil carbon and microbial communities. Soil Biology & Biochemistry 91:169-181, doi:10.1-16/j.soilbio.2015.08.034.

US Census Staff. 2010. US Census. Working paper, US Census Bureau. https://www.census.gov/.

US Congress. 2018. Title IX: Crop insurance. In Agriculture Improvement Act. One Hundred Fifteenth Congress of the United States of America, Second Session. Washington D.C. US Congress. file:///D:/TARLETON/Articles/agricultureimprovementact.2018.pdf.

USDA Office of Environmental Markets Staff. 2016. Environmental Markets. USDA Office of Environmental Markets. Retrieved from https://www.oem.usda.gov/.

Varavasovszky, Z., and R. Brugha. 2000. How to do (or not to do): A stakeholder analysis. Health Policy and Planning; 15(3):338-345. http://dess.fmp.ueh.edu.ht/pdf/Zsuzsa_Varvasovsky_2000_stakeholder analysis.pdf.

Walters, J.P., D.W. Archer, G.F. Sassenrath, J.R. Hendrickson, J.D. Hanson, J.M. Halloran, P. Vadas, V.J. Alarcon. 2016. Exploring agricultural production systems and their fundamental components with system dynamics modelling. Ecological Modelling 333:51-65, doi:10.1016/j.ecolmodel.2016.04.015.

Weeks, M.R., J. Li, D. Lounsbury, H.D. Green, M. Abbott, M. Berman, L. Rohena, R. Gonzalez, S. Lang, and H. Mosher. 2017. Using Participatory System Dynamics Modeling to Examine the Local HIV Test and Treatment Care Continuum in Order to Reduce Community Viral Load. American Journal Community Psychology 60:584-598, doi:10.1002/ajcp.12204.

Wichelns, D. 2010. Agriculture Water Pricing in the United States: Background report for Organization for Economic Co-Operation and Development. Hanover College, Indiana. www.oecd.org/water.

Wu, J., and J.L. David. 2002. A spatially explicit hierarchical approach to modeling complex ecological systems: theory and applications. Ecological Modelling 153:7-26.

Zeman, K.R. 2019. Modeling Farmer Decision-Making Using an Agent-Based Model for Studying Best Management Practice Adoption Rates: A Typological Approach. M.S. Thesis. University of Illinois at Urbana-Champaign. Urbana, IL.

Zhang, X.C., M.A. Nearing. 2005. Impact of climate change on soil erosion, runoff, and wheat productivity in central Oklahoma. Catena 61:185-195, doi:10.1016/j.catena.2005.03.009.

APPENDICES

APPENDIX A

Questionnaire

1. What is the gender of the primary decision-maker? **M / F / Joint**
2. What is/are the age groups of the primary operator(s)? (Check all that apply)
    a. Under 35 years |b. 35 to 44 years |c. 45 to 64 years |d. 65 years and over
3. What is/are the highest education level of the primary operator(s)? (Check all that apply)
    a. High school diploma/GED |b. Some college |c. Higher education degree (circle one): agriculture/non-agriculture
4. What Ethnicities are represented on your farm?
    a. White |b. HI or Pacific Islander |c. Asian |d. American Indian or AK Native
    e. Spanish, Hispanic, or other Latino |f. Black or African American
5. What is your role of participation?
    a. Owner |b. Operator |c. Primary Decision-Maker |d. Joint decision-maker
6. How many decision-making operators does the farm have? _________ What are their responsibilities? (Check all that apply)
    a. Field work |b. Labor management |c. Financial management |d. Other (Obtained open ended responses to this question for several producers).
7. How many days are worked off farm by the primary operator(s)? (Check all that apply)
    a. None |b. Less than 200 |c. More than 200
8. What is the primary occupation of the primary operator(s)? (Check all that apply)
    a. Farming | b. Other
9. Does the spouse(s) of the primary operator(s) work off farm? (Check all that apply)
    a. No | b. Yes, but Less than 200 days |c. Yes, and more than 200 days
10. How many acres are used in the agriculture production you participate in?
11. What percentage of the land operated is leased to the decision-making operator?

12. How many years have the same decision-making operator(s) managed the same land? (Please check all that apply)
    a. 2 years or less |b. 3 to 4 years |c. 5 to 9 years |d. 10 years or more
13. What is the length of the lease? (Check all that apply)
    a. More than 5 years |b. 2- 5 years |c. 2 years or less

(Obtained open ended responses to this question for several producers).

14. What is the gender of the primary owner?
    a. M |b. F |c. Corporation |d. Joint Ownership with both genders represented

(Obtained open ended responses to this question for several producers).

15. If an absentee landowner openly disapproves or ridicules the best management practices (BMPs) without strictly saying no, will the primary operator practice BMPs anyway? **Yes/ No**
16. To measure biodiversity, please list all plant types used currently on the land.

