ECOTONE ANALYTICS

Impact Analysis
and **Social Return on Investment**

Technical Document for:

Green Lands Blue Waters

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Ecotone Analytics Impact Analysis

TECHNICAL DOCUMENT FOR GREEN LANDS BLUE WATERS

About this Report

Ecotone Analytics conducted this impact analysis and calculated the projected social return on investment for Green Lands Blue Waters. This report considers the impact generated from implementing Perennial Forage and Grazing practices in the Upper Midwest.

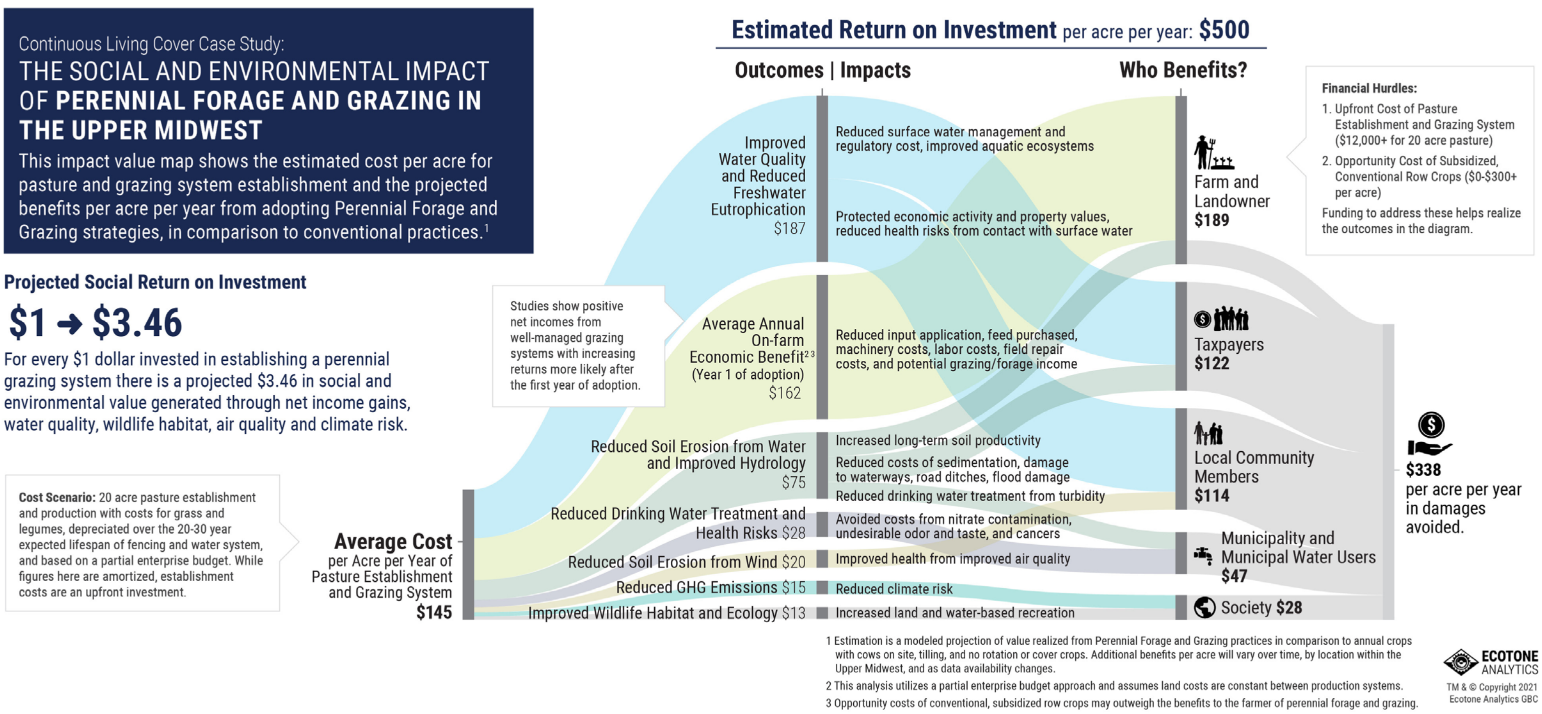
About Ecotone Analytics

Ecotone Analytics is an impact accounting organization that does benefit-cost analysis for clients' social and environmental impacts. Combining evidence-based research analysis and monetization of impact outcomes, Ecotone derives a social return on investment ratio and identifies the key stakeholder groups to whom those impact benefits accrue. Results are communicated using a proprietary visualization of the flows of value that result from the initial investment.

IMPACT VALUE MAP

THE SOCIAL AND ENVIRONMENTAL IMPACT OF PERENNIAL FORAGE AND GRAZING IN THE UPPER MIDWEST

This impact value map shows the estimated cost per acre for pasture and grazing system establishment and the projected benefits per acre per year from adopting perennial forage and grazing strategies, in comparison to conventional practices.



EXECUTIVE SUMMARY

Green Lands Blue Waters (GLBW) is a network node, an unincorporated coalition that acts as a connector, collaborator, convener, and communicator for a network of partners to support the development of and transition to a new generation of multi-functional agricultural systems in the Upper Mississippi River Basin and adjacent areas that integrate more perennial plants and other Continuous Living Cover into the agricultural landscape.

Ecotone Analytics conducted an impact analysis and calculated a social return on investment (SROI) for Green Lands Blue Waters (GLBW), analyzing Continuous Living Cover (CLC) strategies, with an SROI projection for the Perennial Forage and Grazing (PFG) strategy. The analysis began with an agreed upon depiction of the GLBW, the CLC and the PFG Logic Models, i.e. the roadmap for how a given set of inputs and activities will generate the outcomes and impact desired. From there, external literature's study of the effects of CLC and PFG on water quality, soil erosion, carbon sequestration, streamflow, rural economies among other subjects, informed the identification of outcomes to monetize.

