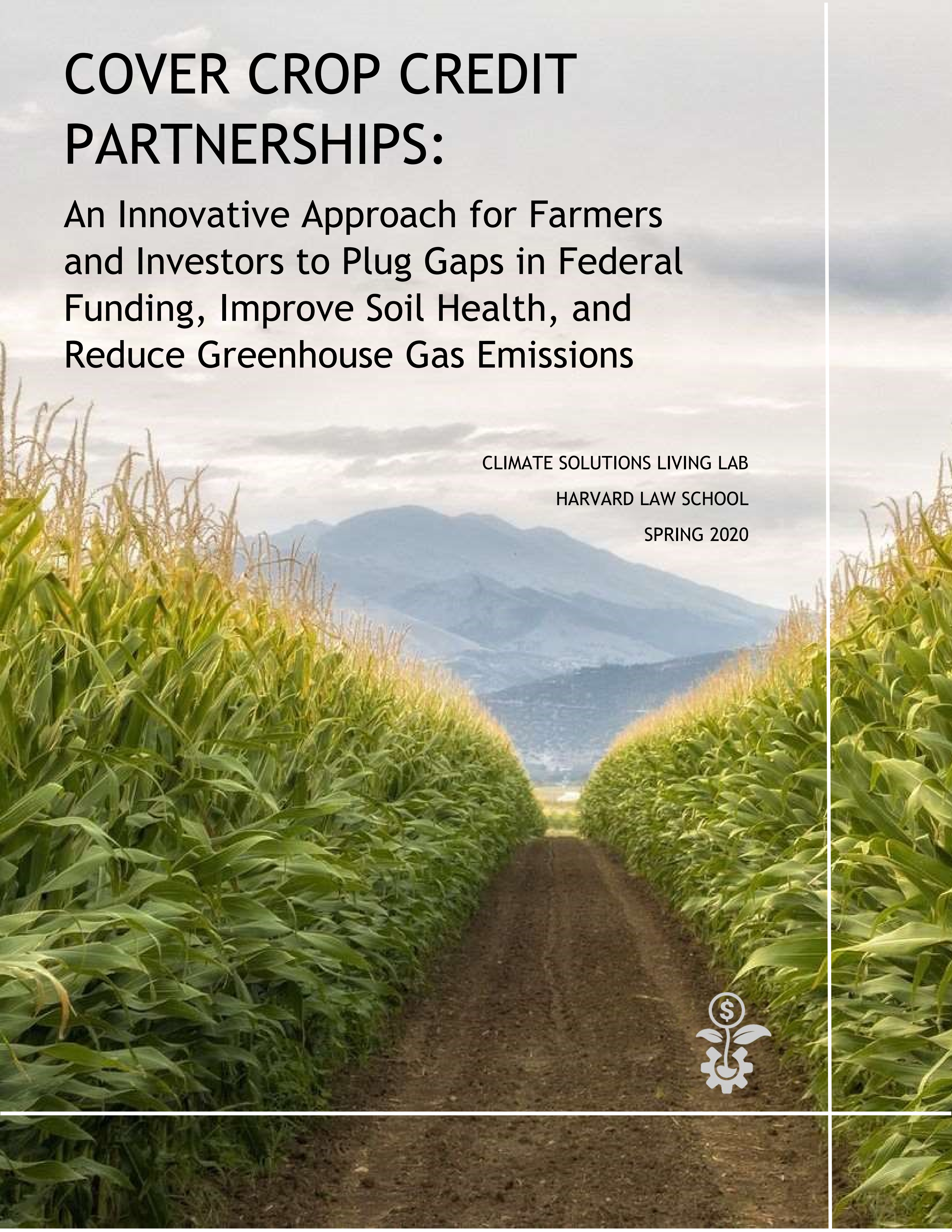
COVER CROP CREDIT PARTNERSHIPS:

An Innovative Approach for Farmers and Investors to Plug Gaps in Federal Funding, Improve Soil Health, and Reduce Greenhouse Gas Emissions



CLIMATE SOLUTIONS LIVING LAB

HARVARD LAW SCHOOL

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APPENDICES AND MODEL DOCUMENTS

ACKNOWLEDGEMENTS

This Guide is a student work product completed to fulfill the requirements of the Climate Solutions Living Lab, a 12-week course offered at Harvard Law School. The student authors created this Guide to answer specific questions posed by their course instructor. Professor Jacobs has since reviewed and edited this Guide so that it can be circulated for reference, use, and implementation.

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EXECUTIVE SUMMARY

This Guide describes a way to promote and pay for planting cover crops to improve soil health, improve crop yield, and also create legitimate, valuable greenhouse gas (GHG) emission offsets. The mechanism is a partnership between farmers and investors that we call the Cover Crop Credit Partnership. The basic idea is that an investor who wants to offset its own GHG emissions would partner with a farmer and compensate the farmer for the first three years of costs to plant cover crops. For many farmers, the cost of initiating cover cropping (which includes purchasing cover crop seed, planting, and managing the cover crops) is prohibitively high. Yet, cover crops build healthy soils, reduce erosion, protect water quality, reduce the need for synthetic fertilizer, and reduce agricultural GHG emissions. After about the first three years of cover cropping, farmers realize a profit due to increased yields and decreased costs for fertilizer, weed control, and erosion repair. Investors and farmers can both benefit from Cover Crop Credit Partnerships. Farmers who participate receive front-loaded payments to defray the initial cost of cover cropping. In the example presented here, the investor receives emissions offsets (and sustainability dividends) over five years at an average cost of $11 per ton of carbon dioxide equivalent (CO_2e).[1] This number is consistent with the pricing others have assigned to this type of offset.[2] Over these five years of cover cropping, the farmer will earn a cumulative return of about $23 per acre.

The science of cover cropping. Cover crops draw carbon dioxide down into the soil and reduce GHGs in the atmosphere. Cover crops also increase nutrient levels in the soil, allowing farmers to reduce the amount of synthetic fertilizer they apply to the soil. When less synthetic nitrogen is applied, the soil releases less nitrous oxide (N_2O), a potent GHG, into the atmosphere.[3] And, less carbon dioxide is released from the production and transportation of synthetic fertilizers.[4]

Barriers to cover cropping. Cover crops typically lose money for about the first three years. During these first three years, the farmer's costs of purchasing seed, planting, and terminating the cover crop outweigh the cost-savings from decreased fertilizer use, decreased weed control

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[1] The global warming potential of nitrous oxide and of methane, key GHGs associated with agriculture, have been converted into carbon dioxide (CO_2) equivalents. Releasing one ton of nitrous oxide into the air is equivalent to releasing about 298 tons of CO_2; releasing one ton of methane is equivalent to releasing about 25 tons of CO_2.

[2] For example, Indigo Agriculture estimates a price per credit for carbon sequestration or emissions reduction via regenerative farming practices of approximately $15 based on the 2019 payment rate. See https://www.indigoag.com/for-growers/indigo-carbon.

[3] The majority of farm-related GHG emissions are methane and nitrous oxide. The largest sources of emissions are the addition of fertilizers to soils (nitrous oxide) and enteric fermentation (methane). See Stephen Russell, WRI, "Everything You Need to Know About Agricultural Emissions," May 29, 2014, https://www.wri.org/blog/2014/05/everything-you-need-know-about-agricultural-emissions.

[4] Fertilizer manufacturing is an energy-intensive process that emits significant amounts of GHGs. *See* N. Gilbert, "One-third of our greenhouse gas emissions come from agriculture," *Nature.com News*, Oct. 31, 2012, https://www.nature.com/news/one-third-of-our-greenhouse-gas-emissions-come-from-agriculture-1.11708#:~:text=Using%20estimates%20from%202005%2C%202007,related%20anthropogenic%20greenhouse%2Dgas%20emissions.

and erosion repair, and increased revenues from better yields from the field crop that follows the cover crop. After these first three years, the financial benefits to farmers of cover cropping outweigh the costs. While farmers understand these long-term financial benefits of cover cropping, they face a strained agricultural economy, and they respond by limiting their short-term financial risk. The Federal Crop Insurance Program's rules and policies impose additional barriers to cover cropping: these rules and policies prevent farmers from insuring cover crops against loss and deny farmers the opportunity to sell their cover crops at a profit (the cover crops are required to be destroyed).[5] Federal programs that promote cover crops, such as the Environmental Quality Incentives Program,[6] are underfunded and oversubscribed. As a result, while the use of cover crops is growing in the U.S., cover crops are still planted on only a small fraction of farmlands that could benefit from them.

Cover Crop Credit Partnership's structure. The Cover Crop Credit Partnership entails a five-year partnership between farmers and investors. During the first three years, investors make guaranteed payments to the farmer to compensate for the farmer's net costs of cover cropping. In the example presented here, these payments are about $27 per acre in the first year, $14 per acre in the second, and $5 per acre in the third year. In exchange for these payments, investors receive high-quality carbon offsets with numerous co-benefits, such as improved water quality. After the first three years of cover cropping, cover crops pay for themselves through increased yields and decreased costs to farmers,[7] and the farmer no longer needs guaranteed payments from the investor. During the last two years of the partnership, the investor continues paying for monitoring of the farm's emissions and continues receiving the offsets produced, but no longer makes guaranteed payments to the farmer. If the farm's emissions decrease more than expected (based on modeling of the farm's emissions, as discussed below), the investor makes a bonus payment to the farmer and receives additional offsets.

The tables below summarize the financial aspects of the Partnership from the investor's perspective (Table ES-1) and from the farmer's perspective (Table ES-2). Section 3 contains a more in-depth financial analysis. Note that the financial summaries in this Guide are meant to be illustrative and assume a farm with a baseline fertilizer use of 195 pounds/acre.

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[5] *See* 7 U.S.C. §1508a(b) and 7 U.S.C. § 1508(a)(11).

[6] 16 U.S.C. §§ 3839aa–3839aa-9.

[7] *See* USDA, Sustainable Agriculture Research & Education (SARE), "Cover Crop Economics: Opportunities to Improve Your Bottom Line With Cover Crops," Sustainable Agriculture Research and Education Program Technical Bulletin, June 2019. https://www.sare.org/Learning-Center/Bulletins/Cover-Crop-Economics.

Table ES-1. Cover Crop Credit Partnership – Investor Perspective
Hypothetical 1000-acre corn and soybean farm

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Payments to farmer	($27,000)	($14,000)	($5,000)	$0	$0
Additional investor costs*	($4,660)	($1,660)	($1,660)	($1,660)	($1,660)
Total investor costs	($31,660)	($15,660)	($6,660)	($1,660)	($1,660)
Offsets (tons CO_2e) to Investor**	911	1,425	990	994	919
$/ton	($35)	($11)	($7)	($2)	($2)
				Investor costs over 5 years	($57,000)
				Total offsets over 5 years	*5,239*
				Average $/ton over 5 years	*($11)*

Source: Authors
* Includes $3000 start-up costs, $1500 annual administrative costs, and $0.16/acre annually to monitor.
** Offsets are a combination of N_2O emission reductions (about 19% of offsets), carbon sequestration (80%), and avoided emissions in fertilizer production (1%).
Note: All figures are rounded for simplicity. Additional bonus payments from investor to farmer are possible if on-farm emission reductions and soil sequestration are greater than the model predictions.

Table ES-2. Cover Crop Credit Partnership – Farmer Perspective
Hypothetical 1000-acre corn and soybean farm ($ per-acre)

Year	*1*	*2*	*3*	*4*	*5*
Benefits to farmer from cover cropping					
Decreased costs from reduced fertilizer use, reduced weed control, and reduced erosion repair	$13	$23	$33	$36	$38
Increased revenue from higher yields	$8	$12	$16	$20	$24
Additional costs to farmer when initiating cover cropping					
*Seeds, planting, and termination**	($51)	($50)	($49)	($48)	($47)
Farmer's net returns from cover cropping	($30)	($15)	$0	$8	$15
Introduction of Partnership					
Guaranteed payments from investor to farmer	$27	$14	$5	$0	$0
Farmer's net return, with Partnership	($3)	($2)	$5	$8	$15
Farmer's return over 5 years with Partnership, 1000 acres					*$23,000*

Source: Authors.
* Assumes 2% annual efficiency improvements.
Note: All figures are rounded for simplicity. Additional bonus payments (approx. $9/ton) from investor to farmer are possible if on-farm emission reductions and soil sequestration are greater than the DNDC model predictions.

Monitoring and measuring GHG emissions. Direct measurement of GHG emissions from agriculture is notoriously difficult and expensive. Two fields on the same farm may release different greenhouse gases, in varying quantities, at the same time. This reality makes continuous, direct measurement costly. Random sampling and periodic monitoring do not offer a solution. A collection of samples reveals very little about a large, complex farm's emissions. Rather than rely on direct measurement and sampling, our Cover Crop Credit Partnership proposes to model annual emissions using the well-established, continuously verified DeNitrification-DeComposition Model (DNDC).[8] DNDC uses farm-specific data that farmers routinely compile, including fertilizer application, tillage, crop rotation, planting, and harvest. These data would be input into the DNDC model, which combines the farm's inputs with satellite and weather data to project soil carbon and nitrogen dynamics, nutrient leaching, and GHG emissions, including carbon dioxide, nitrogen, and methane, from that particular farm. The privacy of farmers' data is protected by means of confidentiality agreements. A sample agreement is included in Appendix A.

Environmental and eco-system co-benefits. Cover crops improve human health and environmental outcomes. For instance, cover crops reduce runoff. This means that cover crops prevent nutrients like nitrogen and phosphorus from draining into ponds, lakes, and rivers where those nutrients contaminate drinking water, cause algal blooms, create dead zones, and destroy aquatic life. Cover crops also prevent nutrients from leaching into the groundwater that many communities rely on for household and agricultural use. The ecosystem services provided by cover crops have real-world economic value. A 1,000-acre farm that uses cover crops and reduces its use of synthetic fertilizer by 70 pounds per acre will save the local community between $1 million and $3 million in health-related and environmental costs over the farm's life.[9]

Contents of this Guide. This Guide contains model documents, including an agreement, DNDC sample model farm projections, and a health impact assessment to facilitate the formation of Cover Crop Credit Partnerships. In addition, below we present more detail about each of the items mentioned above.

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[8] Institute for the Study of Earth, Oceans and Space University of New Hampshire (2012), User's Guide for the DNDC Model. http://www.dndc.sr.unh.edu/model/GuideDNDC95.pdf.

[9] Sobota, D. J., Compton, J. E., Mccrackin, M. L., & Singh, S. (2015). Cost of reactive nitrogen release from human activities to the environment in the United States. *Environmental Research Letters*, *10*(2), 025006. doi: 10.1088/1748-9326/10/2/025006.

1 BARRIERS to COVER CROPPING

Despite Farmers' Increased Use of Cover Crops, Barriers Remain

Cover crops offer farmers an opportunity to build healthy soils, protect fields from erosion, and bolster their farms' yields, resilience, and long-term profitability. Most farmers know the benefits of cover cropping, yet too few plant cover crops. This is true even in regions that stand to benefit the most from cover crops, like the Corn Belt, where farms depend instead on synthetic fertilizer to compensate for depleted soils and stressed fields. Cover crops could reverse soil depletion across the Corn Belt and save farms money in the long-run. Given all that farmers might gain, why don't more choose to plant cover crops?

First, farmers face a strained agricultural economy, and they respond by limiting their short-term financial risk. Second, the Federal Crop Insurance Program dissuades farmers from planting cover crops. And third, federal programs that promote cover crops are underfunded and oversubscribed.

Farmers Face Significant Financial Strain

Farming is a challenging business in the best of times, and these are particularly bad times for farmers. The majority of American farmers have lost money every year since 2013, and farmers carry more debt than ever before, at about $416 billion.[10] As the Federal Reserve Bank of Minneapolis put it, the "nagging economic strain of low commodity prices on farmers . . . is starting to show up not just in bottom-line profitability, but in simple viability."[11]

Farmers are less likely to begin planting cover crops in a bad economy, as cover crops are expensive and do not yield short-term returns. Instead, cover crops save farmers money in the medium- and long-run by reducing fertilizer, herbicide, and pesticide purchases, as well as by preventing erosion. While cover crop acres increased by 50% from 2012 to 2017, in most states, less than ten percent of available cropland is planted with cover crops. For instance, in Iowa, despite a three-fold increase in cover crops between 2012 and 2017, only four percent of available cropland is currently planted with cover crops.[12] See Figure 1.

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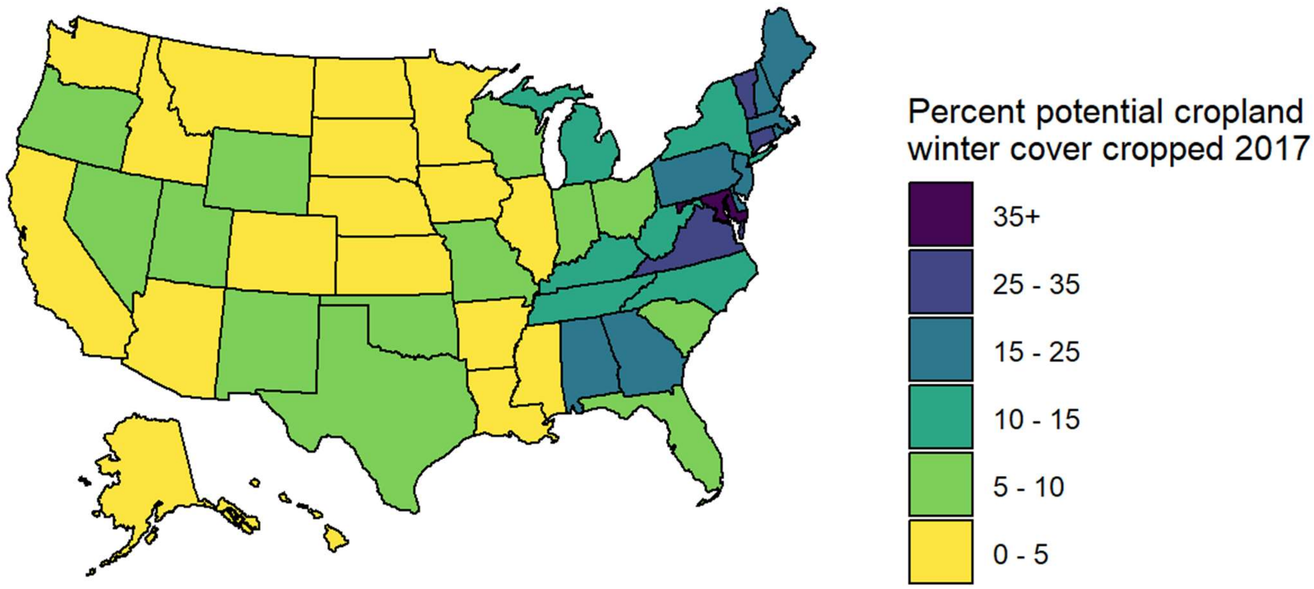
[10] Alana Semuels, *'They're Trying to Wipe Us Off the Map.' Small American Farmers Are Nearing Extinction*, TIME, Nov. 27, 2019, https://time.com/5736789/small-american-farmers-debt-crisis-extinction/.

[11] FEDERAL RESERVE BANK OF MINNEAPOLIS, https://www.minneapolisfed.org (Nov 20, 2019).

[12] J. LaRose and R. Myers, Soil Health Institute, "Progress Report: Adoption of Soil Health Systems Based on Data from the 2017 U.S. Census of Agriculture," (2019), pp. 1, 14-15, and Table 6.

Figure 1. Percent of U.S. cropland planted with cover crops in 2017, by state



Source: J. LaRose & R. Myers, "Progress Report: Adoption of Soil Health Systems Based on Data from the 2017 U.S. Census of Agriculture," Figure 6 (2019), https://soilhealthinstitute.org/soil-health-institute-releases-progress-report-on-adoption-of-soil-health-practices/.

The Federal Crop Insurance Program Disincentivizes Cover Cropping

Farming is a capital-intensive business characterized by small margins, variable prices, low liquidity, and large, geographically-correlated risks.[13] These features have three important consequences. First, farmers need crop insurance. Few farms are large enough to self-insure, and few can survive losing one year's crop, an event that every farm will face at some time. Second, private insurers are unwilling to insure crops without substantial federal aid. Correlated risk, which refers to risk that results in simultaneous losses, exposes insurers to large, simultaneous payments that could cripple their business. If one insured farm suffers catastrophic crop loss, it is likely that many other insured farms will too. Private companies are unwilling to insure large correlated risks.[14] Third, crop insurance is expensive. Because losses and risks are significant, premiums are high. Many farmers would not be able to afford unsubsidized insurance. In response, the Federal Farm Bill establishes the Federal Crop Insurance Program[15] to subsidize

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[13] CONG. RESEARCH SER., R45193, FEDERAL CROP INSURANCE: PROGRAM OVERVIEW FOR THE 115TH CONGRESS, at 3-4 (2018).

[14] Similar logic supports the disaster-relief programs that the Federal Government operates through the Federal Emergency Management Agency (FEMA).

[15] 7 U.S.C. §§ 1501–1524.

and reinsure crop insurance policies that protect 86 percent of eligible acres across the United States.[16] Most farmers consider this insurance to be indispensable.

Covered farmers who suffer crop losses and claim benefits under the Federal Crop Insurance Program must establish that they adhered to good farming practices while managing the lost crop.[17] Only farmers who practice good farming are eligible to receive an insurance payment. Cover cropping is considered a good farming practice if farmers terminate their cover crop – usually by spraying it with an herbicide to kill it, or by chopping it down before it matures – according to the National Resource Conservation Service's (NRCS) Cover Crop Guidelines.[18] Farmers, of course, cannot sell and profit from cover crops that they terminate or chop rather than harvest. In addition, the Farm Bill prevents farmers from insuring both their cover crop and a subsequent crop.[19] Farmers who cultivate cover crops typically choose to insure the subsequent crop, which is usually a field crop.

Taken together, the Federal Crop Insurance Program's rules and policies have two important consequences: they prevent farmers from insuring cover crops against loss, and they deny farmers the opportunity to sell their cover crops at a profit. Farmers who choose to plant cover crops bear the full risk associated with their cover crops, but they cannot claim the full reward.

Federal Agricultural Conservation Programs Are Not Adequate

The Farm Bill's conservation program[20] establishes the Environmental Quality Incentives Program[21] (EQIP) and the Conservation Stewardship Program[22] (CSP), which pay farmers to adopt conservation practices, including planting cover crops.[23]

EQIP provides financial and technical assistance to farmers who adopt new practices that address environmental and natural resources problems. About half of the EQIP applications that NRCS approves and funds include proposals to plant cover crops. This suggests that many farmers could depend on EQIP to overcome cover cropping's initial financial hurdles. Unfortunately, demand for EQIP funding significantly outpaces the program's appropriations. Less than half of applications to EQIP in fiscal year 2018 were approved.[24]

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[16] CONG. RESEARCH SER., R45193, at 9 (2018).

[17] 7 U.S.C. § 1508(a)(3)(A)(iii).

[18] *Id.*, at ¶ 25(A).

[19] 7 U.S.C. §1508a(b).

[20] 16 U.S.C. §§ 3830–3839bb6.

[21] 16 U.S.C. §§ 3839aa–3839aa-9.

[22] 16 U.S.C. §§ 3839aa-21–3839aa-25.

[23] NAT. RES. CONSERVATION SERV., *2020 State Payment Schedules*, https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/?cid=nrcseprd1328426, (last visited Apr. 3, 2020).

[24] CONG. RESEARCH SER., R40763, at 16 (2019).

CSP is similar to EQIP, but Congress tailored CSP to support farmers who already implement conservation practices. Farmers in most states may sign CSP contracts to plant cover crops, but payments vary from state to state.[25] CSP pays farmers less to plant cover crops than EQIP does. For example, Wisconsin farmers receive a basic rate of $45.07 per acre of cover crops from EQIP[26] but receive just $6.01 per acre from CSP.[27] In short, CSP offers too little funding and EQIP lacks adequate funds to pay all farmers who would plant cover crops. Our proposed Cover Crop Credit Partnership is intended to fill this gap.

[25] NAT. RES. CONSERVATION SERV., *2020 State Payment Schedules*, (last visited Apr. 3, 2020).

[26] NAT. RES. CONSERVATION SERV., ENVIRONMENTAL QUALITY INCENTIVES PROGRAM PAYMENT SCHEDULE - WISCONSIN, at 8 (2020).

[27] NAT. RES. CONSERVATION SERV., CONSERVATION STEWARDSHIP PROGRAM PAYMENT SCHEDULE – WISCONSIN, at 1 (2020).

2 Cover Crop Credit Partnership: A Win-Win

A Win-Win Investment

The Cover Crop Credit Partnership allows farmers to be compensated for planting cover crops. Farmers agree to plant cover crops and practice no-till agriculture. Investors compensate farmers for these practices and receive rights to the averted emissions as offsets. Farmers secure the funds they need to invest in their farms' resilience and profitability. Investors secure offsets to mitigate their effect on the climate and promote sustainable agriculture.

Structure of the Cover Crop Credit Partnership

There are three partners in the Partnership: farmer, investor, and monitor.

The **farmer** agrees to plant legume cover crops (such as alfalfa, clover, or vetch) over the winter and commits to planting cover crops for five consecutive years. To qualify for a partnership with an investor, the farmer must stipulate that s/he was not planning to plant cover crops without financial support from the investor and had not planted cover crops on that land within the past five years. The farmer also commits to using no-till practices and sharing data about soil nutrients and planting practices for purposes of determining baseline emissions from the farm and measuring emission reductions and soil sequestration at commencement of and throughout the term of the Partnership. The investor agrees to protect and maintain the confidentiality of the farmer's data; the farmer agrees that the investor may share the data with the monitor.

Investors, such as universities and other private or public entities that have committed to reduce their own GHG emissions, often purchase offsets in the voluntary or compliance market to meet their goals. By investing in and taking ownership of Cover Crop Credit offsets, such entities can legitimately take credit for the measurable GHG emission reductions and the associated co-benefits (*e.g.*, improved water quality) achieved by the Partnership's cover cropping.

