Pasture Project
AN INITIATIVE OF THE WALLACE CENTER

Wallace Center
AT WINROCK INTERNATIONAL

FULL TRIAL REPORT
Benefits of Planting and Grazing Diverse Cover Crops

In collaboration with:

PRACTICAL farmers of Iowa — working together, always learning

sustainable farming association — sfa — FARMER-to-FARMER NETWORK

LAND STEWARDSHIP PROJECT

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EXECUTIVE SUMMARY

Cover crops are effective at improving water quality, reducing field nitrogen losses by 31% and phosphorus loads by 50%[1]. However, cover crops have been adopted slowly across the Upper Mississippi River Basin, partially due to high cost and low short-term return on investment. The Pasture Project, Sustainable Farming Association, Practical Farmers of Iowa, and Land Stewardship Project partnered on a 3-year USDA Conservation Innovation Grant to demonstrate the economic and soil health benefits of cattle grazing on cover crops.

Adaptive high stock density grazing is a type of grazing management characterized by high livestock stocking densities, frequent moves, and long rest periods for paddocks. Adaptive grazing can build soil health rapidly by having an even impact across a field, rather than manure overload in some areas and manure deficiency in others. Grazing cover crops using adaptive management improves soil health and productivity, thereby producing economic benefits which can make cover crops more financially viable and sustainable. This project has completed 3 years comparing the use of diverse winter cover crops and adaptive livestock grazing in cash crop production (treatment) to plots that were conventionally managed without cover crops or livestock grazing impact (control) on 8 cooperating farms in Minnesota and Iowa.

Soil health results show distinct soil biological improvements (improvements in 7 or more of 11 soil biology variables) in 7 of 8 cooperating farms. 5 of 8 farms showed slight to significant advantages in at least 5 of the 10 nutrient profiles in the treatment plots compared to the control plots. These results show early positive signs of improved soil health and fertility.

Preliminary economic results indicate that all 8 cooperators had a positive long-term economic benefit from grazing cover crops, including from forage value, increased water storage, and improved soil health leading to use of fewer inputs. Long-term financial impacts ranged from $25.78/acre/year to $364.94/acre/year, with a mean economic benefit of $135.05/acre/year. These findings indicate that grazing cover crops may have significant soil health benefits and that the practice may offset the cost of cover cropping in many cases.

[1] Iowa Nutrient Reduction Strategy. (2016). Iowa Department of Agriculture and Land Stewardship, Iowa Department of Natural Resources, and Iowa State University College of Agriculture and Life Sciences.

PROJECT OVERVIEW

The Pasture Project, Sustainable Farming Association, Practical Farmers of Iowa, and Land Stewardship Project partnered on a 3-year USDA Conservation Innovation Grant in 2014 to demonstrate the economic and soil health benefits of livestock grazing on cover crops. Concluding in 2018, the project worked with 8 farmers in Minnesota and Iowa to conduct on-farm research and demonstration on over 600 acres of control and treatment plots. The project has completed 3 years of trials comparing the use of cover crops and livestock integration in cash crop production (treatment) to plots that were conventionally managed between cash crops with no cover crop planted or livestock grazing impact (control). 3 farms completed 2 years of the trial, and 5 farms completed 3 years of the trial.

Data were collected to measure impacts of grazing cover crops, including soil chemical, physical, and biological tests, along with an economic analysis that considered livestock performance, days grazed, forage produced, cash crop yields, and economic value of ecosystem services provided by the practice.

SUMMARY OF SOIL HEALTH RESULTS

During the trial period, subtle to distinct differences were noted in the treatment plots compared to the control plots in 7 out of the 8 farms. Though soil health changes can be difficult to detect on a 3-year timeline, changes in soil biology and nutrient availability were seen on cooperating farms. As with most field trials conducted on cooperating farms, there were differences in management practices applied. All farms planted a diverse cover crop (at least 2 brassica species, 2 legume species, and 2 grass species), and integrated grazing as cover crop forage was available, but stocking densities, timing of cover crops, and cultivation practices varied. However, even with these differences, this trial noted positive changes on most of the participating farms.