Following our research and analysis, we project that the SROI achieved by the PFG strategy will be approximately \$3.46.[1] That is, **for every \$1 dollar in investment made in supporting the establishment of a perennial pasture and grazing system on farms with livestock, a projected \$3.46 in social and environmental value** will be generated, with benefits flowing to farms, taxpayers, community members, municipal water users, and the broader global society. The largest outcome monetized was the projected reduced costs of eutrophication due to avoided nutrient runoff, followed by the financial returns accruing to the farm.

Based on this analysis, we have identified recommendations for future impact measurement, operational management, and strategic opportunities to consider pursuing. This includes leveraging the UN Sustainable Development Goals as well as the Impact Management Project's 5 dimensions of impact to communicate the type of change being facilitated by Perennial Forage and Grazing as well as Continuous Living Cover strategies more broadly.

Further discussion on recommendations are included starting on page 35.

1 The SROI here is communicated as a benefit-cost ratio. SROI can also be communicated as a percent return, similar to a financial ROI. Using the two definitions, PFG's SROI can be framed as \$3.46 or 246%. Each is valid although we utilize the benefit-cost ratio framing throughout for consistency and to minimize potential confusion.

INTRODUCTION and RESEARCH QUESTION

Ecotone Analytics conducted an impact analysis and calculated a social return on investment (SROI) for Green Lands Blue Waters (GLBW), focusing on the Perennial Forage and Grazing (PFG) strategy of Continuous Living Cover (CLC). This analysis takes a benefit-cost approach to external literature of the highest available level of evidence of causality to estimate the total social, environmental and economic value generated by PFG.

The analysis is guided by the following research question:

What is the estimated social return on investment in the adoption of Perennial Forage and Grazing systems, the key outcomes experienced and to whom do the benefits accrue?

The research question itself is straightforward enough, but once a range of factors including variation in grazing practices, pasture types, cash crop values, changes in on-farm investments, climate and weather conditions, area freshwater use and dependency, drinking water treatment needs, recreation values, and so forth, are taken into account, our research question becomes a multi-sectoral deep dive into the agricultural economy and its interconnectedness to broader society.

As a result, this analysis also served to support the recognition of where current research gaps exist that, once filled, could further support the field's understanding of the costs and benefits associated with PFG. For now it is important to note the uncertainty in these estimations as they will vary from field to field, and acre to acre. The final SROI ratio is dependent on the underlying numbers which are derived from agronomy, natural sciences, and social sciences. Given the subject is still receiving and deserving considerable rigorous scientific study, this analysis represents a story of Perennial Forage and Grazing, a narrative that is still being written rather than a concrete, singular truth. As a result, this analysis can be considered a starting point, to show the potential social, economic, and environmental value created per acre from the adoption of PFG. Given the varying current understandings of the effects of PFG systems, development of robust point estimates (a precise dollar value) for many of these outcomes are based on conservative evidence-informed estimations.

STRUCTURING THE ANALYSIS

SCOPING

The scope of this analysis was developed in collaboration with the GLBW team, its network partners as well as our own review of external literature which focused on approaches to valuing the long-term outcomes resulting from PFG.

It began with an understanding of what PFG encompassed based on the GLBW definition:

> ***"Perennial forage refers to land planted with perennial plants that feed livestock like alfalfa, white clover, and red clover. . . Carefully managed grazing can benefit the environment by improving soil, reducing runoff and soil erosion, creating wildlife habitat, sequestering carbon, and conserving resources. However, studying the environmental benefits is challenging and additional research is needed to fully understand its impact on carbon sequestration and conservation."***

The Working Group added nuance, noting there is a difference between perennial and continuous living cover. They are mutually inclusive but shouldn't be used synonymously given that annuals can be a part of CLC. The goal can be restated as 'roots in the ground year round' in an effort to better mimic nature. In the case of PFG, the system is meant to mimic the prairies with year round ground cover and periodic grazing by ruminants.

Well-managed grazing is thus the key assumption for this analysis. Grazing has traditionally been mismanaged leading to lots of negative connotations. Poor grazing management may have the same level of negative effects as annuals and it is important to draw this distinction.

SCOPE OF ECOTONE ANALYSIS

SCOPE OF ECOTONE ANALYSIS	Projecting costs and benefits of CLC strategies, with a focus on Perennial Forage and Grazing. This included supporting framing on a networked approach strategy to further CLC adoption (accompanying document).
GOALS OF ANALYSIS	Develop big puzzle pieces in making the case for CLC and perennial agriculture in a way to: inform and attract private and public funding and other project support, and more strategically organize and coordinate networked efforts.
TARGET AUDIENCE FOR ANALYSIS	• Public and private funders to position GLBW network partners and GLBW itself • State & Local government - Municipalities, County, Joint Powers Boards, State
POPULATION SERVED	Upper Midwest geographic focus
SCALE	Vision of a landscape scale approach - cost-benefit analysis takes a per acre valuation approach to align with literature base.
THEORY OF CHANGE	A networked approach for supporting CLC to foster landscape scale change to create profitable, equitable and sustainable food systems

As a part of each Ecotone analysis, we also work to highlight the range of stakeholders impacted by the program.

