A report for:

A Bird in the Hand

Leveraging short term profits for long term sustainability

by Ruth McCabe

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Executive Summary

Iowa is an agricultural state in the Midwest United States. Farmland management practices are intensive which lead to nutrient and soil loss from our farm fields. Conservation farming adoption is on the rise in Iowa but is slow compared to other regions of the world. To achieve widespread adoption of more conservation farming practices (CFP) in Iowa, we need to make them economically preferable to the alternative, which is immediate short-term profit. As I learned while traveling, if the CFP itself generates better short-term profit for farmers (owners or tenants), then the result will likely be widespread adoption. But if the CFP has negligible or negative impact on short-term profit, then the uncertain potential future profitability is not enough of a draw to entice a broad majority of farmers to adopt that practice. In some parts of the world, there are some CFPs like no tillage (NT) that make absolute common sense because they are an agronomic game changer for the farmer. But in Iowa, some of those same CFPs make zero sense because they either do not have enough of a positive agronomic impact and they may even cause a yield loss. And while there are some early adopters and intrepid farmers and landowners who can recognize that long-term sustainability is worth a short-term loss, they are not the norm. If we want to see widespread adoption of CFPs in Iowa, we need the middle adopters, the average tenant farmers, to be on board. But it seems that middle adopters are more comfortable sticking with the status quo than taking a hit to their profits on a CFP that is, at best, a gamble for them in the long-term. In other words, for many middle adopter farmers, a bird in the hand is worth two in the bush. If we want to preserve the voluntary model that we are currently working with, we need to prioritize making CFPs profitable for tenant farmers in the short term so that we can have long-term farmland sustainability. This report is not comprehensive, but I attempt to offer several suggestions on this subject. The audience for this report is anyone who works to increase the adoption of conservation agriculture in Iowa, including but by no means limited to farmers, landowners, researchers, public agency staff, policy makers, and ag retailers.

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Foreword

My goal for this project was to discover if there were motives for conservation farming adoption in other countries that were not being considered in Iowa. I currently work as the Conservation Manager for a team of Conservation Agronomists at Heartland Cooperative, a large agricultural retailer in the Midwest. My team's purpose is to help farmers adopt conservation farming practices that reduce the loss of sediment or nutrients from their farm fields. Iowa is an agricultural state where over two thirds of our land is devoted to commodity grain and livestock production. This industrious agricultural output does not come without drawbacks, namely in the form of reduced ecosystems services from the landscape and increased nutrient and sediment loads to our water courses. The current public narrative in Iowa is that farmers are not doing enough to reduce nutrient and sediment loss from our farm fields. Exploring the drivers behind conservation farming adoption in other countries might give me some ideas to bring back to Iowa that we are not already trying.

A few caveats must be mentioned before I move into the body of my report. First, my observations and conclusions will not capture the whole picture of agricultural conservation adoption around the world. I worked full time while completing my Nuffield Scholarship and travelled intermittently for five months over the last two years. I could not travel everywhere and doubtless there are concepts that I have missed. Second, I was asking myself the question "Is this something we are thinking about in Iowa?" Therefore, I do not expect that my conclusions can be extrapolated beyond Iowa. Third, this report includes my personal observations for why conservation farming adoption differs between Iowa and other grain producing regions of the world. My personal observations are supported by subject interview quotes and citations compiled from the broader research community. Based on what I have learned from my interview subjects, my travel experiences, and my time spent reviewing current scientific literature on the subject, I end this report by offering direct suggestions for several conservation stakeholders in my region on how we can support and increase the adoption of conservation farming practices in Iowa. Finally, I will not be addressing a regulatory approach because my hope for this project is to shed light on why the voluntary approach falls short in some places and how we can improve adoption by changing our approach to cost share programs, academic research, and conservation tax incentive policies. In addition, my suggestions are meant to emphasize the need for the agricultural retail community's action on supporting and increasing Iowa's current voluntary approach.

Acknowledgments

First and foremost, I want to thank my husband, Kenneth McCabe, for supporting me and remaining my rock while I travelled around the world, researched on weekends, and stayed up late on many a weeknight to draft this report. When I returned from my travels, exhausted and cranky, my home was a welcome respite that my husband improved every time that I was away! Second, without the flexible and forward-thinking support of my company, Heartland Cooperative, and my director, Thomas Fawcett, I would not have been able to embark on my Nuffield adventure. I would also like to thank my Nuffield Scholarship sponsors: Iowa Soybean Association, Iowa Farm Bureau, Iowa Pork Producers Association, and People's Company. Without the generous support of donors like these organizations, my scholarship and travel opportunity would not have been possible.

Travel in other countries where you speak the language is difficult enough but travel in countries where you are unable to communicate lands on a whole different level. I want to thank all the Nuffield scholars who opened their doors (and their professional networks) to me while I travelled. I especially want to thank Júlia Cristinia Campos and Renata Rossetto Lopes for arranging and joining me on a most-epic trip through Brazil. My research would not have been possible without the gracious welcome from countless farmers, researchers, government representatives and agricultural retailers around the world who welcomed me into their spheres. Special thanks go to Ed Kee and Willard Agri-Service in Delaware, Sheldon Dowling and family in Canada, Vicente Bissoni Neto, Douglas Bissoni, and Gustavo Graziano Malimpence in Brazil, and Lachlan Ingram in Australia.

Finally, I want to thank Vincent Gauthier, Stuart Tait, Susan Kozak, and Kate Bussanmas who were willing to edit this report and give it the professional and scholarly polish that it needed to justify publication. Writing in an echo chamber is useless if my goal is to share my knowledge in an impactful way. These editors helped me see past some of my blind spots to build this report into what it is.

Abbreviations

CFP	Conservation Farming Practice
CA	Conservation Agriculture
GOM	Gulf of Mexico
INRS	Iowa Nutrient Reduction Strategy
NRCS	Natural Resources Conservation Service
USDA	United States Department of Agriculture
N	Nitrogen
P	Phosphorus
GFP	Global Focus Program
CT	Conservation Tillage
NT	No Tillage or Zero Tillage
CC	Cover Crop or Cover Cropping
GBR	Great Barrier Reef
ILPF	Integrated Livestock Pasture Forestry System
EQIP	Environmental Quality Incentives Program
Ag	Agricultural
US	United States
USD	United States Dollar
EPA	US Environmental Protection Agency

Objectives

Objective 1: What is happening in conservation farming around the world?

Objective 2: What factors influence short-term financial impact?

Objective 3: How can agricultural and conservation stakeholders support and increase the adoption of conservation farming practices in Iowa?

Chapter 1: Introduction to Iowa and my study topic

Iowa's agricultural history is deeply rooted in its fertile soil and favourable climate, making it one of the most productive agricultural regions in the world. Before European settlers arrived, Iowa was a tall grass prairie region that was seasonally inhabited by migrating Native American tribes who utilized the state for their summer camps [1] [2] [3]. With the arrival of European settlers in the 19th century, the landscape underwent significant changes as agriculture became the dominant land use. The fertile soil of Iowa, composed of rich loess deposits left by glaciers during the last Ice Age, provided an ideal foundation for farming [3]. The introduction of the steel plough by John Deere in the mid-1800s revolutionized farming practices, making it easier to till the soil and expand agricultural production, leading to rapid conversion of prairie into farmland [3]. The 20th century brought further innovations, including the widespread adoption of hybrid seeds, chemical fertilizers, and pesticides, which significantly boosted yields [3] and made Iowa the top producer of corn, hogs, soybeans, and eggs in the United States (US) [4] [5].

The intensification of farming also had significant environmental consequences. The widespread use of soil tillage, synthetic fertilizers, and drainage water tiling have led to soil erosion and nutrient runoff from agricultural fields directly into the streams and creeks which flow to one of two major rivers on either side of the state: the Missouri and the Mississippi [2] [6] [7] [8]. Sediment and nutrients from farm fields throughout the Midwest eventually find their way into those two rivers and down into the Gulf of Mexico (GOM), famously causing the "Dead Zone," a large hypoxic area that forms in the delta where the Mississippi River meets the Gulf [7] [9]. Iowa is not alone in contributing to the GOM hypoxic area. In 2008, US Environmental Protection Agency's (EPA) Gulf of Mexico Hypoxia Task Force released the Gulf Hypoxia Action Plan, calling for states along the Upper Mississippi to develop strategies to reduce their respective contributions in nutrients and sediment to the Mississippi River [10]. Iowa's response was to draft the Iowa Nutrient Reduction Strategy (INRS). According to the INRS website, "The Iowa Nutrient Reduction Strategy is a framework to reduce nutrients that move via surface water from Iowa in the Mississippi River Basin and down to the Gulf of Mexico" [9]

With this backdrop in mind, the INRS framework outlines a variety of conservation farming practices (CFP) that can be used to reduce the environmental impact from our farm fields [10]. Practices such as no tillage (NT) or reduced tillage, cover cropping (CC), improved nutrient management, grassed waterways, buffers, bioreactors, saturated buffers, and nutrient-treatment wetlands, among others, are all effective at reducing nutrient and sediment loss from agricultural land [8] [10] [11]. The goal of the INRS is to reduce the total nitrogen (N) and phosphorus (P) loads coming from Iowa non-point sources by 41% (N) and 29% (P) by 2035 [8] [10]. The INRS is eleven years old and since progress tracking began, Iowa has not met its nutrient or sediment reduction goals, although we are very close to achieving our P reduction goal due to several decades' worth of sediment control structure adoption [12] [13]. We can't help but hear in popular press articles that we grow too much corn (and therefore use too much fertilizer) and not enough farmers are willing to use CFPs [14] [15]. At the same time, if you have received an education as an agronomist in the Midwest, you have surely heard about the higher rates of CFP adoption in other countries. It is frequently acknowledged that while CFP technologies like NT and CC

research were pioneered in the United States, percentagewise, we have some of the lowest adoption rates in the world [16]. Globally, conservation agriculture (CA) is on the rise [17] but, sometimes the public discourse in Iowa would suggest the opposite in our part of the world.

With the above in mind, I set out with the following premise: “Iowa lags other major grain producing countries in using conservation farming practices. My goal is to understand the reasons for increased rates of adoption happening elsewhere. By studying the primary drivers of conservation adoption in other countries, I hope to improve the direct support that agricultural retailers in Iowa can offer to their conservation-minded customers.” I chose to visit western Canada and Brazil because they are our closest neighbours who also produce a significant amount of grain and I chose to visit the Chesapeake Bay and Australia because they are areas of agricultural industry that also impact a significant natural water resource [18] [19] [20]. In all four places, NT adoption rates are higher than Iowa, and I assumed that high NT rates would mean high CFP adoption in general. In each country and region, I conducted long-form interviews with farmers, ag retailers, and non-profit or research professionals (Appendix 1 & 2) about their experiences with CFP adoption or support. I also travelled with a group of Nuffield Scholars to England, Singapore, Borneo, and Denmark as part of the Nuffield Global Focus Program (GFP), a trip designed to introduce scholars to global agriculture. When I was able to, I conducted long-form interviews with some of the professionals we met on the GFP as well. In total, I interviewed 117 agricultural professionals from six countries and the Chesapeake Bay in the US. So, what did I learn?

Chapter 2: What is happening in conservation farming around the world?

My early impression that NT adoption rates were higher in the four main countries or regions that I visited was correct. However, NT adoption was the only consistent CFP that I saw practiced in the regions I visited. Cover cropping as we know it in Iowa was not widely practiced, mostly because of moisture constraints. And other forms of permanent or perennial CFPs, such as grassed waterways or shelterbelts, were mostly used only if regulatory compliance required them. Meanwhile, soil erosion and other forms of soil degradation, not something I expected to see as widely as I did, was everywhere we visited (Figure 1). In fact, in many respects, the greatest lesson I learned while traveling was that Iowa was not doing as badly as I previously thought.

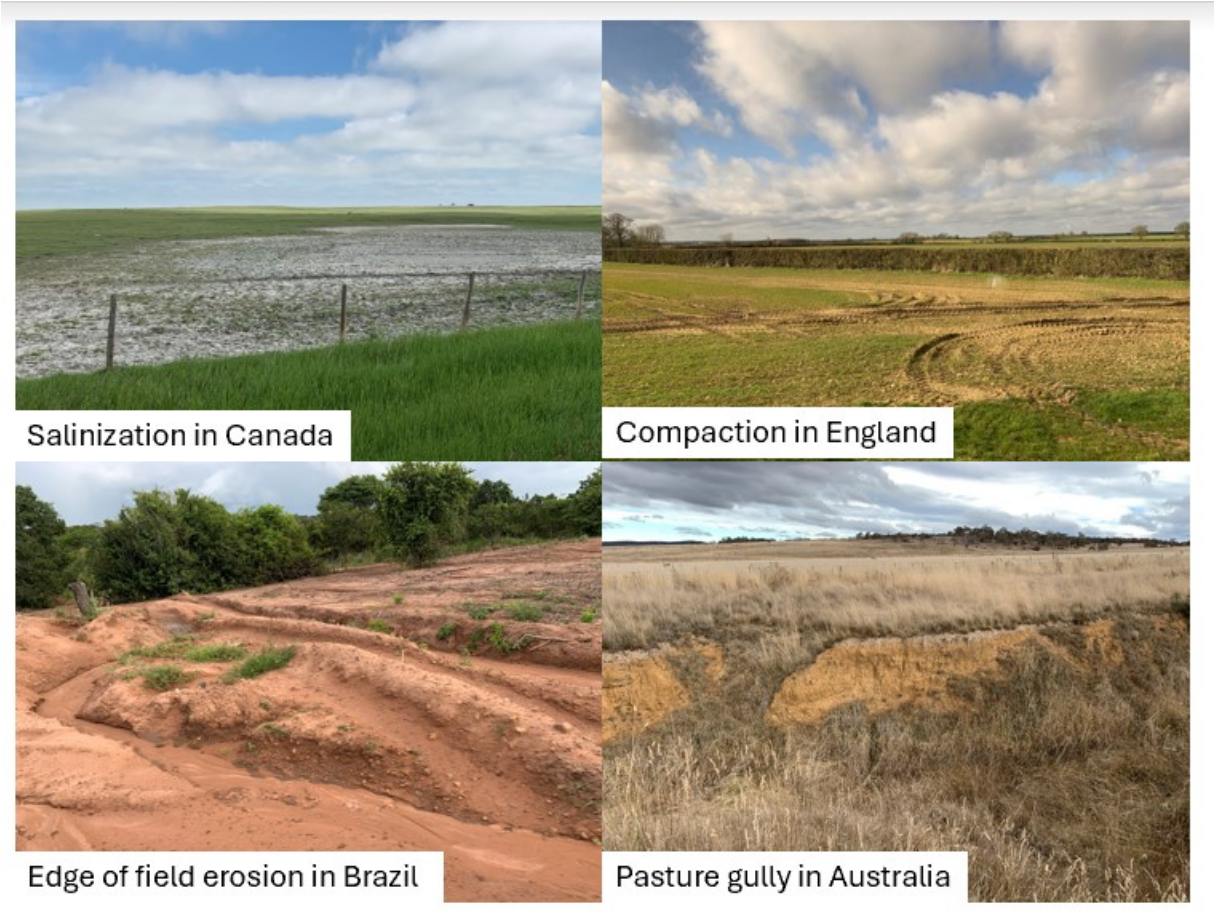


Figure 1. Soil degradation knows no boundaries.