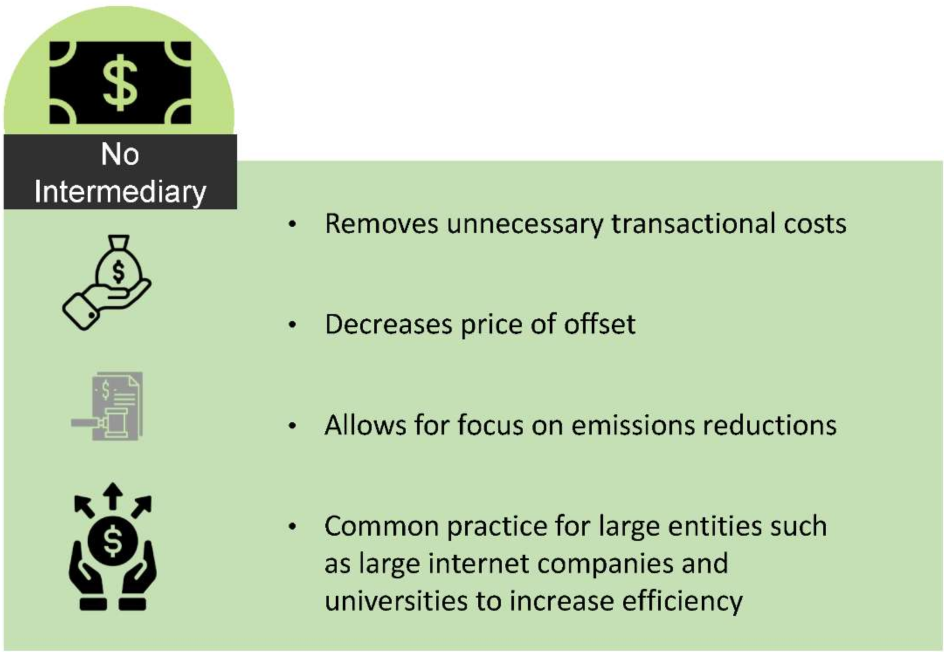
The **monitor** calculates baseline and ongoing emissions from the farm, using data provided by the farmer in combination with publicly accessible weather and satellite data. The monitor calculates both the amount of nitrous oxide released into the atmosphere and the amount of carbon stored in the farmer's soils. Our research indicates that monitoring companies can complete these calculations for about $0.16 per acre per year using the DNDC model discussed below.[28] Our proposed methods for calculating emissions reductions and offsets are clear and transparent. By eliminating expensive intermediaries (*i.e.*, third-party certification companies),

[28] Authors' conversations with Dagan, Inc.

our Partnership eliminates costly transaction costs. This arrangement keeps the offset at an affordable price for investors and enables more money to be spent on climate goals. The monitor also calculates the amount of nitrogen that the cover crops naturally add to the farmer's soils. Therefore, the farmer can use the data to make precise and efficient decisions about how much to reduce use of synthetic fertilizers without harming crop yield. These benefits are summarized in Figure 2.

A sample contract that details the terms and structure of the agreements between the three parties can be found in Appendix A.

Figure 2. Benefits from Cover Crop Credit Partnership not using an intermediary



Source: Authors

3 FINANCIAL ANALYSES

Making It Work for Farmers and Investors

Without the Partnership, the farmer on a typical 1,000-acre corn and soybean farm would lose money during the first three years of cover cropping. The goals of the Partnership are to (1) eliminate these losses and create a reliable stream of funding for the farmer, while (2) creating offsets with valuable co-benefits, at a reasonable price, for investors.

To achieve these goals, the guaranteed payments to the farmer are equal to the farmer's net expected costs in the first three years of cover cropping. In the first and second years of the partnership, the farmer receives guaranteed payments equal to 90% of his/her net expected costs in each year. In the third year, the farmer receives guaranteed payments equal to the remaining net costs from the first three years of cover cropping; or a total of 100% of net costs over the first three years. This structure creates a durable multi-year partnership, allowing the investor to claim offsets at a reasonable per-ton price. The Partnership also requires the investor to make bonus payments to the farmer for any emission reductions that exceed the DNDC model's projections. There are a variety of contractual mechanisms that could be used to address situations where the farmer fails to perform, whether intentionally, negligently, or due to circumstances beyond the farmer's control.

Our modeling example predicts that an investor partnering with a typical 1,000-acre corn and soybean farm will receive between 4,700 and 5,200 metric tons (CO_2e) of offsets at an average cost of about $11 per ton ($35/ton in the first year, $11/ton in Year 2, $7/ton in Year 3, and less than $2/ton in Years 4 and 5, when the investor pays only monitoring and administrative costs). The number of offsets the investor will receive within this range depends on the farm's baseline rate of fertilizer application. The farmer on this hypothetical farm would realize a return of about $23,000 over five years from the Partnership. These figures are derived from two key sources: USDA's Sustainable Agriculture Research & Education (SARE) program, which aggregates farmers' expected costs and financial returns from using cover crops,[29] and the DNDC model,[30] which predicts the emission reductions from the use of cover crops. Together, these two sources allowed us to create a competitive financial model that ensures farmers receive guaranteed

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[29] USDA, "Cover Crop Economics: Opportunities to Improve Your Bottom Line With Cover Crops," S*ustainable Agriculture Research and Education Program Technical Bulletin*, June 2019, https://www.sare.org/Learning-Center/Bulletins/Cover-Crop-Economics.

[30] Institute for the Study of Earth, Oceans and Space, University of New Hampshire (2012), User's Guide for the DNDC Model, http://www.dndc.sr.unh.edu/model/GuideDNDC95.pdf.

payments sufficient to mitigate the initial financial risks of planting cover crops, while investors receive offset credits at a reasonable price.[31]

Farmer's Perspective on Cover Cropping

The costs to the farmer of initiating a legume cover crop operation include seed purchase, planting, and termination.[32] The USDA's SARE survey of 2,000 farmers using cover crops provides the basis for our cost estimates. It found that the median cost of cover cropping is $37 per acre annually. Seed is typically the highest single cost, although the cost of seed is highly variable. Using legumes as cover crops maximizes the nitrogen benefits, but comes at a steeper seed cost. See Figure 3 for a summary of the SARE survey results.

Figure 3. Farmer's costs when initiating cover cropping

ITEM	COST PER ACRE
Cover crop seed purchase	$10-$50
Planting cover crop seeds	$5-$18
Termination	$0-$10
Subtotal range	***$15-$78***
Median cost from survey	***$37***

Source: USDA, "Cover Crop Economics: Opportunities to Improve Your Bottom Line with Cover Crops," Sustainable Agriculture Research and Education Program Technical Bulletin, June 2019, *https://www.sare.org/Learning-Center/Bulletins/Cover-Crop-Economics*

In our model, we assume the farmer will use crimson clover seed ($23/acre), which is a legume and provides a good source of nitrogen.[33] We use the high-end of the SARE survey's range for seeding and termination ($18 and $10, respectively, see Figure 3) to account for this being the farmer's first time implementing cover crops. Altogether, we estimate the cost of a legume-based cover crop operation at $51 per acre in Year 1, with a 2 percent efficiency improvement year-over-year. This estimate is the basis for our modeling assumptions regarding farmer costs in Tables 1 and 2, below.

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[31] Ecosystem Marketplace, Financing Emissions Reductions for the Future: State of the Voluntary Carbon Markets 2019, December 2019, *available at* https://www.ecosystemmarketplace.com/carbon-markets/.

[32] As will be explained later, the Federal Farm Bill effectively prohibits harvesting of cover crops. *See* Appendix C: Additional Legal References.

[33] USDA, Natural Resource Conservation Service, "Cover Crop Basics," March 2014, https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/mopmsbr12100.pdf. Seed price from this publication was converted to 2020 dollars.

Cover crops create two primary financial benefits to the farmer: input cost savings and increased crop yields. Input cost savings include fertilizer reductions, weed control savings, and erosion repair savings. Figure 4 shows the expected per-acre input savings after one, three, and five years of consecutive cover crop use. Our model uses the low ends of these ranges for savings from reduced weed control and erosion repair. Cover crops also increase yields by improving soil health. Figure 5 shows the percent increases in corn and soybean yields after one, three, and five years of consecutive cover crop use.

Figure 4. Farmer input cost savings (per acre) with cover crops

	Years of Cover Cropping		
Budget Item	*One*	*Three*	*Five*
Fertilizer (savings with corn)	$0	$14	$22
Fertilizer (savings with soybeans)	$0	$6	$8
Weed control	$0-$15	$10-$25	$10-$25
Erosion repair	$2-$4	$2-$4	$2-$4

Source: USDA, "Cover Crop Economics: Opportunities to Improve Your Bottom Line With Cover Crops," Sustainable Agriculture Research and Education Program Technical Bulletin, Tables 4 and 5 (June 2019)

Figure 5. Percent increase in corn and soybean yields after cover cropping

	ONE YEAR	THREE YEARS	FIVE YEARS
Corn	0.52%	1.76%	3%
Soybeans	2.12%	3.54%	4.96%

Source: USDA, "Cover Crop Economics: Opportunities to Improve Your Bottom Line With Cover Crops," Sustainable Agriculture Research and Education Program Technical Bulletin, Table 2 (June 2019)

The following two tables show the farmer's return with and without the Cover Crop Credit Partnership.

Table 1. Without Partnership

Initial 5 years of legume cover cropping on hypothetical 1,000-acre corn and soybean farm

($/acre)

Year	*1*	*2*	*3*	*4*	*5*
Revenue from higher yields	$8	$12	$16	$20	$24
Cost Savings*	$13	$23	$33	$36	$38
Additional Costs**	($51)	($50)	($49)	($48)	($47)
Farmer's net return	($30)	($15)	$0	$8	$15
Farmer's return over three years, 1000 acres			*($45,000)*		
Farmer's return over five years, 1000 acres					*($23,000)*

Source: Authors

* Savings from reduced fertilizer use, reduced weed control, and reduced erosion repair.

** Cost of seeds, planting, and termination; assumes 2% annual efficiency improvements.

Note: All figures are rounded for simplicity.

Table 1. *With the Partnership*
Initial 5 years of legume cover cropping on hypothetical 1,000-acre corn and soybean farm
($/acre)

	Year	***1***	***2***	***3***	***4***	***5***
Benefits to farmer of cover cropping						
	Revenue from higher yields	$8	$12	$16	$20	$24
	Reduced fertilizer expenses	$11	$16	$21	$24	$26
	Reduced weed control expenses	$0	$5	$10	$10	$10
	Reduced erosion repair expenses	$2	$2	$2	$2	$2
Cost of cover cropping*						
	Seed purchase	($23)	($23)	($22)	($22)	($21)
	Seed planting	($18)	($18)	($17)	($17)	($17)
	Termination of cover crop	($10)	($10)	($10)	($9)	($9)
Farmer's return, without Partnership		**($30)**	**($15)**	**$0**	**$8**	**$15**
Guaranteed payments from Partnership		*$27*	*$14*	*$5*	*$0*	*$0*
Farmer's return, with Partnership		**($3)**	**($2)**	**$5**	**$8**	**$15**
Farmer's return over five years with Partnership, 1000 acres						*$23,000*

Source: Authors
* Assumes 2% annual efficiency improvements.
Note: All figures are rounded for simplicity. Additional bonus payments from investor to farmer are possible if on-farm emission reductions and soil sequestration are greater than the DNDC model predictions.

As demonstrated in Tables 1 and 2, the farmer realizes a net positive return with the Partnership but a net loss without it. This is because the investor pays 90% of the farmer's net costs for cover cropping in years 1 and 2, and the remaining 10% in the third year. Additional, bonus payments are also possible but not reflected on the tables. These bonus payments are for any emission reductions that exceed the DNDC model's projections. The purpose of these bonus payments is to ensure farmers have an incentive to continue putting their best effort into sustainable practices. The price of these bonus payments would be negotiable.

Investor's Perspective on Cover Cropping

The investor is paying for:

1. The farmer's net expected costs of cover cropping in the first three years,
2. Administrative costs of the Partnership, including payments to the monitor, and
3. Bonus payments for emission reductions that exceed predictions of the DNDC model, if any.

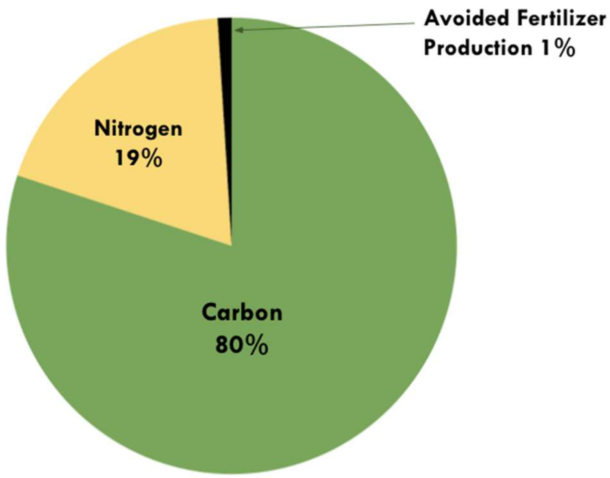
In return, the investor can reasonably take credit for the resulting emission offsets. These offsets provide health and environmental impacts and value-added co-benefits, as discussed in the health impacts section of the Guide.

The number of emission credits vary from farm-to-farm based on soil conditions, location, and, most importantly, the baseline nitrogen fertilizer application applied to cornfields.[34] As discussed in detail in Appendix B, planting legume cover crops, along with no-till practices, decreases GHG emissions and sequesters GHGs in several ways:

- Year-round ground cover reduces CO_2 emissions and enhances soil sequestration of CO_2
- Legume cover crops increase nitrogen fixation, making nitrogen more biologically available to plants; this increases nitrogen uptake by plants, leading to decreased nitrous oxide emissions
- Improved soil health leads to decreased need for nitrogen fertilizer on corn, which leads to additional decreased nitrous oxide emissions
- Decreased nitrogen fertilizer use leads to less fertilizer production, thereby decreasing CO_2, nitrous oxide, and methane emissions from fertilizer production

Our estimates, using the DNDC model, find that roughly 80 percent of emission credits from cover cropping will come from boosting the soil's carbon content (*i.e.*, sequestration of carbon dioxide), 19 percent from reduced fertilizer use and resulting nitrous oxide emissions, and one percent from avoided emissions in fertilizer production. See Figure 6.

Figure 6. Sources of expected emission reductions



[34] Soybean fields require little nitrogen fertilizer, because soybeans produce their own nitrogen. *See* USDA SARE Technical Bulletin, "Cover Crop Economics: Opportunities to Improve Your Bottom Line in Row Crops" (June 2019), p. 17, https://www.sare.org/Learning-Center/Bulletins/Cover-Crop-Economics.

Table 3 summarizes the costs the investor would incur over the five-year Partnership. The number of offsets that the investor-partner receives from this investment will vary depending largely on the baseline fertilizer use on the cornfields of the farmer-partner.

Table 2. Investor's costs and returns in 5-year partnership with farmer 1,000-acre corn and soybean farm

Year	*1*	*2*	*3*	*4*	*5*
Payments to farmer	($27,000)	($14,000)	($5,000)	$0	$0
Additional investor costs*	($4,660)	($1,660)	($1,660)	($1,660)	($1,660)
Total investor costs	($31,660)	($15,660)	($6,660)	($1,660)	($1,660)
Offsets (tons CO2e)**	911	1425	990	994	919
$/ton	($35)	($11)	($7)	($2)	($2)
				Investor costs over 5 years	*($57,000)*
				Total offsets over 5 years	5,239
				Average $/ton over 5 years	($11)

Source: Authors

* Includes $3000 start-up costs, $1500 annual administrative costs, and $0.16/acre/year monitoring costs.

** Offsets are a combination of nitrous oxide emission reductions (about 19% of offsets), carbon sequestration (80%), and avoided emissions in fertilizer production (1%).

Note: All figures are rounded for simplicity. Additional bonus payments (negotiable) from investor to farmer are possible if on-farm emission reductions and soil sequestration are greater than the DNDC model predictions.

Table 3. Total offsets generated by varying baseline fertilizer use, Initial 5 years of legume cover cropping on 1000-acre corn and soybean farm

Baseline fertilizer use (lb/acre)	*Offsets over 5 years (tons CO_2e)*	*Average $/ton over 5 years*
195	5239	($11.00)
175	4949	($11.50)
155	4699	($12.00)

Source: Authors

Note: All figures are rounded for simplicity.

4 MODELING

In this section, we describe the modeling that underlies our calculations. We selected and applied the DeNitrification-DeComposition (DNDC) model, which is well-known, regularly updated, and deemed reliable by numerous experts.

Nitrogen and Carbon Cycling in Agroecosystems

Nitrogen is a vital nutrient for crop growth and is often the limiting factor in yield maximization. Sources of nitrogen include organic crop residuals, manure or agricultural waste products, and synthetic or organic fertilizer. Most sources of nitrogen are in the atmosphere as nitrogen gas (N_2) and cannot be accessed by plants. Therefore, farmers supplement crops with nitrogen-rich fertilizer. Improper fertilizer application or excessive fertilizer use is directly correlated with N_2O emissions and is a major source of GHG emissions from the agriculture sector.[35]

Crops are largely comprised of carbon. It is also the main component and indicator of soil health and quality. Higher soil carbon content is better for farmers, as it enhances crop growth and productivity, promotes soil structure and water retention, and reduces nutrient leaching. Increasing the amount of carbon stored in soil is good for plants, soil quality, and the atmosphere.

Cover cropping intersects with both carbon and nitrogen cycling to decrease GHG emissions, enhance soil carbon storage, and reduce the need for synthetic fertilizer. Three recent studies demonstrate the benefits of cover cropping. A University of Nebraska-Lincoln study demonstrates that cover crops significantly contribute to soil aggregation and improve the soil's ability to sequester carbon. This study found a 14% increase in soil particulate organic matter in cover cropping fields as compared to control sites.[36] A 2017 meta-analysis discussing the benefits of cover cropping practices on various field sites throughout the United States found a rate of soil carbon sequestration of 0.22 tons per acre per year.[37] Additionally, a study conducted by the USDA provided even more optimistic measures of soil carbon sequestration potential through the practice of cover cropping with the potential to sequester carbon at a rate of three tons per acre per year.[38] Cover cropping is very useful, but the exact rates of carbon sequestration depend

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[35] Park, S., Croteau, P., Boering, K. *et al.* (2012) Trends and seasonal cycles in the isotopic composition of nitrous oxide since 1940. *Nature Geosci* 5, 261–265. https://doi.org/10.1038/ngeo1421.

[36] J. McDowell (2019) Cover Crops and Carbon Sequestration: Benefits to the Producer and the Planet. University of Nebraska-Lincoln Institute of Agriculture and Natural Resources Cropwatch. https://cropwatch.unl.edu/2019/cover-crops-and-carbon-sequestration-benefits-producer-and-planet.

[37] Ruis, S.J., and H. Blanco-Canqui. (2017) Cover Crops Could Offset Crop Residue Removal Effects on Soil Carbon and Other Properties: A Review. Agronomy Journal 109(5): 1785.

[38] USDA Sustainable Agricultural Research & Education (2012) Cover Crops and Carbon Sequestration. https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops/Ecosystem-Services-from-Cover-Crops/Cover-Crops-and-

on farming practices, soil quality, and environmental conditions. For this reason, the World Resources Institute is skeptical: it agrees that cover cropping practices improve soil health and yield valuable environmental benefits, but questions the ability of these practices to achieve large-scale emissions reductions through carbon sequestration.[39] The DNDC model, as discussed more fully below, can verify the legitimacy of the sequestration offsets.

DNDC Software Models Nutrient Cycling to Assess Yields and Emissions

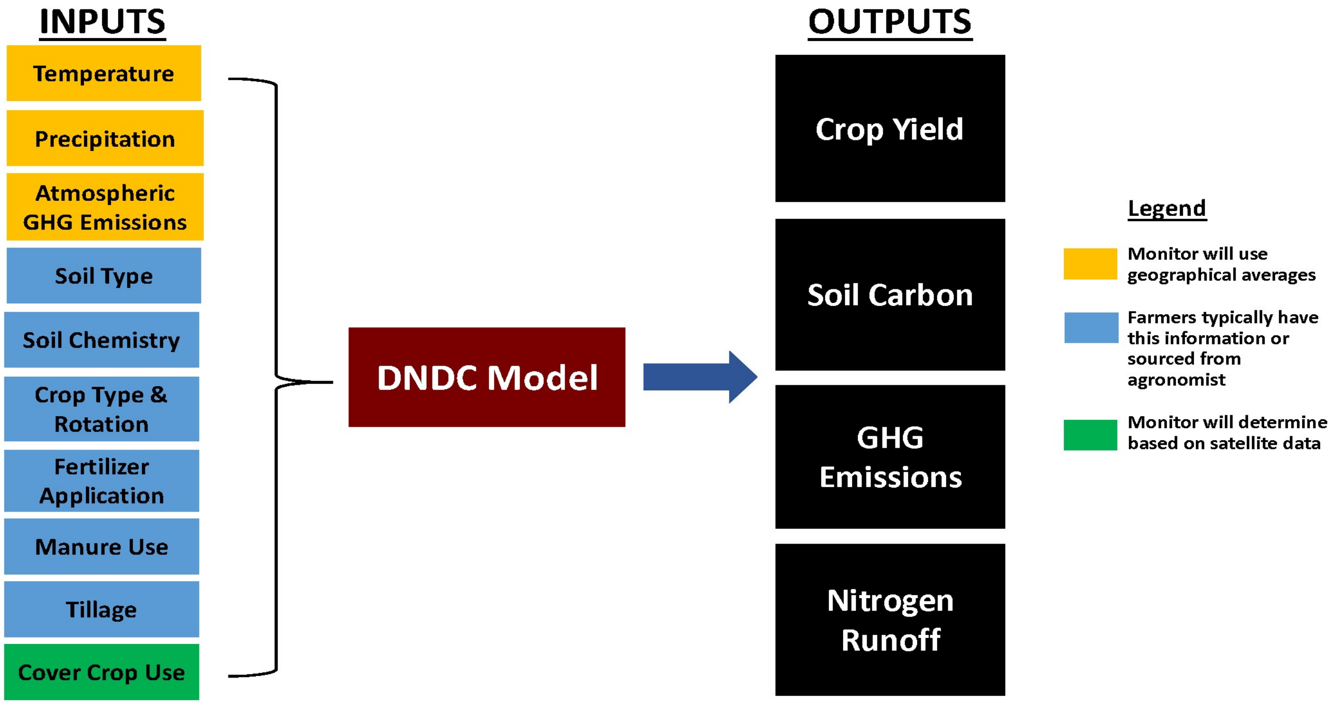
The DNDC model was specifically developed to quantify carbon sequestration and to predict GHG emissions on agricultural lands. Baseline farm conditions, as well as management practices, are calculated and simulated over an allotted time frame to estimate emissions. The input parameters match with biogeochemical processes for targeted greenhouse gases. Emissions predictions are derived from quantification of microbe-mediated soil processes, including decomposition, nitrification, denitrification, fermentation, and methanogenesis.[40] The rates of these five processes are simulated based on actual soil and actual climate conditions and on inputted modifications to environmental conditions that may impact carbon or nitrogen cycling. The model is divided into two components: environmental factors (specific agricultural conditions) and gaseous flux (carbon and nitrogen cycling). Specifically, the simulation of carbon and nitrogen cycling through the agricultural system is conducted using a series of equations to model decomposition, urea hydrolysis, NH_3 production and emission, and NH_3 absorption by plants. See Appendix B for further details. Figure 7 summarizes the inputs to the DNDC model and the outputs that the model generates.

Carbon-Sequestration

[39] J. Raganathan et al., WRI, "Regenerative Agriculture: Good for Soil Health, but Limited Potential to Mitigate Climate Change," May 12, 2020, https://www.wri.org/blog/2020/05/regenerative-agriculture-climate-change.

[40] Institute for the Study of Earth, Oceans and Space University of New Hampshire (2017) DNDC Version 9.5 Scientific Basis and Processes. http://www.dndc.sr.unh.edu/papers/DNDC_Scientific_Basis_and_Processes.pdf.

Figure 7. Inputs and Outputs of DNDC Model



Source: Authors

DNDC Model is Continuously Verified

The DNDC model has been extensively evaluated against real-world datasets and compared against monitoring data. A 2014 Biogeosciences study used the model to simulate various management practices on agricultural outcomes, including yield, GHG emissions, runoff, and nitrate leaching. The model was determined to be an accurate predictor of future biogeochemical cycling.[41] A 2016 study in China also confirmed the validation of modeled results in vineyard systems. The study concluded DNDC has powerful predictive and verification power for greenhouse gas emissions.[42] A verification study was conducted on onion and carrot fields in Japan with additional applications of nitrogen fertilizer. The model estimates of N_2O flux were compared to observed field N_2O emissions data based on seasonal patterns (and confirmed the model's prediction accuracy).[43] An additional study conducted in Canada found a 3%

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[41] F. Cui et.al. (2014) Assessing biogeochemical effects and best management practice for a wheat–maize cropping system using the DNDC model. Biogeosciences, 11, 91–107. https://doi.org/10.5194/bg-11-91-2014.

[42] Y. Zhang et al. (2016). Application of the DNDC model to estimate N_2O emissions under different types of irrigation in vineyards in Ningxia, China. Agricultural Water Management,163, 295-304. https://doi.org/10.1016/j.agwat.2015.10.006

[43] Cai et. al. (2003) Field validation of the DNDC model for greenhouse gas emissions in East Asian cropping systems. Global Biogeochemical Cycles, 17(4). doi:10.1029/2003GB002046

overestimation by the DNDC model in comparison to N_2O field samples during the calendar year.[44] The DNDC model is continuously edited and reconfigured based on field data to ensure the most accurate predictions possible. Project contracting with the monitor will ensure the latest model with the highest degree of confirmed accuracy is used to predict, monitor, and verify GHG emissions reductions.

Why DNDC Modeling Instead of Direct Emissions Monitoring

Directly measuring GHG emissions in an agroecosystem can be difficult, expensive, and often inaccurate. Nitrous oxide and carbon dioxide are traditionally measured using gas chromatography; soil carbon is analyzed using dry combustion techniques. Both methods are costly, time-consuming, and expensive. Further, since carbon and nitrogen are always in flux within the ecosystem, samples taken from the soil or air will not fully capture the total GHG emissions or stored carbon content and may provide inaccurate results. Instituting a monitoring system would significantly increase transactional costs for investors, and direct monitoring devices would be time-consuming and would rely heavily on correct user operation to retrieve accurate results. As noted previously, the DNDC model has been verified using scientific monitoring procedures to provide in-depth comparisons to the estimated model. Therefore, the projected emissions from modeled agriculture scenarios will be based on recent and precise verification data to confirm GHG emissions and sequestration of soil carbon, and no direct monitoring system need be deployed to participating farms.