Table 1a. Key Stakeholder Groups

1. FARMER / LANDOWNER	2. GOVERNMENT	3. COMMUNITY MEMBERS	4. CLC FACILITATORS
• Older farmers near retirement • Young farmers • Neighboring farmers • Resident landowners • Absentee landowners • Multi-generational farming families • Large-scale farms • Small-scale farms	• Conservation districts • Municipal governments • State agencies • Federal agencies (NRCS - CSP, EQIP, Crop insurance - drought and flood; FEMA - flood risk; EPA - drinking water)	• Residents of the Midwest • Rural towns and communities • Consumer of final products (made from farmers' crops) • Tourists / Visitors / Hunters / Fishers to Midwest • Downstream residents • Gulf of Mexico residents • Global society	• Soil Health partnerships, interest groups and other non-profits • Local non-profits • Academia and research institutions, extension programs • Investors

Table 1b. Key Stakeholder Groups

5. BUSINESSES	6. LIVESTOCK	7. NATURE
• Agricultural retailers / agronomists • Agribusinesses and agri-tech companies • Food product supply chain • Banks and insurance companies • Local commercial and industrial water users • Biofuel companies • Non-Biofuel energy companies • Carbon market participants • Private investors / donors	• Beef cattle • Dairy • Sheep/lamb • Alpaca, llama • Goat • Other grazing animals • Other livestock fed with non-CLC based feed	• Wildlife, birds, fish • Pollinators and other beneficial insects • Surface water • Ground water • Ecosystems • Air

PROCESS

We continued by addressing a series of questions to guide our literature review and frame the analysis:

- What does Perennial Forage and Grazing encompass in the literature?
- What aspects of PFG has the literature reviewed? And how does it describe PFG?
- How much does it cost to implement PFG systems?
- What are the obstacles / opportunities for PFG? What leverage points are noted in the literature?
- What type of benefits do farmers/ landowners realize from implementing PFG strategies?
- What are potential off-farm outcomes from PFG?
- How much does PFG impact ecosystem services?

Our literature review on the subject done in collaboration with the GLBW and the network partners found limited research that encompassed the entirety of a PFG strategy and did so in a manner to compare to an alternative conventional practice. Where possible our estimation focuses on the known cumulative effects of these practices, but where data limitation exists, we utilize conservative median figures from across the multiple practices to protect against overclaiming impact.

The process to identify potential costs and benefits associated with off-farm impacts relevant for perennial forage and grazing included a broad literature review encompassing research on:

- Research on land use best practices and in particular for agriculture,
- The study of agricultural practices with perennials and the different CLC strategies,
- Federal conservation programs and cost-share valuations,
- Ecosystem service markets already established and their learnings/approaches to accounting for CLC strategies

This was then followed by a more focused scan of the literature to isolate specific costs and benefits for off-farm impacts and provide the necessary information to quantify impact. This review included:

- Local surface freshwater use
- Conditions for eutrophication
- History of surface water quality as a health risk
- Local drinking water dependencies and health risks from drinking water
- Costs and options for drinking water alternatives
- Tourism and recreation expenditures (boating, fishing, hunting, swimming, camping, sailing, etc.)
- Local infrastructure and water treatment costs
- Existence value of natural areas and water bodies
- County, State and Federal investments and assets in the agricultural Midwest (e.g. roads, ditches, reservoir maintenance)
- Historical and potential flood damage
- Opportunity costs to farmers of different practices as compared to direct costs of the practice

SROI SCENARIOS

Grazing is a highly flexible and adaptable tool for management of forage, soil health and herd health (GLBW - Integrating Livestock Manual, 2014). To manage the many potential scenarios PFG could be implemented we had to select one to focus on for our storytelling. This required both mapping out the variety of scenarios that could exist, and assessing the extent the evidence base represents comparisons between those scenarios as well as the extent each comparison captures the goals and positioning of GLBW and its network amid the sustainable agriculture fundraising landscape.

Table 2. SROI scenario selection

SELECTION OF SCENARIOS				**Livestock Location** - (assume for Beef production)		
				Cows on site	**Cows coming from off site**	**Forage being brought to the cows**
Field Use - selection of scenarios	Annuals - no rotation, no cover crops, and tilling	No grazing	Buying and growing some feed	**Counterfactual**		
		Grazing	Rotational or Adaptive			
			Continuous			
	Annuals with cover crops	No grazing	Buying feed			
		Grazing	Rotational or Adaptive			
			Continuous			
	Perennials	No grazing	Buying feed			
		Grazing	Rotational or Adaptive	**Practice adopted**		
			Continuous			
	Natural Pasture	Grazing	Rotational or Adaptive			
			Continuous			
	CRP	Grazing	Rotational or Adaptive			
	Woodlands	No grazing	Buying feed			
		Grazing	Rotational or Adaptive			
			Continuous			

Table 3. Leverage Points from the PFG meeting

PERENNIAL FORAGE WORKING GROUP LEVERAGE POINTS
Economic argument is worth addressing as there is potential for financial gain from PFG however it is not well-suited to a blanket statement of profitability.
Contracts for grazing exchanges are an underdeveloped tool for assigning responsibility and facilitating the scaling of the practice.
Transportation of animals can be an obstacle if having to bring animals to their grazing site.
It is important to think about the targeting of resources. One route to pursue is targeting those new farmers who can receive funding support when starting out with a livestock integration operation.
Farmers can point unequivocally to reduced erosion - this is an important strength to be communicated.
Crop insurance payouts influence what investments are made and as a result should be adjusted so as to better reflect the risk being born in perennial forage grazing systems.

ASSUMPTIONS

To develop a suitable model for the Social Return on Investment estimation, the analysis relies on a series of assumptions. Below are the core assumptions that dictated the scope of the analysis. Additional assumptions are built into the individual outcome estimates and will be discussed later in this report as well as described in Appendix B.