Small grains, wheat (*T. aestivum)*	Corn (*Z. mays*)	Guar beans (*C. tetragonoloba),* legumes	cotton (*G. hirsutum)*
Vegetables, melons, tubers	Fruits, tree nuts, berries	Native grass and legume species	Introduced grass and legume species
Pastureland	Other crops and hay (*Triticale*)		

17. What category of Net Farm Income applies to the operation you are associated with?

Loss	Less than $1,000	$1,000 to $9,999	$10,000 to $49,999
$50,000 to $99,999	$100,000 to $249,999	$250,000 to $499,999	$500,000 or more

18. Average total farm production expenses per Texas farm are $98,931. Is your farm a. above or |b. below average?
19. What farming generation is currently represented on the land you operate?

Circle all that apply: **1 2 3 4 5+ Corporation**

(Obtained open ended responses to this question for several producers).

20. What conservation agriculture outreach programs have you learned from?

Field Days	Short Course	Soil health videos	Other

(Obtained open ended responses to this question for several producers).

21. Have the outreach program techniques improved the soil health on your land?

    Yes / no / maybe

22. If you have attended multiple agriculture outreach programs, have you found the messages to be **Confusing / complimentary / consistent / contradictory** to each other. Please provide more detail: ___________________________

    (Obtained open ended responses to this question for several producers).

23. Have you requested assistance from the Natural Resources Conservation Service (NRCS)?

    Requested and received / request is pending / requested and denied / not requested

24. Have you requested assistance from Texas A & M AgriLife Extension?

    Requested and received / request is pending / requested and denied / not requested

25. Have you requested assistance from any other source?

    ____

    Requested and received / request is pending / requested and denied / not requested

26. Did or would the length of an incentive/benefit contract (e.g., 10 yr. vs. 5 yr. contract) influence your decision to implement conservation agriculture practices?

    Major persuasion factor/ hindered decision/ minor influence

(Obtained open ended responses to this question for several producers).

27. Did or would the provider of the incentive/benefit (e.g., government, reputable market, or other private source) influence your decision to implement conservation agriculture practices? **Major persuasion factor/ hindered decision/ minor influence**

    Preference

    ____

28. Average government incentives is $12,293 for all Texas farms including crops and livestock. Is your farm **above** or **below** average?
29. Would extended/additional funding enhance your willingness to adopt or continue the use of conservation practices?

    Major persuasion factor/ hindered decision/ minor influence
30. What out-of-pocket costs might you be willing to pay to implement conservation management practices? ____
31. How much would you be willing to pay for a crop consultant or similar specialist to verify that your conservation practices have been implemented to the specifications needed for ecosystem service market trading?
32. What return on investment (ROI) do you expect for the investment?
33. What type of payback period is acceptable to you?
34. What percentage of the land is dryland? _____________________
35. Please list all conservation agriculture techniques (a.k.a, BMPs) you currently use.

conservation tillage/no till	cover crops	crop rotation
Manure fertilization	water conservation	integrated pest mgmt.
biodiversity	Improved grazing mgmt.	Other

36. How long have you used each of these techniques? Please place the letter associated with techniques beside all that apply.

2 years or less	3 to 4 years	5 to 9 years	10 years or more

37. If respondent says yes to cover crops and/or crop rotation, Please describe:
    a. How do you terminate cover crops/crop rotation? (if crop remains year round, NA)
       Herbicide_____ Winter kill _____ Harvest ______Grazing ________
       Other ________
    b. How many months out of the year does the cropland/rangeland have a growing root of some kind in the soil (weeds included)? **12 / 7-11 / 1-6**
    c. What percentage of the crop remains as organic matter?
       100% (the whole plant) 60% (the non-harvested portion) 0% (the crop is cleaned up)

d. How do you handle pests in the organic matter? ______________________________

e. How many years in a row do you plant the same crop on the same plot? ____________

f. Other comments ____

38. How much of a cost difference do you need to account for cover crops in your acre (e.g., $50/acre for seed)? ____

39. Are the cover crop costs:
    a. a deterrent to adopting cover crops
    b. a limitation to continuing cover crops
    c. both
    d. neither

40. What environmental benefit/loss have you experienced as a result of this implementation?
    a. Biodiversity: **increase/ decrease**
    b. Soil health: **increase/ decrease**
    c. Crop/forage quality: **increase/ decrease**
    d. Chemical pesticide amount/frequency: **increase/ decrease**
    e. Tillage frequency and depth: **increase/ decrease**
    f. Antibiotics: **increase/ decrease**
    g. Other: ____

(Obtained open ended responses to this question for several producers).

41. What economic benefits/losses have you seen as a result of this/these implementation(s)?
    a. Diversity of enterprises and products sold: **increase/ decrease/ same**
    b. Commodity yield: **increase/ decrease/ same**
    c. Product quality: **increase/ decrease/ same**
    d. Average total cost (ATC): **increase/ decrease/ same**
    e. Average variable cost (AVC): **increase/ decrease/ same**

(Obtained open ended responses to this question for several producers).