As the Cover Crop Credit Partnership develops and monitoring technology expands, direct field sampling is not out of the realm of possibility to ensure offset legitimacy. Although we have not done so in our example, we also recommend that the monitor make appropriate adjustments to the model to take into account potential uncertainty in the modeling.

Verifiable Offset Credit Analysis

Predictive values determined by the DNDC model will be the basis for the Partnership's reported greenhouse gas emissions credits. A baseline five-year projection model would be simulated for each participating farm to show emissions estimates if no intervention took place. A second baseline five-year projection would be simulated for each farm showing emissions estimates with the planned intervention techniques. Annual modeling inputting actual, site-specific data will then show the implementation of reduced fertilizer and cover crop uses to calculate emissions for that year. The annually modeled data will be compared to the first predicted baseline emissions estimates with no intervention. Annual emissions will be subtracted from the first

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[44] W.N. Smith et. al. (2002) Testing the DNDC model using N_2O emissions at two experimental sites in Canada. Canadian Journal of Soil Science, 82(3), 365-374. https://doi.org/10.4141/S01-048

baseline emissions to determine the total emissions reductions. As mentioned earlier, we recommend that the monitor make appropriate adjustments to the model to take into account potential uncertainty in the modeling. Comparisons of soil carbon, crop yield, and nitrogen runoff will also be calculated. Using the current Intergovernmental Panel on Climate Change (IPCC) carbon dioxide equivalents conversions, the total CO_2 equivalents of all greenhouse gases will be totaled. The price payout of offset credits will be based on emissions reductions of total CO_2 equivalents, as calculated by the monitor, and additional payments will be made if the farmer's emissions reductions exceed those of the second baseline predictive model where interventions were simulated. The extra payments will be calculated on an annual basis using the annually-conducted model. The projected emissions from that year will be subtracted from the annual model run using annual data inputs. The difference will be multiplied by the offset cost for the expected emission credits to determine additional payouts to the participating farmers.

The DNDC model is continuously evolving and improving, providing quantification and verification of emissions reductions and confirmation of high-quality offsets. DNDC modeling and verification efforts will ensure that the offsets meet permanence requirements, through the continued practice of cover cropping, consistency of reduced fertilizer usage, and adoption of no-till farmer methods to conserve soil carbon and guarantee offset permanence. Potential failure of the farmer, investor, or monitor to perform their agreements will be addressed in the contract governing the Partnership. These offsets also meet additionality requirements because, without the investor's payments, farmers would be unable to overcome the financial barriers to cover crop implementation and the associated fertilizer reduction procedures. Therefore, the offset is additional in actively reducing GHG emissions.

5 Environmental and Health Impact Assessment

of Synthetic Nitrogen Fertilizer

Overview

The use of synthetic nitrogen fertilizer has significant environmental and health impacts. We conducted environmental and health impacts assessments of nitrogen fertilizer use on Midwestern farms, focusing on three major pathways of ecological and human health: water, soil, and air.

Environmental Impacts of Synthetic Fertilizer Use

Water. Farmers use synthetic nitrogen fertilizer because it improves crop yield; however, the nitrogen (in the form of nitrate) that is not used by the plants can leach and run off into nearby bodies of water. Since nitrogen is a limiting nutrient in aquatic ecosystems, runoff containing nitrates will result in eutrophication, algal blooms, and hypoxia in water bodies. The impacts of nitrate leaching can be local. However, leached nitrates can be transported long distances through various watershed systems, such as the Mississippi River Watershed. Eutrophication caused by nutrient loading can result in harmful algal blooms that can impact local freshwater and marine fisheries, as well as local economies. It can lead to the loss of recreational activities, property value, and ecosystem services.[45]

Soil. The use of synthetic nitrogen fertilizer also reduces soil biodiversity, making crops more susceptible to weeds and disease.[46] This situation occurs because the synthetic fertilizer impacts the physical, chemical, and biological properties of soil, changing the composition of soil fungal communities and causing imbalances in the nutrients taken up by the plants, leaving them more susceptible to disease.[47,48,49]

Air. Synthetic nitrogen fertilizer use contributes to N_2O emissions because the excess nitrate in soils is used by bacteria in the denitrification process, producing N_2O as a byproduct. Nitrous

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[45] Good, A. and Peatty, B. 2011. "Fertilizing Nature: A Tragedy of Excess in the Commons," PLOS Biology, available at http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001124

[46] Altieri, M. A., & Nicholls, C. I. (2003). Soil fertility management and insect pests: Harmonizing soil and plant health in agroecosystems. *Soil and Tillage Research, 72*(2), 203-211. doi:10.1016/s0167-1987(03)00089-8

[47] Altieri, M. A., & Nicholls, C. I. (2003). Soil fertility management and insect pests: Harmonizing soil and plant health in agroecosystems. *Soil and Tillage Research, 72*(2), 203-211. doi:10.1016/s0167-1987(03)00089-8

[48] Geisseler, D., & Scow, K. M. (2014). Long-term effects of mineral fertilizers on soil microorganisms – A review. *Soil Biology and Biochemistry, 75*, 54-63. doi:10.1016/j.soilbio.2014.03.023

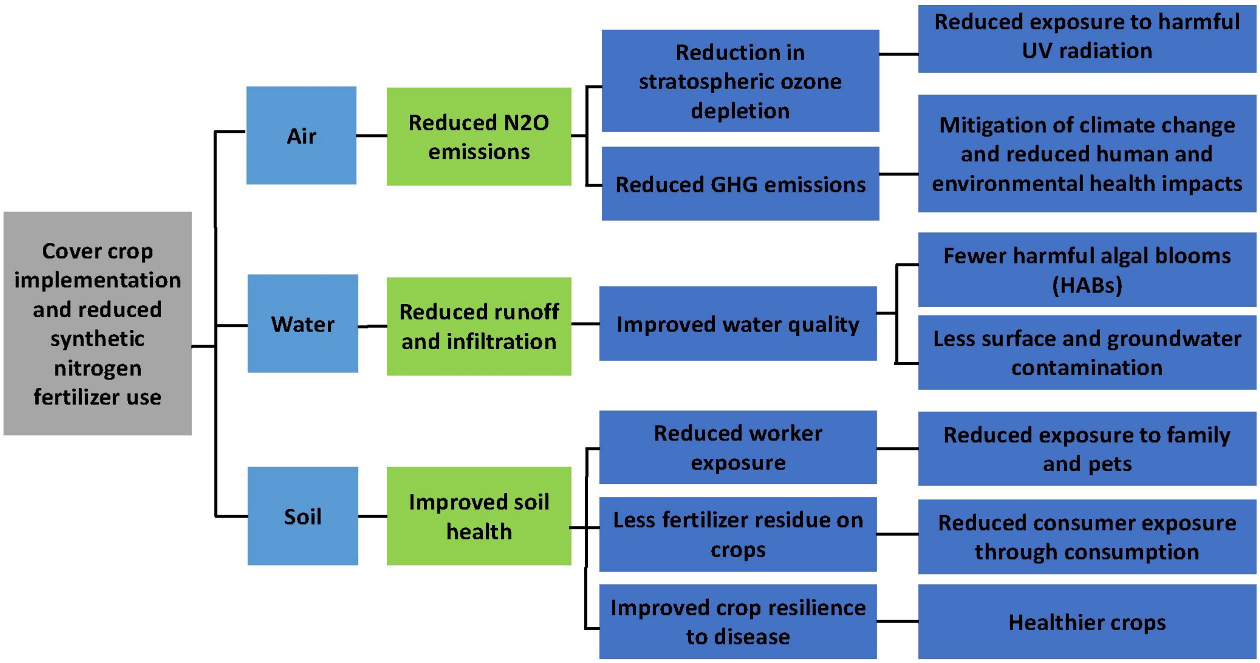
[49] Paungfoo-Lonhienne, C., Yeoh, Y. K., Kasinadhuni, N. R., Lonhienne, T. G., Robinson, N., Hugenholtz, P., . . . Schmidt, S. (2015). Nitrogen fertilizer dose alters fungal communities in sugarcane soil and rhizosphere. *Scientific Reports,5*(1). doi:10.1038/srep08678

oxide contributes to increasing global temperature, sea-level rise, changing weather patterns, and loss of biodiversity.[50] Nitrous oxide also contributes to stratospheric ozone depletion, which increases exposure to ultraviolet (UV) radiation from the sun.[51]

Human Health Impacts of Synthetic Fertilizer Use

The environmental impacts of synthetic fertilizer use directly impact human health (see Figure 8). Additionally, synthetic nitrogen fertilizers themselves have direct impacts on human health.

Figure 8. A summary of major environmental and human health impacts from synthetic nitrogen fertilizer use



Air. Depending on the region and other factors such as socioeconomic status and pre-existing health conditions, certain populations of people will be disproportionately affected by the climate change impacts of synthetic nitrogen fertilizer use. Climate change will have a larger impact on vulnerable populations that do not have the resources or capacity to mitigate the effects of climate change. Climate change impacts human health through a variety of pathways, including flooding and sanitation issues related to sea-level rise and extreme weather conditions (*i.e.*, hurricanes and flooding), the spread of infectious diseases with increased temperature, and

[50] Zickfeld, et al. 2016. "Centuries of thermal sea-level rise due to anthropogenic emissions of short-lived greenhouse gases," Proceedings of the National Academy of Sciences, available at http://www.pnas.org/content/114/4/657.abstract

[51] Portmann, R. W., Daniel, J. S., & Ravishankara, A. R. (2012). Stratospheric ozone depletion due to nitrous oxide: influences of other gases. Philosophical Transactions of the Royal Society B: Biological Sciences, 367(1593), 1256–1264. doi: 10.1098/rstb.2011.0377

malnutrition due to food insecurity from drought.[52] In particular, increased average global temperature is associated with more intense heat waves, which can increase deaths from cardiovascular and respiratory disease.[53] A warmer planet also contributes to tropospheric ozone formation (which further exacerbates cardiovascular and respiratory conditions), and warmer temperatures (which increase pollen levels and trigger more frequent asthma attacks).[54] Nitrous oxide contributes to stratospheric ozone depletion, which increases exposure to UV radiation from the sun. The increased exposure to harmful UV radiation increases the risk of skin cancers.

Water. Residents who source drinking water from the afflicted watersheds and those who recreate in water bodies near agricultural fields are the most at risk for the effects of surface and groundwater nitrate loading as a result of nitrate runoff from agricultural fields. Many Midwesterners source their drinking water from private and shallow wells that are not routinely monitored for nitrate levels. These wells often have nitrate concentrations higher than the regulatory maximum contaminant level of 10mg/L.[55,56,57,58,59] Exposure to high concentrations of nitrate in babies has been linked to infant methemoglobinemia "blue baby," an acute toxic response that prevents oxygen transport in the blood.[60] Studies have also suggested that nitrate exposure is associated with increased risk of cancers, thyroid disease, and neural tube

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52 Climate Change and Public Health - Climate Effects on Health. (2019, September 9). Retrieved April 4, 2020, from https://www.cdc.gov/climateandhealth/effects/default.htm.

53 Climate change and health. (n.d.). Retrieved April 3, 2020, from https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.

54 Climate change and health. (n.d.). Retrieved April 3, 2020, from https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.

55 Schechinger, A. (2019, April 24). Contamination of Iowa's Private Wells: Methods and Detailed Results. Retrieved April 26, 2020, from https://www.ewg.org/iowawellsmethods#_edn12

56 Unger, P. W., & Vigil, M. F. (1998). Cover crop effects on soil water relationships. *Journal of Soil and Water Conservation, 53*(3), 200-206. Retrieved from http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/220950031?accountid=11311.

57 Schechinger, A. (2019, April 24). Contamination of Iowa's Private Wells: Methods and Detailed Results. Retrieved April 26, 2020, from https://www.ewg.org/iowawellsmethods#_edn12.

58 National Primary Drinking Water Regulations. (2020, February 14). Retrieved March 11, 2020, from https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations.

59 A National Look at Nitrate Contamination of Ground Water. (n.d.). Retrieved March 9, 2020, from https://water.usgs.gov/nawqa/nutrients/pubs/wcp_v39_no12/

60 Nitrate and nitrite in drinking-water. Background document for *development of WHO Guidelines for Drinking-water Quality*. Prepared by G.J.A Speijers revised by Mr. J.K. Fawell of the United Kingdom. December 2011, from https://www.who.int/water_sanitation_health/dwq/chemicals/nitratenitrite2ndadd.pdf.

defects.[61,62,63] Studies have observed an increased risk of adverse health effects with consuming water with nitrate levels *below* the EPA regulatory limits.[64]

Excess nitrogen in the water contributes to eutrophication and the formation of harmful algal blooms, which are detrimental to human health because they can be composed of toxin-producing microscopic organisms. For example, harmful algal blooms that occur in freshwater usually contain a large concentration of *Microcystis*, cyanobacteria that can cause gastrointestinal symptoms, and in some cases, liver damage in humans.[65,66] Furthermore, algal blooms can infect fish/shellfish and could have human health consequences if people eat infected fish/shellfish.

Soil. Farm employees, farmers, and families are the most vulnerable when it comes to direct exposure with the fertilized soil through inhalation, direct contact, or consumption. They are also indirectly impacted by poor soil health from synthetic fertilizer use. Fertilizer pollution reduces the water and air purification capacity of the soil. It can also alter the soil microbial community, leading to increased disease in crops, making them unhealthy for human consumption.

Direct exposure to ammonia-based fertilizers has been associated with many adverse health impacts. Acute exposure to ammonia can irritate and burn the skin and eyes and can cause coughing, wheezing, shortness of breath, and pulmonary edema. Chronic exposure to ammonia can cause permanent lung damage or an asthma-like allergic response.[67] Not only are farmers and farm employees exposed to the fertilizer when applying it to fields, but fertilizer particles can also be tracked into homes on clothing and shoes where they expose family, roommates, and pets to the chemical fertilizer. The fertilizer particles can then settle as dust on the floors of homes. Children and pets are among the most vulnerable to this exposure, because both children and pets spend more time closer to the ground. Furthermore, young children exhibit pica behavior and are more likely to put food/objects in their mouth from the floor, and pets are more likely to chew on or eat objects on the floor. The larger community is also at risk, because fruits and vegetables grown in fields where chemical fertilizers are applied can have fertilizer residue present on their surfaces, which may be inadvertently consumed.

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[61] Pediatric Environmental Health Specialty Units. (2014). NITRATES, METHEMOGLOBINEMIA, AND DRINKING WATER: A Factsheet for Clinicians. *NITRATES, METHEMOGLOBINEMIA, AND DRINKING WATER: A Factsheet for Clinicians*.

[62] Ward, M. H., Jones, R. R., Brender, J. D., de Kok, T. M., Weyer, P. J., Nolan, B. T., Villanueva, C. M., & van Breda, S. G. (2018). Drinking Water Nitrate and Human Health: An Updated Review. *International journal of environmental research and public health*, *15*(7), 1557. https://doi.org/10.3390/ijerph15071557.

[63] Weng, H. H., Tsai, S. S., Wu, T. N., Sung, F. C., & Yang, C. Y. (2011). Nitrates in Drinking Water and the Risk of Death from Childhood Brain Tumors in Taiwan. J Toxicol Environ Health A, 74(12), 769–778. doi: 10.1080/15287394.2011.567951.

[64] Ward, M. H., Jones, R. R., Brender, J. D., de Kok, T. M., Weyer, P. J., Nolan, B. T., Villanueva, C. M., & van Breda, S. G. (2018). Drinking Water Nitrate and Human Health: An Updated Review. *International journal of environmental research and public health*, *15*(7), 1557. https://doi.org/10.3390/ijerph15071557.

[65] Algal Blooms. (n.d.). Retrieved March 9, 2020, from https://www.niehs.nih.gov/health/topics/agents/algal-blooms/index.cfm.

[66] Watanabe, M. F., Harada, K.-ichi, Carmichael, W. W., & Fujiki, H. (1996). *Toxic microcystis*. Boca Raton, FL: CRC Press.

[67] Hazardous Substance Fact Sheet: Ammonia. (2016). *Hazardous Substance Fact Sheet: Ammonia*. https://nj.gov/health/eoh/rtkweb/documents/fs/0084.pdf

The use of synthetic nitrogen fertilizer also reduces soil biodiversity, making crops more susceptible to weeds. As a result, more herbicide use is needed, further putting farmers, farm employees, and their families at risk for chemical exposure. Glyphosate can cause severe eye irritation and atrazine can impact human reproductive health, as well as cause other adverse health effects that have been demonstrated in animal studies. Another common herbicide, 2,4-Dichlorophenoxyacetic acid, has been listed as non-carcinogenic by the Environmental Protection Agency (EPA) but the International Agency for Research on Cancer (IARC) has classified it as a 2B carcinogen (possibly carcinogenic to humans).[68,69,70]

Cover Crops: The Pathway to Reducing the Negative Impacts of Synthetic Nitrogen Fertilizer

Using cover crops reduces a farmer's reliance on synthetic nitrogen fertilizer and therefore reduces nitrogen input into the environment, reducing environmental degradation and human health impacts.

Cover crops create healthier soils and reduce the need for synthetic fertilizers and other chemical compounds. Using cover crops and reducing fertilizer use helps to break disease cycles and can prevent outbreaks in plants because cover crops promote healthy microbial soil communities, which provide resiliency against disease.[71] Furthermore, cover crops can help maintain soil moisture depending on local climate patterns. Cover crops further reduce the erosion of the soil by providing soil stability through root structure. With healthier soils, more nitrogen is bioavailable for plants, and less synthetic nitrogen fertilizer is needed. As a result, there is less excess nitrogen in the soil that can be leached into nearby watersheds, reducing the concentrations of nitrates in water that "feed" harmful algal blooms. Additionally, lower nitrate concentrations in drinking water sources reduce the risk of cancer, thyroid diseases, and other health outcomes in people. Healthier soils are also associated with reduced nitrous oxide emissions, which reduce the effects of climate change. Healthier microbial communities in the soil – coupled with reduced fertilizer application – decrease the amount of excess nitrate in the soil that can be used by denitrifying microbes to produce nitrous oxide.

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[68] (n.d.). Retrieved April 3, 2020, from http://pmep.cce.cornell.edu/profiles/extoxnet/dienochlor-glyphosate/glyphosate-ext.html.

[69] Toxic Substances Portal - Atrazine. (n.d.). Retrieved April 3, 2020, from https://www.atsdr.cdc.gov/phs/phs.asp?id=336&tid=59.

[70] 2,4-Dichlorophenoxyacetic acid. (n.d.). Retrieved April 3, 2020, from https://deq.mt.gov/Portals/112/Land/hazwaste/documents/2_4_D.pdf.

[71] Larkin, R. P., Griffin, T. S., & Honeycutt, C. W. (2010). Rotation and Cover Crop Effects on Soilborne Potato Diseases, Tuber Yield, and Soil Microbial Communities. *Plant Disease*, *94*(12), 1491–1502. doi: 10.1094/pdis-03-10-0172

Cover Crops: Potential Negative Health Impacts

Our research did not uncover any scientific literature studying the association of cover crop use and negative human health impacts.

However, while cover crops improve soil health and nitrogen availability to crops, there is inconsistent evidence that all types of cover crops increase crop yields in all circumstances.[72,73,74,75,76,77,78] The impact of cover crops on yield can be difficult to evaluate, because crop yield is dependent on many factors, environmental and practice-based, as well as if the cover crop is leguminous or non-leguminous.[79,80,81,82,83,84,85,86] As noted throughout this Guide, we recommend the use of legumes as cover crops to maximize the benefits of the Partnership. Moreover, farmers can adjust several management practices in efforts to further improve crop yield. These include extending the growing window for the cover crop by choosing

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[72] Andraski, T., & Bundy, L. (2005). Cover Crop Effects on Corn Yield Response to Nitrogen on an Irrigated Sandy Soil. Agronomy Journal, 97(4), 1239-1244.

[73] Sainju, U. M., and B. P. Singh. 2001. Tillage, Cover Crop, and Kill-Planting Date Effects on Corn Yield and Soil Nitrogen. Agron. J. 93:878-886. doi:10.2134/agronj2001.934878x

[74] Tonitto, C., David, M., & Drinkwater, L. (2006). Replacing bare fallows with cover crops in fertilizer-intensive cropping systems: A meta-analysis of crop yield and N dynamics. Agriculture, Ecosystems and Environment, 112(1), 58-72.

[75] Raimbault, B. A., T. J. Vyn, and M. Tollenaar. 1990. Corn Response to Rye Cover Crop Management and Spring Tillage Systems. Agron. J. 82:1088-1093. doi:10.2134/agronj1990.00021962008200060012x

[76] Salmerón, M., Cavero, J., Quílez, D., & Isla, R. (2010). Winter cover crops affect monoculture maize yield and nitrogen leaching under irrigated mediterranean conditions. *Agronomy Journal, 102*(6), 1700-1709. Retrieved from http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/807429471?accountid=11311

[77] Impact of Cover Crop Management on Rainfed Corn Production in Western Nebraska. (2019, July 17). Retrieved April 2, 2020, from https://cropwatch.unl.edu/2019/cover-crop-impact-rainfed-corn

[78] Clark, A., Decker, A., Meisinger, J., & McIntosh, M. (1997). Kill Date of Vetch, Rye, and a Vetch—Rye Mixture: II. Soil Moisture and Corn Yield. Agronomy Journal, 89(3), 434-441.

[79] Andraski, T., & Bundy, L. (2005). Cover Crop Effects on Corn Yield Response to Nitrogen on an Irrigated Sandy Soil. Agronomy Journal, 97(4), 1239-1244.

[80] Sainju, U. M., and B. P. Singh. 2001. Tillage, Cover Crop, and Kill-Planting Date Effects on Corn Yield and Soil Nitrogen. Agron. J. 93:878-886. doi:10.2134/agronj2001.934878x

[81] Raimbault, B. A., T. J. Vyn, and M. Tollenaar. 1990. Corn Response to Rye Cover Crop Management and Spring Tillage Systems. Agron. J. 82:1088-1093. doi:10.2134/agronj1990.00021962008200060012x

[82] Impact of Cover Crop Management on Rainfed Corn Production in Western Nebraska. (2019, July 17). Retrieved April 2, 2020, from https://cropwatch.unl.edu/2019/cover-crop-impact-rainfed-corn

[83] Clark, A., Decker, A., Meisinger, J., & McIntosh, M. (1997). Kill Date of Vetch, Rye, and a Vetch—Rye Mixture: II. Soil Moisture and Corn Yield. Agronomy Journal, 89(3), 434-441.

[84] Andraski, T., & Bundy, L. (2005). Cover Crop Effects on Corn Yield Response to Nitrogen on an Irrigated Sandy Soil. Agronomy Journal, 97(4), 1239-1244.

[85] Salmerón, M., Cavero, J., Quílez, D., & Isla, R. (2010). Winter cover crops affect monoculture maize yield and nitrogen leaching under irrigated mediterranean conditions. *Agronomy Journal, 102*(6), 1700-1709. Retrieved from http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/807429471?accountid=11311

[86] Clark, A., Decker, A., Meisinger, J., & McIntosh, M. (1997). Kill Date of Vetch, Rye, and a Vetch—Rye Mixture: II. Soil Moisture and Corn Yield. Agronomy Journal, 89(3), 434-441.

a late kill date (late April-early May) and practicing no-till.[87,88,89,90] Making these adjustments when growing cover crops has resulted in increased corn yields compared to using earlier kill dates and other till or plowing practices.

Recommendations Based on Environmental and Health Assessments

Based on the environmental and health assessments, implementing cover cropping on corn and soy fields in the Midwest will have significant positive environmental and health impacts. Using numbers from peer-reviewed literature, the lifetime costs saved from the health and environmental impacts (atmosphere and water) by using cover crops and reducing nitrogen fertilizer use by 70 lbs./acre for a hypothetical 1000-acre farm could range from approximately $1,000,000 to $3,000,000.[91]

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[87] Sainju, U. M., and B. P. Singh. 2001. Tillage, Cover Crop, and Kill-Planting Date Effects on Corn Yield and Soil Nitrogen. Agron. J. 93:878-886. doi:10.2134/agronj2001.934878x

[88] Raimbault, B. A., T. J. Vyn, and M. Tollenaar. 1990. Corn Response to Rye Cover Crop Management and Spring Tillage Systems. Agron. J. 82:1088-1093. doi:10.2134/agronj1990.00021962008200060012x

[89] Clark, A., Decker, A., Meisinger, J., & McIntosh, M. (1997). Kill Date of Vetch, Rye, and a Vetch—Rye Mixture: II. Soil Moisture and Corn Yield. Agronomy Journal, 89(3), 434-441.

[90] Wittwer, R. A., Dorn, B., Jossi, W., & Marcel G. A. Van Der Heijden. (2017). Cover crops support ecological intensification of arable cropping systems. *Scientific Reports*, *7*(1). doi: 10.1038/srep41911

[91] Sobota, D. J., Compton, J. E., Mccrackin, M. L., & Singh, S. (2015). Cost of reactive nitrogen release from human activities to the environment in the United States. *Environmental Research Letters*, *10*(2), 025006. doi: 10.1088/1748-9326/10/2/025006

CONCLUSION

The Cover Crop Credit Partnership described in this Guide will benefit both farmers and investors. Farmers will receive payments enabling them to plant cover crops that will eventually increase the efficiency and health of their farm. By the time the Partnership concludes, the cover crops will pay for themselves through reduced need to purchase fertilizer and increased soil quality and crop yields. In addition, farmers will be paid for their emissions reductions. The investor will benefit by receiving emissions offsets. The investor can also claim co-benefits, such as cleaner water, healthier soils, and farms with reduced climate risks.

Nitrous oxide emissions will be lowered by reducing the need for synthetic nitrogen fertilizer and increasing the naturally available nitrogen in soils. Cover crops will draw down carbon dioxide from the atmosphere and store it as organic matter in soils and plants. Increasing soil organic content is not only good for global climate change concerns, but also increases the soil's ability to hold water and makes farms more resilient to drought.