Chapter 2.1: No-tillage is more common outside the United States; Cover cropping was sporadic.

According to the INRS Interactive Data Dashboard, NT was used on 41% of Iowa's farmed acres, conservation tillage (CT) on 23%, and cover crops on 10% [13]. These numbers closely align with data from the USDA 2017 Ag Census [5] as well as more current increases estimated in the last few years by Iowa State University [21] [22] and the Iowa Nutrient Research and Education Council [23]. All of these are improvements from ten years ago [21] but none so

much as cover crops, which have seen a 370% percent increase in Iowa since 2009 [12]. So how did Iowa compare to the other countries I visited?

In the Chesapeake Bay region, the NRCS reports that 88% of the agricultural cropland in the Bay watershed is under some form of CT with 48% considered NT and another 40% defined as reduced-till, mulch-till, or strip-till [24]. In an interview with a government agency agricultural professional from the Chesapeake region, Interviewee L described adoption of NT as 60 to 70% for Delaware but as high as 90% for some form of CT (Figure 2). Those numbers, he explained, differ greatly depending on the state you are in within the watershed. Similarly, although many Brazilian farmers and ag retailers I interviewed believed NT adoption rates to be close to 100% across their country, that statistic dropped significantly when I spoke with government agency staff or consulted academic literature. I met with one agricultural researcher in central Brazil (Interviewee R1) who is also a farmer and his estimation of NT adoption in Brazil, anywhere from 50 to 100% depending on the cropping system, mirrored literature estimates of 50 to 60% across central-western Brazil and closer to 80% in southern Brazil [25] [26] [27] (Figure 2). Canada and Australia had similar results (Figure 2). While most interviewees in Western Canada believed NT adoption to be widespread across the Prairie Provinces, academic literature reports that NT is used on 50 – 60% of the region with CT used on 75 – 80% of the region [28] [29] [30]. Australian interviewees also believed NT adoption to be almost universal in Australia, but academic research indicates that across grain cropping acres, NT adoption sits at approximately 75% with most states reaching of plateau of 80 – 90% adoption [31] [32] [33] [34].

Figure 2. Conservation tillage around the world.

Cover cropping (CC) was more complicated and not as popular as I assumed it would be. I quickly realized that I had mostly chosen world regions with sandy, weathered, shallow, or infertile soils and with climates that had hot dry spells and/or infrequent rainfall all together. Where I did see CC in use, they were primarily grown with another cash crop in the form of intercropping, or they were used for grazing purposes. In Canada, almost everyone I interviewed stated that CC, by itself, was not very popular because no one would sacrifice the moisture for a crop they were not planning or able to harvest. As an agronomist (Interviewee D1) from Saskatchewan, Canada said, "Cover crops around here with our limited moisture? It would be crazy to waste that on a cover crop." In Australia, CC in general was very rare, again due to the moisture concerns. The farmers who did use CC used it in context with grazing, which was commonly thought to be the only way that CC pays off in the short term (Figure 3). Intercropping, however, was growing in interest among the more conservation-minded interviewees and I met with a handful of farmers and researchers in Canada and Australia who were attempting to find a diversified intercropping rotation that still yielded economically valuable grain crops. This was the first time I had ever seen something like "peaola" or "fabax" cropping, which is when a farmer grows peas with canola (peaola) or faba beans with flax (fabax) together and separates the grain from each other during the harvesting and cleaning process (Figure 3).

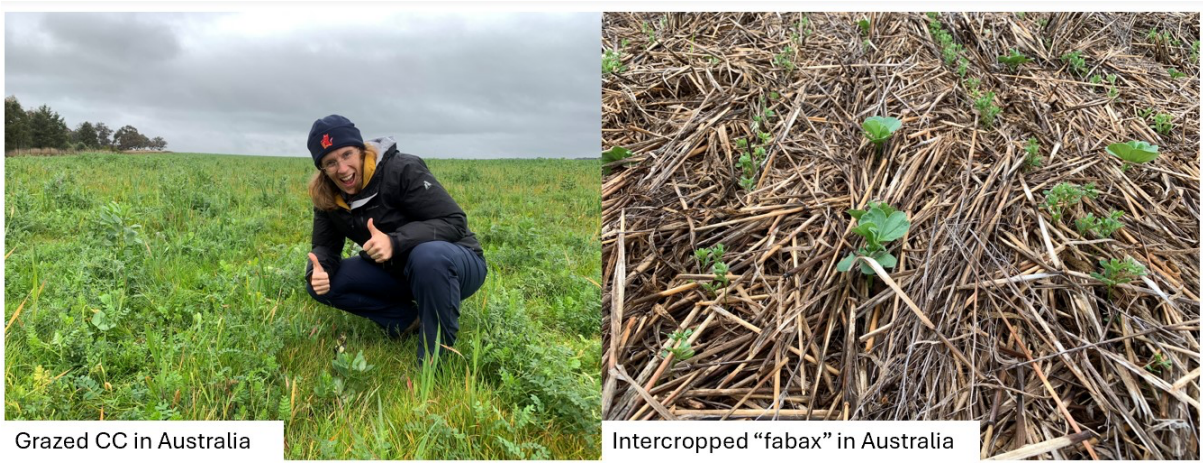


Figure 3. Cover cropping with purpose in Australia.

In Brazil, CC intercropping was practiced with either soybean and annual ryegrass (southern Brazil) or corn and Brachiaria (central-western Brazil) (Figure 4). Cover cropping in Brazil is practiced predominately on NT acres to protect the soil and is estimated at 60% adoption across the country although actual adoption varies widely [35]. My observation was that CC was used frequently by farmers who ran cattle through the crop stubble afterward for grazing purposes. I also observed some central-western Brazilian farmers using Crotalaria with their corn in attempt to sequester some nitrogen, but this was far less common (Figure 4). Interestingly, the only place in my travels where I saw some significant CC usage was in the Delmarva region of the Chesapeake Bay. The soils in that region are very sandy and moisture for cash crop growth is always a concern. I was fascinated to learn that several farmers used CC ahead of their corn, even winter rye, which is notorious for causing yield hits to corn [36]. I learned quickly that CC cost share programs in those states are high-paying and not limited in acres. One farmer (Interviewee E) from the Chesapeake Bay region explained, "Sure I sometimes take a small hit to my [corn] yield but since I get paid so well to participate in the program, I plant cover crops every year and on all my acres. It pencils out every time and that is what matters to me."

Figure 4. Cover crop intercropping in Brazil.

Chapter 2.2: Soil degradation and water quality problems are not unique to Iowa.

The Natural Resources Conservation Service (NRCS) estimates that Iowa's current erosion rate is 5.1 tons of topsoil per acre per year [37] but other studies report almost double that rate of loss across the region over time [38] [39] [40]. Iowa started with an average of fourteen inches of topsoil in the mid 1800's and we are now down to about five to six inches (Figure 5) on average across the state. Many of our streams, rivers, and beaches are routinely impaired due to nutrient and/or bacterial contamination [41] and it is not uncommon that roughly half of our state beaches are closed in the summer due to bacterial or algal concerns [42]. Financially, soil erosion and reduced soil health in the Midwest is estimated to cost approximately $2.8 billion USD per year in yield-related losses [39]. Another more tactile example is that between 2014 and 2023, it cost an average of $45.4 million USD per year to dredge sediment from the Upper Mississippi River, keeping it open and navigable despite continued sediment deposition [43]. As I travelled around the world, I quickly came to the realization that soil degradation (and its related environmental issues) was everywhere, and we were not alone in our struggle in Iowa. Not surprisingly, it turns out that global soil degradation (i.e. erosion, chemical, and physical) is on the rise [44] and related water quality impacts are tracking with it [45] (Figure 6). Compounding the issue is a global push to farm increasingly marginal land, partially in response to ever shrinking margins for farmers and a slowly decreasing global food production rate [45] [46] [47].

Figure 5. Soil erosion in Iowa since 1850. Source: Iowa Department of Transportation

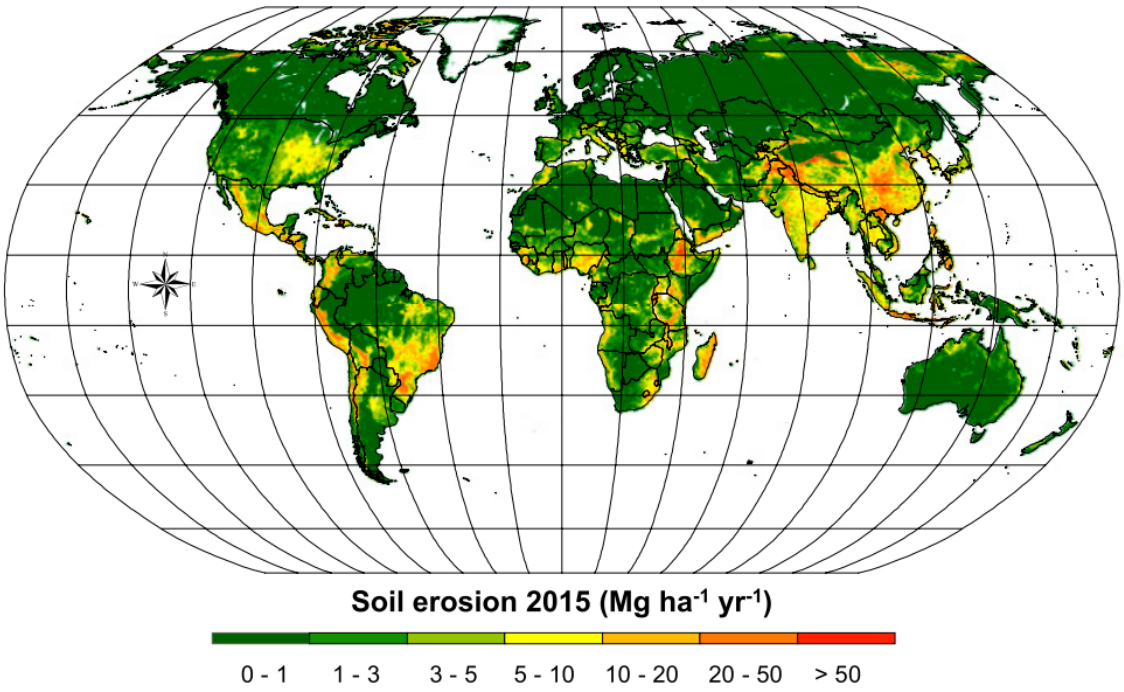


Figure 6. Average global soil erosion estimates in 2015. Source: Borelli et al 2020 [48]

I was astonished at the level of soil erosion that I saw in Brazil, especially since NT and CC adoption rates are so high there. I naively assumed that the high usage of NT and CC would correspond to reduced environmental impacts of farming, but as I travelled through Southern

and Central-Western Brazil, erosion was commonplace. It was particularly severe in the places where there was no groundcover: degraded pastures, deforested land, recently planted reforestation sites, intensively cropped fields, and on particularly steep slopes. Every river I drove over was brown or red with suspended sediment (Figure 7). Estimates in academic literature for Brazil corroborate what I saw while traveling: erosion rates that ranged from 6 to 50 tons of topsoil per acre per year, depending on the land use, with most reported erosion averages falling between 20 and 30 tons of topsoil per acre per year [49] [50] [51] [52] [53] [54]. The more elevated erosion rates were associated with annual and semi-annual cropping systems.

Figure 7. Erosion and river sediment in Brazil.

Western Canada, in contrast to Brazil, had minimal erosion that I could see, and this is supported by analysis from their federal government [28]. Canada's erosion risk has fallen significantly since the 80's and much of that improvement is due to the voluntary adoption of conservation and zero tillage in the Prairie Provinces [28]. As of now, 12% of Canadian farmland still falls in the moderate to very high-risk category of erosion (anywhere from 4.5 to 13.5 tons of topsoil per acre per year) and these are areas where slope and climate render conservation or zero tillage less effective [28]. In contrast to this official opinion, many Canadian farmers that I interviewed indicated that wind erosion was still a severe problem on ag land when the soil surface was not protected and snowmelt on frozen ground could cause significant soil loss events as well. The larger problem, as told to me in several interviews, was decreasing soil organic matter and increasing soil salinization as farmers expanded into marginal acres with high water tables or relied more heavily on irrigation. Both concerns are reflected in research literature [29] [55] as well as water quality issues due to snowmelt-induced water erosion [56]. I saw salinization

firsthand as I drove through Canada and had anecdotal conversations with farmers who suggested that it was getting worse and not better (Figure 8).