CORE ASSUMPTIONS

- PFG system is implemented at a farm that has livestock on site and is establishing a pasture in a portion of their field that would otherwise be annual row crops such as corn and soybeans and is using conventional farming practices.
- The management of the livestock previous to the PFG system is assumed to be a feeding operation with some amount of poorly managed grazing likely.
- The PFG system is adopted on existing cropland, not adopted on rangeland, and does not include conversion of fallowed or CRP land
- Benefits are estimated over a 1 year time horizon and on a per acre basis
- Costs are based on the establishment of a 20 acre pasture and grazing system, assuming that livestock (in this case cows) are already on site but the farm has not utilized a well-managed rotational grazing system on perennial forage to date.
- Costs are estimated based on the combined establishment cost and production costs. Because establishment costs are a significant upfront investment, to compare against the annual projected benefits, we annualized the costs based on the 20-30 year lifespans expected for the fencing and water systems.
- On-farm net income benefits are estimated for the first year of system implementation to be more conservative (estimates of net income gains show livestock integration with cover crops increasing over time and are further increased with drought or flood conditions that will support faster realization of benefits in comparison to conventional practices). Net income in the visualization does not include opportunity cost of annual row crops which are considered a likely alternative to the PFG system.
- Environmental and social benefits are assumed to begin to accrue in year 1 of practice adoption. There are however many factors which may influence the speed and scale of impact realized given varying weather and rainfall conditions, soil types, pre-existing cropping practices, field contours, and location within a watershed.

CORE ASSUMPTIONS CONTINUED

- Environmental benefits of PFG system adoption are assumed to only occur for the duration the PFG system is in place. If land is converted back to annual row crops with conventional practices, we assume the environmental benefits are lost at that time as well.
- We do not specify where in the Upper Midwest the PFG system is being implemented, but utilize research from around the Upper Midwest to guide valuation of the ecosystem services included in the analysis.
- We do not directly account for location in the Upper Midwest, but note the variation of impacts that will result from implementation in high priority areas as compared to low priority areas. We are unable to account for the specificity within the Upper Midwest due to the current limitations of understanding the extent surface water and drinking water quality will change on a field by field basis. For example, for water quality impacts there is often a specific threshold that once crossed creates large costs for society, but understanding the extent different farm locations within the region will increase the risk of triggering a threshold to be crossed is difficult to attain. These thresholds include exceeding the EPA's 10mg/L limit of Nitrate in drinking water, the existence of an algal bloom, the decision to visit a river due to water quality, the decision to go swimming due to water quality, the diagnosis of cancer from high nitrate consumption, etc. In each of these cases, the costs incurred prior to crossing the threshold may be minimal, but upon reaching the threshold, regulatory and health related expenditures begin to occur and in the case of behavior change, spending is redirected to other outlets. Given this limitation, it is more conservative for our analysis to note the average potential value created, and recognize it is most likely to be realized in high priority areas of the region.

ADDITIONAL CONSIDERATIONS

As we are making an initial point estimate of potential social, economic and environmental value creation for the PFG strategy, many characteristics were noted to maximize alignment with the literature on PFG and ecosystem services to ensure the appropriateness of the benefits transfers utilized. Those characteristics taken into consideration included:

- Acres of cropland in production in the Upper Midwest
- Conventional cropping practices in the Upper Midwest including average nutrient application rates (for corn, wheat, and soybeans), tillage practices, use of cover crops (if any)
- Perennial crop and forage markets in the Upper Midwest
- Average rainfall and water runoff
- Water quality conditions and Hydrology of major waterways and water bodies in the Upper Midwest
- Water quality conditions of drinking water sources in the Upper Midwest including the current and potential future risk
- Climate in the Upper Midwest
- Soil types in the Upper Midwest and the implications for increased water storage in soil and the relation to yield stability, drought resistance, moderated soil temperatures from heat waves
- Potential downstream marine impacts while not necessarily directly valued and their importance, particularly with regard to the dead zone in the Gulf of Mexico.

Clarifications regarding our analysis include:

- This analysis did not include primary data collection beyond interviewing members of the Midwest Perennial Forage and Grazing Working Group
- Assumptions were greatly informed through the support and discussion with the contributing partners on this project.
- We chose a point estimate for benefits and costs which will have varying values across the Upper Midwest and by practices implemented (e.g. types of forage, grazing intensity, etc.). The above assumptions were necessary to arrive at estimates of the potential benefits of soil health improvements in the Upper Midwest and the broader implications for multiple off-farm stakeholders.

With a scoping review conducted, we established a logic model to map the analysis.

LOGIC MODEL

The following table [see next page] shows the logic model, identifying the planned inputs, activities, and outputs for the PFG strategy, and from there, describing the outcomes accruing from all those activities conducted. These outcomes can be distinguished by whether they were short-term outcomes, intermediate outcomes or long-term outcomes (those achieved indirectly from the short-term and intermediate outcomes achieved). Last are the impacts directly attributed to PFG. The logic model serves as the map of the analysis, as intermediate and long-term outcomes are those we seek to monetize to calculate the final SROI.

Of note, while pursuing monetization for all those pathways identified in the logic model, inevitably some have a better evidence base than others, and in some cases, the data is too lacking to pursue monetization with a reasonable causal understanding. The following sections will describe in detail those pathways that were successfully monetized.

Table 4. Logic Model Key

1. HOW TO READ IT	2. RELATIONSHIP BETWEEN COLUMNS	3. PURPOSE	4. IN COMPARISON TO WHAT
Reads from left to right, with each column collectively influencing the column to its right and being influenced by the column on its left.	Individual cells do not necessarily link directly to those immediately on their left or right, although these specific causal chains will be established in our next steps.	Connects 'Inputs' (those resources required to begin) with the projected final 'Impact' resulting from and attributed to PFG strategies.	Outcomes and Impact described in the logic model are assumed to be in comparison to not having implemented PFG strategies.