Evident from the analysis was that the farms optimizing the factors of cover crop species mix diversity, timing of planting, grazing impact, and cultivation had the greatest overall improvement in soil physical, chemical, and biological characteristics. Timing of planting was critical to achieving a successful stand of cover crops to support grazing through the fall, winter, and spring harvest and planting of cash crops. Farms which used higher stocking densities and were able to fit in both fall and winter grazing showed more positive results, likely due to higher manure application, as did farms that practiced minimal till or no-till.

Trials and studies over the past ten years have strongly indicated that multi-species cover crops mixes improve soil health more rapidly than single species mixes.[2] Analysis from trials attribute this improvement to several factors:

1. Plants have different root exudates that attract varying soil-microbial species to the plant rhizosphere.
2. Recruiting a more diverse soil microbial population increases the total population in the soil.
3. The diverse population of soil microbes metabolizes a wider spectrum of macro- and micro-nutrients in soils, making them plant available, and leading to a reduction in the need to synthetic input to achieve similar yields.

[2] Salon, P.R. Diverse Cover Crop Mixes Good for Soil Health. USDA Natural Resources Conservation Service.

4. Different plant species have root systems of various depths. This allows plants to tap into different strata of the soil, reducing the "mining" of nutrients that occurs when the root zone is limited to a homogenous level in the soil.

A 9-year study at Pennsylvania State University compared pastures with 2 species of plants against pastures with 5 species. Results indicate that the pasture with greater plant diversity produced higher amounts of forage in 8 of the 9 years.[3] The authors attributed increased production to improved drought tolerance, higher soil organic carbon (SOC) and higher nitrogen levels within the pasture with greater plant diversity.

SOIL HEALTH METHODS AND ANALYSIS

Soil Health Parameters

There were 6 farm participants in Minnesota and 2 farm participants in Iowa. Soil health parameters measured included a soil chemistry analysis (Waypoint Labs S3M Test), soil carbon analysis (Quorum Labs), soil biological analysis (Ward Lab PLFA Test), and a soil metagenomic analysis (Quorum Labs Bio-Profile 1 Test). Soil samples were collected at approximately the same time each year during the warm active growing season (May – June) to optimize soil biological profile assessment.

Soil Chemistry Analysis

The soil chemistry panel was conducted by Waypoint Labs using their S3M test. Variables measured included soil pH, organic matter (OM), Cation Exchange Capacity (CEC), the Potassium to Magnesium ratio (K/Mg), the Calcium to Magnesium ratio (Ca/Mg), and a nutrient panel (mineral) consisting of P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn. The 3-year means for each variable for the control and treatment plots were compared to determine differences between the plots over the 3-year period.

For the 10 nutrients profiled in the test panel, 5 of the 8 farms showed slight to significant advantages in at least 5 of the 10 nutrient profiles in the treatment plots compared to the control plots. 3 farms showed an advantage in the treatment nutrient profile for 7 or more of the 10 total nutrients measured (Table 1).

Soil pH differences between the treatment and the control plots for the 3-year period were insignificant in 4 of the 8 farms, slightly higher to higher for the treatment plots in 2 of the 6 farms, and slightly lower for the treatment compared to the control in the remaining 2 farms. Soil OM was slightly higher to higher for the treatment plots in 5 of the 8 farms, slightly higher in the control plots for 2 farms, and no difference in 1 farm. Soil CEC was slightly higher to higher in 7 out of the 8 farms for the treatment plots vs the control plots. At one farm, the CEC was slightly higher in the control plot (Table 2).

[3] Skinner, R.H. & Dell, C.J. (2016). Yield and Soil Carbon Sequestration in Grazed Pastures Sown with Two or Five Forage Species. *Crop Science 56*.