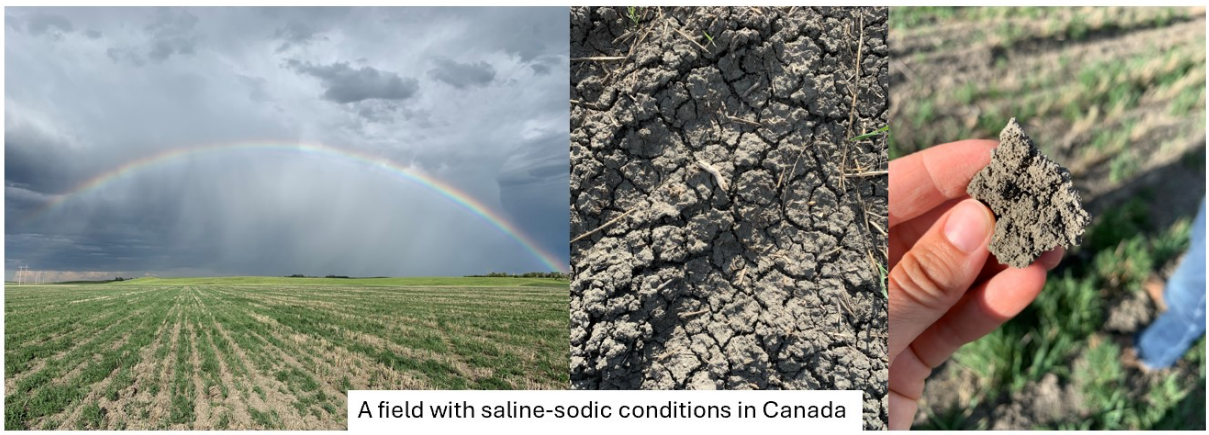


Figure 8. Salinization in southwestern Saskatchewan, Canada.

Like Western Canada, Western Australia deals with soil salinization that is largely linked to their abundant natural salts in the soil combined with a reduction in native perennial vegetation and intensive annual cropping systems [44]. Australia's soil erosion rates are estimated to be relatively low, at only a quarter of a ton per acre per year [48] and this is presumed to be due to a widespread adoption of CA principles [57]. And yet when talking with farmers in southeastern Australia, I routinely heard that both wind and water erosion were serious concerns and that only careful vegetation management would prevent either of those forms of erosion from occurring. Overgrazing combined with intermittent droughts were mentioned in every interview I conducted with Australian grazers as one of the primary recipes for erosion. When I travelled to northeastern Queensland, I learned about the impacts of agricultural land usage in the watersheds that drain to the Great Barrier Reef (GBR). Just like the Mississippi River Watershed and the GOM, Queensland deals with nutrient loss to the GBR and sedimentation of coastal marine habitats, both of which cause similar eutrophication and habitat loss issues [18] [19]. Most of the GBR catchment area is used for grazing and impact to the Reef predominately comes from grazed lands and intensive sugarcane production in the region [58].

The one region in my travels where I did not observe overt signs of soil degradation was Chesapeake Bay. Like Iowa, the Bay watershed has a nutrient reduction strategy called the Chesapeake Bay Program which seeks to reduce overall N, P, and sediment loading to the Bay from the surrounding states [59]. The Bay deals with very similar water quality issues as the GOM due to nutrients and sediment attributable to upstream agricultural land use [20]. Also, like Iowa, Chesapeake farming is under a microscope of scrutiny with popular press articles keeping tabs on the progress in achieving the Bay Program's goals [60]. The Bay Program is 40 years in the works and has had mixed results. I learned that the region is on track to reach its sediment load reduction goal [61] which is impressive given that an estimated 69% of sediment in the bay is predicted to have come from agricultural sources in the watershed [62]. However, despite significant gains in CFP adoption by upstream farmers, the program's nutrient reduction goals are not on track to be met by 2025 [60]. In conversations with farmers, researchers, and agricultural professionals alike, the issue with nutrient loading is not just from soil erosion, but also from the manure that is produced in the region. Chesapeake is one of the leading producers of poultry in the nation and all that manure must go somewhere, a story that is also very familiar to Iowa.

Chapter 2.3: Permanent CFPs are not as common in other countries as they are in Iowa.

Iowa farmers have not just increased their use of CCs and NT in the last decade. Permanent and perennial conservation practices have also increased dramatically over the last few decades, and we are now first in our nation for several permanent vegetation CFPs [63]. There are approximately 304,308 acres of grassed waterways, 85,320 miles of terraces, 12,209 miles of water and sediment control basins, and 340,248 acres of contour buffer strips, which represent increases of 165%, 61%, 204%, and 238% since the 1980's [12] [64] [65]. Around the world, I visited thousands of acres of farmland under some version of NT and CC and on many occasions, I still saw evidence of soil and nutrient loss in the form of rill and gully erosion, murky lakes, and sediment-laden rivers. Farmers in other countries may be using much higher rates of NT and CC than Iowa is, but when I looked for other permanent CFPs that might slow the loss of soil and nutrients that I was seeing, the picture fell apart rapidly for the places I visited.

It is no secret that deforestation is the first step in soil erosion [66] [67]. And it is well documented that permanent vegetation practices like grassed waterways, buffer strips, or strategically placed shelterbelts, especially in combination with NT practices, can significantly reduce erosion [11] [68] [2] [8] and multi-year perennial forage production can help combat soil salinization [69] [70]. When I asked farmers in other regions and countries if they had considered adoption of permanent CFPs that would help with some of their continued soil degradation issues, I encountered a common two-part belief that permanent solutions were either unnecessary (because NT adoption had solved their erosion problems) or they didn't make "financial sense." While I was traveling, I made it a point to start showing my farmer interviewees aerial imagery of Iowa farm fields. Specifically, I was pointing out grassed waterways and contour buffer and filter strips that can easily be seen across the state using Google Maps' satellite view (Figure 9). A farmer-agronomist (Interviewee E2) from Brazil said, "Why would you do that? I would farm through those spots because while they might wash out, you would probably get a yield there every few years. Why would you sacrifice the potential production?" And he was not alone in his opinion. The responses I received to that demonstration were the same across Brazil, and in Canada and Australia. Interviewees Q (agronomist) and S (farmer) from Canada both pointed out that grassed waterways were complicated to farm around if you did not have auto-shutoff nozzles on your sprayers. I found myself realizing that, in other countries, there did not seem to be a compelling financial reason to adopt a permanent CFP like there was for adopting NT or CC practices.

Figure 9. Grassed waterways and stream buffers in Iowa. Source: Google Maps

The country where I saw the most perennial vegetation incorporated into farming systems was Brazil and this is due almost entirely to their regulatory Forest Code. My first introduction to the Forest Code was during my interviews with representatives from the Brazilian Ministry of Agriculture. A member of the Ministry of Agriculture in Brazil (Interviewee Z2) explained to me, the Brazilian Forest Code is the most comprehensive federal mandate for protecting native forest anywhere in the world. The code requires riparian vegetation along water courses as well as a percentage of land area that is excluded from annual cropping and retained in perennial vegetation [71]. But as I travelled through the country, I saw this code manifesting as isolated postage stamps of scrub forest and very minimal actual buffer or filter strips along streams or rivers. There did not seem to be consistency with how the Forest Code was interpreted or enforced. And my observation is supported by research which suggests that forest code implementation and enforcement is fragmented and mired in bureaucracy and occasional political upheaval [72] as well as in interviews with Brazilian farmers. Interviewee D2 (farm owner) explained that the Forest Code is bureaucratic at best and does little to prevent actual illegal deforestation while simultaneously hindering law-abiding farmers from participating in international markets due to a backlog of Forest Code applications that have not been reviewed in years.

As I travelled, I saw even less incorporation of permanent or perennial CFPs in the Chesapeake Bay Region, Canada, or Australia. In the Chesapeake, for example, while the Bay Program estimates that the region will achieve their sediment reduction goal by 2025, the bulk of this reduction is due to conservation tillage and pasture fencing (reducing in-stream erosion due to livestock) [62]. But their nutrient loading issues to the Bay are still exacerbated by surface runoff and could be improved by higher adoption rates of grassed waterways and buffer strips [60] of which I saw very little when traveling the region. Interviewee N, a federal conservation employee in the Chesapeake region, explained that buffer strips are simply not popular because they take land out of annual crop production, and they are not covered 100% by cost share – there is some out of pocket costs to the farmer or landowner on top of the loss in revenue from those acres.

In Canada, I had several conversations with interviewees that touched on the virtual elimination of shelterbelts and buffers. Reasons were many, but the most frequently cited explanation was the increased size of machinery, the increase in rented acres and the decrease in publicly funded programming that supported them. This trend is supported by research as well [73]. At the same time, Canadian farmers are increasingly making the decision to farm through sloughs, or wet

spots, removing shrubs and perennial scrub and planting annual crops in these places to maximize their ever-decreasing margins – especially on rented acres. As Interviewee Y (farmer) said to me, "I try to do the right thing but it's hard to justify on rented acres when I could be getting a harvest out of those places." But this exacerbates salinity issues, which are hard to correct after soils eventually become too saline to support annual crops. Western Australia deals with similar salinity issues caused by removal of permanent vegetation and annual cropping systems as well [44]. I spoke with farmers in both western Canada and western Australia, who corroborated that irrigation-exacerbated salinity problems are on the rise as well. But, as several farmers from these countries explained to me, the solution to these salinity problems (i.e. planting perennial forages) is not financially lucrative because there simply isn't enough demand for the types of forage that can grow in saline soils and the margin is so much lower per acre than can be gained from annual crops.

Chapter 2.4: Short-term financial impact greatly influences the decision to adopt a CFP.

It did not take long for me to realize that there was a stark contrast between farmers' willingness to adopt NT or CC in other countries versus their willingness to adopt a permanent or perennial CFP. And when you dive into academic literature, you can find all sorts of reasons why isolated and widespread adoption of certain CFPs occurs: an influential community leader, a strong farmer support network or farmer-led mentor groups, robust education and information resources, cost share programming, to name only a few [25] [32] [74] [75] [76] [77] [78]. But what I noticed almost immediately upon reviewing my interview responses was that farmers tended to adopt the CFPs that gave them almost immediate positive yield impacts or that earned them cost-share support which was lucrative enough to offset any average yield hits they experience from adopting the CFP. In the instances where short-term financial gain from a CFP was less certain or even known to be negative, the farmers that I interviewed were far less likely to want to adopt that practice.

The impact to short-term financial bottom line being a major driver (or barrier) to CFP adoption is heavily supported by academic research [79] [80] [74] [76] [81]. In fact, while concern or consideration for environmental impacts frequently came up in my interviews and conversations, it seemed as if that was a tertiary driver to CFP adoption and sometimes felt as if it were an afterthought. I also noticed that the negative perceptions of CFPs outweighed the positive perceptions among the people that I interviewed. It was almost as if the potential positive impact is not believed the way the potential negative impact is believed. And these observations are also supported by research literature [82] [83]. I found myself realizing that NT and CC systems in other regions and countries were not widespread because they were the "right thing to do," they were widespread because they were financially viable practices in the short term that turned around immediate profits for the farmers adopting them. And, as I could see from the lack of other permanent or perennial CFP adoption that would have ostensibly solved worse issues with soil degradation in other countries, the lack of short-term financial gain from those practices meant that farmers in other countries were far less likely to adopt them. Because short-term financial impact was the variable that was most frequently discussed with me in my interviews, I decided to focus on exploring the factors that influenced it.

Chapter 3: What factors influence short-term financial impact?

After reviewing my interview responses on the subject, I quickly realized that I could draft a novel about what factors influence short-term financial impact. I can only cover the themes that were mentioned most often in my interviews, and I have attempted to support them here with a robust literature review. Many themes were entangled, meaning that it was difficult to discuss one theme without mentioning the other themes. In general, I realized there were either upfront or implied costs or returns. Upfront costs and returns were obvious (i.e., the cost of seed or a doubling of crop yield). But implied costs and returns (i.e., additional time investment or long-term soil improvement) were not overt and sometimes required significant conversation to uncover. The factors that came up most often in discussion and are the most impactful, from my perspective, are as follows:

- Does the CFP have an upfront cost for transitioning or adopting?
- Is the CFP a yield or management "game changer" for the operation?
- Is the farmer adopting the CFP an owner-operator or are they a tenant?
- Is there sufficient or accessible cost-share programming or supportive public infrastructure for adopting CFPs?

A final note on the factors that influence short-term financial impact: something I will not be exploring in this chapter (but that certainly plays a role) is crop insurance. This was infrequently mentioned in every country that I visited. Either the interviewee referenced the crop insurance that existed in their country, or they discussed the system that we have in the United States, which surely incentivizes certain farming systems over others [46] [84]. Crop insurance can reinforce the market price of dominant commodity crops which disincentivizes other crop rotations or land use. It also undoubtedly plays a role in the decisions that a farmer makes regarding conservation practices that might affect their ability to access it. Given its complicated nature and how infrequently it was mentioned in my conversations with farmers that I interviewed, I decided to leave out discussing it in this report.

Chapter 3.1: Does the CFP have an upfront cost for transitioning or adopting?