INPUTS → ACTIVITIES → OUTPUTS → IMPACT

INPUTS	ACTIVITIES	OUTPUTS
Farmer		
• New farm investments and equipment • Learning Costs, adaptability, risk compensation, support network • Livestock (generally cattle?) • Access to grazing land with appropriate forage • Grazing land division, temporary paddocks	• Application of best practices to farm and animal context • Harvesting of hay/haylage • Transporting and feeding hay/haylage • Transporting livestock to grazing site • Rotational Grazing • Managing stocking density and rest, and moving cattle in timely ways	• Number of acres of Perennial Forage and Grazing • Number of acres in high priority areas • Number of cattle/other livestock grazing • Number of acres converted to perennial forage
Public Programs		
• Grassland Reserve Program; Farm and Ranch Land Protection Program; Conservation Stewardship Program; EQIP		

INPUTS → ACTIVITIES → OUTPUTS → **IMPACT**

PERENNIAL FORAGE AND GRAZING

In comparison to no additional Perennial Forage and Grazing practices being implemented

SHORT-TERM	INTERMEDIATE	LONG-TERM	IMPACT
• Potentially reduced water infiltration from grazing • Soil fertility, soil formation and soil aggregate stability in water • Increased fungal diversity • Increased organic matter • Increased biomass production • Increased soil microbial biomass • Potential reduced soil porosity with livestock • Improved dairy herd health • Increased soil organic carbon • Longer growing season • Increased use of erodable land	• Increased water holding capacity • Better regulated soil temperatures • Increasec soil carbon and transfer carbon to more stable forms in the pores between soil aggregates. • Increased wildlife and pollinator habitat - Alters grasslands to provide a variety of nesting, brood-rearing, cover, and foraging habitat for wildlife • Reduced feed expenses • Increased carrying capacity on existing acreage • Reduced soil erosion from water and wind • Reduced surface water and nutrient runoff • Potential shifts in labor needs • Reduced streambank erosion • Reduced invasive species • Increased nutrient cycling and increased nitrogen in soil • Interrupted disease, pest, and weed cycles	• Potential increased net incomes • Increased productivity of land • Increased economic resiliency (potential long term increase in profitability) • Cleaner water, reduced eutrophication and sedimentation • Increased carbon sequestration • Increased biodiversity and birds • Improved value and aesthetic of land • Stability of water flows and reduced flood risk • Reduced particulate matter in air	• Water quality and quantity • Soil health • Climate adaptation and climate change mitigation • Rural economic/ social vitality • Nurtured ecosystems • Enhancing justice, equity, and inclusion in food and agricultural systems • Healthy people • Biodiversity • Landscape resiliency • Air quality

PERENNIAL FORAGE AND GRAZING DRAFT COMPLETE LOGIC MODEL (AN AGGREGATION OF THE PREVIOUS TWO PAGES)

INPUTS	ACTIVITIES	OUTPUTS	*In comparison to no additional perennial forage and grazing practices being implemented*			
			SHORT-TERM	INTERMEDIATE	LONG-TERM	IMPACT
Farmer		• Number of acres of Perennial Forage and Grazing • Number of acres in high priority areas • Number of cattle/other livestock grazing • Number of acres converted to perennial forage	• Potentially reduced water infiltration from grazing • Soil fertility, soil formation and soil aggregate stability in water • Increases fungal diversity • Increased organic matter • Increased biomass production • Increased soil microbial biomass • Potential reduced soil porosity with livestock • Improved dairy herd health • Increased soil organic carbon • Longer growing season • Increased use of erodable land	• Increased water holding capacity • Better regulated soil temperatures • Increase soil carbon and transfers carbon to more stable forms in the pores between soil aggregates. • Increased wildlife and pollinator habitat - Alters grasslands to provide a variety of nesting, brood-rearing, cover, and foraging habitat for wildlife • Reduced feed expenses • Increases carrying capacity on existing acreage • Reduced soil erosion from water and wind • Reduced surface water and nutrient runoff • Potential shifts in labor needs • Reduced streambank erosion • Reduced invasive species • Increased nutrient cycling and increased nitrogen in soil • Interrupted disease, pest, and weed cycles	• Potential increased net incomes • Increased productivity of land • Increased economic resiliency (potential long term increase in profitability) • Cleaner water, reduced eutrophication and sedimentation • Increased carbon sequestration • Increased biodiversity and birds • Improved value and aesthetic of land • Stability of water flows and reduced flood risk • Reduced particulate matter in air	• Water quality and quantity • Soil health • Climate adaptation and climate change mitigation • Rural economic/ social vitality • Nurtured ecosystems • Enhancing justice, equity, and inclusion in food and agricultural systems • Healthy people • Biodiversity • Landscape resiliency • Air quality
• New farm investments and equipment • Learning Costs, adaptability, risk compensation, support network • Livestock (generally cattle?) • Access to grazing land with appropriate forage • Grazing land division, temporary paddocks	• Application of best practices to farm and animal context • Harvesting of hay/haylage • Transporting and feeding hay/haylage • Transporting livestock to grazing site • Rotational Grazing • Managing stocking density and rest, and moving cattle in timely ways					
Public Programs						
• Grassland Reserve Program; Farm and Ranch Land Protection Program; Conservation Stewardship Program; EQIP						

Green Lands Blue Waters IN PARTNERSHIP WITH ECOTONE ANALYTICS

EVIDENCE MAP & GAP ANALYSIS

An important aspect to this analysis and to complement the above leverage points was a review of the literature and recognition of where and to what extent evidence exists for the impacts of CLC associated practices and thus, a recognition of the gaps in the research that are needed to strengthen this analysis. This led to the creation of a Evidence Map and Gap Analysis (included as separate documents). We arranged the Evidence Map along a portion of the logic model, focusing on the short-term, intermediate, and long-term outcomes, and from there the monetization points required to attach a dollar value to the long-term outcomes. This serves to structure the existing evidence along a causal chain as well as to maintain an orientation towards long-term outcomes through which changes are experienced by stakeholders.

The Evidence Map and Gap Analysis are designed to serve as "living" documents that are continually added to and refined. The logic model pathways can be rearranged to allow for new evidence that may develop as well as the recognition of new outcomes not previously recognized.