Using satellite imagery and verified models, the investor can directly monitor the greenhouse gas from each acre of land enrolled in the Cover Crop Credit Partnership. This low-cost technology allows for investors to verify their offsets while allowing farmers to benefit from any additional greenhouse gas savings they are able to achieve.

State laws that regulate agricultural runoff and nutrient management may have implications for Cover Crop Credit Partnerships and should be researched on a case-by-case basis prior to implementation. We provide some examples in Appendix C.

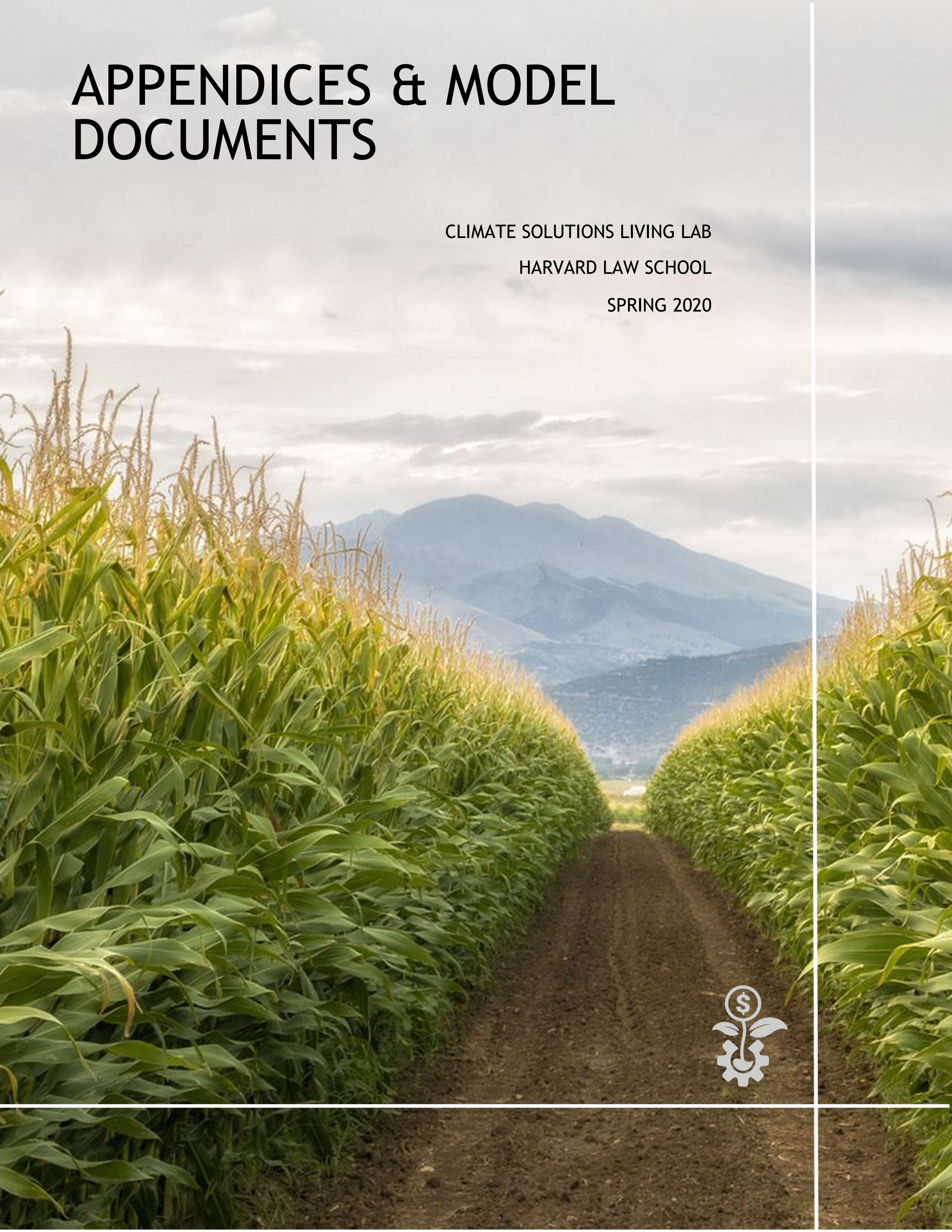
Congress and the States have not responded to the climate change impacts on or from the agricultural sector quickly enough. The Cover Crop Credit Partnership provides a method for farmers and investors to partner and address their personal impact on climate change, environmental health, and our agricultural economy.

APPENDICES & MODEL DOCUMENTS

CLIMATE SOLUTIONS LIVING LAB

HARVARD LAW SCHOOL

SPRING 2020



APPENDIX A: COVER CROP CREDIT PARTNERSHIP MODEL AGREEMENT

This Cover Crop Credit Partnership Agreement ("Agreement") is entered into between___________ (the "Farmer"), ___________ (the "Investor"), and ________ (the "Monitor"). The Effective date is _____, ___.

Definitions

A. "Cover Crops" are legumes planted on Enrolled Land over the winter season.
B. The "Data Reporting Website" is the confidential, non-public website with URL ______________ for Farmer to use.
C. "Emissions" means the release of carbon dioxide, methane, or nitrous oxides into the ambient air. Methane and nitrous oxide are significantly more potent greenhouse gases than carbon dioxide. Calculations of Emissions are converted into carbon dioxide equivalent (CO_2e) numbers.
D. The "Enrolled Land" is the specific acreage of Farmer's land that is subject to this Agreement. Enrolled Land is further described in Attachment A.
E. "Expected Emissions Reductions" are the Emissions reductions calculated by the Monitor to occur as a result of this Agreement.
F. "Fertilizer" means any material that is applied to land in order to supply nutrients to plants, including organic and synthetic materials such as manure, plant waste, compost, sludge, anhydrous ammonium nitrate, and urea.
G. The "Guaranteed Payment" is equal to one-hundred percent (100%) of the Farmer's net costs to plant and harvest Cover Crops on the Enrolled Land for three years, at the end of which time the parties expect Farmer to begin profiting from the investment in Cover Crops.
H. The "Investor" includes Investor's principals, employees, agents, and contractors.
I. The "Monitor" is [identify name], including its principals, employees, agents, and contractors.
J. The "Premium Payment" is equal to [$---] multiplied by the difference between Actual Emissions and Expected Emissions. If Actual Emissions are equal to or greater than Expected Emissions, then the Premium Payment is equal to $0.00.

I. Farmer's Agreement:

A. Farmer represents that it has not planted Cover Crops during any of the five years that precede the Effective Date.
B. Farmer represents that but for the Guaranteed Payments it would not be able to plant Cover Crops as of the Effective Date.
C. Farmer represents that the Enrolled Land is not subject to any contract, easement, lien, or other legal device that will prevent Farmer from performing this Agreement.
D. Farmer shall plant Cover Crops during each of the five winter planting seasons that follow

the Effective Date.

E. Farmer shall use no-till practices on Enrolled Land for the duration of this Agreement.

F. Farmer shall report the following information to the Monitor [one month] [two months] after the Effective Date via the confidential Data Reporting Website. The Farmer represents that such information is accurate and complete as of the Effective Date and for the year prior to the Effective Date:

   1. Description of soils on Enrolled Land, including: (1) clay composition, expressed as percentage of clay by mass; (2) organic carbon composition, expressed as percentage of organic carbon by mass; (3) acidity, expressed as pH; (4) bulk density, expressed as grams per cubic centimeter; and (5) nitrogen concentration, expressed as milligrams of nitrogen per kilogram of soil.
   2. Description of crops on the Enrolled Land, including: (1) type of crop planted; (2) whether such crop is a perennial or annual; (3) whether such crop is a legume; (4) the most recent date that Farmer planted the crop; and (5) a map depicting the locations of the crops on the Enrolled Land.
   3. Description of Farmer's application of synthetic fertilizer to the Enrolled Land, including: (1) the type of synthetic fertilizer applied; (2) the amount of synthetic fertilizer applied, expressed as pounds per acre; (3) the depth at which such fertilizer was applied; (4) whether the applied synthetic fertilizer incorporated either a nitrification or urease inhibitor; and (5) a map depicting the locations on the Enrolled Land where synthetic fertilizer was applied.
   4. Description of Farmer’s application of organic fertilizer to the Enrolled Land, including: (1) the type of organic fertilizer applied; (2) the amount of organic fertilizer applied, expressed as pounds per acre; (3) the depth at which such organic fertilizer was applied; (4) whether such organic fertilizer incorporated either a nitrification or urease inhibitor; and (5) a map depicting locations on the Enrolled Land where organic fertilizer was applied.
   5. Description of Farmer’s application of any fertilizer other than synthetic or organic fertilizer to the Enrolled Land, including: (1) the type of fertilizer; (2) the amount of such fertilizer applied expressed as pounds per acre, (3) the ratio of carbon to nitrogen in the fertilizer applied; (4) the method used to apply the fertilizer; (5) the depth at which the fertilizer was applied; (6) the date(s) of application; and (7) a map depicting the location on the Enrolled Land where such fertilizer was applied.
   6. Description of irrigation practices on the Enrolled land, including: (1) the amount of water applied, expressed as gallons per acre; and (2) the method used to irrigate.

G. After the Effective Date, Farmer shall report the information specified in Section I.E. above at least twice per year and also include (1) purchase receipts for all fertilizer applied to Enrolled Land; and (2) seed receipts for cover crops planted on Enrolled Land.

H. Farmer agrees to defer to Monitor’s determinations of Emissions.

I. Farmer accepts sole responsibility for yields on Enrolled Land.

J. Farmer shall not advertise, sell, or otherwise claim rights to any greenhouse gas emissions reductions generated on or by the Enrolled Lands during the term of this Agreement; Farmer agrees that Investor shall have exclusive ownership of and right to advertise, market, or otherwise claim credit for any greenhouse emissions reductions and carbon sequestration in soils on the Enrolled Lands, except as provided in Section III below.

K. If Farmer sells or rents Enrolled Land to a third party, Farmer shall condition such transaction on the requirement that the third party takes responsibility for compliance with this Agreement. Farmer shall also provide Investor at least 30 days' advance written notice of any plan to rent or sell Enrolled Land.

II. Investor's Agreement:

A. Investor shall pay Monitor to create the confidential Data Reporting Website and maintain it at Investor's expense.
B. Investor shall pay Farmer a lump sum on or before [date] of each year that this Agreement is in effect, except as provided in Section III below.
C. Each year of this Agreement, Investor shall pay Farmer the Guaranteed Payment plus the Premium Payment, if the Premium Payment is applicable.
D. Investor shall maintain confidentiality of any data Farmer provides to Investor or Monitor.
E. All information that Farmer reports to the Data Reporting Website is Farmer's property.
F. Investor shall indemnify Farmer for damages resulting from Investor's or Monitor's breach of this confidentiality agreement.
G. Emissions data and reports pertaining to Enrolled Land that Monitor produces shall belong to Farmer.
H. Investor shall defer to Monitor's determinations of Emissions.
I. Investor shall have the option to terminate the Agreement if Farmer sells or rents Enrolled Land to a third party.

III. Monitor's Agreement:

A. By entering into this Agreement, Monitor represents that it has expertise using the Denitrification-Decomposition model developed by the University of New Hampshire to calculate emissions.
B. Monitor shall calculate Expected Emissions taking into account potential uncertainty in the modeling, and shall report Expected Emissions to Investor and Farmer no later than 30 days after Farmer initially submits information to the confidential Data Reporting Website.
C. Monitor shall calculate Emissions and Expected Emissions semi-annually, taking into account potential uncertainty in the modeling, so long as this Agreement is in force.
D. Monitor shall independently obtain any additional data necessary to calculate Emissions and Expected Emissions.
E. Monitor shall maintain the Data Reporting Website in serviceable condition. The Data Reporting Website is serviceable if it permits Farmer to upload information and if it permits the Monitor to access such information.

IV. Remedies for Breach

A. If Investor fails to pay Farmer as required by this Agreement, Farmer shall regain rights to any greenhouse gas emissions reduction credits achieved by Farmer.
B. If Investor or Monitor fails to maintain the confidentiality of Farmer's submittals, Investor shall indemnify Farmer for resulting damages.

C. If Farmer fails to plant Cover Crops during one of the five winter planting seasons following the Effective Date for whatever reason, then Farmer may, in its sole discretion, extend this Agreement for one year by providing written notice to the Investor. In such an event, Farmer's and Investor's respective obligations under this Agreement shall be suspended for one year.

D. If Farmer fails to plant Cover Crops during any two of the five winter planting seasons that follow the Effective Date without re-negotiating this Agreement with Investor, then this Agreement shall automatically be terminated. Farmer shall not be entitled to any further payments from Investor. Farmer shall refund to Investor payments made by the Investor during the year before the Agreement's termination. Investor shall retain rights to any greenhouse gas emissions reduction credits or offsets achieved as a result of Investor's payments to Farmer.

E. If this Agreement will prevent Farmer from securing crop insurance subsidized by the Federal Crop Insurance Corporation or cause Farmer to lose crop insurance subsidized by the Federal Crop Insurance Corporation, then this Agreement may be terminated by Farmer by providing written notice to Investor. If Farmer has already planted cover crops pursuant to this Agreement, then Investor shall compensate Farmer as required by this Agreement until the September 1st following termination.

F. If Investor fails to pay Monitor, Monitor may terminate its services, provided that its agreement to maintain confidentiality of Farmer's information shall survive termination of this Agreement.

G. If Monitor fails to provide its calculations and reports on a timely basis, Investor may replace Monitor with another firm.

H. If Farmer markets, sells, or otherwise claims or transfers credit for any greenhouse gas emissions reductions achieved by this Agreement, then Farmer shall refund to Investor the Guaranteed Payments and Premium Payments applicable to such emissions reductions.

V. Change of Law or Regulation

A. Farmer shall notify Investor in writing or by email no later than 15 days after learning that any federal, state, county, or local law passed after the Effective Date will prevent Farmer from performing this Agreement.

B. Investor shall notify Farmer in writing or by email no later than 15 days after learning that any federal, state, county, or local law passed after the Effective Date will prevent Farmer or Investor from performing this Agreement.

VI. Change of Control of Enrolled Lands

A. Farmer shall promptly notify Investor of any plan to lease, rent, sell, or otherwise change control of the Enrolled Lands.

B. Investor, in its sole discretion, may agree to continue or modify this Agreement in such event.

VII. Termination of Agreement

A. If Farmer files for bankruptcy, Investor shall have the sole discretion to terminate or continue this Agreement.

B. If any federal, state, county, or local law passed after the Effective Date will prevent Farmer from performing this Agreement, then this Agreement may be terminated by Farmer. Neither Investor nor Farmer will be held liable for such termination. Investor is required to compensate Farmer as if the Agreement continued until the September 1st following termination if Farmer has planted Cover Crops for which Investor has not yet compensated Farmer. Farmer is entitled to retain any compensation paid by Investor before the Agreement is terminated; Investor is entitled to retain rights to any greenhouse gas emissions reductions achieved by Farmer as a result of this Agreement.

VIII. Integration

A. This Agreement constitutes the entire Agreement between Farmer and Investor. There are no representations or other Agreements, oral or written, between Farmer and Investor other than as set forth in this Agreement.

IX. Modification

A. This Agreement may not be modified or replaced, in whole or in part, except by written amendment signed by both Investor and Farmer.

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Investor	**Farmer**
By: ______________________	By: ______________________
Print: ____________________	Print: ____________________

Monitor

By: ______________________

Print: ____________________

Attachment A

Map of Enrolled Land - Please Partition into One-acre Segments
Narrative Description of Enrolled Land

APPENDIX B: DNDC Sample Model Farm Projections

The DeNitrification-DeComposition (DNDC) model is an extensively reviewed and verified tool for predicting greenhouse gas emissions from agro-ecosystems based on readily available meteorological, geographic, and farm-specific data. The model calculates the emissions reductions achieved by cover cropping by estimating nitrogen and carbon cycling through the agro-ecosystem to predict crop growth, soil carbon dynamics, and, most importantly, nitrogen cycling and greenhouse gas emissions (CO_2, N_2O, CH_4).[1] The model can simulate five-year prediction scenarios for nitrogen fluctuations within the ecosystem using real-world data provided by the participating farms. Verification studies across the United States, China, Japan, and Canada have confirmed the accuracy of the DNDC model's predicted emissions fluxes against real-world agricultural emissions productions and thus its reliability. The model's simplicity provides benefits to the farmer and the investor as emissions projections can be quickly evaluated on a semi-annual basis. DNDC uses a simple interface with basic inputs. The transactional costs associated with running the model long term will require minimal financial and time investment for all parties, including the farmer, the investor, and the monitor.

We tested the model ourselves using illustrative data. Our example demonstrates that a typical farm in the Midwest will successfully achieve reductions in nitrous oxide and carbon dioxide emissions by planting legume cover crops that enable the farmer to reduce its use of fertilizers (both synthetic and organic). The sample results also demonstrate meaningful soil carbon sequestration will occur as a result of the cover cropping and yields of corn and soybeans will be constant or better. The inputs and calculations are explained below.

Inputs

Input variables and the parameters for the model farm are listed in detail below:

> *Timeline*. To simulate a real-world agricultural system, both baseline and cover crop models were run over 60-year farming periods with crop rotation between corn and soybean crops. The first 50 years were used to ensure maximal yield were achieved and soil conditions matched those of a heavily- used agricultural land. The last 10 years in the baseline model were used for comparison with the cover crop model to simulate 5 corn growing seasons and 5 soybean growing years (*i.e.*, a five-year period for each type of crop).
>
> *Site*. We input data from an actual farm located in Story City, Iowa that was used in a previously published paper using the DNDC model to evaluate agricultural management practices.[2] This farm was chosen because it is representative of Midwestern farming due to its central location. Iowa is also known for a high production of corn and soybean crops which were the crops chosen for the simulated model.

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[1] Institute for the Study of Earth, Oceans and Space University of New Hampshire (2012) User's Guide for the DNDC Model. http://www.dndc.sr.unh.edu/model/GuideDNDC95.pdf

[2] N. Farahbakhshazad et al. (2007) Modeling biogeochemical impacts of agricultural management practices for row-crop field in Iowa. Agriculture Ecosystems & Environments, 123(1-3), 30-48. https://doi.org/10.1016/j.agee.2007.04.004

Climate. Weather and climate patterns have important implications for the flux of greenhouse gases in the agroecosystem. The cycling of GHG is dependent on outside air temperature and precipitation patterns, which impact emissions. We obtained detailed climate inputs from Daymet-NASA and included information on minimum and maximum temperature (°C) and precipitation (mm) values for the site at coordinates (42.164, -93.603).[3] Model background ambient air measures for the site were 407.4 ppm[4] for CO_2 and 0.28 ug N/m^3 for background NH_3 concentrations.[5] Assumptions of no acid rain or increases in ambient air carbon dioxide concentrations were made for model simplicity.

Soil. Soil cycling of nitrogen and carbon is critical to the understanding of soil carbon sequestration and GHG emissions from agricultural systems. The model inputs regarding soil health and quality we used were drawn from previously published literature and geographic information. Soil type (Sandy Loam) was the same soil type used in the previously mentioned study about a farm in Story City, Iowa. Additional soil data including bulk density of 1.15, pH of 6.0 and soil organic carbon (SOC) of 0.025 kg C / kg soil were also obtained from that study. For generalizability across Midwestern farms some soil model defaults were used, such as initial nitrogen concentration at soil surface, microbial activity, slope, salinity, and rainwater collection index.

Crops (Corn and Soybeans). Crop management and rotation is crucial for GHG emission quantification. Traditionally farmers practice crop rotation to prevent soil nutrient depletion. Typical rotations for a Midwestern farm include corn and soybeans as these crops are subsidized by the government and economically viable in large scale operations. We used the dates of May 1st for corn crop planting and October 20th for harvesting.[6] We assumed dates of May 20th for soybean crop planting and October 15th for harvesting.[7]

Cover Crops. The cover crop chosen for this model system was crimson clover seed, which is a legume.[8] We assumed that cover crops were planted on September 15th and harvested on April 30th.[9] For maximum emissions reduction and carbon sequestration, the cover crops were used after both corn and soybean crops through the winter and early spring season over a five-year period for each crop.

Tillage. Tillage is the agricultural preparation of land for planting. This normally involves the overturning of soil to increase oxygen flow and control weed growth. Best practices for farm

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[3] NASA (2020). Single Pixel Extraction Tool. Daymet ORNL DAAC. https://daymet.ornl.gov/single-pixel/

[4] R. Lindsey (2020) Climate Change: Atmospheric Carbon Dioxide. NOAA Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

[5] U.S. EPA (2016) Toxicological Review of Ammonia Noncancer Inhalation: Executive Summary. https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0422_summary.pdf

[6] Iowa State University Department of Agronomy (2020). Crop and Climate Calendars, Iowa Crop Calendars, Corn http://agron-www.agron.iastate.edu/courses/Agron541/classes/541/lesson03a/3a.2.html

[7] Iowa State University Department of Agronomy (2020). Crop and Climate Calendars, Iowa Crop Calendars, Soybeans http://agron-www.agron.iastate.edu/courses/Agron541/classes/541/lesson03a/3a.2.html

[8] USDA, SARE (2012) Types of Cover Crops. https://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition/Text-Version/Cover-Crops/Types-of-Cover-Crops

[9] K. Koehler-Cole (2019) Optimum Planting Times to Establish Cover Crops Following Corn. University of Nebraska-Lincoln, Cropwatch. https://cropwatch.unl.edu/2019/research-optimum-planting-times-cover-crops

management are moving towards conservation tillage or no-till procedures. Increased tillage can increase nitrous oxide emissions. The modeled simulations utilized no-till practices.[10] We assumed that mulching applications (where no soil is overturned) were done at the time of either corn or soybean planting and after harvest to maximize soil health.

Fertilization. The major determinant of nitrogen emissions is fertilizer use and application rate. Excess fertilizer use is often responsible for high nitrous oxide emissions and can lead to runoff and diminish water quality. Fertilizer is applied to crops at various points throughout the growing cycle. This is true for both corn and soybean growth in Midwestern states. As soybeans are a legume, we assume that additional fertilizer is only applied during corn growing seasons. The baseline model assumed a total fertilizer application rate of 218.56 kg of N /ha (195 lbs. per acre)[11] in the form of urea delivered evenly over three application cycles in May, June, and August.[12] The baseline model also assumes a total phosphorus application rate of 69 kg of P /ha in the form of phosphate delivered evenly over the same three application cycles.[13] The cover crop model uses the same fertilizer projections as the baseline model for the first 50 simulated years and continued the use of 218.56 kg N per hectare for the first corn growing cycle after starting cover crop use. As phosphorus does not significantly contribute to GHG emissions, the three phosphate applications are kept constant in the cover crop model. We calculate estimated fertilizer reductions based on USDA projections for every corn growing season after the use of cover crops; this is shown in Table 1.[14]

Table 1: Fertilizer Use Reduction on Corn after Start of Cover cropping

Years after start of cover cropping	Use of fertilizer after cover cropping begins (kg of N /ha)	Amount of fertilizer reduced each year (kg of N /ha)
1	218.58	0
2	187.74	30.84
3	156.93	61.65
4	148.5	70.08
5	140.1	78.48
Total	**851.85**	**241.05**

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[10] USDA, NRCS (2012) Conservation Practice Standard Overview. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1254982.pdf

[11] D. Kaiser (2018) Fertilizing corn in Minnesota. University of Minnesota Extension. https://extension.umn.edu/crop-specific-needs/fertilizing-corn-minnesota

[12] SMART Fertilizer Management (2020) Timing and Frequency of Fertilizer Application. https://www.smart-fertilizer.com/articles/timing-fertilizer-application/

[13] USDA, National Agriculture Statistics Service. (2019) Iowa Ag News-Chemical Use. https://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/Other_Surveys/2019/IA-Ag-Chem-Corn-Soybeans-2019.pdf

[14] USDA, SARE. (2012) When Fertilizer Costs are High or Manure Nutrients Need to be Sequestered. https://www.sare.org/Learning-Center/Bulletins/Cover-Crop-Economics/Text-Version-of-Cover-Crop-Economics/An-In-Depth-Look-at-Management-Situations-Where-Cover-Crops-Pay-Off-Faster/When-Fertilizer-Costs-are-High-or-Manure-Nutrients-Need-to-be-Sequestered

Manure. Manure is an additional nitrogen source often added to soil to promote crop growth; sometimes it is used as a substitute for synthetic fertilizer. Although manure can be a significant source of nitrogen for an agro-ecosystem, for purposes of our simulation of the model, we assumed a no-manure system because not all farmers have access to a reliable source of manure. The monitor would modify this input to reflect farm-specific practices.

Irrigation. The amount and type of irrigation impacts nitrogen flux. Avoiding excess irrigation is important for managing greenhouse gas emissions. Our model location is in Iowa, which historically had sufficient rainfall to satisfy crop growth needs without irrigation systems.[15] Due to climate change, the Midwest has been receiving increasing amounts of rainfall and a larger number of extreme rainfall events, making irrigation potentially detrimental to crop growth.[16]

Grazing and Cutting. Grazing is the practice of allowing animals to feed on farmland. Grazing can be beneficial and cost effective for the agro-ecosystem. Although grazing systems are utilized throughout the Midwest, our modeling simulation does not include inputs regarding grazing.

Flooding. The model allows inputs for flooding events; however, we did not include potential flooding in our model simulation.[17]

Plastic Film Usage. Plastic film can be used as a substitute for mulch and has been shown to decrease greenhouse gas emissions in addition to controlling weeds and conserving water. Use of plastic film has been identified as a potential drawback to instituting cover cropping.[18] However, due to its overall lack of adoption by farms in the Midwest, we did not include it in our inputs to the model.

Using the above-described inputs, both the baseline and cover crop scenarios were run through a 60-year simulation. The last ten years of each 60-year simulation were used for comparison calculations; as described above, this includes a five-year simulation each for corn and soybeans. Cover crop model inputs are summarized in Table 2. All inputs remained the same for the baseline model with the use of 1 cropping system lasting 60 years with three fertilizer applications of 72.86 kg N / ha of Urea and 23 kg P / ha of Phosphate and no implementation of cover crops. Both baseline and cover crop models were simulated assuming 500 acres of corn and 500 acres of soybean in the first year with corn and soybean rotations throughout each five-year partnership period. All geographic and background data as well as soil data was consistent between the two models to eliminate potential error or confounding in emissions reductions.