Most CFPs have upfront costs to adopt. Transitioning to NT or CT systems requires either retrofitting your existing planter equipment or upgrading to new equipment. Installing terraces, grassed waterways, or wetlands requires earthwork and removing some land from production, not to mention some design or engineering in more complicated instances. In many cases, the CFPs that might be most beneficial to the environment or downstream consumers, are also the CFPs with the least positive impact to the financial bottom line of a farm operation. In an article for the Bay Journal, a newspaper in the Chesapeake Bay, Karl Blankenship summarizes this point perfectly: Many CFPs "do little to help farmers or the economic viability of their [farmers'] operations. They require time to install and maintain, they may take land out of production, and some incur expenses without improving productivity" [60]. And this was a constant theme that I encountered in my interviews with farmers in the Chesapeake Bay region. As Interviewee N (federal employee) explained, "Farmers aren't putting in buffer strips because they don't get back what they think they are losing in profits from farming those acres." Research in the Bay area supports that if a CFP has upfront costs that are greater than any

perceived benefit from the practice, it is unlikely that farmers will be willing to assume that out-of-pocket cost [20].

A good example that is closer to home is the use of CC in Iowa. Although the subject of whether CC pays off in the long term is debated [74] [85] [86], it is well understood that they do not pay off in the short term unless you are grazing them [87]. After factoring in cost-share options, farmers in Iowa are paying an average out-of-pocket cost of $23 per acre [88] although this has been estimated to be as high as $50 per acre when factoring in lost revenue from reduced yield [85] and neither of these estimates account for expense related to added time management. From my experience working with farmers, and predominately tenant farmers, these immediate upfront costs are not worth the uncertain future benefits. And this is supported by the next theme that I discuss: whether the CFP is an immediate "game changer" for yield or management costs.

Chapter 3.2: Is the CFP a yield or farm management "game changer"?

As I travelled, I quickly realized that NT was widespread in other regions not because those farmers were more concerned about preventing erosion than US Midwestern farmers, but because NT adoption was an immediate yield "game-changer" for their operations [82]. I consistently heard from my interviewees that NT was widespread because it imparted an almost immediate positive yield or financial benefit over using soil tillage practices. Interviewee K1 (farmer) from Canada stated, "The diesel savings from switching to NT were worth it alone." Interviewee Q3 (researcher) from Australia stated, "In reality, a lot of the reasons why farmers adopted conservation practices around here was simply financial in nature." Interviewee A3 (researcher) from Brazil said "Our NT system with double cropping was the second revolution of agriculture in Brazil. NT was the game changer that allowed for double cropping here." Interviewee E (farmer) from the Chesapeake said, "NT has saved me a lot of fuel, time, machinery costs and it preserves moisture which means I can get out on the land earlier. Time is money too." I heard similar statements from the farmers who had adopted CC or intercropping. Interviewee E2 (agronomist-farmer) from Brazil explained that using Brachiaria CC with their corn helps to control most of their compaction issues and saved on the time and expense of subsoiling. Interviewee U (farmer) from Canada explained that intercropping things like peas with canola gave him slightly lower yields for both crops compared to growing them alone but gave him overall greater yield when added together. In all these instances, farmers were able to capture additional measurable yield in the first year or two of adopting the practice, or they cut their input expenses considerably.

After reviewing scientific literature for these regions of the world, I found that CFPs which have an overall and immediate positive financial benefit are almost always widespread with farmer-led adoption [89] [82] [34] [55] [29] [28] [26] [25]. So, what makes a CFP a "game changer?" A lot of it comes down to how the CFP interacts with the soil, climate, or environment of the region it is being used in. Inadvertently, the places I chose to visit for my Nuffield project also had more arid climates and more weathered or less naturally fertile soils than Iowa. Semi-arid to arid regions "possess inherently limited capabilities to withstand long-term soil cultivation" [46] and these types of environmental and soil conditions are strongly correlated with high rates of NT adoption and, in some places, CC adoption [32] [34] [26] [27]. The reasons for this are numerous but often revolve around increased water holding capacity, and/or reduced soil surface temperatures.

But what about when the CFP is a negative game changer and imparts a yield hit or requires a significant amount of labour? In Western Canada, several interviewees commented that CC was

not popular there because no one wanted to sacrifice the moisture. And in both Canada and Brazil, several interviewees were shocked by Iowa's inclusion of grassed waterways in our fields when it was obvious that that meant additional management considerations and lost profit due to lost acres. Interestingly, in the Chesapeake, CC seemed to be as popular as they were because of the lucrative public cost-share available to support them. As Interviewee E (farmer) from the Chesapeake region said, "I'd lose money on CC if it weren't for the cost share, which gives me a slight profit, so I continue to sign up for it."

Bringing this back home to Iowa, it turns out that CFPs like NT and CC are not immediate operational or yield "game changers" here like they are in Canada, Australia, Brazil, or the Chesapeake Bay. In fact, it is well documented that NT will virtually guarantee a 3–5-year yield hit for most farmers who transition to the practice in the Midwest and yet there is little to no research that supports a concurrent long-term yield increase from NT adoption in the Midwest [81] [79] [90] [91] [92]. Additionally, NT transition creates an almost total reliance on chemical weed control. This alone is enough for some farmers to say "no" to full NT adoption, either because they are organic farmers or because they want to reduce their usage of herbicides due to expense or other rationale [81] [79]. Cover crops, which undeniably have many long-term soil health benefits, are also known to cause yield hits to the beginning adopter in a variety of statistically likely scenarios, despite careful management [86] and literature is divided on whether CC imparts long-term financial benefits in the Midwest [74]. Only recently has research come out which supports the anecdotal experience of countless Midwestern farmers that CC adoption can be associated with slight yield decreases in both corn and soybeans [85].

These facts are enough to discourage many of the farmers that I work with in my professional day to day who are unwilling to take a short-term yield loss for practices that have out-of-pocket costs associated with them, even with cost-share factored in. It makes sense that a farmer would be more likely to adopt a CFP if that practice has a dramatic positive impact on operational expenses or immediate yield gains. However, as I learned while traveling and can support from my professional experiences, when the CFP is not a "game changer" and when its benefits are nebulous at best, it is much harder to convince a farmer to take the gamble of adopting the practice. This is compounded significantly by land tenure. What happens to CFP adoption when the farmer is not the landowner?

Chapter 3.3: Is the farmer adopting the CFP an owner-operator or are they a tenant?

Early on in my interview process, I noticed right away that there were differences in opinion about the value of different CFPs depending on whether I was speaking with an owner-operator, tenant, or a non-operating landowner. In Brazil, for example, a regenerative farm management system that is quickly rising in popularity is the "Integrated Livestock Pasture Forestry" system (ILPF) where farmers integrate perennial pasture with agroforestry systems (Figure 10). Sometimes they even integrate their annual cropping systems into the rotation, creating a truly diversified farm system that drastically reduces erosion and improves the health of both livestock and soil [53]. However, in my interviews in Brazil, the people who had a favourable impression of the ILPF system were the owner-operators or the landowners, for whom the initial investment seemed worth the cost. As Interviewee D2 from Brazil (farm owner) said, "The biggest improvement we've made to the farm is to use ILPF, but it is expensive, and I think that prevents many tenant farmers from using it." When I asked farm employees in Brazil about their thoughts on ILPF, their comments were a stark contrast to the landowners. Interviewee B2 (farm employee) stated, "I suppose it's better for the longevity of the farm, but it loses money

because you're not getting annual crops every year." I heard similar comments from tenant farmers that I interviewed in Canada, many of whom commented that they knew they should be keeping some of their shelterbelts, but high rent and low commodity prices incentivized farming those acres instead.

Figure 10. Integrated Livestock Pasture Forestry (ILPF) system in Goiás, Brazil.

It made financial sense to me that a tenant farmer would be hesitant to adopt a permanent or perennial CFP given that the practice would not improve their yield nor provide any other short-term financial benefit [93]. In the context of Iowa, where similar logic could be applied to practices like CC or NT, could it be that uncertain land tenure, or the additional overhead of rent costs were particularly detrimental to the adoption of those practices by tenants? This is a particularly prescient question for Iowa as our land is increasingly farmed by someone who does not own it. Historically speaking, full owner-operators (people who owned 100% of the land that they farmed) were more common but in the last several decades, this has changed considerably [93] and now approximately 60% of Iowa farmland is rented [76] [22]. Of those rented acres in Iowa, approximately 80% are in a cash-rent lease with 70% of those leases on a year-by-year basis [76] [22]. Even more damning is the fact that 20% of Iowa's total farmland is owned by non-Iowans, who are then guaranteed to be tenanting their acres [22].

Given the breadth of Iowa farmland that is farmed by someone with short-term tenure and given the nebulous benefits of CFPs to a tenant farmer, our low adoption rates of NT and CC started to make more sense to me. But the scientific literature I explored to better understand this dynamic had little to say about the different incentives that drive a landlord to adopt a CFP versus a tenant. In fact, most studies I read called for more research that explored this exact dynamic [75] [74]. While literature generally acknowledges that the incentives between these two groups are different (without really identifying those differences), there is one incentive that research suggests both groups share: a preference for short-term profit! In fact, studies from around the world support a near-universal preference for short-term profits, especially when the rental relationship is transactional or when the landowner is relatively removed from their land [76] [94] [95] [96].

The more I read into the literature surrounding tenancy issues and CFP adoption, the more I realized that it is important to separate owner-operators from tenants when discussing CFP adoption rates. In general, there are several studies that support the fact that full tenants are less likely to adopt CFPs over owner-operators or farmers who both rent and own [90] [97] [22] [96]. Broadly speaking, research shows that short term land tenure does not support investment in soil health practices or adopting CFPs, especially when those CFPs might be "negative game

changers," as I previously discussed, or when those CFPs only show long-term benefits [44] [76] [79] [53]. Either the landowner or the tenant don't want to lose profits and/or the landowner doesn't want to share in the cost of adoption or the loss in yield that results from adoption [76] [94] [22]. Sometimes the landowners themselves don't support the adoption of CFPs or they think that enough is currently being done on their land and more CFPs are not needed [76] [74]. CFP adoption is also lower on land that is owned by landowners who are either completely disconnected from how their farms are being managed and/or they have no direct knowledge about farming themselves [94] [98] [96]. Whatever the cause(s) may be for lower CFP adoption rates on rented land, there is enough evidence in scientific literature and anecdotally in my interviews to convince me that short-term financial impact is absolutely part of that equation.

Chapter 3.4: Is there sufficient or accessible cost-share programming or supportive public infrastructure for adopting CFPs?

Housed within the United States Department of Agriculture (USDA) is the Natural Resources Conservation Service (NRCS) [99], our federal arm of conservation policy and programming. Each state also has some version of a conservation agency or division, sometimes as standalone agencies and other times housed in Departments of Ag, Environment, or Natural Resources. This infrastructure provides farmers state and federal options for cost-share support to adopt CFPs to preserve their farmland. As I travelled, I realized that we are incredibly unique and fortunate in our country to have such a robust conservation support scaffold [100]. I did not see anything else like it in any of the countries that I visited. Where conservation agencies existed, they seemed limited to conducting research and providing some level of public education. Funding for practice change, especially for permanent or perennial CFP adoption, was mostly non-existent. Several interviewees in Canada and Australia commented that they were envious of the programs we had in the United States. As one government employee (Interviewee A4) in Australia said, "I get pretty tired of telling farmers what it will take to fix their problem and then telling them that I don't have any funding to help them make it happen." It occurred to me that perhaps this is why Iowa rates of permanent CFP adoption are as high as they are compared to the other countries I visited, because we have cost share programs that support them. After all, in the absence of cost share, permanent CFPs would be no more profitable in Iowa than anywhere else in the world. And as I heard from farmers in Chesapeake Bay, even CC would not be nearly as popular were it not for the uniquely high compensation they receive from their state cost share contracts.

Research conducted in the United States has shown higher rates of CFP adoption where there is access to state and federal cost share programs, especially in recent years [88] [101] [102] [103]. But access to cost-share programming can also be affected by the agency itself and the NRCS is not without its shortcomings. NRCS conservation programs can be practically inaccessible due to numerous bureaucratic hurdles that make the trouble to apply for the programs not worth the payout. In my professional day to day, not only do I hear about these shortcomings from my farmers, but I experience them directly myself. Local NRCS offices are often plagued by constant employee turnover, a general lack of customer service skills, constantly changing application goal posts, a complete lack of transparency, and overly complicated engineering design and technical assistance. In a classic example of when "perfect becomes the enemy of good," these shortcomings have led to less adoption overall simply because many "good" projects are either not funded because they're not perfect enough or the farmers give up on the application process because they realize that the payout will not be worth the trouble associated with the program [104] [105]. Many of these hurdles and shortcomings are reflected in academic literature as well [2] [46] [100] [106] [105] [107].

In addition to being difficult to access, NRCS programming often doesn't completely cover the costs of adoption, leaving landowners and farmers to assume some level of out-of-pocket costs ranging from 10% to 25% the cost of the project. Because NRCS technical guidelines must be followed to access cost share funding and a farmer or landowner must work with an NRCS technician or technical service provider to understand and interpret those guidelines, many projects are often over-complicated and over-engineered, resulting in out-of-pocket costs to the tune of tens of thousands of dollars [2] [105] [60]. Where programming pays an economically viable rate, demand outpaces supply. For example, the Environmental Quality Incentives Program (EQIP) is incredibly popular among tenant farmers [93] [97] [104] [108], but only a quarter to a third of applications receive funding every year [104] [107]. EQIP programs that are specifically aimed at tenant farmers have high payment rates (averages of $75 - $110 per acre), multi-year contracts, and they pay a farmer to adopt in-field, temporary CFPs like NT and CC [97]. Fascinatingly, Iowa state and local NRCS offices have claimed that they aren't getting enough applications for EQIP, but this is in direct contrast to investigative journalists and non-profit organizations like the Institute for Agriculture and Trade Policy, who claim the exact opposite [104] [109]. I can chime in from professional experience here that, at the farm gate level, the program is notoriously difficult to get into in Iowa. I cannot help but wonder what our landscape would look like if more unfunded EQIP applications were successful?