Use and interpretations of the evidence map requires a few introductory points:

1. This is not an exhaustive literature review. The evidence base is deep in aspects of CLC although highly variable in terms of what is being studied. As such this mapping exercise clarifies the subjects of Ecotone's literature review to date.
2. Farm context is an overarching principle for use of this map. The types of outcomes noted are being realized across the Upper Midwest but may not be realized on every field tested.
3. This map focuses on the social, economic and environmental "returns" from the given activities, focusing on water quality, water quantity, carbon emissions and producer economics as qualitatively identified in the logic model.
4. The structure of the Evidence Map does not convey feedback loops, but rather a one-way trajectory towards a cost-occurring event. This is not to say feedback loops are not occurring - indeed we would expect and know that in natural environments there are constant feedback loops responding to changes. Future revisions of the evidence mapping may take this into account.

SUMMARY OF GAPS SEEN IN THE EVIDENCE MAP

To organize the evidence, we broke it down by the given CLC strategy adopted and as feasible noted what counterfactuals were being referenced in each study. The strategies laid out were:

1. Cross-strategy - two or more CLC strategies included
2. Perennial biomass
3. Perennial forage and grazing
4. Agroforestry
5. Perennial grains
6. Cover crops and winter annuals.

As a whole, and as noted by Basche and DeLong (2019), evidence of perennial systems is often limited. Basche and DeLong, even when combining agroforestry, perennial grasses and managed forestry into a single perennials category found only eight total studies that met inclusion criteria for their meta-analysis.

The research gaps discovered in this analysis are multi-fold. Gaps to be addressed include:

- CLC as an aggregate area of study rather than isolated strategies.
- The change in economic, environmental and health effects from moving between a conventional practices to perennial and CLC practices
- Social impacts of CLC have only lightly been addressed or considered
- CLC's on-farm economic benefits appear understudied - existing evidence is tied most strongly to subjects such as cover crops, livestock integration and grazing (although not necessarily perennial forage grazing).
- Ecosystem service valuation literature is varied and can be highly context specific
    - Valuations can vary significantly by economic valuation approach as well as from study to study within approaches
    - Ecosystem service valuation is not often tied to cropping practices or grazing systems but the results of those agricultural systems, such as nitrogen, phosphorus, water quality, sedimentation, etc.
    - Quality of valuations vary by type of outcome (e.g. health effects of poor surface water quality vs. changes in recreational use of water vs. fish and wildlife habitat vs. property values from being near surface water vs. property value from unstable/risky drinking water supply)

KEY TAKEAWAYS

Based on these findings a few takeaways became apparent.

1. Compared with annual counterparts, **perennial crops tend to have longer growing seasons and deeper rooting depths**, and they intercept, retain, and utilize more precipitation. Longer photosynthetic seasons resulting from earlier canopy development and longer green leaf duration increase seasonal light interception efficiencies, an important factor in plant productivity. Greater root mass reduces erosion risks and maintains more soil carbon compared with annual crops. Annual grain crops can lose five times as much water and 35 times as much nitrate as perennial crops. Perennial crops require fewer passes of farm equipment and less fertilizer and herbicide, important attributes in regions most needing agricultural advancement. (Glover et al., 2010)

2. **Agriculture perennial-moderate diversity, ecosystem services:** soil formation, maximizes SOM, resistant to pathogens and insects, regulated nutrient losses, weed establishment surpassed, high functioning soil microbiome, high precipitation use efficiency, reduced fossil fuel dependence (Crews et al., 2018)

3. **Carbon sequestration is the most straightforward pathway to monetization** (even if on-field measurement is not so straightforward) due to already established estimations of the social cost of carbon and the global impacts of carbon.

4. Changes in **net income from PFG systems are by their nature, monetized, and thus straightforward to incorporate** in a cost-benefit analysis (albeit existing evidence is not well developed).

5. **Water Quality, Water Quantity and Air Quality tend to utilize a benefits transfer valuation approach** (as this analysis does). This means we are more reliant on regional-level estimations that are less specific to a given field.

USES OF THE EVIDENCE MAP AND GAP ANALYSIS

These documents can serve multiple purposes for partner organizations.

Library of resources and Research needs:

- A tool for GLBW and Network Partners to add to as resources are discovered/ studies implemented;
- A library for studies on specific causal mechanisms;
- A signal for future specific research needs;
- Resource mapping for future SROI estimations (the cells are the puzzle pieces that can be rearranged to monetize individual pathways);
- Continued increase in valuation efforts;

Community and Stakeholder engagement:

- Tool for stakeholder engagement and value propositions for stakeholders
- Help farmers/landowners quickly recognize potential costs/benefits from specific practices
- Foster specific discussions with local farmers, networks, knowledge sources, to help understand how best to go about realizing the benefits noted here
- Ask local farmers to contribute to the evidence map - creating a community-building tool as well as a local evidence base.

PROJECTED COSTS

Costs were framed as the annualized 20 acre pasture establishment and production with costs depreciated over the 20-30 year expected lifespan of the fencing and water system purchased for the system.

COST ASSUMPTIONS

Throughout this analysis we are utilizing a partial enterprise budget approach - that is to say we are not taking into account the land costs, the debt service costs, etc. which would be a part of the farm's total enterprise budget. This is in an effort to isolate those components of the farm's operation that are changing to accommodate a Perennial Forage and Grazing system.

See Tables 5 & 6 for more details.