Table 1. Soil Mineral Data – Control (Con) vs. Treatment (Trt) in PPM

Farm[4]	Plot	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
1*	Con	48	119	1097	102	10	.26	.86	102	33	2.6
	Trt	32	77	1099	162	13	.20	.88	104	33	1.4
2*	Con	31	89	1428	238	8	0.23	0.99	112	123	2.7
	Trt	32	95	1560	320	11	0.25	1.3	136	140	2.9
3^	Con	23	134	2768	531	21	.8	1.73	139	79	2.5
	Trt	15	147	3584	709	17	1.07	2.33	90	106	2.5
4*	Con	100	388	9474	605	531	4.00	3.10	36	91	6.78
	Trt	176	570	11287	684	1467	5.95	3.30	27	109	9.03
5*	Con	28	130	3267	602	12	0.93	2.3	133	99	3.98
	Trt	43	159	3674	589	17	0.85	2.6	141	78	3.85
6*	Con	32.5	96	1255	237	9	0.38	0.95	143	148	3.3
	Trt	26.5	113	1218	251	12	0.33	1.0	152	139	2.55
7^	Con	39	150	4132	479	21	1.33	1.33	146	70	6.77
	Trt	41	143	3444	668	10	1.00	1.97	117	102	2.97
8^	Con	45	152	3613	311	16	1.10	1.85	85	100	4.55
	Trt	45	171	4132	298	10	1.10	1.80	56	87	4.75

Table 2. Soil pH, Organic Matter, CEC, and Ratios

Farm	Plot	pH	OM (%)	CEC	K/Mg	Ca/Mg
1*	Con	5.76	1.78	8.54	0.38	6.59
	Trt	5.48	2.12	9.88	0.12	3.24
2*	Con	6.2	2.5	10.6	0.11	3.69
	Trt	6.2	2.6	12.4	0.07	2.92
3^	Con	5.97	4.20	23.07	0.09	3.12
	Trt	6.90	4.43	24.77	0.07	3.09
4*	Con	7.43	5.35	53.7	0.19	10.06
	Trt	7.50	6.25	63.9	0.27	11.08
5*	Con	6.56	4.13	23	0.07	3.28
	Trt	6.38	4.53	27	0.085	3.82
6*	Con	6.05	3.03	10.2	0.13	3.23
	Trt	5.75	2.93	10.9	0.13	2.13
7^	Con	6.73	5.73	26.47	0.10	5.41
	Trt	6.30	4.77	25.97	0.07	3.19
8^	Con	7.4	4.2	21.15	0.14	7.07
	Trt	7.8	4.2	23.65	0.46	8.66

[4] ^ denotes 2-year participant and * denotes 3-year participant

Table 3. Soil Total Organic Carbon (TOC), Inorganic Carbon (IC), and Total Carbon (TC) in PPM

Farm	Plot	TOC	IC	TC
1*	Con	301	2	303
	Trt	308	18	326
2*	Con	300	18	318
	Trt	309	18	327
3^	Con	285	5	300
	Trt	276	48	324
4*	Con	298	28	326
	Trt	319	71	390
5*	Con	250	3	253
	Trt	287	4	291
6*	Con	318	18	336
	Trt	281	17	298
7^	Con	126	2	128
	Trt	314	31	345
8^	Con	323	23	346
	Trt	365	35	400

Soil Carbon Analysis

Measurements of total carbon (TC), total organic carbon (TOC), and inorganic carbon (IC) were measured for each farm for both the treatment and control plots using a single soil sample collected in year two for each farm (Table 3). Soil Carbon analysis was performed by Quorum Labs. Results from the 8 farms showed increased TOC and TC in the treatment plots in 7 of the 8 farms measured. Inorganic carbon (IC) was higher in 6 of the 8 farms, with 1 farm showing no difference between treatment and control. Only 1 farm had increased TOC, IC, and TC in the control plot.

Soil Biological Analysis

A soil biological assessment was performed using the Ward Lab Phospholipid Fatty Acid (PLFA) test. This test assesses eleven specific microbial parameters that include total living microbial biomass (TLMB), soil bacteria, fungi, and protozoa, along with a fungi:bacteria ratio (F:B), predator:prey ratio (P:P), and Gram+:Gram- bacteria (G+:G-) ratio. There are 11 different individual microbial variables measured with the PLFA analysis, along with the ratios (Table 4).

In comparing the 3-year means for each of the 11 variables measured, 7 out of the 8 farms showed slight to significant advantages for the treatment plots in 7 or more of the 11 variables. 2 out of the 8 farms exhibited an advantage in all 11 variables. Only 1 of the 8 farms did not show an advantage for the treatment plot compared to the control.