Chapter 3.5: Certain short-term profitability versus uncertain long-term profitability.

Based on what I heard in my interviews while traveling and what I have read in the research literature, we need to look at short-term financial impact from the perspective of certain versus uncertain profitability. Another way to say this is: "I prefer the devil I know to the devel I don't" or "a bird in the hand is worth two in the bush." In so many cases, I have seen evidence for farmers and landowners opting to choose the farming practices that ensure the most predictable short-term profits over farming practices that might ensure long-term sustainability but do not guarantee making up the profits lost in the short-term. This can be illustrated very well by an Australian study that explored the factors which influenced adoption of conservation tillage in Australia's cropping regions [82]. In that study, most farmers interviewed in their survey expressed certainty that switching to NT systems would increase their reliance on chemicals and would likely result in herbicide resistant weeds at some point in the future. But because NT so positively impacted their short-term yields, they were willing to make the switch. Their guaranteed benefit in the short term was more compelling than an uncertain future result. And from a logical perspective, they can always return to burning or tilling if chemical resistance becomes a problem for them in the future. Knowing the factors that influence short term profitability and understanding that most farmers seem inclined to want to prioritize farming practices that will deliver known short-term profitability, I found myself wondering: could these factors be anticipated when building conservation farming programs?

Chapter 4: How can agricultural and conservation stakeholders support and increase the adoption of conservation farming practices in Iowa?

As a part of my interviews in the different regions of the world that I visited, I asked questions about how the interviewee thought ag retailers should get involved in conservation. If the conversation allowed for it, I also asked questions related to their view of the future of conservation farming. Here are five major themes that arose in those conversations, along with a few pointed interviewee quotes:

- Ag retailers should prepare for a regulatory future that may limit what they can sell and when they can sell it and they should work to inform that regulation as best as possible.
    - "It is already happening elsewhere, and we are fooling ourselves if we think that it 'can't happen here.'" Interviewee P, Ag Retailer, Canada
    - "You are either currently regulated or you will be soon. Do you want to drive the conversation, or do you want to be driven?" Interviewee H, Ag Retailer, Chesapeake Bay

- Ag retailers should figure out which conservation practices can be supported by their business, lean into those practices, and be transparent when they cannot support something.
    - "Things like NUE, split application, better tech and timing, better genetics…our business supports these things and so we've begun to emphasize them more." Interviewee H, Ag Retailer, Chesapeake Bay
    - "Be upfront with your bias! Tell your farmers where you can help them and where you cannot. They know you need to make money and they will respect your honesty." Interviewee L1, Farmer and Researcher, Canada

- Ag retailers can support farmers who want to learn more about conservation by helping them learn more about and providing education about it.
    - "We need a new breed of farmers and professionals who have an awareness of the intended and unintended consequences of their management practices. Perhaps ag retailers can start talking about how much soil we are losing instead of how much yield we are losing? That might change things." Interviewee G2, Researcher, Brazil
    - "Around here, the lack of extension education on basic concepts of sustainability creates a vacuum of education where 'snake oil salesmen' can move in make money off a farmer and the farmer can wind up in a bad situation with poor pasture health. It would be great if ag retailers would start to provide extension education on those basic topics." Interviewee M3, Farmer, Australia

- The conservation and agricultural communities are going to have to compromise and work together.
    - "We face the challenge that we will need to produce more food on less land in a climate conducive way. We now force the conversation with everyone. You cannot

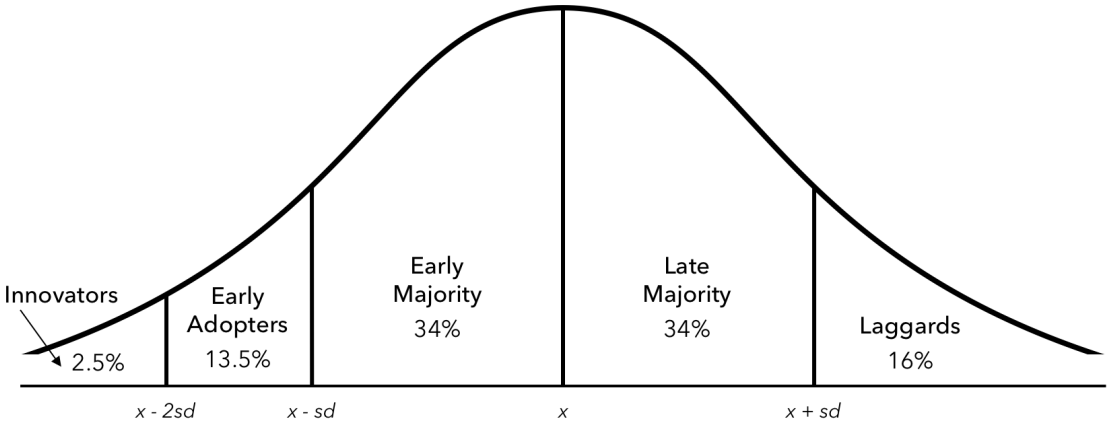
have your cake and eat it too. Compromise from all stakeholders is going to be mandatory." Interviewee O2, Ag Retail NGO, Denmark
    - "I think it comes back to willingness to create compromises that work for everyone rather than the all or nothing approach that both sides have right now. Retail interests are just as stubborn as environmentalists, and it must stop." Interviewee Q, Ag Retailer, Canada

- Bottom line? Conservation must be more lucrative than current practices.
    - "Barriers are more financial than anything. If they are making money, they are not going to change unless they can make more money out of sustainability, or they are forced to changed due to regulation or natural disaster." Interviewee Z3, Farmer, Australia
    - "We need our growers to be sustainable and profitable in the future, but no one is going to adopt conservation or sustainable practices unless they're profitable." Interviewee D4, Ag Retailer, Australia

Based on these themes and based on my previously described observations as I travelled, I came to many conclusions about how conservation stakeholders in Iowa could work to improve CFP adoption in the state. I cannot include or support every conclusion that I came to, either for lack of space in this report or lack of research to support my conclusions. What follows are recommendations where I either have enough professional experience or research to justify them.

Chapter 4.1: Work with an ag retailer to build conservation programming.

My first suggestion for improving CFP adoption in Iowa is for ag retailers and conservation agencies to partner on developing alternative forms of conservation cost share programming. When considering an innovation adoption curve, we need the middle adopters (the middle and late majority) to be on board if we want to see widespread adoption of CFPs (Figure 11). Ag retailers have access to many farmers who would fall in the middle portion of the innovation adoption curve. Most conservation staff that I work with in public or non-profit agencies struggle to connect with middle adopters in the same way that an ag retailer can engage with this demographic. Therefore, it is reasonable to suggest that the two groups work more closely together when building conservation cost share programs. This has already been happening in Iowa, with great success, in the form of saturated buffer and bioreactor "Batch & Build" programs and the "Conservation Agronomist" network that has grown over the last few years [110] [111].



Relationship between types of adopters classified by innovativeness and their location on the adoption curve.

SOURCE: Everett M. Rogers, *Diffusions of Innovations*, 5th ed. (New York: Free Press, 2003), p. 281.

Figure 11. Innovation Adoption Curve based on Everett Rogers' Diffusions of Innovations.

Ag retailers that are moving into the conservation space can meet the needs of their more conservation-minded farmers, but they are also able to promote conservation programs to farmers who would normally not have thought of conservation as a viable solution to an agronomic or management problem. We also have a sales and sociological perspective on our customer base and our industry that could genuinely improve whatever research or conservation programs our public agency colleagues are trying to build. An important caveat to address here is our need for a "product" to sell or for financial support to promote the conservation program. The "product" in this instance would be a lucrative cost share program for farmers that would give us an opportunity to improve their bottom line and therefore improve our sales relationship with them. Failing that, we need some sort of alternative financial support to justify hiring the staff and taking the time to promote conservation that would otherwise be devoted to promoting other products and services for which we receive payment. Like farmers, ag retailers are also subject to considering their immediate, short-term bottom line when making business decisions.

Chapter 4.2: Ag retailers need to engage in conservation work.

My second suggestion for improving CFP adoption is for the broader ag retail community to actively engage in conservation work. Based on interview responses and my own experience leading a conservation team at a large agricultural retailer in the Midwest, I have concluded that the premise of the ag retail business model relies on the existence of an agricultural industry that needs us. If we go by rates of soil degradation alone, we should at least be promoting practices that reduce soil loss and improve soil health for our farmers. Soil erosion is not a figment of our collective imagination and I have provided ample evidence for its impact on our state [112] and other regions around the world earlier in this report. Voluntary conservation adoption is in every agricultural stakeholder's best interest. If we cannot prove a voluntary model like the INRS can work, we will likely be facing a future where regulatory compliance is a reality [113].

You only need to visit states in the Chesapeake Bay watershed to learn about mandatory nutrient management plans and phosphorus application restrictions and the lost revenue, expense, and frustration associated with those requirements. Minnesota, Iowa's northern neighbour, recently passed a nitrogen application restriction rule in areas where ground water concerns are

heightened, effectively everywhere there are coarse textured soils [114]. The farmed acres that are impacted by this recent legislation are significant (Figure 12). Even in Iowa, our "Highly Erodible Land" compliance rules for accessing federal crop insurance programs could be considered a form of regulation, albeit a very mild one. This change to our crop insurance eligibility has absolutely helped reduce our soil loss (and by extension, our phosphorus losses) [115] [93]. If voluntary measures continue to fail and if nutrient application restrictions begin to show success, it is only a matter of time until a more comprehensive regulatory response will be seriously considered. As an example, in April of 2023, environmental groups in Minnesota successfully petitioned the US EPA to force drinking water protections in Minnesota under the federal Safe Drinking Water Act because, according to those groups, the Minnesota agencies in charge of enforcing current fertilizer use regulations weren't moving fast enough [116] [117]. The same approach is now being employed in Iowa in April of 2024 and is expected to have similar success as the Minnesota effort [116] [118].

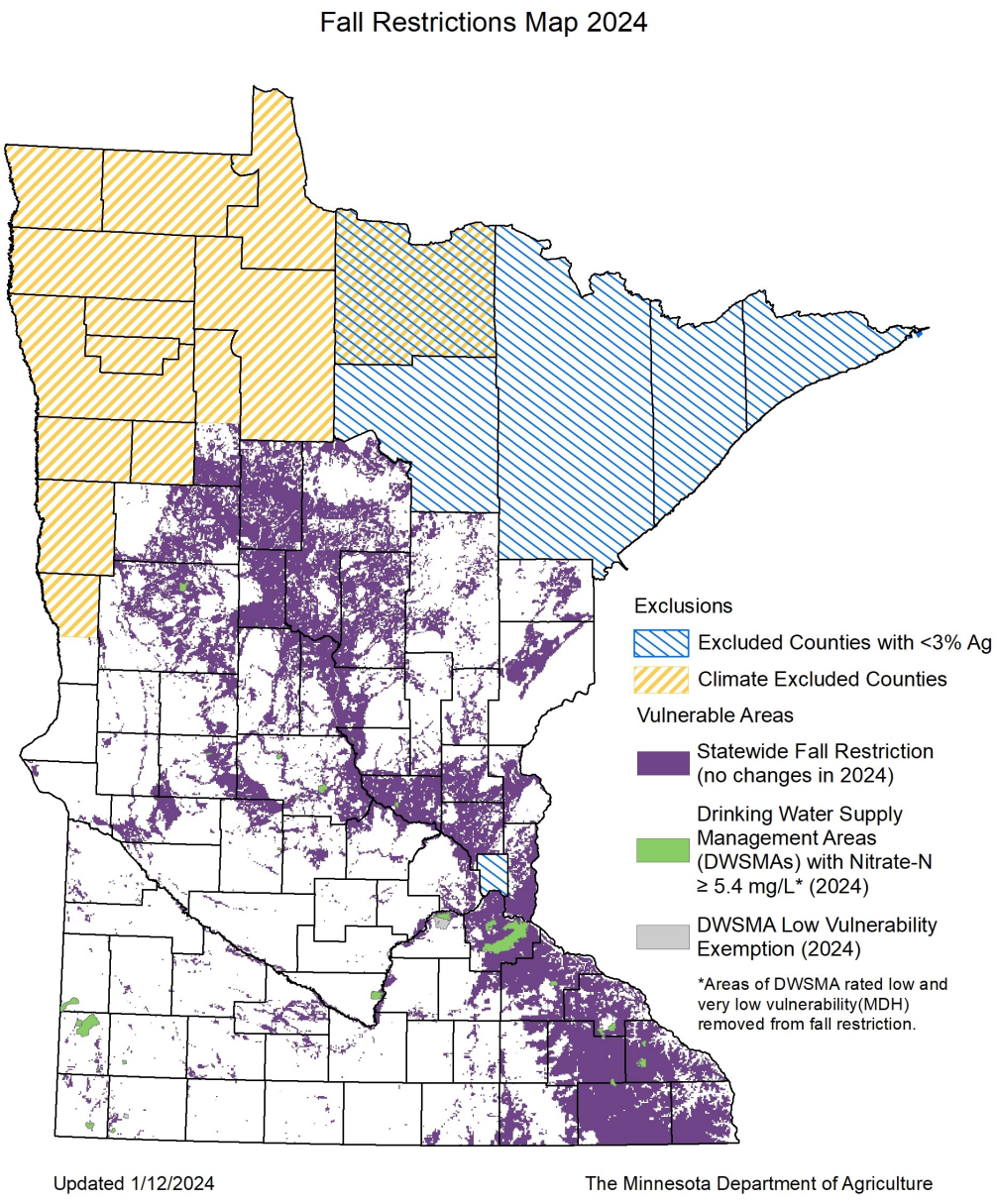


Figure 12. Fall nitrogen application restrictions (purple colouring) in Minnesota. Source: MN Dept. of Ag.