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[15] C. Hadish, (2012) Some Iowa farmers turning to irrigation to help crops. The Gazette. https://www.thegazette.com/2012/07/28/some-iowa-farmers-turning-to-irrigation-to-help-crops

[16] NCA (2014). Midwest. https://nca2014.globalchange.gov/highlights/regions/midwest

[17] California Rice. (2020) How Rice Grows. https://calrice.org/industry/how-rice-grows/

[18] W. Nan et al. (2016) Effects of plastic film mulching on soil greenhouse gases (CO_2, CH_4 and N_2O) concentration within soil profiles in maize fields on the Loess Plateau, China. Journal of Integrative Ag. 15(2), 451-464. https://doi.org/10.1016/S2095-3119(15)61106-6

Table 2: Inputs for Cover Crop Model

Variable	Input Value
Geographic and Background Data	
Longitude	42.164
Climate	NASA Daymet: Using geographic coordinates (42.164, -93.603)
Simulated Years	60
Rainfall N Concentration (ppm)	0
Atmospheric background NH_3 (ug N/m^3)	0.28
Atmospheric background CO_2 (ppm)	407.4
Annual increase rate of atmospheric CO_2 (ppm)	0
Soil Data	
Land- Use	Upland Crop Field
Soil Texture	Sandy Clay
Bulk Density	1.15
Soil pH	6.0
SOC at surface soil (kg C / kg soil)	0.025
Initial N concentration at surface soil (mg N/ kg) Nitrate, Ammonium	0.50, 0.05
Microbial Activity Index (0-1)	1
Slope (0-90 degrees)	0
Soil Salinity Index (0-100)	0
Rain Water Collection Index	1
Cropping Data (6 Cropping Systems)	
Cropping System Number	1
Years this cropping system lasts	50
Years of a cycle within this cropping system	2
Cropping System Number	2
Years this cropping system lasts	2
Years of a cycle within this cropping system	2
Cropping System Number	3
Years this cropping system lasts	2
Years of a cycle within this cropping system	2
Cropping System Number	4
Years this cropping system lasts	2
Years of a cycle within this cropping system	2
Cropping System Number	5
Years this cropping system lasts	2
Years of a cycle within this cropping system	2
Cropping System Number	6
Years this cropping system lasts	10
Years of a cycle within this cropping system	2
Farming Management Practices (Two Year Cycle)	
1st Year Cycle	
Crop Type	Corn
Planting Month	5/01
Harvest Month	10/20

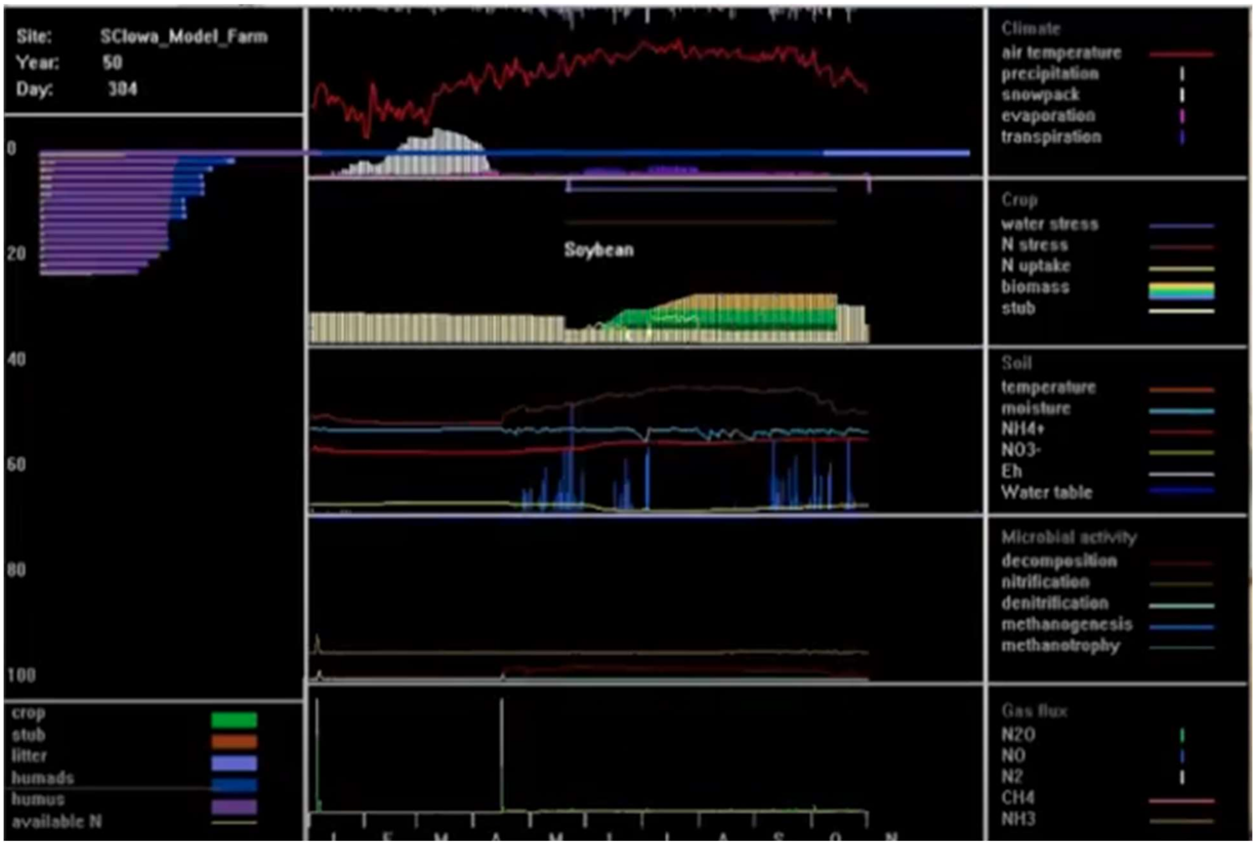
Crop Type	Legume Hay
Planting Month	9/15
Harvest Month	4/30
2nd Year Cycle*	
Crop Type	Soybean
Planting Month	5/20
Harvest Month	10/15
Crop Type	Legume Hay
Planting Month	9/15
Harvest Month	4/30
Constant Inputs for Farming Management Practices	
Tillage Application	2
Application Dates	Planting Date & 10/30
Tilling Method	Only mulching 0 cm
Fertilization (only applied in 1st year crop cycles)	
Applications	3
Application Dates	5/1, 6/15, 8/1
Baseline & First Year of Cover Cropping	
Applied Fertilizers for Each Application	Urea, Phosphate
Urea (kg N /ha)	72.86
Phosphate (kg P /ha)	23
Third Year of Cover Cropping	
Applied Fertilizers for Each Application	Urea, Phosphate
Urea (kg N /ha)	62.58
Phosphate (kg P /ha)	23
Fifth Year of Cover Cropping	
Applied Fertilizers for Each Application	Urea, Phosphate
Urea (kg N /ha)	52.31
Phosphate (kg P /ha)	23
Seventh Year of Cover Cropping	
Applied Fertilizers for Each Application	Urea, Phosphate
Urea (kg N /ha)	49.5
Phosphate (kg P /ha)	23
Ninth Year of Cover Cropping	
Applied Fertilizers for Each Application	Urea, Phosphate
Urea (kg N /ha)	46.7
Phosphate (kg P /ha)	23

*No fertilizers were applied to 2nd year cropping cycles with soybeans since they do not normally require fertilizer

Model Simulation

The DNDC model uses equations to calculate nitrogen and carbon flux within the agricultural system based on data input. The simulations simultaneously compile information on annual weather conditions, including: air and soil temperature and daily precipitation, and simulates crop growth between the planting and harvesting seasons based on nutrient and water availability. An example year of model simulation is below; it shows the parallel calculation of information.

Figure 1: Example model simulation



Window 1 (up-left corner) shows site name, simulated year, and crop type. Window 2 (middle-left) shows soil carbon and nitrogen profiles for 0-50 cm. Window 3 (top in the middle) shows daily air temperature, precipitation, snow-pack, evaporation, and transpiration. Window 4 (second in the middle) shows crop biomass, N uptake, water stress and N stress. Window 5 (third in the middle) shows soil temperature, moisture, Eh, ice content, available N, and water leaching flow. Window 6 (forth in the middle) shows daily rates of decomposition, nitrification, denitrification, methanogenesis, and methanotrophy. Window 7 (bottom-middle) shows daily fluxes of NH_3, CH_4, N_2O, NO, and N_2.

Calculations

As the model does not allow for simulation of field splitting, a common practice used by farmers, five corn and five soybean systems were modeled with a rotation over a ten-year period to account for five seasons of corn growth and five seasons of soybean growth. This model data was separated depending on whether it belonged to a corn or soybean growing season. Separate estimates were compiled and combined to simulate a 1,000-acre farm split evenly between corn (500 acres) and soybean (500 acres) in a rotational pattern for the five-year period. The calculations of total carbon dioxide (emissions and soil content), and nitrous oxide emissions reductions was conducted by multiplying the total kg/ha figure for corn CO_2 or N_2O reductions by 202.34 to simulate a 500-acre corn field. This was also done for 500 acres of soybean, taking the total kg/ha figure for soybean CO_2 or N_2O reductions by 202.34 to simulate a 500-acre soybean field. These two values were added together to give the total CO_2 or N_2O reductions for a 1,000-acre farm. This value was divided by 1,000 to give the kilograms per acre estimate of emissions reductions and divided by 1,000 again to give the metric tons per acre estimate of emissions reductions over the five-year period.

Total GHG emissions reductions were calculated in a similar manner. The three major GHGs included in the model CO_2, N_2O and CH_4 were all included in total GHG emissions calculations. All GHGs were first converted to CO_2 equivalents using their 100-year EPA global warming potential (GWP), N_2O has a GWP of 298 and CH_4 has a GWP of 25.[19] Total CO_2 equivalents were calculated separately for corn and soybeans by totaling CO_2 equivalent reductions for CO_2, N_2O and CH_4 on each respective 500 acre section. The totaled tons per acre figures were multiplied by 500, separately for corn and soybean, and added together. This figure was divided by 1,000 to give a ton per acre estimate of total CO_2 equivalent reductions over the five-year period.

Results

Crop Yields:

Over the 5 years of corn growth and 5 years of soybean growth, yields fluctuate slightly between the baseline model and cover crop model. There was no decrease in yield in any one given corn growing season. There was less than a 3% decrease in yield change in any one given soybean growing season with a trend upward in soybean yield during the last growing season.

[19] EPA Center for Corporate Climate Leadership. 2018. Emissions Factors for Greenhouse Gas Inventories. https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

Figure 2: Example Crop Yield Model Output

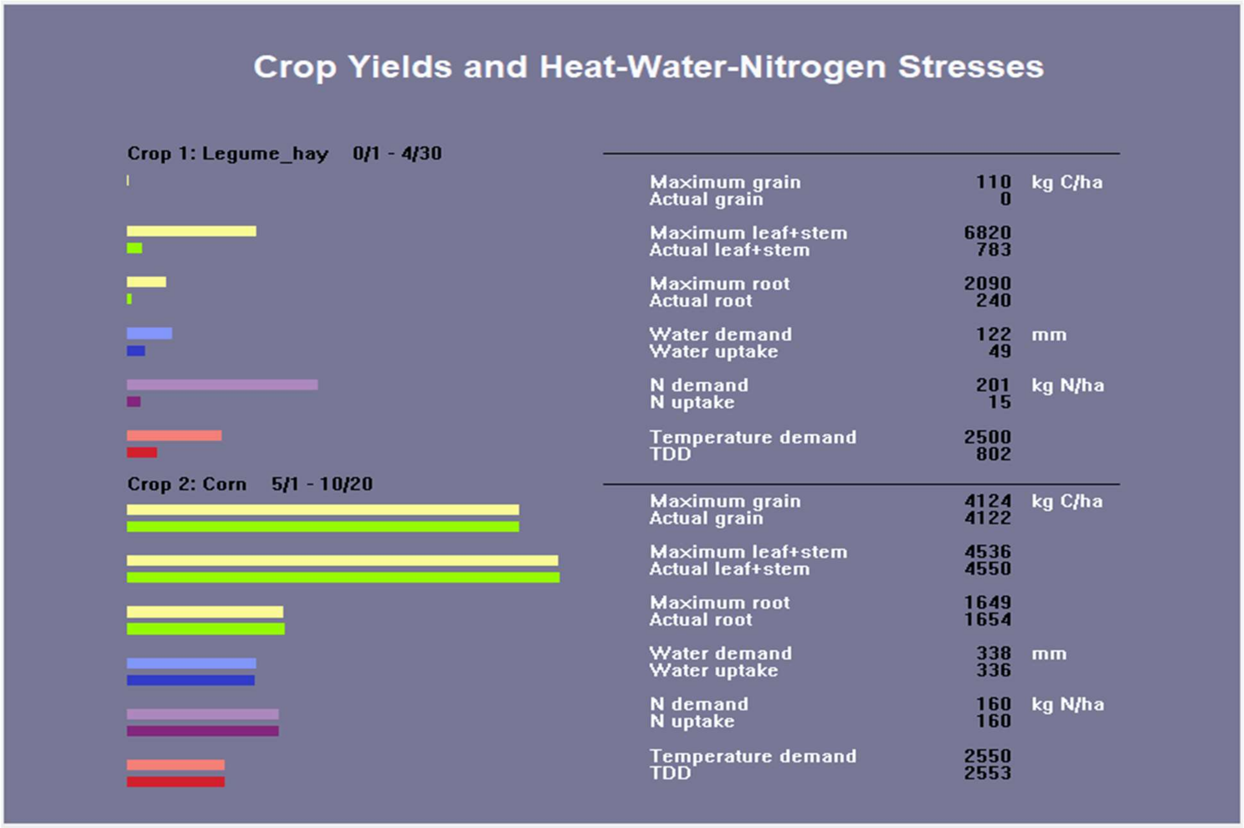


Table 3: Corn Yields over five growing seasons (Kg C/ha)

Year	Corn yields after cover cropping begins	Percent Change
1	4217.63	0.00
2	4174.31	0.01
3	4114.78	0.01
4	4119.14	0.01
5	4121.87	0.01
Total	**20747.73**	**0.01**

Graph 1: Corn yield over five years comparing baseline and cover crop models

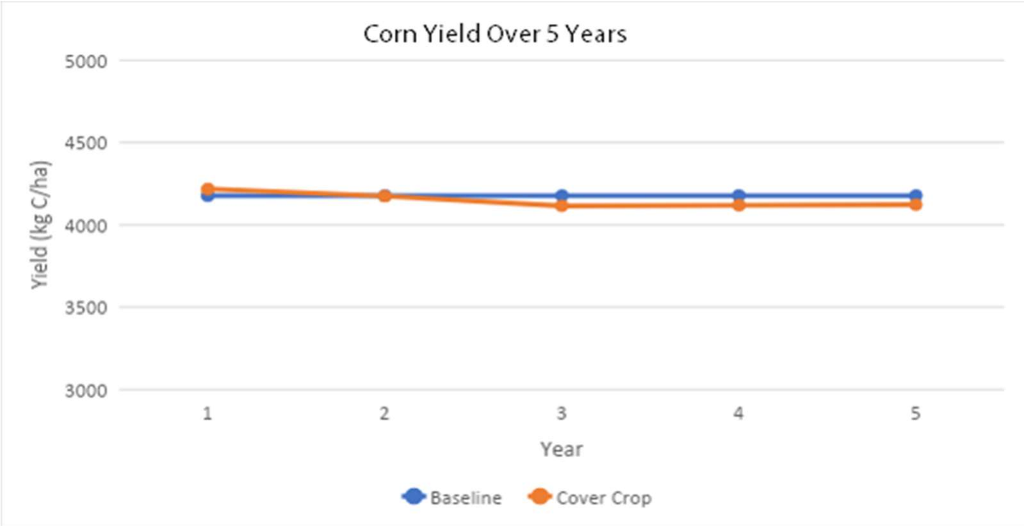
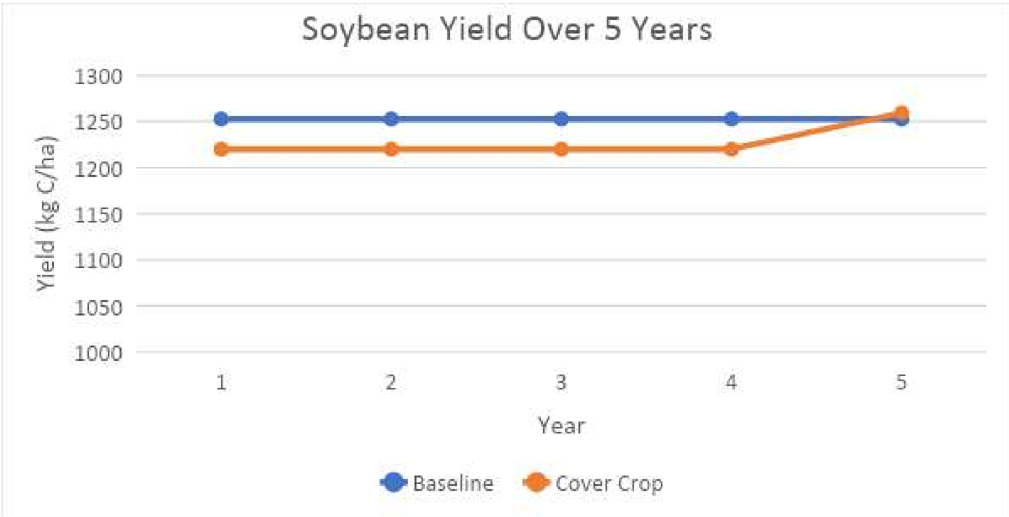


Table 4: Soybean yields over five growing seasons (Kg C/ha)

Year	Soybean yields after cover cropping begins	Percent Change
52	1219.93	2.61
54	1219.93	2.61
56	1219.93	2.61
58	1219.93	2.61
60	1259.27	-0.53
Total	**6138.99**	**1.98**

Graph 2: Soybean yield over five years comparing baseline and cover crop models



Carbon Cycling:

Throughout the five-year period instituting the use of cover crops and fertilizer reductions there was a decrease in the carbon dioxide emissions from the cover crop simulation when compared to the baseline simulation. Over the five-year period total carbon dioxide emissions reductions were 4.15 metric tons of CO_2 per acre. Additionally, a total of 12.02 metric tons of CO_2 per acre were sequestered in soils over the five-year period. This soil sequestration figure is accounted for by the model in the carbon flux calculations.

Figure 3: Example Carbon Flux Model Output

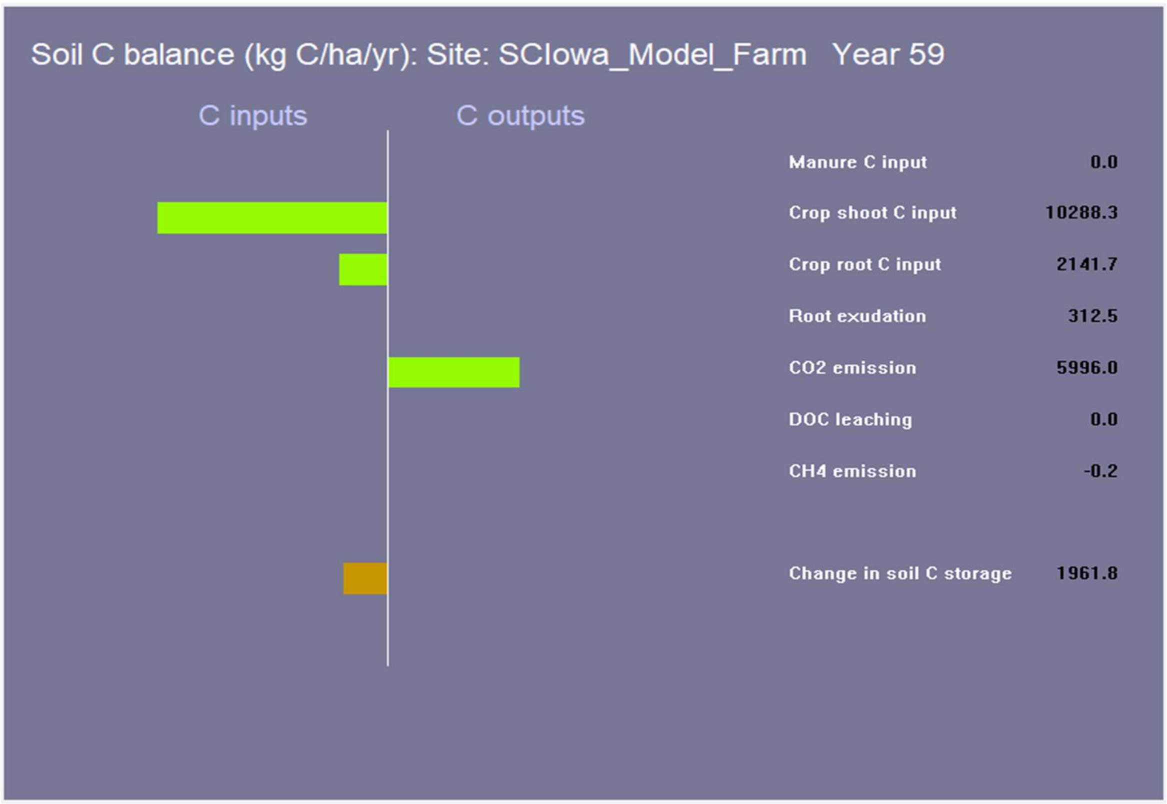


Table 5: Corn Carbon Emissions over five years

Year	Carbon emissions after cover cropping begins (Kg C /ha)	Emission reduction (Kg C /ha)	CO_2 Equivalents (Kg CO_2 Eq / ha)*
1	-1664.13	40.68	149.30
2	-2542.95	926.7	3400.99
3	-2133.36	524.12	1923.52
4	-1994.34	391.46	1436.66
5	-1961.77	364.75	1338.63
Total	**-10296.55**	**2247.71**	**8249.10**

*Note: One metric ton of carbon equals 3.67 metric tons of CO_2

Graph 3: Corn Carbon emissions over five years

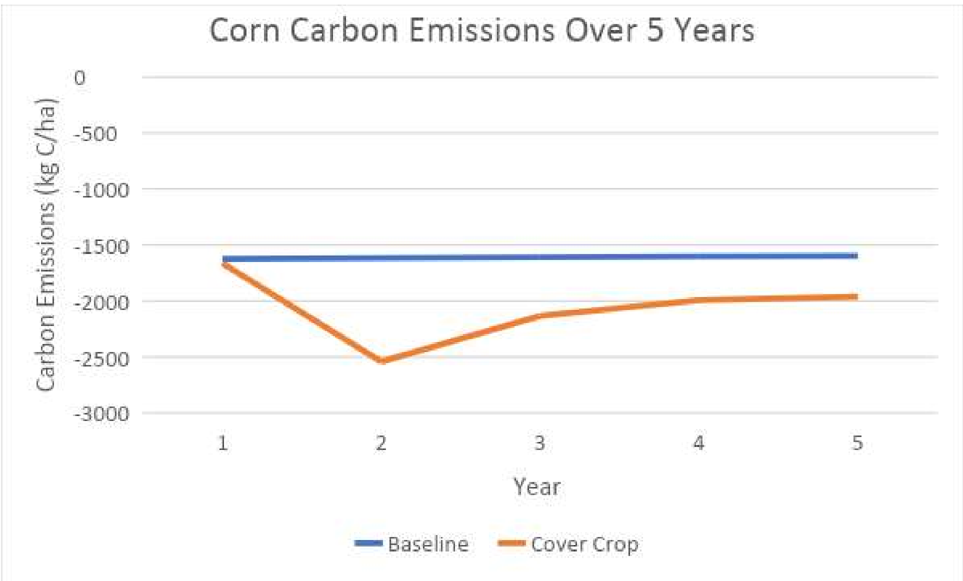


Table 6: Soybean Carbon Emissions over five years

Year	Carbon emissions after cover cropping begins (Kg C /ha)	Emission reduction (Kg C /ha)	CO_2 Equivalents (Kg CO_2 Eq / ha)*
1	233.09	977.92	3588.97
2	474.85	743.86	2729.97
3	632.4	592.83	2175.69
4	706.07	525.75	1929.50
5	744.05	493.95	1812.80

*Note: One metric ton of carbon equals 3.67 metric tons of CO_2

Graph 4: Soybean Carbon Emissions over five years

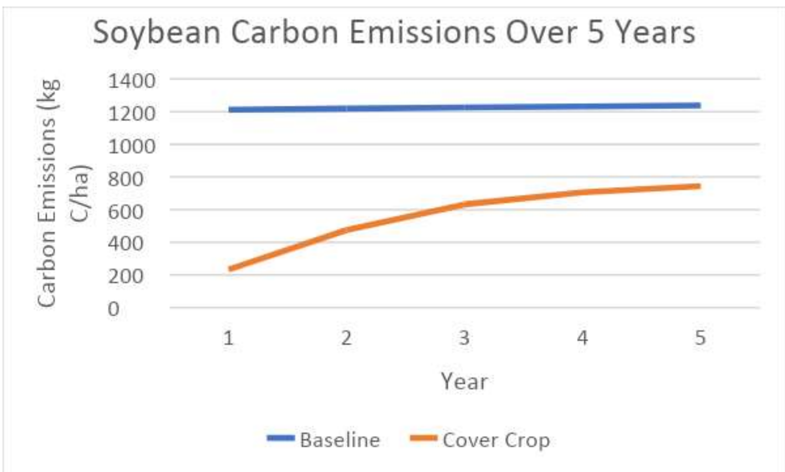


Table 7: Corn soil carbon content over five years (Kg C/ha)

Year	Soil carbon content after cover cropping begins (Kg C /ha)	Carbon sequestered (Kg C /ha)	CO_2 Equivalents (Kg CO_2 Eg / ha)*
1	3808.5	-13.76	-50.50
2	5262.7	1433.32	5260.28
3	5819.94	1983.53	7279.56
4	5963.29	2120.66	7782.82
5	5996	2147.53	7881.44
Total	**26850.43**	**7671.28**	**28153.60**

*Note: One metric ton of carbon equals 3.67 metric tons of CO_2

Graph 5: Corn soil carbon content over five years

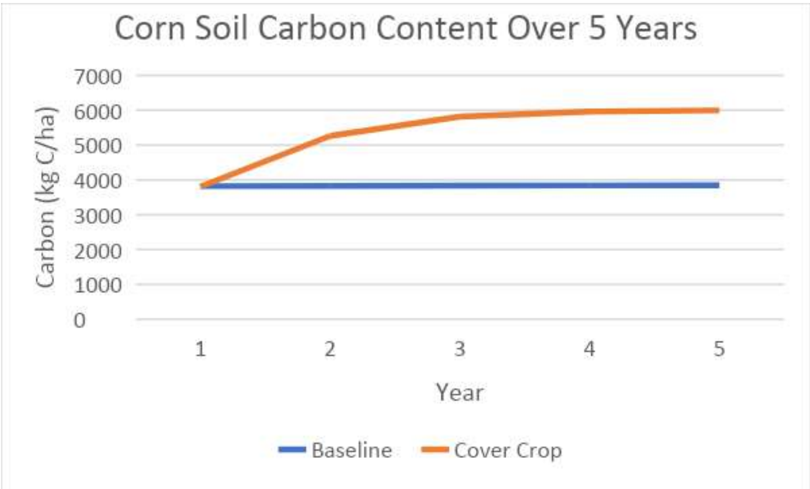
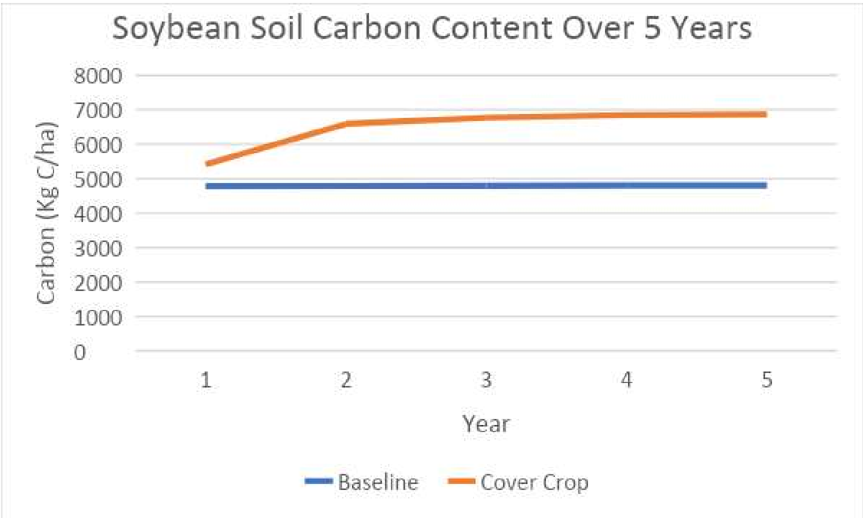


Table 8: Soybean soil carbon content over five years

Year	Soil carbon content after cover cropping begins (Kg C /ha)	Carbon sequestered (Kg C /ha)	CO_2 Equivalents (Kg CO_2 Eq / ha)*
1	5413.43	631.09	2316.10
2	6590.46	1800.52	6607.91
3	6773.4	1976.97	7255.48
4	6847.82	2044.92	7504.86
5	6868.47	2059.33	7557.74
Total	**32493.58**	**8512.83**	**31242.09**

*Note: One metric ton of carbon equals 3.67 metric tons of CO_2

Graph 6: Soybean soil carbon content over five years



Nitrous Oxide Cycling:

Throughout the five-year period after planting cover crops and reducing fertilizer use the model shows a decrease in nitrous oxide emissions when compared to the baseline simulation. Over the five-year period total nitrous oxide emissions reductions were 0.0034 metric tons of nitrogen per acre. Due to nitrous oxide's high global warming potential this translates to a total of 0.998 metric tons of CO_2 equivalents per acre over 5 years.