Table 4. PLFA Data – Control vs. Treatment Plots (ng/g)

Farm	Plot	TLMB	GD	TBB	G+	Act	Rhiz	G-	TF	AMF	SF	Prot
1*	Con	821	1.2	402	286	79	0	116	19	0	19	0
	Trt	1169	1.1	580	429	117	0	151	21	0	22	0
2*	Con	1701	1.4	815	523	160	3	292	109	35	74	4.8
	Trt	2321	1.4	1155	795	266	15	359	166	57	109	8.1
3^	Con	2630	1.47	1519	980	331	67	538	283	85	198	29
	Trt	3831	1.53	2145	1369	477	53	776	440	160	280	42
4*	Con	4181	1.59	2080	1399	516	97	965	510	158	352	36
	Trt	4990	1.53	2825	1677	620	101	1145	578	198	379	49
5*	Con	2807	1.47	1523	961	322	57	568	254	71	182	18
	Trt	3653	1.44	1945	1223	397	66	722	345	106	239	45
6*	Con	2710	1.39	1355	834	270	33.4	521	240	58	183	15.1
	Trt	2644	1.33	1361	896	257	0.00	464	188	41	145	9.65
7^	Con	2284	1.36	1233	887	8.51	314	345	155	52	103	8.28
	Trt	2135	1.48	1257	845	35.42	303	410	198	65	133	14.9
8^	Con	3164	1.32	1688	1127	352	.00	560	210	89	122	9.9
	Trt	3822	1.44	2094	1276	387	18	818	434	160	274	41

Table 5. PLFA Data – Control vs. Treatment – Microbial Population Ratios

Farm	Plot	Fungi:Bacteria	Predator:Prey	Gram+:Gram-
1*	Con	0.11	0.00	2.32
	Trt	0.04	0.00	2.81
2*	Con	0.13	0.006	1.87
	Trt	0.14	0.007	2.28
3^	Con	0.16	0.01	2.36
	Trt	0.19	0.02	1.83
4*	Con	0.23	0.02	1.46
	Trt	0.19	0.02	1.78
5*	Con	0.15	0.01	2.06
	Trt	0.15	0.01	2.61
6*	Con	0.14	0.008	1.71
	Trt	0.12	0.004	1.98
7^	Con	0.12	0.01	3.06
	Trt	0.15	0.01	2.26
8^	Con	0.11	0.00	2.11
	Trt	0.19	0.02	1.79

Similarly, the treatment plots showed an advantage in the F:B, P:P, and G+:G- ratios for 6 out of the 8 farms (Table 5).

Soil Bio-Profile (Metagenomic) Analysis

A relatively new test available for soil biological analysis is the metagenomic analysis performed by Quorum Labs. This test was not available at the start of the 3-year trial but was added as an additional analysis in year two. Soil samples were collected from both the control and treatment plots for each farm participating in the trial. Included in the metagenomic profile was the total microbial phyla present, total bacterial species, and breakdown by biomass of each species (Table 6). Differences between the control and treatment plots were observed for each farm for these variables. Final assessment of these differences requires more detailed analysis to discern favorable vs. unfavorable impact. For metagenomic analysis, conclusions cannot be drawn from whether variables were simply higher or lower in the control vs. treatment plots. The total number of phyla and species present are important, but to understand the meaning of these variables, an understanding is needed for specific phyla and species present and their function in the soil ecosystem, along with their specific microbial biomass. It is important to note that there are both favorable and unfavorable species present in the soil (some potentially pathogenic) and their ratio to each other in the soil must be accounted for.

Table 6. Soil Bio-Profile: Microbial Phyla and Species.

Farm	Plot	Phyla	Species
1*	Con	18	11500
	Trt	18	18800
2*	Con	13	30000
	Trt	13	17500
3^	Con	14	24000
	Trt	16	28000
4*	Con	10	5000
	Trt	8	4000
5*	Con	17	40000
	Trt	11	11000
6*	Con	18	70000
	Trt	16	42000
7^	Con	12	17000
	Trt	12	15000
8^	Con	12	13000
	Trt	15	28000

SUMMARY OF ECONOMIC RESULTS

Final economic results are based on information and data gathered from each cooperator by the project partners: Land Stewardship Project (LSP), Practical Farmers of Iowa (PFI) and the Sustainable Farming Association (SFA). This project tracked costs of cover crop management (labor, seed costs, planting costs, and termination costs), grazing costs (labor, water, fencing), and benefits including forage production, erosion reduction, estimated soil fertility improvement, herbicide reductions, increased water storage, and any yield benefit.