Are there short-term incentives for ag retailers to engage in conservation sales? Truthfully, not really. Heartland's conservation team is financially solvent only because of the projects and partnerships that we have built with partners who are willing to compensate us for the time we spend selling conservation. This model is not particularly lucrative, but it does allow us to engage in a space where previously we had no foothold. Although I argue that the conservation community must find a way to make CFPs financially lucrative in the short term for farmers to adopt them, for the ag retail community I can only plead the case for the long-term benefits of creating a conservation program. Ultimately, we must stay relevant as an industry. If conservation practices eventually become the norm, which given our likelihood of degrading our soils further, is on the horizon, then we must understand how these practices work. We must be able to help a farmer who is using them, otherwise we cease to be useful as a business partner [113]. Based on this premise of why we need to get engaged in conservation work, the first thing an ag retailer should do is to calculate how to work conservation into their business plan. I highly recommend reading "Ag Retail in Transition," an on-going study by Purdue University's Center for Food and Agricultural Business [113]. They do not come to any definitive conclusions in this paper, but they explore questions and themes related to an ag retailer's role in "selling conservation." Heartland's Conservation Department navigated these issues as we developed our business plan and here are some of the conclusions we have reached:

- We do not run a charity and there is nothing wrong with that. A business is only successful if it is sustainable so you must build a conservation program that earns income.
- Be honest and transparent about the CFPs you can and cannot support.
- Work with your location(s) to understand what CFPs will work well with the machinery, staff, and operations you already have at hand.
- Work with your conservation-minded farmers to understand how CFPs can be used in production agriculture.
    - What do they need that you cannot do for them right now?
    - Where do they need more support?
- Find trusted ancillary partners in the conservation space who have a need that you know you can support and ask for the financial bottom line that will support building a business model.
- Treat conservation sales like regular sales. Find a product or program that will sell, set sales goals, and support those goals like you would any other new product push.
- No matter what, support needs to come from the top!
    - You cannot just "start a conservation team" or higher a conservation agronomist and expect them to be successful.
    - You need support at all levels including your board, your CEO, your leadership team, your operations team, and your sales agronomists.
    - This support is easier to receive when your board, your leadership team, and your CEO are all invested in the success of the conservation team.

Chapter 4.3: We need research that explores how CFP adoption decisions change depending on landowner status.

Recent research literature has highlighted a need for exploring farmland tenancy issues in depth. From my perspective, research on this topic does not capture the complexity of the relationship between CFP adoption and whether the farmer is the landowner or the tenant [75] [74]. My

favourite quote from a meta-analysis about CFP adoption in the Midwest was, “All of the studies we reviewed made the normative assumption that adoption of conservation practices was a good thing for a farmer to do. Future research should query this assumption more directly. [75]” I could not agree more!

The following are questions that I think should be explored in academic research:

- How do CFP adoption decisions differ for a farmer when they do not own the land?
- Do farmers use different (or any) CFPs on acres they do not own?
- What are the reasons for using or not using CFPs on rented acres?
    - Would financial support or assistance from a landowner change this?
    - Would access to a long-term lease change this?
- How do landlords react when farmers ask them if they can adopt CFPs and/or when the tenant asks the landlord to share in the expense?
- How are short-term financials affected when a tenant farmer adopts a CFP, both with and without financial support from the landowner?

Chapter 4.4: We need tenant and landowner specific cost share programming with realistic payment rates.

From what I saw while traveling, where conservation cost share was accessible and competitively paid, higher rates of non-lucrative CFPs followed. And where there was little to no yield or management incentive to adopt the practice and little to no cost share support, CFPs fell to the wayside. If you are someone who has direct impact on cost share programming, consider creating separate programs that are aligned with the practices and needs of tenants or landowners. The majority of Iowa’s farmland is tenanted [76] [22] and this dynamic is only going to increase in the future: “By 2022, 88% of leased farmland was under a cash rent arrangement. The rise in cash rent arrangements is accompanied by a drop in owner-operated land and leasing via crop share. Regions with better soil quality tend to have higher occurrences of cash rent arrangements, which also is associated with the rising share of land owned by landowners who do not live in Iowa. [22]” Farm operations across Iowa and the nation are getting bigger and more farms are frequently managed by tenants instead of owners [93]. These people have the least incentive for adopting CFPs because their margin is already razor thin due to costs associated with renting. Many cost share programs are out of touch with this reality and are geared towards the landowner rather than the tenant. We should create programs that are unique to both those demographics.

For landowners or owner-operators, I would suggest aggressively incentivizing permanent or perennial CFPs (like buffer strips, filter strips, grassed waterways) which have far greater impact at reducing erosion and providing habitat but for which tenants have little say on adoption. Furthermore, I would recommend incentivizing both the initial installation and maintenance of those practices for several years, and at a rate that offsets the cost of installation and average rent so that the landowners are not incentivized to continue renting those acres instead. Consider creating “easy button” programs that take the mental labour out of the equation for these landowners [76], such as modifying the “batch & build” program for practices like grassed waterways or filter strips [110]. For farmland tenants, consider incentivizing in-field, temporary CFPs (like CCs or NT) regardless of the acres they farm [92]. Let the program follow the tenant, not the acre, in case a tenant loses access to a farm and needs to rent another property. Consider increasing payment rates to one that is competitive with actual costs associated with the practice as well as estimated profit losses due to yield hits. In

other words, consider payment rates that are competitive in the short term [74] [119]. Also, consider programs that are multi-year (like a multi-year lease) and consider greater flexibility, like allowing for alternating no-till beans but vertical-till corn. Finally, consider eliminating acreage caps [74]. As I described earlier, if the goal is to achieve widespread adoption, the middle adopters (larger-scale tenant farmers) need to be attracted to these types of programs. As they stand now, many are simply not worth the expense or trouble to someone who is trying to make margin on a large business where every decision needs to pay for itself.

Chapter 4.5: Modify tax code to incentivize landowner CFP adoption and a new land value index that incorporates soil health.

Another suggestion is to modify our current tax code to more appropriately reward the landowners who are sharing in the costs of CFP adoption on their farmland. There is a relationship between soil erosion and farmland values and, on average, CFPs such as NT are associated with increased land values in the Midwest [92]. Given that land value is often determined by predicted future income, there is certainly long-term incentive here for landowners to want CFPs on their land, but I think we need to create tax incentives to support this in the short-term to align with the long-term incentives for landowners (just like what I'm suggesting that we do for tenants) [92]. Policy makers should also consider modifying our tax code to support landowners who enter long-term leases and/or share in the expense of adopting CFPs through deductions or some other incentivized tax structure [76] [22]. There are no clear incentive pathways through our land tax code the way there are incentivized pathways for CFP adoption now baked into things like crop insurance. It makes sense to create this opportunity for landowners.

Related to incentivizing landowners to adopt CFPs through preferential tax code, I think we should consider creating or selecting an existing soil health score card that could be used by tenants and landlords for incentivized tax deductions. Right now, the only real land value indicator that we know of (universally) is the Corn Suitability Rating index [120], which is effectively built on factors that indicate the suitability of the soil to produce a cash crop like corn. There are no other consistent criteria that renters or landowners can use (other than dollars generated by yield) to assess the value or long-term sustainability of a parcel of land [94]. I would argue that we really need a better land value indicator than CSR and I think something like soil health depreciation over time, a "soil health score card," or "soil health potential rating" ought to do the trick [76] [94] [46]! Because at the end of the day, static land value indexes do not create necessary incentives for landowners to take their soil health seriously [76].

Chapter 5: Conclusions

The objectives of this Nuffield project were to learn the following: 1) What is happening in conservation farming around the world? 2) What factors influence short-term financial impact? and 3) How can agricultural and conservation stakeholders support and increase the adoption of conservation farming practices in Iowa? These objectives were addressed in depth in Chapters 2 through 4 of this report. But if I had to summarize what I learned during this scholarship in one sentence, it is the following: To achieve widespread adoption of one or more CFPs, we don't just need to make those CFPs economically break-even for the farmer or landowner, we need to make them economically preferable to the alternative, which is immediate short-term profit. If the CFP itself generates better short-term profit for farmers (owners or tenants), then the result will most likely be widespread adoption. But if the CFP has negligible impact on short-term profit and may even reduce that figure for a short amount of time, then the uncertain potential future profitability is not enough of a draw to entice a broad majority of farmers to adopt that practice. If we want to see widespread adoption of CFPs in Iowa, we need the middle adopters, the average tenant farmers, to be on board. But it seems that middle adopters are more comfortable sticking with the status quo than taking a hit to their profits on a CFP that is, at best, a gamble for them in the long-term. In other words, for many middle adopter farmers, a bird in the hand is worth two in the bush. There are many options available to us to change this dynamic but if we want to preserve the voluntary model that we are currently working with, we need to prioritize making CFPs profitable for tenant farmers in the short term so that we can have long-term farmland sustainability.

Recommendations

- Public and non-profit agencies should work with an agricultural retailer to build conservation programming.
- Agricultural retailers need to engage in conservation work.
- Academic researchers should explore how CFP adoption decisions change depending on landowner status.
- Public agencies should consider separate tenant- and landowner-specific cost share programming with realistic payment rates.
- Policy makers should consider modifying tax code to incentivize landowner CFP adoption and a new land value index that incorporates soil health.

References

[1] D. Schwieder, "History of Iowa," 2015. [Online]. Available: https://publications.iowa.gov/135/1/history/7-1.html.

[2] A. E. Becker, R. A. Anderson and A. C. Blair, "Eastern Iowa Farmers' Attitudes Towards the Incorporation of Prairie Strips in Agricultural Fields and Economic Incentives," *RURALS: Review of Undergraduate Research in Agricultural and Life Sciences,* vol. 12, no. 1, pp. 1-17, 2019.

[3] C. C. Sheaffer and K. M. Moncada, Introduction to Agronomy: Food, Crops, and Environment, Boston: Cengage Learning, 2012.

[4] G. Thessen, C. Adamson and B. Parks, "2020 Iowa Agricultural Statistics," NASS Upper Midwest Regional Office, Des Moines, 2020.

[5] U. NASS, "2017 Census of Agriculture," USDA NASS, 2017.

[6] B. Dougherty, "Regenerative Agricutlure: The Path to Healing Agroecosystems and Feeding the World in the 21st Century," Nuffield International, Moama, 2018.

[7] R. H. Caffey, P. Coreil and D. Demcheck, "Mississippi River Water Quality: Implications for Coastal Restoration," 2002.

[8] T. J. Rundhaug, G. R. Geimer, C. W. Drake, A. A. Amado, A. Bradley, C. F. Wolter and L. J. Weber, "Agricultural conservatoin practices in Iowa watersheds: comparing actual implementation with practice potential," *Environmental Monitoring and Assessment,* vol. 190, pp. 1-17, 2018.

[9] ISU, "The Iowa Nutrient Reduction Strategy," 14 February 2024. [Online]. Available: https://nrstracking.cals.iastate.edu/iowa-nutrient-reduction-strategy.

[10] INRS, "Iowa Nutrient Reduction Strategy," 2013.

[11] U. NRCS, "Conservation Choices: Your guide to 32 Conservation and Environmental Farming Practices," United States Department of Agriculture, 2020.

[12] Z. Bader, *Longtime water quality expert shares proof of Iowa's progress,* 2022.

[13] Iowa State University, "Tracking the Iowa Nutrient Reduction Strategy: Interactive Data Dashboards," 2024. [Online]. Available: https://nrstracking.cals.iastate.edu/tracking-iowa-nutrient-reduction-strategy. [Accessed 18 February 2024].

[14] G. Gerlock, "What does Iowa water quality look like after 10 years with the Nutrient Reduction Strategy?," *Iowa Public Radio,* 18 October 2023.

[15] B. J. Miller, "Ripple Effects: Have 10 years of efforts made a difference in Iowa's water quality?," *The Gazette,* 30 December 2023.

[16] A. Kassam, T. Friedrich, R. Derpsch and J. Kienzle, "Overview of the Worldwide Spread of Conservation Agriculture," *Field Actions Science Reports,* vol. 8, 26 September 2015.

[17] A. Kassam, T. Friedrich and R. Derpsch, "Global Spread of Conservation Agriculture," *International Journal of Environmental Studies,* vol. 76, no. 1, pp. 29-51, 2019.

[18] J. H. Tsatsaros, J. E. Brodie, I. C. Bohnet and P. Valentine, "Water Quality Degradation of Coastal Waterways in the Wet Tropics, Australia," *Water, Air, & Soil Pollution,* vol. 224, p. 1443, 2013.

[19] P. R. Stork and D. J. Lyons, "Phosphorus loss and speciation in overland flow from a plantation horticulture catchment and in an adjoining waterway in coastal Queensland, Australia," *Soil Research,* vol. 50, pp. 515-525, 2012.

[20] R. Fox, T. Fisher, A. Gustafson, E. Koontz, M. Lepori-Bui, K. Kvalnes, D. Bunnell-Young, J. Gardner, J. Lewis, J. Winsten, K. Fisher and K. Silaphone, "An evaluation of the Chesapeake Bay management strategy to improve water quality in small agricultural watersheds," *Journal of Environmental Management,* vol. 299, no. 113478, 2021.