Figure 4: Example Nitrogen Flux Model Output

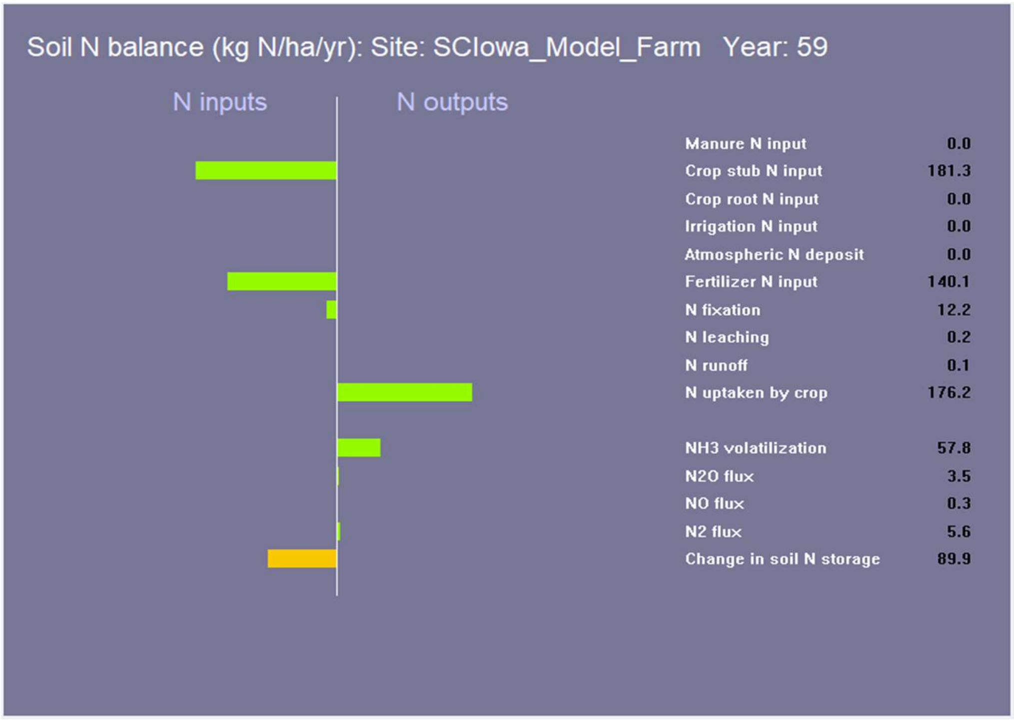


Table 9: Corn Nitrous Oxide emissions over five years

Year	Nitrous oxide emissions after cover cropping begins (Kg N /ha)	Emission reduction (Kg N /ha)	N_2O reduction (Kg N_2O / ha)	CO_2 Equivalents (Kg CO_2 Eq / ha)
1	3.74	0.83	1.30	388.32
2	3.75	0.92	1.44	430.43
3	3.59	1.17	1.84	547.40
4	3.38	1.47	2.31	687.75
5	3.47	1.46	2.29	683.08
Total	**17.93**	**5.85**	**9.18**	**2736.98**

Graph 7: Corn Nitrous Oxide emissions over five Years

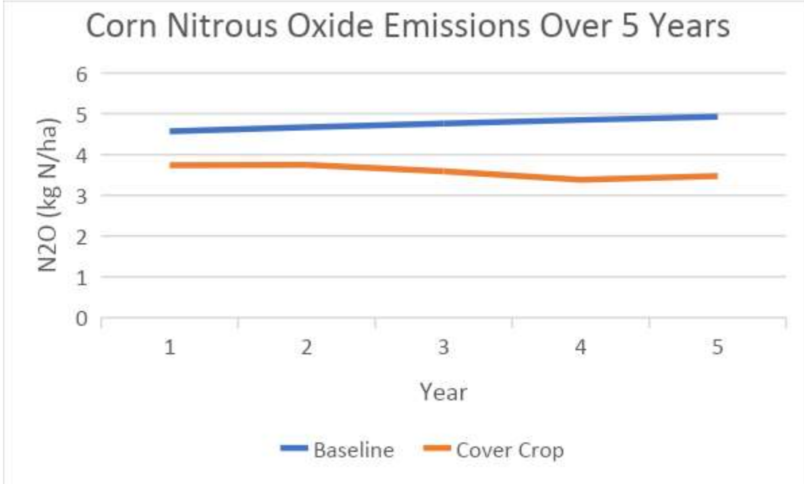
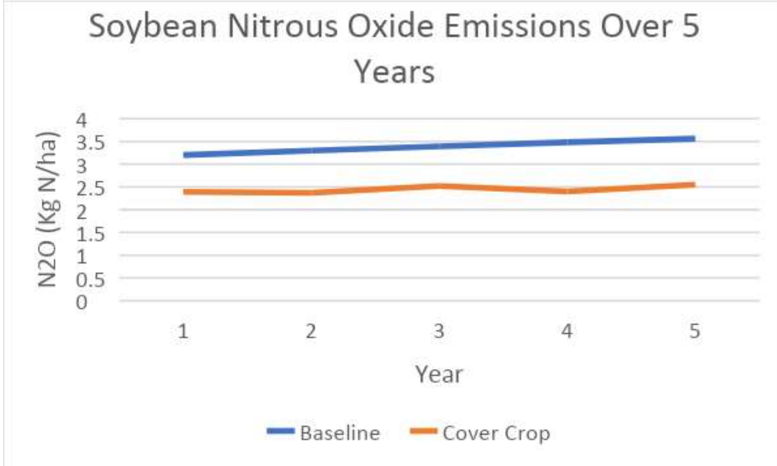


Table 10: Soybean Nitrous Oxide emissions over five years

Year	Nitrous oxide emissions after cover cropping begins (Kg N /ha)	Emission reduction (Kg N /ha)	N_2O reduction (Kg N_2O / ha)	CO_2 Equivalents (Kg CO_2 Eq / ha)
1	2.39	0.81	1.27	378.97
2	2.37	0.93	1.46	435.11
3	2.52	0.87	1.37	407.04
4	2.4	1.08	1.70	505.29
5	2.55	1.01	1.59	472.54
Total	**12.23**	**4.7**	**7.38**	**2198.94**

Graph 8: Soybean Nitrous Oxide emissions over five years



Total Greenhouse Gas Emissions

Throughout the five-year period after planting cover crops and reducing fertilizer use, the model shows a decrease in the total greenhouse gas emissions when compared to the baseline simulation. Over the five-year period total greenhouse emissions reductions were 5.08 metric tons of CO_2 equivalents per acre.

Figure 5: Example Total Greenhouse Gas Model Output

Greenhouse Gases: Site: SCIowa_Model_Farm Year: 59

Greenhouse gas	dSOC	N2O	CH4
Flux rate	-1962 kg C/ha	3.5 kg N/ha	-0 kg C/ha
GWP	-7193 kg CO2-equivalent/ha	1690	-6
Net GWP	-5509 kg CO2-equivalent/ha		

Table 11: Total GHG emissions for corn over five years (tons CO_2 Eq/acre)

Year	GHG emissions after cover cropping begins	Emission reduction
1	-1.74637428	0.21558376
2	-3.0343426	1.53283608
3	-2.46300752	0.98850064
4	-2.2982264	0.85003296
5	-2.23357068	0.80881724
Total	**-11.77552148**	**4.39577068**

Graph 9: Total GHG emissions for corn over five years

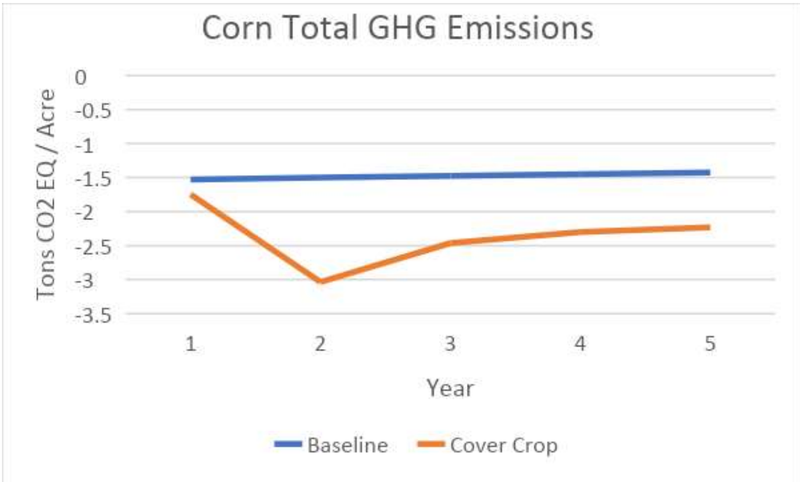
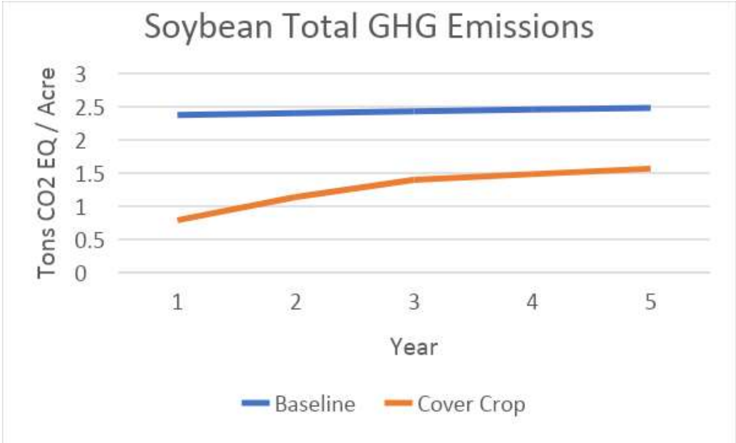


Table 12: Total GHG emissions for soybeans over five years (tons CO_2 Eq/acre)

Year	GHG emissions after cover cropping begins	Emission reduction
1	0.78703828	1.5870392
2	1.13819908	1.2658964
3	1.39755408	1.03295572
4	1.48311036	0.97391652
5	1.5669366	0.91413404
Total	**6.3728384**	**5.77394188**

Graph 10: Total GHG emissions for soybeans over five years



Impacts of Cover Cropping on GHG Emissions

Experimental studies have confirmed that cover crops actively contribute to the soil carbon sequestration process; however, the exact carbon sequestration amount depends on soil type, cover crop species, and baseline soil chemistry. A University of Nebraska-Lincoln study demonstrated that cover crops significantly contributed to soil aggregation and improved the soil's ability to sequester carbon. Their study found a 14% increase in soil particulate organic matter in cover cropping fields as compared to control sites.[20] A 2017 meta-analysis discussing the benefits of cover cropping practices on various field sites throughout the United States found a rate of soil carbon sequestration of 0.22 tons per acre per year.[21] Additionally, a study conducted by the USDA provided even more optimistic measures of soil carbon sequestration potential through the practice of cover cropping with the potential to sequester carbon at a rate of three tons per acre per year.[22] The modeling projections in our example show an emissions reduction on par with these published estimates at just over one ton per acre per year when combining cover cropping practices with decreased nitrogen fertilizer application rates.

DNDC Software

DNDC was specifically developed for carbon sequestration quantification and predicting GHG emissions on agricultural lands. Baseline farm conditions, as well as management practices, are calculated and

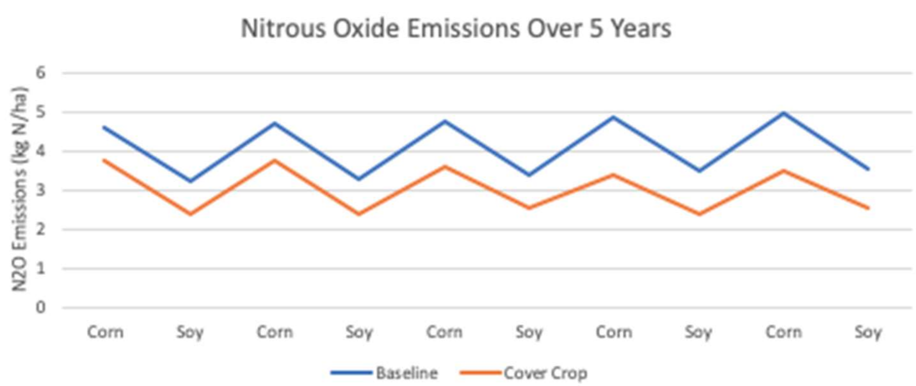
[20] J. McDowell (2019) Cover Crops and Carbon Sequestration: Benefits to the Producer and the Planet. University of Nebraska-Lincoln Institute of Agriculture and Natural Resources Cropwatch. https://cropwatch.unl.edu/2019/cover-crops-and-carbon-sequestration-benefits-producer-and-planet

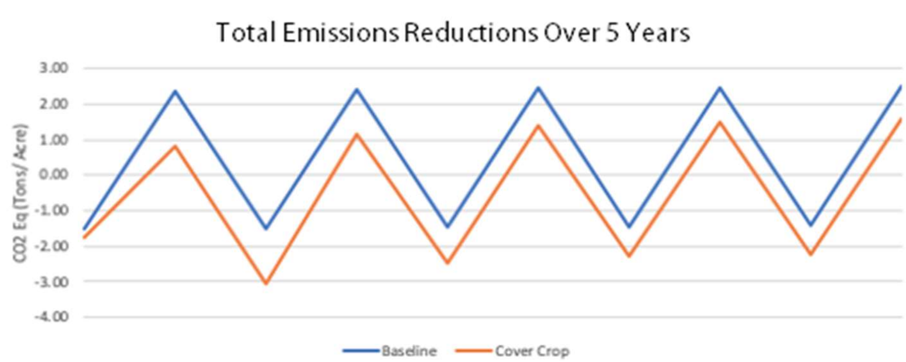
[21] Ruis, S.J., and H. Blanco-Canqui. (2017) Cover Crops Could Offset Crop Residue Removal Effects on Soil Carbon and Other Properties: A Review. Agronomy Journal 109(5): 1785.

[22] USDA Sustainable Agricultural Research & Education (2012) Cover Crops and Carbon Sequestration. https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops/Ecosystem-Services-from-Cover-Crops/Cover-Crops-and-Carbon-Sequestration

simulated over an allotted time frame to estimate emissions. Default options are provided based on the type of farmland for inputs where data may not be readily available. Emissions predictions are derived from quantification of microbe-mediated soil processes, including decomposition, nitrification, denitrification, fermentation, and methanogenesis.[23] The rates of these five processes are simulated based on soil and climate conditions and on inputted modifications to environmental conditions that may impact carbon or nitrogen cycling.

The model is divided into two components: environmental factors and gaseous flux. Environmental factors are agricultural concentration profiles based on ecological and geographic conditions (soil climate, crop growth, temperature, moisture, pH, Eh). Greenhouse gas fluxes are based on cycling-related to nitrification, denitrification, and fermentation, which can predict C and N gas emissions based on environmental factors. The modeled results combine carbon and nitrogen cycling, incorporating data about a variety of pertinent environmental factors. Figure 2 shows the full details of the modeled processes.





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23 Institute for the Study of Earth, Oceans and Space University of New Hampshire (2017) DNDC Version 9.5 Scientific Basis and Processes. http://www.dndc.sr.unh.edu/papers/DNDC_Scientific_Basis_and_Processes.pdf

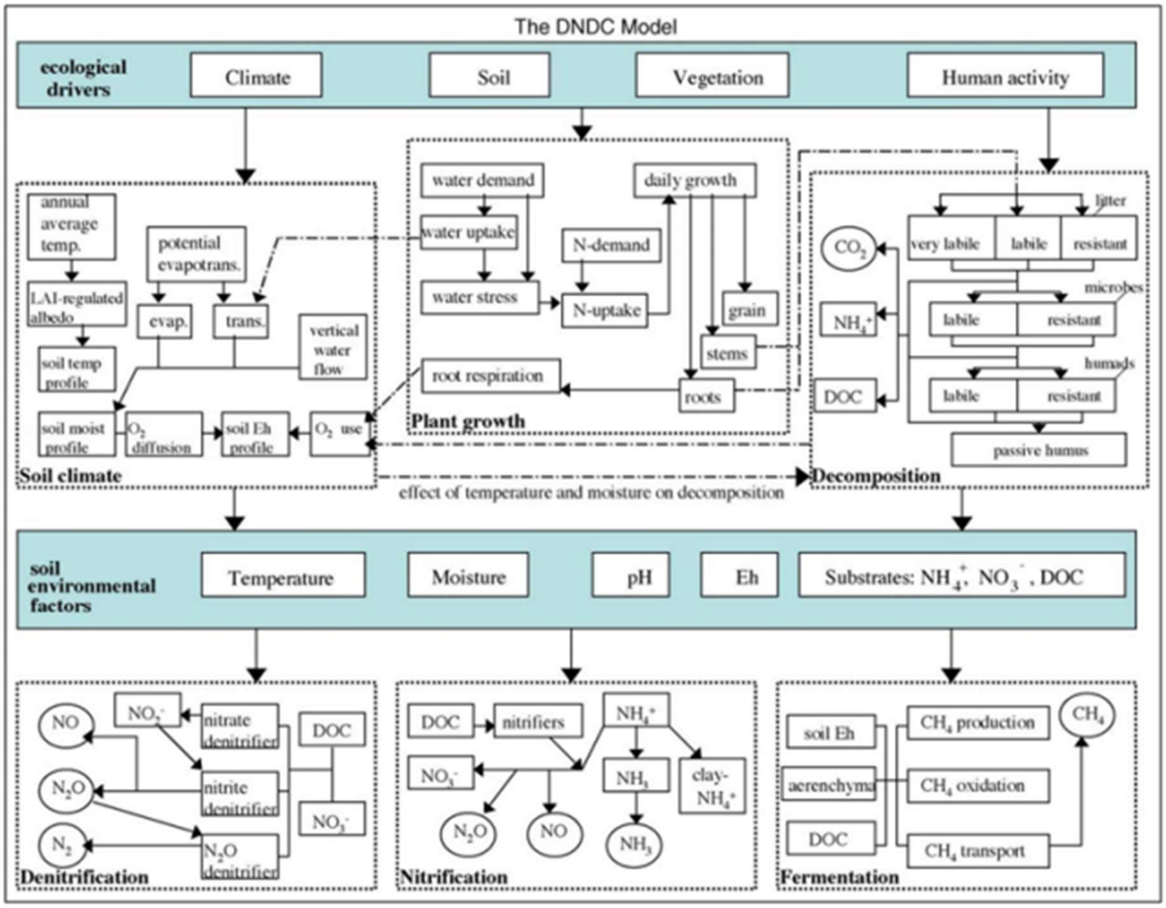

Figure 2: Modeled links between environmental factors and emissions cycling.[24]

DNDC is based on the hypothesis that greenhouse gases (CO_2, N_2O, CH_4) are the results of oxidation-reduction reactions where soil microbes act as mediators of electron exchange. Two primary equations are responsible for calculating GHG emissions: The Nernst Equation (Eq. 1) and the Michaelis-Menten equation (Eq. 2).

(1) Nernst Equation: Eh = E0 + RT/nF • ln([oxidant]/[reductant])

Eh is redox potential of an oxidation-reduction system (V), E0 is standard electromotive force (V), R is the gas constant (8.314 J/mol/k), T is absolute temperature (273 + t, ºC), n is transferred electron number, F is the Faraday constant (96,485 C/mol), [oxidant] is concentration (mol/l) of dominant oxidant in the system, and [reductant] is concentration (mol/l) of dominant reductant in the system.

[24] Institute for the Study of Earth, Oceans and Space University of New Hampshire (2017) DNDC Version 9.5 Scientific Basis and Processes. http://www.dndc.sr.unh.edu/papers/DNDC_Scientific_Basis_and_Processes.pdf

To simulate oxidation-reduction systems under anaerobic soil conditions, the Michaelis-Menten Equation is used. Without oxygen, microbes consume oxidants and lower soil Eh.

*(2) Michaelis-Menten Equation: F[oxidant] = a [DOC / (b + DOC)] * [oxidant / (c + oxidant)]*

F[oxidant] is the fraction of the oxidant reduced during a time step, Dissolved Organic Carbon (DOC) is the concentration of DOC, oxidant is the concentration of dominant oxidant in the oxidation-reduction system, and a, b, and c are coefficients.

Since these equations share a commonality of oxidant concentration, they can be mathematically related to account for soil microbe cycling simultaneously in aerobic and anaerobic conditions. Based on estimates of soil dynamics and cycling of reductive/oxidative reactions (including CO_2, N_2O, and CH_4), DNDC models denitrification and nitrification simultaneously to fully evaluate GHG fluxes within the agro-ecosystem.

The simulation of carbon and nitrogen cycling through the agricultural system is conducted using a series of equations to model decomposition, urea hydrolysis, NH_3 production and emission, and NH_3 absorption by plants. Relevant equations for GHG emissions are included in Table 2. A full listing of equations and processes models can be found in Appendix D, as well as in the DNDC Version 9.5 Scientific Basis and Processes.[25]

Table 2: DNDC Equations for GHG Emissions Projections

Process	Equation	Variables
Nitrification rate	RN=0.005* $[NH_4]$* Nitrifier* pH	$[NH_4+]$ = concentration of ammonium (kg N/ha) pH= soil pH
N_2O production through nitrification	N_2O=0.0024*RN	RN=Nitrification Rate
Consumption of DOC and CO_2 production through denitrification	dc/dt=(u/Yc+Mc)dCO_2/dt=dc/dt-dDenitrifier/dt	Mc=maintenance coefficient of C Yc=maximum growth yield on soluble carbon

[25] DNDC (Version 9.5) Scientific Basis and Processes. (2017) Institute for the Study of Earth, Oceans, and Space University of New Hampshire. http://www.dndc.sr.unh.edu/papers/DNDC_Scientific_Basis_and_Processes.pdf

Model Verification and Accuracy

The DNDC model has been extensively evaluated against real-world datasets and compared against monitoring data. A 2014 Biogeosciences study used the model to simulate various management practices on agricultural outcomes, including yield, GHG emissions, runoff, and nitrate leaching. The model was assessed to be an accurate predictor of future biogeochemical cycling.[26] A 2016 study in China also confirmed the validation of modeled results in vineyard systems. The study concluded DNDC has powerful predictive and verification power for greenhouse gas emissions.[27] DNDC has been included in additional studies to confirm results with real-world data, and the model is continuously updated and improved with new input parameter specificities and improved modeling estimates. A verification study was conducted on onion and carrot fields in Japan with additional applications of nitrogen fertilizer. The model estimates of N_2O flux were compared to observed field N_2O emissions data based on seasonal patterns (Figures 5 and 6) and confirmed the model's prediction accuracy.[28] An additional study conducted in Canada found a 3% overestimation by the DNDC model in comparison to N_2O field samples during the calendar year (Figure 6)[29]. The DNDC model is continuously edited and reconfigured based on field data to ensure the most accurate predictions possible. Project contracting with the monitor will ensure the latest model with the highest degree of confirmed accuracy is used to predict, monitor, and verify GHG emissions reductions.