Based on previous field observations and farm experience, project partners wanted to explore the application of multi-species cover crop blends to enhance soil microbial diversity and populations and increase nutrient availability in the soil. Partners also wanted to explore and document the economic potential of grazing diverse cover crops to offset winter forage costs. These economic results indicate that grazing cover crops can generate forage value and other on- and off-farm benefits that more than cover the cost of planting and grazing.

ECONOMIC METHODS AND ANALYSIS

The economic data collected from each cooperator was entered into the NRCS Cover Crop Economic Version 2.1 tool. This tool calculates both short- and long-term costs and benefits associated with implementing a farm management practice. All costs and benefits are calculated on a $/acre basis.

For short-term cover crop costs, data collected included seed, planting, fertilizer, termination, and management time costs. Short-term costs of grazing included costs for fencing, watering systems, haying or baling, and management time.

Short-term cover crop benefits include cost savings due to reductions in chemical and/or fertilizer usage for the subsequent cash crop planted. Chemical and fertilizer usage was reported by farm throughout the trial. Short-term economic benefits due to erosion reductions are also included in this economic analysis tool. To estimate each farms' reduction in soil loss due to cover cropping, the Revised Universal Soil Loss Equation 2 (RUSLE2) was used. Each farm's crop rotation and management practices were included in the model, as well as the soil type, location (for climate), and approximate slope/length of slope for the cover cropped treatment plot. Simulation was performed twice, with the cover crop and grazing activities included in one simulation and excluded in the other. An estimate of soil saved by cover cropping was calculated by subtracting soil erosion in the grazed cover crop scenario from the soil loss in the no cover crop scenario.

Results ranged from 0.1 tons/acre/year to 4.0 tons/acre/year of soil erosion prevented through cover cropping, with an average of 0.7 tons/acre/year. Larger erosion benefits on some farms may have been due to steeper slopes and soil types. Prevented soil loss was valued at $2.10/ton.[5]

[5] Duffy, M. (2012). Value of Soil Erosion to the Land Owner. Iowa State University Extension and Outreach. *Ag Decision Maker.* https://www.extension.iastate.edu/agdm/crops/html/a1-75.html

Short-term benefits of grazing are attributable to value of forage produced from the cover crop. For this project, the forage benefit was calculated by taking the number of animal units grazed multiplied by the number of days grazed multiplied by animal dry matter (DM) needs (estimated to be 3.2% of body weight) per day. The resulting forage production was then multiplied by the average forage price during the trial: $90 per ton for farms in Minnesota and $110 per ton for farms in Iowa. Forage prices are based on USDA NASS data for the trial period.

For long-term analysis, the cover crop and grazing tool is designed to take multiple factors in consideration:

1. Timeline of cover crop and grazing practices. This analysis assumes a fifteen-year time horizon; i.e. grazing cover crops will be used each year for fifteen years.

2. Starting level of soil organic matter (SOM) and the years it will take to increase SOM by 1%. This analysis used average soil analysis results for each farm as a starting point and estimated the change in SOM will increase by 1% every 5 years using the described management practices.[6]

3. Short-term costs and benefits associated with grazing a cover crop (described above), amortized at 3% over fifteen years.

4. Increased nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and carbon (C) in the soil, based on increasing SOM by 1%. Average regional market prices were used to place a value on nutrients, with N valued at $0.30/lb, P valued at $0.25/lb, K valued at $0.20/lb, and S valued at $0.10/lb. The change in P, K, C, and S amounts is based on Oldfield et al 2017.[7]

5. Cover crop value in reducing soil loss, based on the same RUSLE2 calculations used for short-term analysis. RUSLE2 considers soil type and slope of each farm.

6. The water storage benefit from increasing SOM by 1%. The tool recommends using $12.50 per acre as the value of water storage. The project team used higher calculations based on USDA ERS research[8] into the potential impact of droughty conditions on Midwest corn and soybean yields. A 1% increase in SOM equals 27,000 gallons of water per acre stored in the top 6 inches of topsoil.[9] This increased water storage capacity can be beneficial to corn and soybean yields, during drought years. Based on the USDA-ERS study cited above, we calculated that the market value in increased productivity would be $46.90 per acre per year in a conventional corn-soybean rotation. This value was used for all cooperators in the trial except on Farm #6, where the cooperator planted corn on the treatment acres in both years. The benefit on increased water storage capacity per acre has a higher impact on corn productivity than soybeans.