[21] A. Plastina and W. Sawadgo, "Cover Crops and No-till in the I-States: Non-Permanence and Carbon Markets," *Agricultural Policy Review,* 2021.

[22] J. Tong and W. Zhang, "Iowa Farmland Ownership and Tenure Survey 1982 - 2022: A Forty-Year Perspective," CARD Iowa State University, Ames, 2023.

[23] Iowa Nutrient Research & Education Council (INREC), "Iowa NREC," 2022. [Online]. Available: https://www.iowanrec.org/programs-resources. [Accessed 18 February 2024].

[24] NRCS, USDA, "Impacts of Conservation Adoption on Cultivated Acres of Cropland in the Chesapeake Bay Region, 2003-06 to 2011," NRCS, 2013.

[25] P. de Freitas and J. Landers, "The transformation of agriculture in Brazil through development and adoption of Zero Tillage Conservation Agriculture," *International Soil and Water Conservation Research,* vol. 2, no. 1, pp. 35-46, 2014.

[26] L. P. Gianessi, "Importance of Herbicides for No-Till Agriculture in South America," November 2014. [Online]. Available: https://croplife.org/case-study/importance-of-herbicides-for-no-till-agriculture-in-south-america/. [Accessed 25 February 2024].

[27] I. Mello and B. van Raij, "No-Till for Sustainable Agriculture in Brazil," *Proceedings of World Association of Soil and Water Conservation ,* vol. P1, pp. 49-57, 2006.

[28] D. Lobb, S. Li, B. McConkey and T. Martin, "Soil Erosion Risk Indicator," Government of Canada, 2023. [Online]. Available: https://agriculture.canada.ca/en/environment/resource-management/indicators/soil-erosion-risk-indicator. [Accessed 25 February 2024].

[29] N. Badreldin and D. Lobb, "The Costs of Soil Erosion to Crop Production in Canada between 1971 and 2015," *Sustainability,* vol. 15, no. 5, p. 4489, 2023.

[30] L. Awada, C. Nagy and P. P, "Contribution of land use practices to GHGs in the Canadian Prairies crop sector," *PLoS ONE,* vol. 16, no. 12, p. e0260946, 2021.

[31] R. S. Llewellyn, F. H. D'Emden and G. Kuehne, "Extensive use of no-tillage in grain growing regions of Australia," *Field Crops Research,* vol. 132, pp. 204-212, 2012.

[32] R. Llewellyn and J. Ouzman, "Conservation agriculture in Australia: 30 years on," in *Australian Agriculture in 2020*, Wagga Wagga, Agronomy Australia and Charles Sturt University, 2020, pp. 21-33.

[33] Australian Bureau of Statistics, "Land Management and Farming in Australia," Australian Bureau of Statistics, 26 June 2018. [Online]. Available: https://www.abs.gov.au/statistics/industry/agriculture/land-management-and-farming-australia/2016-17. [Accessed 25 February 2024].

[34] B. Bellotti and J. Rochecouste, "The development of Conservatoin Agriculture in Australia - Farmers as innovators," *International Soil and Water Conservation Research,* vol. 2, no. 1, pp. 21-34, 2014.

[35] C. Malins, "Multiple and cover cropping in Brazil," Ceruology, January 2022. [Online]. Available: https://theicct.org/wp-content/uploads/2022/01/cover-cropping-biofuel-brazil-jan22.pdf. [Accessed 25 February 2024].

[36] D. Quinn, "Grow corn successfully after cereal rye," *Farm Progress,* 1 February 2023.

[37] M. Duffy, "Value of Soil Erosion to the Land Owner," ISU Ag Decison Maker, Ames, 2012.

[38] E. A. Thaler, J. S. Kwang, B. J. Quirk, C. L. Quarrier and I. J. Larsen, "Rates of Historical Anthropogenic Soil Erosion in the MIdwestern United States," *Earth's Future,* vol. 10, no. 3, pp. 1-16, March 2022.

[39] E. A. Thaler, I. J. Larsen and Q. Yu, "The extent of soil loss across the US Corn Belt," *Proceedings of the National Academy of Sciences,* vol. 118, no. 8, pp. 1-8, December 2020.

[40] J. Veenstra, "Is soil really eroding at tolerable rates?," in *Fifty years of agricultural soil change in Iowa*, Ames, Iowa State University, 2010, pp. 36-42.

[41] Iowa Department of Natural Resources, "ADBNet," 2022. [Online]. Available: https://programs.iowadnr.gov/adbnet/. [Accessed 14 February 2024].

[42] Iowa Environmental Council, "Beach Monitoring: Safe to Swim?," 2024. [Online]. Available: https://www.iaenvironment.org/our-work/clean-water-and-land-stewardship/swimming-advisories. [Accessed 14 February 2024].

[43] C. Johnson, "Dredging kept the Mississippi River open this year but creates its own problems," *Minnesota Star Tribune,* 13 December 2023.

[44] L. Stringer, "Global land and soil degradation: challenges to soil," in *1st Global Soil Week: Soils for Life*, Berlin, 2012.

[45] M. Sartori, G. Philippidis, E. Ferrari, P. Borrelli, E. Lugato, L. Montanarella and P. Panagos, "A linkage between the biophysical and the economic: Assessing the global market impacts of soil erosion," *Land Use Policy,* vol. 86, pp. 299-312, 2019.

[46] B. Turner, J. Fuhrer, M. Wuellner, H. Menendez, B. Dunn and R. Gates, "Scientific case studies in land-use driven soil erosion in the central United States: Why soil potential and risk concepts should be included in the principles of soil health," *International Soil and Water Conservation Research,* vol. 6, no. 1, pp. 63-78, 2018.

[47] S. Morgan, K. Fuglie and J. Jelliffe, "World Agricultural Output Growth Continues to Slow, Reaching Lowest Rate in Six Decades," Amber Waves, 5 December 2022. [Online]. Available:

https://www.ers.usda.gov/amber-waves/2022/december/world-agricultural-output-growth-continues-to-slow-reaching-lowest-rate-in-six-decades/. [Accessed 20 March 2024].

[48] P. Borrelli, D. Robinson, P. Panagos, E. Lugato, J. Yang, C. Alewell, D. Wuepper, L. Montanarella and C. Ballabio, "Land use and climate change impacts on global soil erosion by water (2015-2070)," *Proceeedings of the National Academy of Sciences,* vol. 117, no. 36, pp. 21994-22001, 2020.

[49] G. Lense, L. Lammle, J. Ayer, G. Lama, F. Rubira and R. Mincato, "Modeling of Soil Loss by Water Erosion and Its Impacts on the Cantareira System, Brazil," *Water,* vol. 15, p. 1490, 2023.

[50] W. Alves, A. M. W. Martins, É. C. R. Possa and D. de Moura, "USLE modelling of soil loss in a Brazilian cerrado catchment," *Remote Sensing Applications: Society and Environment,* vol. 27, p. 100788, 2022.

[51] G. Lense, T. Parreiras, V. Spalevic, J. Avanzi and R. Mincato, "Soil Losses in the State of Rondonia, Brazil," *Ciencia Rural,* vol. 51, 2021.

[52] M. Bezerra, M. Baker, M. Palmer and S. Filoso, "Gully formation in headwater catchments under sugarcane agriculture in Brazil," *Journal of Environmental Management,* vol. 270, p. 110271, 2020.

[53] J. Polidoro, L. de Freitas, L. Hernani, L. Anjos, R. Rodrigues, F. Cesário, A. Andrade and J. Ribeiro, "The impact of plans, policies, practices, and technologies based on the principles of conservation agriculture in the control of soil erosion in Brazil," *Authorea,* 2020.

[54] G. Medeiros, A. Giarolla, G. Sampaio and M. Marinho, "Estimates of Annual Soil Loss Rates in the State of Sao Paulo, Brazil," *Revista Brasileira de Ciencia do Solo,* vol. 40, 2016.

[55] L. Awada, C. Lindwall and B. Sonntag, "The development and adoption of conservation tillage systems on the Canadian Prairies," *International Soil and Water Conservation Research,* vol. 2, no. 1, pp. 47-65, 2014.

[56] S. Li, J. Elliott, K. Tiessen, J. Yarotski, D. Lobb and D. Flaten, "The Effects of Multiple Beneficial Management Practices on Hydrology and Nutrient Losses in a Small Watershed in the Canadian Prairies," *Journal of Environmental Quality,* vol. 40, no. 5, pp. 1627-1642, 2011.

[57] H. Teng, R. Rossel, Z. Shi, T. Behrens, A. Chappell and E. Bui, "Assimilating satellite imagery and visible-near infrared spectroscopy to model and map soil loss by water erosion in Australia," *Environmental Modelling and Software,* vol. 77, pp. 156-167, 2016.

[58] F. Kroon, P. Thorburn, Schaffelke and S. Whitten, "Towards protecting the Great Barrier Reef from land-based pollution," *Global Change Biology,* vol. 22, no. 6, pp. 1985-2002, 2016.

[59] R. Felver, "Chesapeake Bay Program," 20 July 2018. [Online]. Available: https://www.chesapeakebay.net/news/blog/chesapeake-bay-program-sets-new-targets-for-nutrient-reductions. [Accessed 2 March 2024].

[60] K. Blankenship, "Chesapeake Bay cleanup faces difficult trade-offs with agriculture," *Bay Journal,* 1 May 2023.

[61] Chesapeake Bay Program, "2025 Watershed Implementation Plans (WIPs)," Chesapeake Progress, [Online]. Available: https://www.chesapeakeprogress.com/clean-water/watershed-implementation-plans. [Accessed 2 March 2024].

[62] G. Noe, M. Cashman, K. Skalak, A. Gellis, K. Hopkins, D. Moyer, J. Webber, A. Benthem, K. Maloney, J. Brakebill, A. Sekellick, M. Langland, Q. Zhang, G. Shenk, J. Keisman and C. Hupp, "Sediment dynamics and implications for management: State of the science from long-term research in the Chesapeake Bay watershed, USA," *Wiley Interdisciplinary Reviews: Water,* vol. 7, no. 4, p. e1454, 2020.

[63] Farm Service Agency, "Conservation Reserve Program Monthly Summary - December 2023," United States Department of Agriculture, 2023.

[64] Iowa Department of Natural Resources, "DNR News Releases," 31 July 2018. [Online]. Available: https://www.iowadnr.gov/About-DNR/DNR-News-Releases/ArticleID/1998/Initial-statewide-mapping-of-conservation-practices-now-complete. [Accessed 6 April 2024].

[65] Iowa State University Geographic Information Systems, "Iowa BMP Mapping Project," Iowa State University, [Online]. Available: https://www.gis.iastate.edu/BMPs. [Accessed 6 April 2024].

[66] D. R. Montgomery, Dirt, The Erosion of Civilizations, Berkeley: University of California Press, 2007.

[67] W. C. Lowdermilk, Conquest of the land through 7,000 years (No. 99), US Department of Agriculture, Soil Conservation Service, 1953.

[68] Resilience Rising, "The Itaipú Dam: How natural ecosystems support this modern technological wonder," Resilience Rising, September 2020. [Online]. Available: https://resiliencerisingglobal.org/the-itaipu-dam-how-natural-ecosystems-support-this-modern-technological-wonder/. [Accessed 28 February 2024].

[69] Manitoba Agriculture and Food, "Forages for Improving Saline Soils," Manitoba Agriculture and Food, [Online]. Available: https://www.gov.mb.ca/agriculture/crops/crop-management/forages/forages-for-improving-saline-soils.html. [Accessed 3 March 2024].

[70] P. Whelan, "Managing soil salinity for the long haul," *Canadian Cattlemen,* 7 May 2021.

[71] G. Merten and J. Minella, "The expansion of Brazilian agriculture: Soil erosion scenarios," *International Soil and Water Conservation Research,* vol. 1, no. 3, pp. 37-48, 2013.

[72] C. Lopes, M. Segovia and J. Chiavari, "Where does Brazil stand in the implementation of the forest code?," Climate Policy Initiative, Rio de Janeiro, 2023.

[73] A. Stewart, S. Reedyk, B. Franz, K. Fomradas, C. Hilliard and S. Hall, "A planning tool for design and location of vegetative buffers on watercourses in the Canadian prairies," *Journal of Soil and Water Conservation,* vol. 66, no. 4, pp. 97A - 103A, 2011.

[74] G. Roesch-McNally, A. Basche, J. Arbuckle, J. Tyndall, F. Miguez, T. Bowman and R. Clay, "The Trouble with cover crops: Farmers' experiences with overcoming barriers to adoption," *Renewable Agriculture and Food Systems,* vol. 33, no. 4, pp. 322-333, 2017.

[75] L. Prokopy, K. Floress, J. Arbuckle, S. Church, F. Eanes, Y. Gao, B. Gramig, P. Ranjan and A. Singh, "Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature," *Journal of Soil and Water Conservation,* vol. 74, no. 5, pp. 520-534, 2019.

[76] R. Dell, "Non-operating landowners and conservation on rented farmland," The Nature Conservancy, 2019.

[77] L. Asprooth, M. Norton and R. Galt, "The adoption of conservation practices in the Corn Belt; The role of one formal farmer network, Practical Farmers of Iowa," *Agriculture and Human Values,* vol. 40, pp. 1559-1580, 2023.

[78] A. Kassam, T. Friedrich and R. Derpsch, "Successful Experiences and Lessons from Conservation Agriculture Worldwide," *Agronomy,* vol. 12, no. 4, p. 769, 2022.

[79] Y. Che, R. Rejesus, M. Cavigelli, K. White, S. Aglasan, L. Knight, C. Dell, D. Hollinger and E. Lane, "Long-term economic impacts of no-till adoption," *Soil Security,* vol. 12, p. 100103, 2023.