[26] F. Cui et.al. (2014) Assessing biogeochemical effects and best management practice for a wheat–maize cropping system using the DNDC model. Biogeosciences, 11, 91–107. https://doi.org/10.5194/bg-11-91-2014

[27]Y. Zhang et al. (2016). Application of the DNDC model to estimate N2O emissions under different types of irrigation in vineyards in Ningxia, China. Agricultural Water Management,163, 295-304. https://doi.org/10.1016/j.agwat.2015.10.006

[28] Cai et. al. (2003) Field validation of the DNDC model for greenhouse gas emissions in East Asian cropping systems. Global Biogeochemical Cycles, 17(4). doi:10.1029/2003GB002046

[29] W.N. Smith et. al. (2002) Testing the DNDC model using N_2O emissions at two experimental sites in Canada. Canadian Journal of Soil Science, 82(3), 365-374. https://doi.org/10.4141/S01-048

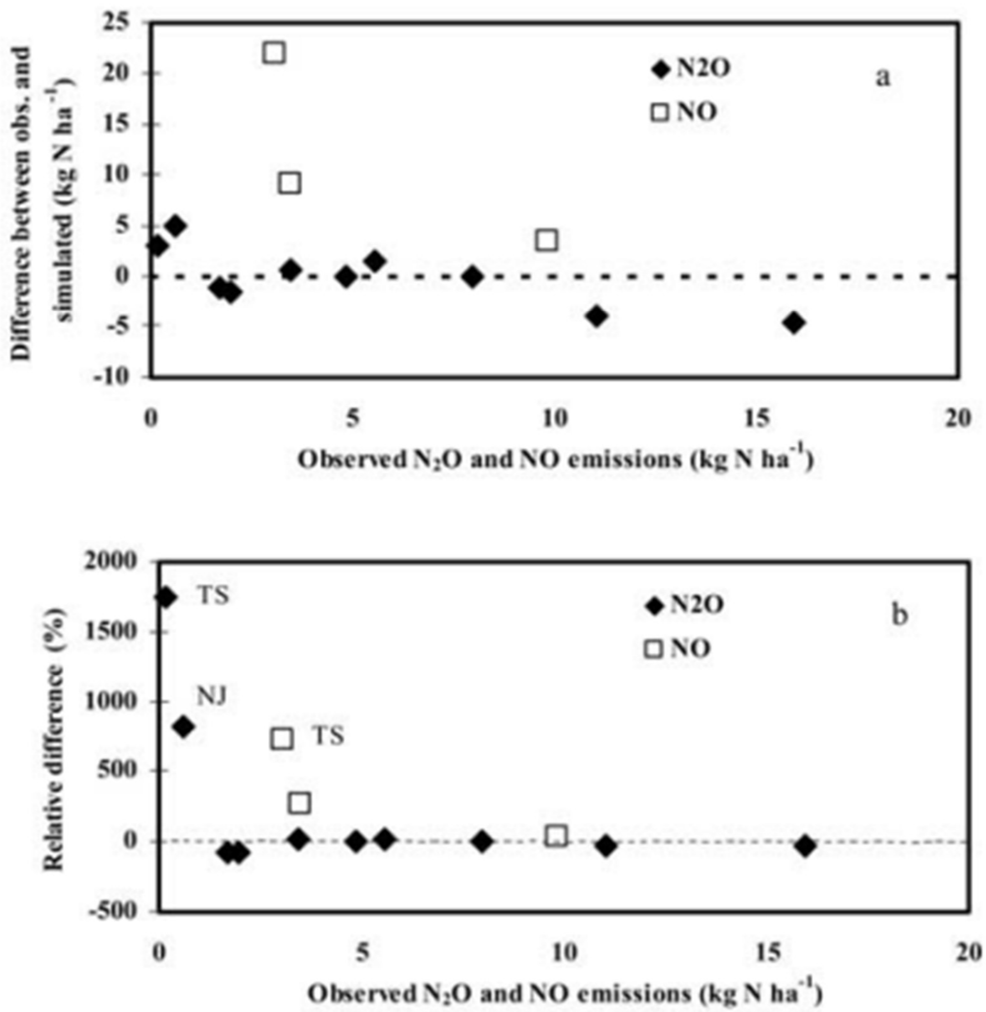

Figure 4: Comparison between observation and DNDC simulation of N_2O and NO emissions, respectively, indicating (a) absolute and (b) relative differences; record labels are only given for strong deviations (>50%) between observed and simulated values.

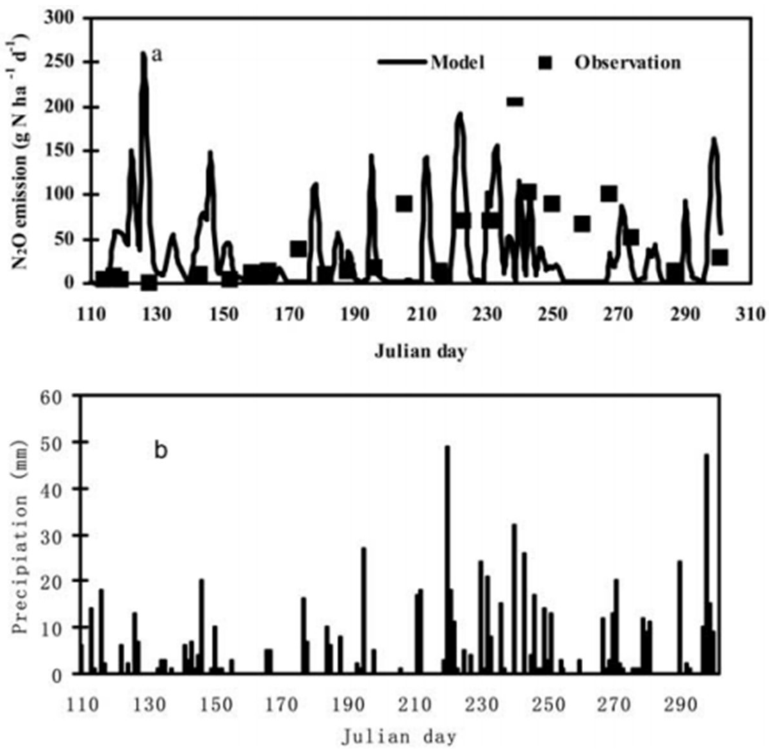

Figure 5: (a) Comparison between observation and DNDC-simulation of seasonal patterns of N_2O emission indicating absolute differences and (b) concomitant precipitation for lowland soil under onion production in Mikasa, Hokkaido/Japan in 1995.

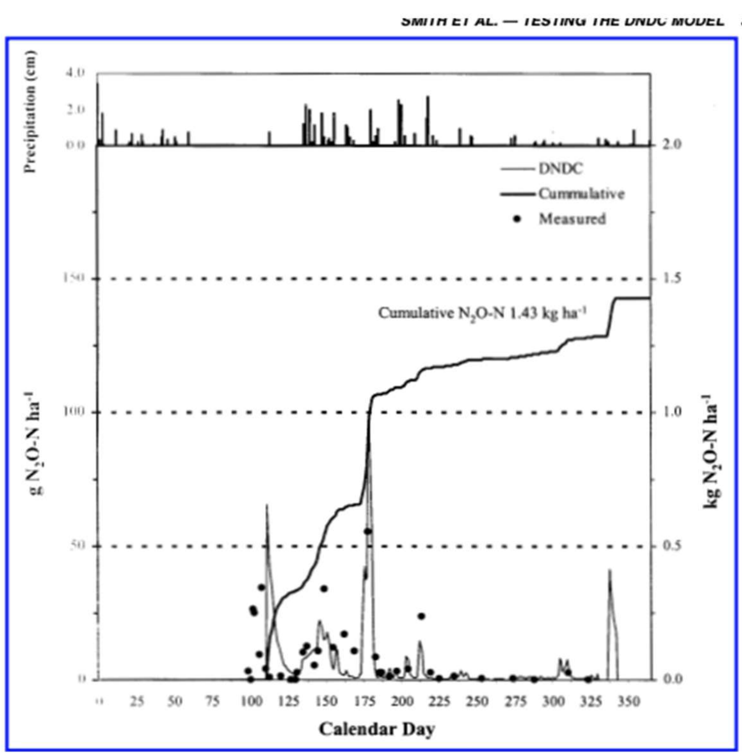

Figure 6: Rainfall, and measured and estimated emissions of N_2O for the 200 kg Nha–1 NH_4 +NO_3 – manure treatment in 1994 at the Ottawa site

Requirements for Participating Farmers

Farms wishing to participate in the fertilizer reduction plan via the use of cover crops would have to submit all data associated with their farming system. This data includes all information required for model inputs including farm location, temperature, precipitation, soil type, soil quality, baseline soil nitrogen content, crop planting, crop rotation, harvesting dates, fertilizer application rates, dates of fertilizer application, tillage practices and dates of practice, manure application and dates of application, information on grazing and cutting practices and plastic film usage. As most farmers already partner with an agronomist, information on baseline soil health, nitrogen, and carbon content should be readily available. Baseline greenhouse gas emissions and nutrient cycling will be modeled using current farm data, satellite data, and geographical averages (Figure 7). This baseline data will also include five-year projections for greenhouse gas emissions, soil carbon, and nitrogen runoff for each participating farm agro-ecosystem. Farmers will also be required to submit receipts for fertilizer and cover crop seed purchases over the past year to verify fertilizer application reductions are occurring, and the correct legume cover crops are being applied during the five-year contract period. Relevant data must also be submitted on an annual basis to confirm projected yield, crop planting dates, harvesting dates, cover crop application, and soil quality data. The submission of agricultural and fertilizer data will be used to run a DNDC model simulation to determine GHG emissions taking place over the contract period.

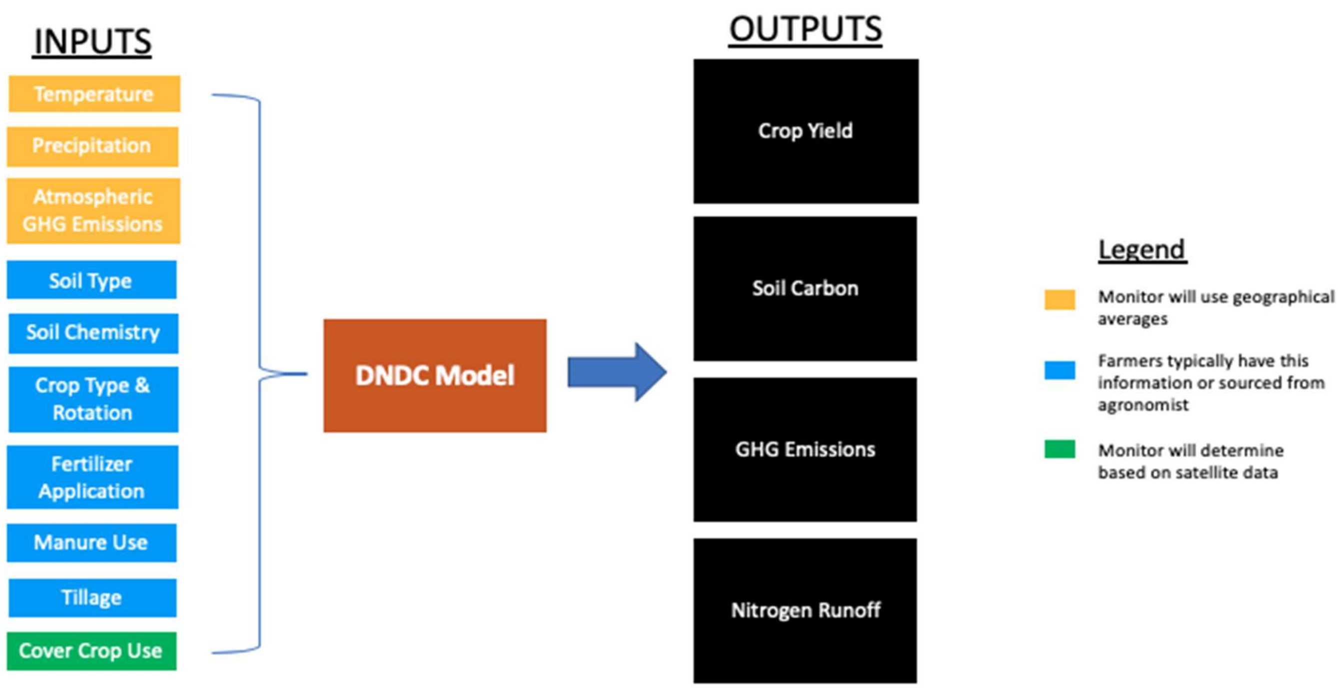

Figure 7: Information source for input and output variables for DNDC modeling

Legitimacy of Offsets

The DNDC model is an experimentally verified model to predict CO_2 and N_2O emissions reductions from the institution of cover cropping and fertilizer reduction practices on farms in the Midwestern United States and internationally. Modeling and verification efforts done through data collection will ensure that the offsets meet permanence requirements, through the continued practice of cover cropping, consistency of reduced fertilizer usage, and adoption of no-till farmer methods to conserve soil carbon and guarantee offset permanence. These offsets also meet additionality requirements because, without the investor's payments, farmers would be unable to overcome the financial barriers to cover crop implementation and the associated fertilizer reduction procedures. Therefore, the offset is additional in actively reducing GHG emissions.

Offset Credit Analysis

Predictive values determined by the DNDC model will be the basis for the reported greenhouse gas emissions credits. A baseline five-year projection model would be simulated for each participating farm to show emissions estimates if no intervention took place. A second baseline five-year projection would be simulated for each farm showing emissions estimates with the planned intervention techniques. Annual models will then show the implementation of reduced fertilizer and cover crop uses to calculate emissions for that year. The annually modeled data will be compared to the first predicted baseline emissions estimates with no intervention. Annual emissions will be subtracted from the first baseline emissions to determine the total emissions reductions and – we recommend that adjustments to the model be made to account for any uncertainty in the modeling results. Comparisons of soil carbon, crop yield, and nitrogen runoff will also be calculated. Using the current Intergovernmental Panel on Climate Change (IPCC) carbon dioxide equivalents conversions, the total CO_2 equivalents of all greenhouse gases will be totaled. The price payout of offset credits will be based on emissions reductions of total CO_2 equivalents, which will be calculated taking into account any uncertainty in the modeling. Additional payments will be made if the farmer's emissions reductions exceed those of the second baseline predictive model where interventions were simulated. The extra payments will be calculated annually based on annually-conducted modeling. The projected emissions from that year will be subtracted from the annual model run using annual data inputs. The difference will be multiplied by the offset cost for the expected emission credits to determine additional payouts to the participating farmers.

APPENDIX C: ADDITIONAL LEGAL REFERENCES

Laws Applicable to the Runoff of Synthetic Fertilizers

A. Federal.

The Federal Clean Water Act[30] (CWA) was enacted "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[31] It therefore prohibits "the discharge of any pollutant" without a permit.[32] The term "pollutant" is defined broadly.[33] The CWA defines "discharge of a pollutant" as "any addition of any pollutant to navigable waters from any point source."[34] The CWA explicitly defines "point source" to exclude "agricultural stormwater discharges and return flows from irrigated agriculture."[35] The statute defines "point source" to be a "discernible, confined and discrete conveyance."[36] With a few exceptions for large animal farms, the CWA treats runoff as nonpoint source pollution.

While the CWA does little to regulate nonpoint source pollution, it does require states to collect information and set water quality standards, and it provides grants that encourage states to implement their own nonpoint source regulatory regimes.

B. State

The CWA requires states to establish water quality standards (WQS) that "consist of the designated uses of the navigable waters involved and the water quality criteria for such waters based upon such uses."[37] States must identify waters, such as lakes and rivers, that fail to meet WQSs.[38] States must then establish the total maximum daily load (TMDL) of pollution both for waters that meet WQSs and for waters that do not meet WQSs.[39] The TMDL for waters that meet WQSs must be sufficient to prevent water quality from degrading, while the TMDL for waters that do not meet WQSs must "assure the attainment of such water quality standard."[40] States must report their WQSs and TMDLs to the EPA.[41] Enforcement of TMDLs is inconsistent.

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[30] 33 U.S.C. §§ 1251–1387.

[31] 33 U.S.C. §§ 1251(a).

[32] 33 U.S.C. § 1311(a); *see* 33 U.S.C. § 1342.

[33] 33 U.S.C. §1362(6).

[34] 33 U.S.C. § 1362(12).

[35] 33 U.S.C. §1362(14).

[36] 33 U.S.C. § 1362(14).

[37] 33 U.S.C. § 1313(c)(2)(A).

[38] 33 U.S.C. § 1313(d)(1)(A).

[39] 33 U.S.C. § 1313(d)(1)&(3).

[40] 33 U.S.C. § 1313(d)(4).

[41] 33 U.S.C. § 1313(d)(2).

The CWA also requires states to identify waters "which, without additional action to control nonpoint sources of pollution, cannot reasonably be expected to attain or maintain" WQSs.[42] States must prepare and submit to the EPA a "management program . . . for controlling pollution added from nonpoint sources."[43] Grants are available from EPA to assist states to implement their management programs.[44]

Many states regulate agricultural fertilizer use and nutrient management, generally in order to protect water quality. Many states also offer grants and other sources of funding to assist farmers who choose to adopt conservation practices. These state regulations and grant programs generally recognize that the CWA does not regulate nonpoint source pollution in a substantial way and attempt to fill the gap.

State laws that regulate agricultural runoff and nutrient management may therefore be important for Cover Crop Credit Partnerships and should be researched on a case-by-case basis.

C. Example of state regulation: Wisconsin

Note that while some states take approaches similar to Wisconsin's, not all states do.

Two key statutes guide Wisconsin's approach to nonpoint source pollution, agricultural runoff, soil management, and nutrient management. These are popularly referred to as Chapter 92[45] and Chapter 281.[46] Chapter 92 declares that "the soil resources of this state are being depleted by wind and water erosion and that the waters of this state are being polluted by nonpoint sources of pollution."[47] Because these processes endanger "the health and welfare of the state's citizens" and its "agricultural productivity," Chapter 92 makes it "the policy of this state to halt and reverse the depletion of the state's soil resources and pollution of its waters."[48]

To this end, Chapter 92 makes the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATC) "responsible for setting and implementing statewide soil and conservation policies and administering the state's soil and water conservation programs."[49] Chapter 281 adds that the Wisconsin Department of Natural Resources (DNR) "shall promulgate rules prescribing performance standards and prohibitions for agricultural facilities and agricultural practices that are nonpoint sources" in consultation with DATC.[50]

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[42] 33 U.S.C. § 1329(a)(1)(A).

[43] 33 U.S.C. § 1329(b)(1).

[44] 33 U.S.C. § 1329(h)(1).

[45] WIS. STAT. § 92.02–92.18.

[46] WIS. STAT. § 281.01–281.99.

[47] WIS. STAT. § 92.02(1).

[48] WIS. STAT. § 92.02(1)–(2).

[49] WIS. STAT. § 92.05(1).

[50] WIS. STAT. § 281.16(3).

Chapters 92 and 281 both involve Wisconsin's county governments and recommend supplementing direct regulation with grant and incentive programs. Chapter 92 requires that each of Wisconsin's county boards create a land conservation committee.[51] It further directs land conservation committees to develop and adopt standards "for management practices to control erosion, sedimentation and nonpoint source pollution" and to distribute funds "made available to the committee for cost-sharing programs or other incentive programs . . . relating to soil and water conservation."[52] Chapter 281 makes these funds available.[53] Chapter 92 directs the land conservation committees to prepare land and water resource management plans.[54]

Wisconsin has also adopted a set of regulations to implement Chapters 92 and 281. These are popularly referred to as NR 151[55] and ATCP 50.[56] NR 151 "establishes runoff pollution performance standards . . . for agricultural facilities and practices designed to achieve water quality standards."[57] NR 151 creates a performance floor for nonpoint sources. It reiterates the CWA requirement for Wisconsin to set WQSs and establish TMDLs for waters throughout the state.[58] It additionally requires farmers to "reduce discharges of pollutants from . . . cropland to surface waters if necessary" to meet TMDLs by adopting best management practices and conservation practices.[59] NR 151 builds on this basic requirement by enumerating specific performance standards for phosphorus management,[60] manure storage facilities,[61] manure application,[62] and many other practices.

NR 151 further requires farmers who choose to apply manure, commercial fertilizer, and other nutrients do so "in conformance with a nutrient management plan."[63] ATCP 50 requires farmers to develop nutrient management plans and review their plans annually.[64] A qualified "nutrient management planner" must prepare or approve each farmer's plan.[65]

ATCP 50 builds on NR 151's performance standards by developing a cost sharing-program to assist farmers who choose to adopt conservation practices that exceed performance standards. ATCP 50 directs county land conservation committees to prepare a water resources management

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[51] WIS. STAT. § 92.06(1).

[52] WIS. STAT. § 92.07(2)–(3).

[53] *See* WIS. STAT. § 281.65.

[54] WIS. STAT. § 92.07(7).

[55] WIS. ADMIN. CODE NR §§ 151.001– 51.32.

[56] WIS. ADMIN. CODE ATCP §§ 50.01– 50.98.

[57] WIS. ADMIN. CODE NR § 151.001.

[58] 33 U.S.C. § 1313(c)–(d).

[59] WIS. ADMIN. CODE NR § 151.005.

[60] WIS. ADMIN. CODE NR § 151.04.

[61] WIS. ADMIN. CODE NR § 151.05.

[62] WIS. ADMIN. CODE NR § 151.075.

[63] WIS. ADMIN. CODE NR § 151.07(1)&(3); *see also* WIS. ADMIN. CODE ATCP §§ 50.04(3)(a).

[64] WIS. ADMIN. CODE ATCP § 50.04(3)(a)&(gm).

[65] WIS. ADMIN. CODE ATCP § 50.04(3)(c); *see also* WIS. ADMIN. CODE ATCP §§ 50.48.

plan and to submit the plan to DATC for approval.[66] County committees may then apply to DATC for funding to finance cost-sharing grants.[67] Committees may use funds that DATC awards them to make cost-sharing grants to landowners.[68] Committees may only issue cost sharing grants to landowners who agree to adopt approved conservation practices that include feed storage runoff control systems, riparian buffers, and ***cover crops***.[69] Grants may be for up to 70 percent of the cost to install and maintain the conservation practice.[70] County committees may grant up to 90 percent of the cost of a conservation practice to farmers who can demonstrate financial hardship.[71]

Thus, Wisconsin provides funding to help farmers who would like to plant cover crops. However, county committee cost-sharing grants have limited funding and cannot meet the demand. Cover Crop Credit Partnerships provide an alternative and complementary source of funding.

D. Federal Farm Bill

In closing, recall that the Farm Bill's Conservation program[72] includes two programs, the Environmental Quality Incentives Program[73] (EQIP) and the Conservation Stewardship Program[74] (CSP), that pay some farmers to adopt various conservation practices, including planting cover crops. However, as described earlier in this Guide and as is the case with state funds, demand for funds under these programs far outstrips available funds.[75] Accordingly, our Cover Crop Credit Partnership provides an alternative source of funding to farmers who would like to plant cover crops.

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[66] WIS. ADMIN. CODE ATCP § 50.12(1).

[67] WIS. ADMIN. CODE ATCP § 50.24(3).

[68] WIS. ADMIN. CODE ATCP § 50.40(1).

[69] WIS. ADMIN. CODE ATCP §§ 50.40(3), 50.705, 50.83, 50.68.

[70] WIS. ADMIN. CODE ATCP §§ 50.42(1)(a).

[71] WIS. ADMIN. CODE ATCP §§ 50.42(1)(b)&(4);

[72] 16 U.S.C. §§ 3830–3839bb-6. *See* CONG. RESEARCH SER., R40763, AGRICULTURAL CONSERVATION: A GUIDE TO PROGRAMS, at i (2019).

[73] 16 U.S.C. §§ 3839aa–3839aa-9.

[74] 16 U.S.C. §§ 3839aa-21–3839aa-25.

[75] Stubbs, M. (2011). Environmental Quality Incentives Program (EQIP): Status and Issues. Congressional Research Service (CRS) Report for Congress; CONG. RESEARCH SER., R40763, at 12, 16 (2019).

APPENDIX D: ASSESSING ENVIRONMENTAL AND HUMAN HEALTH IMPACTS

Introduction

Synthetic fertilizer is heavily used by farmers in the Midwestern United States to maximize crop yield. However, the use of synthetic nitrogen fertilizer has significant environmental and health impacts. In order to determine the efficacy of the Cover Crop Credit Partnership on a given farm, an environmental impacts assessment and health impacts assessment need to be conducted to identify potential benefits, as well as adverse impacts, associated with implementing the Cover Crop Credit Partnership. These assessments help guide projects to maximize the benefits and minimize the risks. The sections in this appendix will help guide users through the process of conducting an environmental and human health impacts assessment. It also provides an expanded explanation of the environmental and health impacts associated with synthetic nitrogen fertilizer use.

How to Conduct a Health Impacts Assessment

To analyze the health benefits and costs of implementing the Cover Crop Credit Partnership, a health impact assessment (HIA) needs to be conducted. According to the World Health Organization, a HIA is a "means of assessing the health impacts of policies, plans and projects in diverse economic sectors using quantitative, qualitative and participatory techniques."[76] A health impacts assessment can be broad, touching upon all the direct and indirect ecological and human impacts of synthetic nitrogen fertilizer use, or it can be more concise and focused on a few main pathways and their major impacts. Furthermore, while there is no one correct technique for conducting a HIA, there are six steps that should be followed in the HIA. These steps are highlighted in the table below.

Screening	Determine whether a HIA is appropriate for the project or policy under consideration. Consider the social determinants of health, existing evidence and data, and the capacity and resources needed. Identify potential stakeholders.
Scoping	Establish a plan for the HIA. Identify the target population for the HIA, who will oversee the HIA, and which decision-makers need to be engaged. Determine the geographical and temporal boundaries for the HIA. Decide on the methods that will be used for gathering information (Is relevant information already being monitored? Are there similar case studies that can be evaluated? Will people need to be interviewed? Etc.)