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[6] Machmuller, M. B., Kramer, M. G., Cyle, T. K., Hill, N., Hancock, D., & Thompson, A. (2015, 04). Emerging land use practices rapidly increase soil organic matter. *Nature Communications, 6*(1). doi:10.1038/ncomms7995

[7] Oldfield, E.E., Wood, S.A., and Bradford, M.A. (2017). Direct effects of soil organic matter on productivity mirror those observed with organic amendments. *Plant and Soil, 423*(1-2), 363-373.

[8] Westcott, P.C. and Jewison, M. (2013). Weather Effects on Expected Corn and Soybean Yields. USDA Economic Research Service. https://www.ers.usda.gov/publications/pub-details/?pubid=36652.

[9] USDA NRCS. Soil Health Key Points. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1082147.pdf

Results:

1. **Short-Term Results (Table 7)**

    a. Cover Crop Costs: Table 7 details costs for each of the cooperating farms. Seed, planting, management, and termination costs varied widely, from a high of $128.46 per acre to a low of $52.60 per acre. This variability is attributable to variation in cover crop seeds costs and management practices. Seed mixes were tailored to the specific needs of each farm based on an assessment of producer goals prior to planting. Goals included enhancing the soil microbial community, addressing compaction, reducing weed pressure, increasing water infiltration, or providing grazing opportunities to integrate cattle. Some cooperators also used chemical means to terminate the cover crop, while others planted the succeeding cash crop directly into the cover crop, leading to termination cost of $0.

    b. Grazing Costs: Grazing costs varied, but over a narrower range. Costs ranged from $4.72 to $42.04 per acre. Variance is due largely to management time required to apply adaptive grazing practices, and establishment and amortization of fencing and watering costs. This was evident where the cooperating farmer was new to grazing or the trial was conducted by a farmer-grazier pair. Of note is the reduction in grazing cost during the trial on Farms #2, #4 and #6. On these farms, cooperator experience and understanding of adaptive grazing methods improved significantly following year 1, leading to reduced management time.

    c. Forage Benefit: Net forage values varied widely, from $19.69 to $360.00 per acre. Weather, rainfall, and temperatures greatly impacted the germination of cover crops planted in the fall following a corn or soybean harvest. Lack of germination led to cover crop failures on Farm #2 in Year 3 and Farm #5 in Years 2 and 3. Cover crop was aerially seeded on both farms, however the same seeding method was also used on Farm #3 which did not experience a cover crop failure. Highest per acre returns were noted on cooperating farms that planted cover crops during the summer, following either a small grains harvest or harvesting the crop for silage. These farms drilled in the cover crop.

    d. Erosion Benefit: Benefit was modeled to be constant over time based on the slope, soil type, and management/crop rotation within the treatment acreage of each farm. Of note is the significant erosion benefit on Farm #2 of $20.40/acre/year, likely due to higher slope on this farm.

Table 7. Short term costs by farm ($/acre/year).

		Short-term costs		Short-term benefits	
Farm	Year	Cover Crop Costs	Grazing Costs	Forage Value	Erosion Reduction
1	year 1	$ 63.03	$ 18.20	$ 32.03	$ 3.06
	year 2	$ 67.37	$ 29.12	$ 64.06	$ 3.06
	year 3	$ 63.49	$ 10.53	$ 19.69	$ 3.06
2	year 1	$ 122.40	$ 6.00	$ 21.40	$ 20.40
	year 2	$ 128.46	$ 6.00	$ 24.48	$ 20.40
	year 3	$ 88.34	$ -	$ -	$ 20.40
3	year 1	$ 98.10	$ 17.00	$ 101.70	$ 1.07
	year 2	$ 108.43	$ -	$ 328.50	$ 1.07
4	year 1	$ 115.11	$ 31.08	$ 54.00	$ 1.43
	year 2	$ 115.06	$ 15.04	$ 72.00	$ 1.43
	year 3	$ 69.86	$ 15.04	$ 72.00	$ 1.43
5	year 1	$ 60.14	$ 25.72	$ 27.00	$ 1.52
	year 2	$ 58.87	$ 4.72	$ -	$ 1.52
	year 3	$ 70.71	$ 4.72	$ -	$ 1.52
6	year 1	$ 74.05	$ 42.04	$ 151.88	$ 1.53
	year 2	$ 58.63	$ 42.02	$ 202.50	$ 1.53
7	year 1	$ 52.60	$ 27.55	$ 63.00	$ 0.51
	year 2	$ 54.20	$ 11.05	$ 108.00	$ 0.51
8	year 1	$ 54.85	$ 22.46	$ 360.00	$ 0.51
	year 2	$ 55.60	$ 22.46	$ 270.00	$ 0.51