[80] T. Telles, M. Guimaraes and S. Dechen, "The costs of soil erosion," *Revista Brasileira de Ciencia do solo,* vol. 35, pp. 287-298, 2011.

[81] D. Toliver, J. Larson, R. Roberts, B. English, D. Ugarte and T. West, "Effects of No-Till on Yields as Influenced by Crop and Environmental Factors," *Agronomy Journal,* vol. 104, no. 2, pp. 530-541, 2012.

[82] F. D'Emden, R. Llewellyn and M. Burton, "Factors influencing adoption of conservation tillages in Australian cropping regions," *The Australian Journal of Agricultural and Resource Economics,* vol. 52, no. 2, pp. 169-182, 2008.

[83] D. Pannell, R. Llewellyn and M. Corbeels, "The farm-level economics of conservation agriculture for resource-poor farmers," *Agriculture, ecosystems and environment,* vol. 187, pp. 52-64, 2014.

[84] B. DeVore, Wildly Successful Farming: Sustainability and the New Agricultural Land Ethic, Madison: The University of Wisconsin Press, 2018.

[85] J. Deines, K. Guan, B. Lopez, Q. Zhou, C. White, S. Wang and D. Lobell, "Recent cover crop adoption is associated with small maize and soybean yield losses in the United States," *Global Change Biology,* vol. 29, no. 3, pp. 794-807, 2022.

[86] H. Blanco, "Economics of Cover Crops," *Crops & Soils Magazine,* pp. 4-12, September 2023.

[87] R. Myres, A. Weber and S. Tellatin, "Cover Crop Economics: When Cover Crops are Grazed," USDA SARE, 2019.

[88] W. Sawadgo and A. Plastina, "Cover crop cost-share programs in Iowa: do they work?," Center for Agricultural and Rural Development (CARD), Iowa State University, 2021.

[89] W. Lindwall and B. Sonntag, Landscapes Transformed: The History of Conservation Tillage and Direct Seeding, Saskatoon: Knowledge Impact in Society, 2010.

[90] T. Wade, R. Claassen and S. Wallander, "Conservation-Practice Adoption Rates Vary Widely by Crop and Region," *Economic Information Bulletin,* vol. 147, no. EIB-147, pp. 1-34, 2015.

[91] D. Petry, S. Avanzini, A. Vidal, F. Bellino, J. Bugas, H. Conant, S. Hoo, S. Unnikrishnan and M. Westerlund, "Cultivating farmer prosperity: Investing in Regenerative Agriculture," Boston Consulting Group, Geneva, 2023.

[92] L. Chen, R. Rejesus, S. Aglasan, S. Hagen and W. Salas, "The impact of no-till on agricultural land values in the United States Midwest," *American Journal of Agricultural Economics,* vol. 105, no. 3, pp. 760-783, 2023.

[93] S. Varble, S. Secchi and C. Gottschalk Druschke, "An Examination of Growing Trends in Land Tenure and Conservation Practice Adoption: Results from a Farmer Survey in Iowa," *Environmental Management,* vol. 57, pp. 318-330, 2016.

[94] S. Kish, "Implementing Regenerative Practices on the Farm: It's Complicated for Renters," *Crops & Soils,* pp. 6-11, March 2023.

[95] P. Sklenicka, K. Molnarova, M. Salek, P. Simova, J. Vlasak, P. Sekac and V. Janovska, "Owner or tenant: Who adopts better soil conservation practices?," *Land Use Policy,* vol. 47, pp. 253-261, 2015.

[96] P. Ranjan, C. Wardropper, F. Eanes, S. Reddy and S. Harden, "Understanding Barriers and Opportunities for Adoption of Conservation Practices on Rented Farmland in the US," *Land Use Policy,* vol. 80, pp. 214-223, 2019.

[97] D. Werner, "Agricultural Conservation Practice Adoption Across Midwest Counties: A Review and Analysis of Determinants," *The Park Place Economist,* vol. 28, no. 1, 2021.

[98] M. Barnett, K. Spangler, P. Petrzelka and J. Filipiak, "Power dynamics of the non-operating landowner-renter relationship and conservation decision-making in the MIdwestern United States," *Journal of Rural Studies,* vol. 78, pp. 107-114, 2020.

[99] USDA NRCS, "Natural Resources Conservation Service," USDA, 17 March 2024. [Online]. Available: https://www.nrcs.usda.gov/about.

[100] E. Friedrich, "An Exploratory Guide to the Work, Efficacy & Potential of the USDA-Natural Resources Conservation Service in Vermont through the Perspectives of NRCS Staff.," *Food Systems Master's Project Reports,* vol. 27, 2022.

[101] Q. Zhou, K. Guan, S. Wang, C. Jiang, Y. Huang, B. Peng, Z. Chen, S. Wang, J. Hipple, D. Schaefer, Z. Qin, S. Stroebel, J. Coppess, M. Khanna and Y. Cai, "Recent Rapid Increase of Cover Crop Adoption Across the U.S. Midwest Detected by Fusing Multi-Source Satellite Data," *Geophysical Research Letters,* vol. 49, 2022.

[102] M. Mezzatesta, D. Newburn and R. Woodward, "Additionality and the Adoption of Farm Conservation Practices," *Land Economics,* vol. 89, no. 4, pp. 722-742, 2013.

[103] N. Adusumilli, R. Dikitanan and H. Wang, "Effect of cost-sharing federal programs on adoption of water conservation practices: results from propensity score matching approach," *Water Economics and Policy,* vol. 6, no. 1, 2020.

[104] M. Happ, "Still Closed Out: More Progress Needed to Connect Farmers with Federal Conservation Programs," Institute for Agriculture & Trade Policy, 2023.

[105] E. Broussard, S. Lemon, K. McClelland, K. Moore and K. Yetman, "NRCS in Arizona: A Brief Assessment of Access to NRCS Programs Among Ranchers in Arizona," Swette Center for Sustainable Food Systems, Arizona State University, 2020.

[106] D. Stroman and U. Kreuter, "Landowner Satisfaction with the Wetland Reserve Program in Texas: A Mixed Methods Analysis," *Environmental Management,* vol. 57, pp. 97-108, 2016.

[107] K. Karnuta, "Too Much Bureaucracy, Too Little Time: A Case Study in Using the Agent Based Approach to Analyze the Efficacy of the Environmental Quality Incentive Program," *Journal of Systems Thinking Preprints,* 2022.

[108] A. Reimer, B. Gramig and L. Prokopy, "Farmers and conservation programs: Explaining differences in Environmental Quality Incentives Program applications between states," *Journal of Soil and Water Conservation,* vol. 68, no. 2, pp. 110-119, 2013.

[109] B. Miller, "USDA programs support conservation in Iowa. They may be underfunded.," *The Gazette,* 30 March 2023.

[110] B. Bjoin, "Batch and build generating enthusiasm," Iowa Farm Bureau, 3 April 2023. [Online]. Available: https://www.iowafarmbureau.com/Article/Batch-and-build-generating-enthusiasm. [Accessed 19 March 2024].

[111] D. McDowell, "IDALS Announces Partnership to Expand Conservation Agronomist Network," Iowa Department of Agriculture and Land Stewardship, 8 March 2023. [Online]. Available: https://iowaagriculture.gov/news/department-announces-partnership-expand-conservation. [Accessed 19 March 2024].

[112] R. Spomer and R. Piest, "Soil Productivity and Erosion of Iowa Loess Soils," *Transactions of the ASAE,* vol. 25, no. 5, pp. 1295-1299, 1982.

[113] L. Neto, B. Brewer, A. Gray and L. Castro, "Ag Retail in Transition: Evaluating a Fee-based Sustainability Service Model," Purdue University Center for Food and Agricultural Business, West Lafayette, 2021.

[114] Minnesota Department of Agriculture, "Know where and when to apply fall nitrogen fertilizer," Minnesota Department of Agriculture, 11 September 2023. [Online]. Available: https://www.mda.state.mn.us/know-where-when-apply-fall-nitrogen-fertilizer. [Accessed 19 March 2024].

[115] G. Gerlock, "What does Iowa water quality look like after 10 years with the Nutrient Reduction Strategy?," Iowa Public Radio, 18 October 2023. [Online]. Available: https://www.iowapublicradio.org/ipr-news/2023-10-18/iowa-water-quality-10-years-nutrient-reduction-strategy. [Accessed 19 March 2024].

[116] D. Eller, "Environmental groups petition EPA to force Iowa to tackle livestock water pollution," Des Moines Register, 17 April 2024. [Online]. Available: https://www.desmoinesregister.com/story/money/agriculture/2024/04/17/groups-petition-epa-to-take-emergency-action-on-iowa-cafo-water-quality/73328893007/. [Accessed 4 May 2024].

[117] D. Shore, "Environmental Protection Agency," 3 November 2023. [Online]. Available: https://www.epa.gov/system/files/documents/2023-11/ao-rmod-reponse-letter_20230510-508.pdf. [Accessed 4 May 2024].

[118] Iowa Environmental Council, "IEC and 12 environmental gropus petition EPA to protect drinking water for Iowans," Iowa Environmental Council, 16th April 2024. [Online]. Available: https://www.iaenvironment.org/newsroom/water-and-land-news/iec-and-12-other-organizations-petition-the-epa-for-emergency-action-pursuant-to-the-safe-drinking-water-act. [Accessed 4 May 2024].

[119] K. Nadella, "An Examination of the Adoption of Conservation Practices on Owned and Rented Farmland in Ontario and Manitoba," The University of Guelph, Guelph, 2013.

[120] A. Plastina, A. Johanns, A. Gleisner, J. Severn, S. Wuebker, R. Ramos, K. Bhandari and M. Dhimal, "Cash Rental Rates for Iowa - 2023 Survey," Iowa State University Ag Decision Maker, Ames, 2023.

Appendix 1: Travel locations and interviewees

Country / Region Visited	Month & Year of Visit	Duration of Visit	Reason for Visit	Interviews
Cheasapeake Bay	Jun 2022	1 Week	The Cheasapeake Bay is often referred to as "ground zero" for regulation on non-point source pollution. With a well known natural resource water feature that is directly impacted by the agricultural activites around it, the Chesapeake was an ideal first region to visit in an effort to understand the attitudes of farmers who are held to regulatory compliance standards for nutrient use and application.	Farmer: 8 Ag Retailer: 5 Public Agency: 5 Other:
Western Canada	Jun 2022 - Jul 2022	3 Weeks	Western Canada is well known for their almost universal adoption of zero till practices and diverse grain and pulse cropping systems. Known as the Prairie Provinces, Manitoba, Saskatchewan, and Alberta are the primary agricultural powerhouses in Canada and have similar farming systems to the Midwest and Western United States.	Farmer: 12 Ag Retailer: 10 Public Agency: 9 Other: 0
Midwestern and Southern Brazil	Feb 2023 - Mar 2023; June 2023	4 Weeks	Brazil is the United States' largest commodity grain producing neighbor and is well known for their adoption of both zero till as well as cover cropping practices. In only a few decades, Brazil went from being a net food importer to a net food exporter and is now a top producer in the world for several commodity crops including soybeans, corn, beef, sugar, coffee, and oranges.	Farmer: 12 Ag Retailer: 1 Public Agency: 14 Other: 1
Southeast Asia (GFP)	May 2023	1 Week	Nuffield Scholars travel as a group on a four to six-week trip through several countries where they meet with leaders in agriculture to learn about the agronomic industries in those countries. My GFP traveled to Singapore, Borneo, Denmark, Brazil, and Australia. While on the GFP, I interviewed a few people for my Nuffield project in each country.	Farmer: 1 Ag Retailer: 0 Public Agency: 2 Other: 1
Denmark (GFP)	Jun 2023	1 Week		Farmer: 5 Ag Retailer: 3 Public Agency: 3 Other: 0
Eastern Australia	Jun 2023 - Jul 2023	4 Weeks	Eastern Australia is known for their adoption of no-till and sustainable grazing systems. Northeastern Australia is also know for the Great Barrier Reef, a world-renowned heritage area that has been studied at length for the impacts that nutrient and sediment export from agricultural activites can have on marine life and coral reef environments.	Farmer: 15 Ag Retailer: 2 Public Agency: 8 Other: 0

Appendix 2: Interviewee Categories and Questions

Farmers/Ranchers:

1) What are your farm goals? What do you want to accomplish on your farm?
2) What conservation farming practices (or regenerative practices) do you use?
3) When did you start using these practices? Always? Recently?
4) Of the practices you use, pick your favourite. Why did you decide to adopt this practice?
5) What are the pros/cons of using the above practice?
6) Thinking back to your farm goals, does the above practice help you reach your goals?
7) What challenges or barriers do you still face to adopting more conservation farming practices?

Ag Retailers:

1) My understanding of your position is that you do XYZ (or) Based on your title, you must work with XYZ…is that correct?
2) What is the mission of your organization/company?
3) What are your team's goals/objectives OR what are your goals/objectives?
4) What conservation farming practices are you seeing the most adoption of?
5) Of these conservation practices, which are the easiest for you to support with your growers?
6) Which practices are more challenging to support?
7) (Can substitute 5&6) What are the pros/cons that you are hearing from your growers?
8) Long term, where do you see this movement going? Is there longevity in adopting conservation?
9) What conservation farming practices would you like to see more of?

NGO/Public Organization:

1) What is the mission of your organization?
2) I looked up your role…can you tell me more about how you support your org's mission?
3) How does your work or your org's work contribute to conservation farming adoption?
4) What regenerative practices are the most common/popular with your constituents?
5) What are the perceived benefits of those common/popular practices?
6) What are the perceived barriers to adopting OTHER conservation farming practices?
7) What practices would you like to see more of on the landscape? Where are there still environmental issues that need to be addressed?