[76] https://www.who.int/hia/en/

Assessment	Identify areas as key human health impact areas and key environmental health impact areas as the two are interrelated. Identify practices that will help to maximize benefits and reduce risks. Discuss how the project or policy may impact the human and environmental health impact areas.
Recommendations	Formulate and prioritize specific recommendations for the decision makers, based on the best available evidence and results of the HIA. What changes need to be made to maximize health gains and minimize harmful impacts?
Engagement	While the HIA serves to support decision making it is not a substitute for decision making. Share results with local public health commissions and stakeholders. Reinforce the value of evidence based recommendations and encourage their adoption and adaptation into the proposal.
Monitoring and Evaluation	Periodic monitoring to assess if the adoption/adaptation of the HIA recommendations were implemented and if they contributed to positive effects on health and equity. If not, review and consider the reasons for this, and how plans might further be adapted.

For more information about HIAs and for further examples of HIAs please visit the websites listed below:

- https://www.who.int/hia/en/
- https://www.epa.gov/healthresearch/health-impact-assessments
- https://hiasociety.org/Model-HIA-Reports

Social Determinants of Health

Social determinants of health include personal factors (*e.g.*, age, genetics), lifestyle factors (*e.g.*, diet, exercise), general socio-economic and cultural factors (*e.g.*, education, occupation, housing, cultural norms and behaviors), and structural factors (*e.g.*, policies, economics). Social determinants have a significant impact on the health of populations, because they determine the access and type of healthcare that people receive. These differences can be seen within and between communities. The structural and social determinants of health are dictated by the environment (government regulation, education systems, labor and housing markets, health care systems, etc.) and are not under control of the individual person being affected by those determinants. It is also important to note that the social and structural determinants of health vary between regions, so they must be evaluated within the context of the specific project or policy.

Conducting a HIA helps to address these social determinations of health because a HIA can identify potential health risks before a project or policy is implemented and can recommend adaptations to reduce that risk. Furthermore, an HIA also works to ensure that vulnerable populations are protected and are not adversely impacted, as they have been historically. Completing a HIA and implementing the recommendations can target the upstream social determinants of health that are responsible for the health inequities we see today.

The Social Determinants of Health

How to Conduct an Environmental Impacts Assessment

To analyze the environmental benefits and costs of implementing the Cover Crop Credit Partnership, an environmental impact assessment (EIA) needs to be conducted. Similar to the health impacts assessment, an EIA assesses the environmental impacts of proposed projects and policies.[77] Depending on the situation an EIA can be broad, touching upon all the direct and indirect pathways for environmental impacts of synthetic nitrogen fertilizer use, or it can be more concise and focused on a few main pathways and their major impacts. Just as with the health impacts assessment, there are several steps that should be followed in the EIA.[78] These steps are highlighted in the table below.

[77] https://www.iisd.org/learning/eia/eia-essentials/

[78] https://www.iisd.org/learning/eia/eia-essentials/

Screening	Determine whether an EIA is appropriate for the project or policy under consideration given the level of impact of the proposed project.
Scoping	Establish a plan for the EIA. Identify the issues that are likely to be of most importance. Determine the geographical and temporal boundaries for the EIA. Decide on the methods that will be used for gathering information (Is relevant information already being monitored? Are there similar case studies that can be evaluated? Will people need to be interviewed? Etc.)
Assessment	Identify areas as key environmental impact areas. Also evaluate the socioeconomic impacts of the proposed project. Identify practices that will help to maximize benefits and reduce risks. Discuss how the project or policy may impact the key environmental impact areas.
Recommendations	Formulate and prioritize specific recommendations for the decision makers, based on the best available evidence and results of the EIA. What changes need to be made to maximize environmental benefits and minimize harmful impacts?
EIA Report	Create a well-organized, detailed document highlighting the results of the EIA that can be used in decision making. Share results with local environmental commissions and stakeholders. Reinforce the value of evidence-based recommendations and encourage their adoption and adaptation into the proposal.
Monitoring and Evaluation	Periodic monitoring to assess if the adoption/adaptation of the EIA recommendations were implemented and if they contributed to positive effects on the environment. If not, review and consider the reasons for this, and how plans might further be adapted.

For more information about EIAs and for further examples of EIAs please visit the websites listed below:

- https://www.iisd.org/learning/eia/eia-essentials/
- https://www.iisd.org/learning/eia/wp-content/uploads/2016/06/EIA-Manual.pdf

Assessing the Environmental and Health Impacts Assessment Results

The environmental and health impacts in this guide were assessed according to the recommended guidelines for conducting an EIA and HIA. However, due to the nature and time constraints of this project, a full EIA and HIA could not be conducted. The results presented here, and in the guide, represent the major environmental and health impacts of synthetic nitrogen fertilizer use in the Midwestern United States, but are not inclusive of all impacts, and should serve as guidance for conducting a full, complete EIA and HIA. The environmental and health damages associated with synthetic nitrogen fertilizer use reported below were evaluated and assigned a damage potential rank from low to high, based on the direction, magnitude, and likelihood of their impact.[79] A sample causal pathway is also shown below to illustrate the connections and pathways between synthetic nitrogen fertilizer use and its associated environmental and health impacts.

Example Causal Pathway

Environmental and Health Damages Associated with Synthetic Nitrogen Fertilizer

System	Nitrogen Damage Type	Geographic Scale	Populations Affected	Direction of Impact	Magnitude	Likelihood	Damage Potential
Air and Climate	Increased ultra-violet light exposure from ozone—humans	Global	Global community but specifically populations with limited means for climate adaptation and resiliency	Negative	Low	High	Medium
Air and Climate	Increased emission of a greenhouse gas (sea level rise, increasing temperature, changing precipitation patterns, etc.)	Global	Global community but specifically populations with limited means for climate adaptation and resiliency	Negative	Low	High	High
Air and Climate	Increased ultra-violet light exposure from ozone—crops	Global	Global community but specifically populations with limited means for	Negative	Low	High	Medium

[79] Sobata et.al., (2015). The Greenhouse Effect. In Introduction to Atmospheric Chemistry. Princeton University Press.

			climate adaptation and resiliency				
Freshwater	Declining waterfront property value	Local and regional	Community members and residents of nearby communities	Negative	Medium	Medium	Medium
Freshwater	Loss of recreational use	Local and regional	Community members and residents of nearby communities	Negative	High	High	High
Freshwater	Loss of endangered species	Local and regional	Native flora and fauna (loss of species changes ecological dynamics), community members (loss of ecosystem services)	Negative	Low	Medium	Low
Freshwater	Increased eutrophication	Local and regional	Community members and residents of nearby communities, pets, wildlife	Negative	High	High	High
Drinking Water	Undesirable odor and taste	Local and regional	Community members and residents of nearby communities	Negative	High	High	Low
Drinking Water	Nitrate contamination	Local and regional	Community members and residents of nearby communities	Negative	High	High	High
Drinking Water	Increased health risks (colon cancer, "blue baby" syndrome, etc.)	Local and regional	Community members and residents of nearby communities	Negative	High	Medium	Medium
Coastal	Loss of recreational use	Regional (Midwest is landlocked but pollutants travel in rivers to coasts)	Coastal communities such as those around the Gulf of Mexico	Negative	Medium	Medium	Medium
Coastal	Declines in fisheries and estuarine/marine habitat	Regional (Midwest is landlocked but pollutants travel in	Coastal communities such as those around the Gulf of Mexico	Negative	High	High	High

		rivers to coasts)					
Soil	Physical, chemical, and biological imbalances in the soil	Local	Local community members	Negative	High	High	High

Information sourced from Sobata et.al., (2015). The Greenhouse Effect. In Introduction to Atmospheric Chemistry. Princeton University Press.

* This table does not include all direct or indirect environmental and health impacts associated with synthetic nitrogen fertilizer use, rather it presents the major impacts.

The estimated lifetime costs associated with synthetic nitrogen use and the costs saved by reducing nitrogen applications by 70 lbs. per acre with the practice of cover cropping (not accounting for costs of cover cropping), is calculated in the table below. For a 1,000-acre hypothetical farm in the Midwest, reducing nitrogen fertilizer application by 70 lbs. per acre resulted in significantly decreased costs associated with the negative environmental and health impacts of nitrogen use; ranging from $1,011,555 to $3,088,005.

Please note that the damage estimates for the different nitrogen inputs were collected from multiple large-scale studies (national or regional). Some data was missing for some areas of the United States so the damage costs reported are estimates. Furthermore, the damage costs assume a linear response function based on current value per unit of nitrogen because there was not enough information to make nonlinear estimates such as with threshold effects (Sobata et. al., 2015).

Estimated Average Lifetime Costs Associated with Added Nitrogen (Sobata et. al., 2015)

Potential Damage Costs of Nitrogen												
				Cost ($/kg N)			**Cost per 1,000 acres at *88.45kg* N/acre**			**Cost per 1,000 acres at *56.70kg* N/acre**		
Pathway	**Pollutant**	**N Damage Type**	**System**	**Low**	**Median**	**High**	**Low Cost**	**Median Cost**	**High Cost**	**Low Cost**	**Median Cost**	**High Cost**
Air	N2O	Increased ultra-violet light exposure from ozone—humans	Air and Climate	$1.29	$1.33	$3.86	$114,100.50	$117,638.50	$341,417.00	$73,143.00	$75,411.00	$218,862.00
	N2O	Increased ultra-violet light exposure from ozone—crops	Air and Climate	$1.33	$1.33	$1.33	$117,638.50	$117,638.50	$117,638.50	$75,411.00	$75,411.00	$75,411.00
	N2O	Increased emission of a greenhouse gas	Air and Climate	$5.15	$13.52	$21.89	$455,517.50	$1,195,844.00	$1,936,170.50	$292,005.00	$766,584.00	$1,241,163.00
Water	Surface Freshwater N Loading	Declining waterfront property value	Freshwater	$0.21	$0.21	$0.21	$18,574.50	$18,574.50	$18,574.50	$11,907.00	$11,907.00	$11,907.00
	Surface Freshwater N Loading	Loss of recreational use	Freshwater	$0.17	$0.17	$0.17	$15,036.50	$15,036.50	$15,036.50	$9,639.00	$9,639.00	$9,639.00
	Surface Freshwater N Loading	Loss of endangered species	Freshwater	$0.01	$0.01	$0.01	$884.50	$884.50	$884.50	$567.00	$567.00	$567.00
	Surface Freshwater N Loading	Increased eutrophication	Freshwater	$6.44	$16.10	$25.75	$569,618.00	$1,424,045.00	$2,277,587.50	$365,148.00	$912,870.00	$1,460,025.00
	Surface Freshwater N Loading	Undesirable odor and taste	Drinking water	$0.14	$0.14	$0.14	$12,383.00	$12,383.00	$12,383.00	$7,938.00	$7,938.00	$7,938.00
	Surface Freshwater N Loading	Nitrate contamination	Drinking water	$0.54	$0.54	$0.54	$47,763.00	$47,763.00	$47,763.00	$30,618.00	$30,618.00	$30,618.00
	Surface Freshwater N Loading	Increased colon cancer risk	Drinking water	$1.76	$1.76	$5.15	$155,672.00	$155,672.00	$455,517.50	$99,792.00	$99,792.00	$292,005.00
	Groundwater N Loading	Undesirable odor and taste	Drinking water	$0.14	$0.14	$0.14	$12,383.00	$12,383.00	$12,383.00	$7,938.00	$7,938.00	$7,938.00
	Groundwater N Loading	Nitrate contamination	Drinking water	$0.54	$0.54	$0.54	$47,763.00	$47,763.00	$47,763.00	$30,618.00	$30,618.00	$30,618.00
	Groundwater N Loading	Increased colon cancer risk	Drinking water	$1.76	$1.76	$5.15	$155,672.00	$155,672.00	$455,517.50	$99,792.00	$99,792.00	$292,005.00
	Coastal N Loading	Loss of Recreational use	Coastal Zone	$6.38	$6.38	$6.38	$564,311.00	$564,311.00	$564,311.00	$361,746.00	$361,746.00	$361,746.00
	Coastal N Loading	Declines in fisheries and estuarine/marine habitat	Coastal Zone	$6.00	$15.84	$26.00	$530,700.00	$1,401,048.00	$2,299,700.00	$340,200.00	$898,128.00	$1,474,200.00
						Total Costs:	**$2,818,017.00**	**$5,286,656.50**	**$8,602,647.00**	**$1,806,462.00**	**$3,388,959.00**	**$5,514,642.00**
						COSTS SAVED:	**$1,011,555.00**	**$1,897,697.50**	**$3,088,005.00**			
							(Low)	(Median)	(High)			

Detailed Description of Human Health and Environmental Health Impacts (Expanded Version of Sections in the Guide)

Environmental Impacts

The use of synthetic fertilizer is associated with degradation of aquatic and terrestrial ecosystems and atmospheric conditions and composition. However, these impacts can be reduced through the use of cover crops because cover crops promote microbial biodiversity in soils and leguminous cover crops aid in nitrogen fixation making more nitrogen available to the cash crop. As a result, farmers who use cover crops can reduce the amount of nitrogen fertilizer used on their fields.

Agricultural runoff is non-point source pollution, coming from many different sources.[80] In the case of the Midwest, the pollution comes from many agricultural fields. In many cases, the excess fertilizer from neighboring farms all drain to the same watersheds. The aggregate effect of all the pollution from each individual farm has strong negative ecological impacts. Therefore, the ecological impacts assessed in this report are all assumed to be due to non-point source pollution at an aggregate scale.

Water: Synthetic Nitrogen Fertilizer Impacts

Implementing the practice of cover crops reduces synthetic nitrogen fertilizer use, reducing the harmful leaching of nitrates into nearby bodies of water. Since nitrogen is a limiting nutrient in aquatic ecosystems, run-off containing nitrates will result in eutrophication, algal blooms, and hypoxia in water bodies. The impacts of nitrate leaching can be local. However, leached nitrates can be transported long distances through various watershed systems, for example the Mississippi Watershed which drains to the Gulf of Mexico. Approximately 8% of the nitrogen that is applied to fields in the U.S. corn belt reaches the Gulf of Mexico.[81] The excess levels of nutrients from agricultural activities cause an overgrowth of algae in the Gulf, depleting the water of dissolved oxygen, creating a "dead zone;" a large area in the water than cannot support marine life.[82] Eutrophication caused by nutrient loading can result in harmful algal blooms that can impact local freshwater and marine fisheries, as well as local economies. It can lead to loss of recreational activities, property value, and ecosystem services.[83] In the Gulf of Mexico, nutrient overloading from nitrogen pollution costs the economy about $1.4 billion annually,[84] and impacts on freshwater ecosystems cost $2.2 billion annually.[85]

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[80] Basic Information about Nonpoint Source (NPS) Pollution. (2018, August 10). Retrieved May 01, 2020, from https://www.epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution

[81] Good, A. and Peatty, B. 2011. "Fertilizing Nature: A Tragedy of Excess in the Commons," PLOS Biology, available at http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001124

[82] NOAA forecasts very large 'dead zone' for Gulf of Mexico. (n.d.). Retrieved April 3, 2020, from https://www.noaa.gov/media-release/noaa-forecasts-very-large-dead-zone-for-gulf-of-mexico

[83] Good, A. and Peatty, B. 2011. "Fertilizing Nature: A Tragedy of Excess in the Commons," PLOS Biology, available at http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001124

[84] Good, A. and Peatty, B. 2011. "Fertilizing Nature: A Tragedy of Excess in the Commons," PLOS Biology, available at http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001124

[85] Dodds W. K, Bouska W. W, Eitzmann J. L, Pilger T. J, Pitts K. L, et al. (2009) Eutrophication of u.s. freshwaters: analysis of potential economic damages. Environ. Sci Technol 43: 12–19.

Soil: Synthetic Nitrogen Fertilizer Impacts

Use of synthetic nitrogen fertilizer reduces soil biodiversity making the crop more susceptible to weeds and disease.[86] This is because the synthetic nitrogen fertilizer impacts the physical, chemical, and biological properties of soil, which can cause imbalances in the nutrients taken up by the plants, leaving them more susceptible to disease.[87] Additionally, urea and ammonia based fertilizers have been shown to temporarily increase the soil pH (making the soil more basic) which negatively impacts the soil microbial community.[88] Furthermore, a study revealed that the concentration of synthetic nitrogen fertilizer changes the composition of soil fungal communities which can have negative impacts on carbon cycling and even may promote pathogenic fungal growth in the soil.[89]

Air: Synthetic Nitrogen Fertilizer Impacts

Synthetic nitrogen fertilizer use contributes to N_2O emissions because excess nitrate in soils can be used by bacteria in the denitrification process, which produces N_2O as a byproduct. Nitrous oxide is a potent greenhouse gas (GHG) and contributes to global warming despite its relatively short residence time in the atmosphere.[90] As a GHG, N_2O contributes to increasing global temperature, sea level rise, changing weather patterns, and loss of biodiversity. Nitrous oxide also contributes to stratospheric ozone depletion which increases exposure to ultraviolet (UV) radiation from the sun.[91] N_2O emissions are not linked to the destruction or creation of tropospheric ozone, a criteria air pollutant, because N_2O requires stronger photons to break the N_2O bonds, and those photons are found in the stratosphere and not the troposphere. However, N_2O emissions indirectly contribute to tropospheric ozone creation because N_2O emissions contribute to global warming, and increased temperatures contribute to tropospheric ozone formation.

Health Impacts

The environmental impacts of synthetic fertilizer use directly impact human health. The human health impacts can be observed through aquatic, terrestrial (soil), and atmospheric pathways and can be observed on multiple geographic scales from local to global.

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[86] Altieri, M. A., & Nicholls, C. I. (2003). Soil fertility management and insect pests: Harmonizing soil and plant health in agroecosystems. *Soil and Tillage Research, 72*(2), 203-211. doi:10.1016/s0167-1987(03)00089-8

[87] Altieri, M. A., & Nicholls, C. I. (2003). Soil fertility management and insect pests: Harmonizing soil and plant health in agroecosystems. *Soil and Tillage Research, 72*(2), 203-211. doi:10.1016/s0167-1987(03)00089-8

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Water: Human Health Impacts

Residents who source drinking water from the afflicted watersheds and those who recreate in waterbodies near agricultural fields are the most at risk for the effects of surface and groundwater nitrate loading as a result of nitrate runoff from agricultural fields. A large proportion of residents in the Midwest source their drinking water from private wells, meaning that the drinking water is not actively monitored for nitrate concentration.[92,93] For example, testing of private wells in Iowa over the past decade revealed unsafe levels of nitrates in thousands of wells.[94] The maximum contaminant level ("MCL") for nitrates in drinking water is currently set at 10mg/L due to the adverse health effects of consuming nitrates.[95] However, scientific studies have indicated that people are being exposed to groundwater nitrate levels above the MCL, especially in areas (such as the Midwest) that have a large nitrate input and shallow wells.[96] Epidemiological studies have linked nitrate exposure to infant methemoglobinemia "blue baby", an acute toxic response to nitrates that reduces nitrates to nitrites, which interact with hemoglobin to prevent oxygen transport in the blood.[97] Studies have also suggested that nitrate exposure is associated with increased risk of cancer, thyroid disease, and neural tube defects.[98,99,100] Furthermore, many studies have observed an increased risk of adverse health effects with the consumption of water with nitrate levels *below* regulatory limits.[101]

Excess nitrogen in the water contributes to eutrophication and the formation of harmful algal blooms, which are detrimental to human health because they can be composed of toxin-producing microscopic organisms. For example, harmful algal blooms that occur in freshwater usually contain a large concentration of *Microcystis*, which is a cyanobacteria that can cause gastrointestinal symptoms, and in

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[92] Schechinger, A. (2019, April 24). Contamination of Iowa's Private Wells: Methods and Detailed Results. Retrieved April 26, 2020, from https://www.ewg.org/iowawellsmethods#_edn12

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[95] National Primary Drinking Water Regulations. (2020, February 14). Retrieved March 11, 2020, from https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

[96] A National Look at Nitrate Contamination of Ground Water. (n.d.). Retrieved March 9, 2020, from https://water.usgs.gov/nawqa/nutrients/pubs/wcp_v39_no12/

[97] Nitrate and nitrite in drinking-water. Background document for *development of WHO Guidelines for Drinking-water Quality*. Prepared by G.J.A Speijers revised by Mr. J.K. Fawell of the United Kingdom. December 2011, from https://www.who.int/water_sanitation_health/dwq/chemicals/nitratenitrite2ndadd.pdf

[98] Pediatric Environmental Health Specialty Units. (2014). NITRATES, METHEMOGLOBINEMIA, AND DRINKING WATER: A Factsheet for Clinicians. *NITRATES, METHEMOGLOBINEMIA, AND DRINKING WATER: A Factsheet for Clinicians*.

[99] Ward, M. H., Jones, R. R., Brender, J. D., de Kok, T. M., Weyer, P. J., Nolan, B. T., Villanueva, C. M., & van Breda, S. G. (2018). Drinking Water Nitrate and Human Health: An Updated Review. *International journal of environmental research and public health*, *15*(7), 1557. https://doi.org/10.3390/ijerph15071557

[100] Weng, H. H., Tsai, S. S., Wu, T. N., Sung, F. C., & Yang, C. Y. (2011). Nitrates in Drinking Water and the Risk of Death from Childhood Brain Tumors in Taiwan. J Toxicol Environ Health A, 74(12), 769–778. doi: 10.1080/15287394.2011.567951.

[101] Ward, M. H., Jones, R. R., Brender, J. D., de Kok, T. M., Weyer, P. J., Nolan, B. T., Villanueva, C. M., & van Breda, S. G. (2018). Drinking Water Nitrate and Human Health: An Updated Review. *International journal of environmental research and public health*, *15*(7), 1557. https://doi.org/10.3390/ijerph15071557

some cases liver damage in humans.[102,103] Furthermore, algal blooms can infect fish/shellfish and could have human health consequences if people eat infected fish/shellfish.

Terrestrial (Soil): Human Health Impacts

Farm employees, farmers, and their families are vulnerable to direct exposure to fertilized soil through inhalation, direct contact, or consumption. Direct exposure to ammonia-based fertilizers has been associated with many negative health impacts. Acute exposure to ammonia can irritate and burn the skin and eyes, can cause coughing, wheezing, shortness of breath, and pulmonary edema. Chronic exposure to ammonia can cause permanent lung damage or asthma-like allergic responses.[104] Not only are farmers and farm employees exposed to fertilizer when applying it to fields, particles of the fertilizer can be tracked into homes on clothing and shoes and can expose family, roommates, and pets to the chemical fertilizer. The fertilizer particles can then settle as dust on the floors of homes. Children and pets are among the most vulnerable to this exposure because both children and pets spend more time closer to, or on the ground, than other people in the household. Furthermore, young children exhibit pica behavior and are more likely to put food or objects in their mouth from the floor, and pets are more likely to chew on or eat objects on the floor. The larger community is also at risk because fruits and vegetables grown in fields where chemical fertilizers are applied can have fertilizer residue present on their surfaces, which may be inadvertently be consumed.

Use of synthetic nitrogen fertilizer also reduces soil biodiversity making the crop more susceptible to weeds. As a result, more herbicide use is needed, further putting farmers, farm employees, and their families at risk for chemical exposure. Glyphosate can cause severe eye irritation, atrazine can impact human reproductive health and other adverse health effects have been demonstrated in animal studies. Another common herbicide, 2,4-Dichlorophenoxyacetic acid, has been listed as non-carcinogenic by the Environmental Protection Agency (EPA) but the International Agency for Research on Cancer (IARC) has classified it as a 2B carcinogen (possibly carcinogenic to humans).[105,106,107]

Atmosphere: Human Health Impacts

All people are exposed to the impacts of climate change. However, depending on the region and a number of factors such as socioeconomic status and pre-existing health conditions, certain populations of people will be disproportionately affected by climate change impacts. Climate change will have a larger impact

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[103] Watanabe, M. F., Harada, K.-ichi, Carmichael, W. W., & Fujiki, H. (1996). *Toxic microcystis*. Boca Raton, FL: CRC Press.

[104] Hazardous Substance Fact Sheet: Ammonia . (2016). *Hazardous Substance Fact Sheet: Ammonia*. https://nj.gov/health/eoh/rtkweb/documents/fs/0084.pdf

[105] (n.d.). Retrieved April 3, 2020, from http://pmep.cce.cornell.edu/profiles/extoxnet/dienochlor-glyphosate/glyphosate-ext.html

[106] Toxic Substances Portal - Atrazine. (n.d.). Retrieved April 3, 2020, from https://www.atsdr.cdc.gov/phs/phs.asp?id=336&tid=59

[107] 2,4-Dichlorophenoxyacetic acid. (n.d.). Retrieved April 3, 2020, from https://deq.mt.gov/Portals/112/Land/hazwaste/documents/2_4_D.pdf

on vulnerable populations that do not have the resources or capacity to mitigate the effects of climate change.

Nitrous oxide is a potent greenhouse gas (GHG) and contributes to global warming despite its relatively short residence time in the atmosphere. A 2017 study revealed that GHGs with short residence times can greatly contribute to climate change and contribute to thermal expansion of oceans on a longer timescale than their atmospheric lifetimes.[108] Climate change impacts human health through a variety of pathways including flooding and sanitation issues related to sea level rise and extreme weather events (*e.g.*, hurricanes and flooding), spread of infectious disease with increased temperature, malnutrition due to food insecurity from drought, etc.[109] In particular, increased average global temperature is associated with more intense heat waves which can increase deaths from cardiovascular and respiratory disease.[110] A warmer planet also contributes to tropospheric ozone formation which further exacerbates cardiovascular and respiratory conditions and warmer temperatures increase pollen levels which can trigger more frequent asthma attacks in people with asthma.[111] Nitrous oxide contributes to stratospheric ozone depletion which increases exposure to UV radiation from the sun. The increased exposure to harmful radiation increases the risk for skin cancers.

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[108] Zickfeld, et al. 2016. "Centuries of thermal sea-level rise due to anthropogenic emissions of short-lived greenhouse gases," Proceedings of the National Academy of Sciences, available at http://www.pnas.org/content/114/4/657.abstract

[109] Climate Change and Public Health - Climate Effects on Health. (2019, September 9). Retrieved Apr il 4, 2020, from https://www.cdc.gov/climateandhealth/effects/default.htm

[110] Climate change and health. (n.d.). Retrieved April 3, 2020, from https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

[111] Climate change and health. (n.d.). Retrieved April 3, 2020, from https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health