2. **Long-Term Results (Table 8)**

   a. Average Costs: Average annual costs include cost of cover crop seed, planting, termination, and management, plus costs of grazing including fencing, watering, and management. Average cost for all farms was $82.87 per acre over the fifteen-year time horizon.

   b. Average Grazing Benefit: This represents the value of cover crop forage over the fifteen-year time horizon. Average benefit to all cooperating farms was $123.06 per acre per year.

   c. Soil Erosion Benefit: The soil erosion benefit represents annual short-term value of reduced soil erosion amortized over fifteen years. Average benefit to all farms was $3.76 per acre per year.

   d. Yield Benefit: One cooperator (Farm #2) experienced a yield benefit possibly attributable to planting a cover. $2.69 per acre per year represents the average of the short-term benefit, attributed every other year due to the cooperator's cash crop rotation, over a fifteen-year time horizon.

   e. Herbicide Reduction Benefit: One cooperator (Farm #5) experienced an herbicide reduction benefit possibly attributable to planting a cover. $6.37 per acre per year represents the average of the short-term benefit, attributed every other year due to the cooperator's cash crop rotation, over the fifteen-year time horizon.

   f. Soil Fertility Benefit: This variable represents the value of long-term increases in soil fertility. Value is based on an expected increase in SOM of a least 1% every 5 years due to the adaptive grazing of complex cover crops. This increase in SOM leads to improved soil fertility and reductions in the amounts of N, P, K, and S that need to be applied to achieve the same crop yields. There is also an accompanying increase in soil organic carbon as SOM increases. This analysis assumes that every cooperator will increase SOM at the same rate because of grazing cover crops. Net soil fertility benefit over fifteen years is $53.93 per acre per year.

   g. Water Storage Benefit: This column shows the value of increased crop productivity based on the improved water storage capability attributable to increases in soil organic matter over fifteen years.

   h. Total and Net Benefit: These columns indicate the total long-term benefits as well as the benefits minus the costs, or the net benefits, of grazing cover crops. On all farms, net returns were positive long-term on a $/acre/year basis for each cooperator participating in the trial.

Table 8. Long term costs-benefits by farm ($/acre/year).

Farm	Average Costs	Average Grazing Benefit	Average Soil Erosion Benefit	Yield benefit	Herb-icide Reduction Benefit	Average Soil Fertility Benefit	Average Water Storage Benefit	Total Benefit	Net Benefit
1	$63.81	$36.44	$3.06	$0	$0	$53.93	$46.90	$140.33	$76.52
2	$113.70	$15.56	$20.40	$2.69	$0	$53.93	$46.90	$139.48	$25.78
3	$142.97	$207.67	$1.07	$0	$0	$53.93	$46.90	$309.57	$166.60
4	$77.45	$65.95	$1.43	$0	$0	$53.93	$46.90	$168.21	$90.76
5	$63.28	$ 9.33	$1.53	$0	$6.37	$53.93	$46.90	$118.08	$54.78
6	$67.04	$133.70	$1.53	$0	$0	$53.93	$53.93	$243.09	$169.02
7	$53.47	$84.13	$0.51	$0	$0	$53.93	$46.90	$185.47	$132.00
8	$55.32	$318.93	$0.51	$0	$0	$53.93	$46.90	$420.27	$364.94
Ave.	**$82.87**	**$123.06**	**$3.76**	**$0.34**	**$0.80**	**$53.93**	**$46.90**	**$215.56**	**$135.05**

LIMITATIONS, CONCLUSIONS, AND NEXT STEPS

Limitations

On-farm research can pose unique challenges. One such challenge is a significant amount of variability in on-farm practices. This variability is needed to understand the real-world spectrum of methods producers use, but such variability can also produce wide-ranging results and limit judgement on causality of each farm's practices and results.