Table 5. Included Cost Assumptions

PASTURE PLANTING ESTABLISHMENT	Accounted for
FENCING SYSTEM	Perimeter and interior fencing accounted for
WATERING SYSTEM	Accounted for
HEATING SYSTEM IN THE FIELD	Not accounted for and not necessarily needed (but noted here for its mention in research)
TRANSPORTATION SYSTEMS	Not accounted for - assumption of on site cows
RENTING PASTURE IF NECESSARY	Out of scope
HANDLING SYSTEMS	Labor is accounted for in the pasture production process and fence maintenance although not necessarily moving the animals
LANES	Accounted for
LIFESPANS OF SYSTEMS	Accounted for
PRODUCTION COST OF PASTURE (IN ADDITION TO ESTABLISHMENT COST).	Accounted for
ANIMAL HOUSING	Out of scope - assumed the housing was already in place.
LABOR COSTS	No additional labor costs from moving cows already on site, barn cleaning or manure handling (which may often be reduced with grazing): For example, "On average, moving the fence each day takes 15–30 minutes, the same amount of time it takes to feed hay. Large herds (greater than 100 animals) take longer to feed but moving them to new pastures takes about the same time as moving smaller herds." (Undersander et al., 2000)
LAND COSTS	Land costs are assumed constant
FORAGE QUALITY	Assuming very good to excellent quality forage

GRAZESCAPE CALCULATOR - COST INFORMATION

Table 6. Pasture Establishment and Production Costs (from Draft Grazescape calculator) - with the average 20 acre pasture scenario being used for this SROI

ACRES	Sward Type	Quality of Forage	Established? (Y/N)	Paddock Shape	Total Establishment Cost ($)	Total Establishment Cost ($/ac/yr)	Prod'n Cost ($/yr)	Prod'n Cost ($/ac/yr)	Total Year 1 upfront cost (establishment + production)	Total Year 1 upfront cost per acre	Total Year 1 cost with establishment cost annual-ized ($/ac/yr)	Averages ($/ac/yr) by size of Pasture
10	Grass	Excellent	No	Square	$11,676	$54	$1,315	$132	$12,991	$1,299	$185	$162
10	G-L Mix	Excellent	No	L:W= <2:1	$8,701	$39	$1,339	$134	$10,040	$1,004	$173	
10	Mostly Legume	Excellent	No	L:W= <4:1	$14,120	$63	$971	$97	$15,091	$1,509	$161	
10	Mostly Legume	Excellent	No	L:W= >4:1	$7,785	$32	$971	$97	$8,756	$876	$129	
20	Grass	Excellent	No	Square	$12,716	$32	$2,631	$132	$15,347	$767	$163	**$145**
20	G-L Mix	Excellent	No	L:W= <2:1	$10,390	$28	$2,679	$134	$13,069	$653	$162	
20	Mostly Legume	Excellent	No	L:W= <4:1	$15,160	$38	$1,943	$97	$17,103	$855	$135	
20	Mostly Legume	Excellent	No	L:W= >4:1	$8,825	$22	$1,943	$97	$10,768	$538	$119	
40	Grass	Excellent	No	Square	$14,795	$21	$5,262	$132	$20,057	$501	$152	$136
40	G-L Mix	Excellent	No	L:W= <2:1	$13,768	$22	$5,357	$134	$19,125	$478	$156	
40	Mostly Legume	Excellent	No	L:W= <4:1	$17,239	$25	$3,885	$97	$21,124	$528	$122	
40	Mostly Legume	Excellent	No	L:W= >4:1	$10,903	$17	$3,885	$97	$14,788	$370	$114	

Costs for the SROI calculation can be framed in multiple ways for this analysis depending on the specific practices incorporated into the estimation. For this analysis, as has been described, the costs derived from the preliminary Grazescape calculator supported our ability to frame the costs for pasture establishment and forage production. This amounted to upfront investment of approximately $12,000 for a 20 acre pasture which when the costs are amortized over the lifespan of the equipment left us with the $145 per acre per year figure used for our SROI.

This aligned with our goal of identifying the costs to transition from one scenario - conventional row crops with livestock on site but limited grazing - to the establishment of a pasture and the implementation of a well-managed grazing system. There are potentially many variations of types of costs incurred in establishing a pasture and a grazing system based on the existing resources on the farm, if grazing is already practiced but done so in a continuous system rather than a rotational system as assumed in this analysis, whether grazing livestock are on site or require transport, and so forth. The variations are numerous. **The scenario communicated here is used as a representation of value creation for the PFG system.** Those farms with grazing systems partially in place may be the most likely adopters of a well-managed PFG system given the potentially lower costs they may have to transition to it.

A select few studies model the potential cost changes over time, however even in these cases they do not approach typical cost-benefit methodology which would include discounting prices over time. Variable commodity prices make this practice difficult, however, other aspects of costs such as equipment, land, inputs, will have less variation and follow a more typical debt repayment schedule which would align with a cost-benefit methodology.

RECOGNITION OF GLBW AND NETWORK PARTNER COSTS

Costs estimated here do not include the investments of other stakeholders. When we start to account for the capacity building and ecosystem investment made by GLBW and the network partners, the analysis, planning, policy making, the knowledge sharing, network building, and tailored supports provided, the additional cost per acre of PFG would increase. However, we would expect that this investment made by these different stakeholders would be largest on a per acre basis during the earlier stages of the adoption of PFG within a given community. As more farms adopt PFG, we would expect fewer external resources to be required to facilitate that transition (less networking support from GLBW, fewer trainings from extensions, etc) such that eventually the total additional cost per acre of PFG, including all stakeholder costs, begins to approach the on-farm cost estimated here.

PROJECTED OUTCOMES

Below are outcome benefits attributed to the implementation of Perennial Forage and Grazing systems, here referred to as the marginal benefit following adoption (the cost/benefit of an event occurring multiplied by the likelihood of that cost/benefit occurring).