42. How did you initially implement conservation agricultural practices on the farm?

Small plot	Large plot	Whole hog	other

(Obtained open ended responses to this question for several producers).

43. Did you experience economic losses during your conversion from conventional to conservation tillage? **Yes / No**

    (Obtained open ended responses to this question for several producers).

44. If you experienced economic loss, how did you overcome/minimize/justify loss
    a. Slow conversion
    b. Rented equipment
    c. Experienced long term gain despite short term loss
    d. Conventional farmers with same conditions also experienced losses
    e. Other

       ____

45. How did economics influence your decision to implement conservation agriculture practices? **Major persuasion factor/ hindered decision/ minor influence**

(Obtained open ended responses to this question for several producers).

46. Did BMP implementation longer than 5 years to produce a difference in the net farm income? **increase/ decrease/ same**

    (Obtained open ended responses to this question for several producers).

47. How did environmental concerns/benefits influence your decision to implement conservation agriculture practices? **Major persuasion factor/ hindered decision/ minor influence**

    (Obtained open ended responses to this question for several producers).

48. What other factors have influenced your decision to implement conservation agriculture practices?
49. What messages do farmers need to hear to get involved in ecosystem benefit services which incur for enhancing soil carbon and improving quality and quantity of water and potentially additional benefits (e.g., biodiversity and habitat conservation)?
50. Do you have any suggestions for communicating the value of BMPs and ecosystem services to absentee landowners?

APPENDIX B

Question Changes

Change (reworded 3): Some expert conservation producers have a high school diploma, what levels of education do the decision-makers on your production have?

Change (reworded 10): Can you tell me about the production?

Change (word change to 15): If **any** landowner openly disapproves or ridicules the best management practices (BMPs) without strictly saying no, will the primary operator practice BMPs anyway?

Change (reworded 18): Other producers think this statistic is way off. Is your production above $98,931 ATC?

Change (clarification as needed to 21): Were you able to implement techniques from the training to improve the soil health?

Change (clarification added for 45, 47, 48): Would you prioritize economic and environmental factors 50:50?

Change (summarizing 49 and 50 to save time): Do you have any messages for other producers, landowners, consumers, or anyone?

APPENDIX C

Open Coding for support personnel information

Sub factor	Support wording typically found in notes
Increase in soil health	Soil health + no-till/red till
Increase in biodiversity	Cover crops
Decrease in chemical pesticides/nutrients	Pollinator habitats = decrease in pesticides Water Quality = decrease in nutrient loading
Increase in crop & forage quality	Double cropping, genetic richness.
Increase of diversity/quality	Diversification of products, improved seed quality for sale.
Average Variable Cost Decrease	Diesel, labor, seed, producers time.
Commodity yield increase	Yield increase.
Average Total Cost decrease	Selling or paying off large bank notes for land, buildings, and equipment.
Educators/Researchers/Sustainable NGO's/Conference	Speakers without experience in ag.
Interact with CAS producers	Current Producers conducting field days etc.
Hands on adaptation/learning	Current Producers conducting their own experiments.
Government conservation funding	EQIP etc.
Land stewardship & Ecosystem Marketplace Consortium	Indigo Ag, Ecosystem Marketplace Consortium.
Above average total government incentives	Non-conservation incentives, or conservation and Non-conservation incentives.
3rd and up generation worked on the same land	Speakers with 3 plus generational experience in ag.
1st & 2nd generation working the land	Speakers with experience in ag.
Sell & buy No-till/strip till	Sell the tillage "iron" etc.
Switch mentality and prefer diverse appearance	Any wording about appearance and conservation mentality.
Expect ridicule and strategize	Any wording about strategies to deal with peer pressure, intimidation, fear.

APPENDIX D

Messages to consumers.

"Vegetarian diets do not improve the land, they lead to deforestation." (R.)

One strategy is to lead annual programs to get the community to support CAS. For example, selling flowering cover crop seeds to gardeners and potential gardeners for a negligible profit gives the community a chance to experience CAS and see firsthand the struggles and benefits. (C.)

The current rate of farmers talking to farmers who have an "aha moment" and begin [to] implement CAS is similar to "chopping down a forest with an axe." Getting various economic sectors involved in CAS may require the same type of "aha moments." (C.)

Messages to producers.

"No-till is a necessary evil, but cheaper to start with than strip till due to necessary equipment." (C.)

"Tillage degrades 100 years of the [soil's] life span." (C.)

Farmers do what they have been taught to do and what they see works. (F.)

Economically, farmers save moisture, cut diesel, reduce time in fields, potentially raise chemical prices, capture more rainfall, typically increase yield, and overall make more money. (F.)

Messages to landowners.

Share cropping systems with a three-year crop rotation including small grains, cotton (*G. hirsutum)* and fallow make the same in two out of three years as cotton on cotton (continuous *G. hirsutum*) in three years. (F.)

"If they are doing a good job (e.g., paying on time) leave them alone." It is about relationships." (C.)