Statistical analysis was not performed for this report, as preliminary assessment showed that any analysis would likely be limited by the small sample size and lack of soil sample replicates, in addition to the variation in farm practices and results. However, future planned work by several partners on this project, including a grazing cover crop trial with 6 new cooperators in Illinois and Missouri by the Pasture Project, will help determine whether the results seen here are statistically significant. The results shown in this project are still valuable in showing relative changes by farm and general trends.

Another challenge for applied, on-farm research is frequently a mismatch of grant funding and the timeline needed to see significant changes in soil health. In this 3-year project, modest improvements in soil health were observed, and the economic analysis predicts larger changes over time. However, more research is needed to confirm the long-term benefits of grazing cover crops, particularly because the literature suggests that there may be a "lag" period of several years before large soil health benefits occur.[10]

[10] Machmuller, M. B., Kramer, M. G., Cyle, T. K., Hill, N., Hancock, D., & Thompson, A. (2015, 04). Emerging land use practices rapidly increase soil organic matter. *Nature Communications*, *6*(1). doi:10.1038/ncomms7995

Finally, research on farms is crucial to understand real farm conditions and constraints, but data collection and data management can still be a challenge for producers. The onus is on the research team to streamline and simplify data collection as much as possible so that farmers are not overburdened and that all necessary support is available. If this does not occur, gaps in data are likely.

Conclusions

Cooperators in this project saw moderate soil health improvements, particularly early signs of improved soil biological health, as well as net financial benefits from forage and soil fertility increases. Projected increases in soil nutrients, soil carbon, and water holding capacity allowed all cooperators to attain positive economic results, even for those cooperators with cover crop failures. The magnitude of the economic benefits of grazing a complex cover crop are a direct result of cover crop productivity and number of grazing days or animal units that can be grazed. Productivity is highly dependent on germination of the cover crop seed.

In this trial, germination was closely associated with the time of year the cover crop was planted and the seeding method used. On cooperating farms where the cover crop was directly seeded, only one failure was noted, and this failure was likely attributable to the type of cover crop mix planted (weighted heavily to brassicas). Many Midwest farms are now direct seeding cover crops into corn at the V-4 to V-6 stage or using a "high boy" planter in later stages during late summer. Because of improved seed-to-soil contact and warmer temperatures, this planting method improves cover crop germination and increases the likelihood of a fall forage stand that can facilitate economical grazing opportunities. Other opportunities for early planting present themselves when small grains or other short season crops such as field peas are used as the cash crop, allowing more growing-degree days for cover crop growth.

Interseeding cover crop into corn using a modified no-till drill planting cover crops between 30" corn rows. (Photo credit: Grass Fed Insights)

Well-established cover crop prior to corn harvest.
(Photo credit: Grass Fed Insights)

Although producers cannot control the weather, management plays a key role in determining the potential success of any crop. Attention to details such as proper seeding rates, equipment calibration and maintenance, prior crop herbicide program, seeding depth, timely seeding, using quality seed, and selection of cover crop seed mixes to meet the goals for a particular field will go a long way toward producing a cover crop that can provide economically viable grazing opportunities. The results of this project show that the combination of a robust complex cover crop stand coupled with a well-managed grazing program will provide the greatest agronomic, economic, and environmental benefits to the targeted field and farm operation.

Next Steps

Replication of the results of this trial are needed to confirm the positive benefits of grazing cover crops. The Pasture Project has begun a new trial with 6 cooperators in Missouri and Illinois, building on the work performed here. Additionally, replication by other organizations will further bolster the soil health and economic case for grazing cover crops.

The potential of grazing cover crops has yet to reach all the farmers that could benefit. Additional outreach to share existing resources, and development and scaling of new resources, such as innovative matchmaking sites like Minnesota's Cropland Grazing Exchange, are needed to reach more livestock and row crop producers.

Additionally, many challenges still exist in cover crop management, and solving these challenges will require that farmers, agronomists, researchers, and conservationists work together. For example, we know that herbicide residuals often impact future cover crop stands for grazing, so solutions are needed to optimize the implementation and integration of cover crops and grazing for as many farmers as possible.