Table 7. Monetized Outcomes

OUTCOMES		Marginal Benefit per acre per year
Outcome	**Monetization Points**	
Avoided soil erosion from water	Reduced surface water treatment costs and cleanup costs	$47
Avoided soil erosion from water	Reduced value of soil due to being lost off-farm	$27
Economic benefits (adding partial enterprise budget net income gains on top of the estimated costs)	Year 1 of practice adoption (economic benefits are expected to increase in future years although there is uncertainty in this outcome)	$162
Reduced GHG emissions	Social cost of carbon	$15
Reduced nutrient runoff/leached in surface and ground water	Reduced water treatment costs and avoided costs from undesirable odor and taste, nitrate contamination, increased colorectal, bladder, thyroid cancer risks (from nitrates)	$28
	Reduced costs from eutrophication	$187
Reduced wind erosion	Reduced health care expenditures from air quality	$20
Increased biodiversity and wildlife habitat	Tourism and recreation revenues - Birds, aesthetic value, human health	$13
	Total	$500.35

KEY METRICS

The key metrics that drive value creation in this estimation include:

- Amount of nutrient runoff avoided from perennial forage
- Amount of soil erosion avoided from perennial forage
- Increased net incomes for perennial forage and grazing systems
- Cost of eutrophication
- Cost of soil lost off-farm
- Cost of health risk from poor water quality and air quality
- Amount of carbon sequestered and GHG emissions avoided
- Social Cost of Carbon

The following paragraphs describe the estimation process in more detail and why these metrics became the most important ones. Additional details on each outcome monetized (the monetized pathways) are included in Appendix B.

CUMULATIVE EFFECT OF PERENNIAL FORAGE AND GRAZING SYSTEMS

There is limited literature that collectively captures the impact of adopting a perennial forage and grazing system and which assesses the impact of the system in comparison to conventional practices. Further the variety of scenarios that may be a part of perennial forage and grazing make establishing an ideal counterfactual a moving target.

As a result, we are limited in our understanding of true value that would be realized from their simultaneous implementation. To manage this limitation we focus research on the dominant features and wherever possible reference literature that takes various combinations of these practices into account. We then utilize these figures for our estimation of per acre values, but when large uncertainties exist in an analysis such as this, we take the average effect size of the various studies for use in our point estimate. That is to say, when the literature references the potential reduced nutrient runoff, soil erosion or increased carbon sequestration from different components of PFG, we take the average value and assume it to be a conservative estimate of the effect size. This is due to the uncertainty regarding how impacts of practices implemented together may be additive, multiplicative, overlapping, or even cancel each other out. Future research into PFG will lead to a revision in these estimates, and perhaps prove our estimate to be too conservative.

The argument of our analysis is that the perennial forage and grazing system can generate a positive return and has many other environmental benefits.

ON-FARM ECONOMIC BENEFITS

We utilize a conservative framing of partial enterprise net income benefits of $17-18 per acre per year. This is the value that exceeds the annual cost of the grazing system. It is important to note however this outcome has limited resources to inform the value in the context of 'perennial' forage. However, literature notes that grazing can reduce the cost of feed, fuel, fertilizer, pesticide, labor, and equipment since less machinery is required (Undersander et al., 2000). The realization of these cost savings is maximized through the full adoption of a grazing system. There are also potential forage revenues beyond that used to feed cows on site.

This figure is considered conservative given a series of studies on grazing management practices and livestock integration.

On-farm economic benefits may not be fully realized in year 1 of practice adoption. Multiple sources note that net income gains are more likely to occur in years 2 and beyond after adoption but also that net income gains may increase further if transitioning marginal farmland from annual crops to perennial grazing, as opposed to transitioning Class A farmland from annuals to perennial grazing. There is limited data to understand what this difference in value may be.

Namken and Flanagan (2000) report that improved grazing management practices resulted in an average productivity increase of 1.3 Animal Unit Months (AUMs) per acre through increased forage production, and that the AUMs were valued at $11.10 each, resulting in per acre value of $21 in 2021 dollars. In studies of integrated livestock systems farm profit was estimated at $17.23 per acre in year 1 of adoption and increasing to $43.61 in year 2 (Tobin et al. 2020). Tobin et al. (2020) expect this value to further increase as cover crops increase water holding capacity, reducing yield risk in drought seasons as well as increasing SOM and reducing the need for N which further reduces costs. Similarly, SARE (2019) notes year 1 net income estimates of $18 per acre for livestock integration with cover crops (with values that grow each year as well).

While these studies are focused on grazing cover crops - we assume the net benefit from integrating livestock is at least as large on a perennial pasture as it is on annual cover crops. For example, Boody et al., (2005) also estimate net income for a whole farm that has partially adopted rotational grazing with perennials - with net incomes ranging from $12 - $105 per acre for the whole farm. Given these multiple angles of approach the net income gains from PFG we take our estimate to be conservative.

Of note, our estimate included in the visualization does not include an opportunity cost from lost income of the cash grain crop the farm is transitioning out of (assuming a perennial system). Income estimates however suggest this value is at least partially offset by grazing income, alfalfa value, alfalfa plowdown value, etc. Similarly, the opportunity cost of annual row crops were not considered an appropriate comparison due to their highly subsidized nature distorting the understanding of potential profitability of grazing. Still, we include in Appendix A sensitivity testing around the incorporation of opportunity costs.

WATER QUALITY

Water quality benefits and their monetization were dependent on benefits transfers from economic valuations that estimated values in contexts around the Upper Midwest. Those most readily applicable were focused on the social costs of nitrogen and the various associated chemical compounds, and the resulting damages that can accrue. This included eutrophication, water treatment costs, and health risks from water quality and air quality tied to nitrogen. Nitrogen costs are used as a conservative proxy for nutrient costs as a whole, given difficulty in disaggregating effects tied to each nutrient and in alignment with evidence base reviewed.

As described previously, it was in the use of these studies that we are controlling for many characteristics of the Upper Midwest to make the alignment with the external literature as reasonable as possible. Still, a benefits transfer approach is limited in its precision and would be improved upon by a watershed-specific valuation.

Our estimation of impacts on water quality from PFG utilized two approaches given the two pathways to monetization the literature laid out for us. The pathway utilized for the visualization was selected due to the higher levels of evidence of the studies as well as the fewer links in the chain needed to reach monetization. Coincidentally this also led to a higher valuation of the impacts. Details on the second approach are included in Appendix A.

A study by Syswerda et al, (2014) measured nitrate leaching levels across several different treatments, ranging from conventional systems, no-till conventional systems, to alfalfa, to a poplar system, among others. Nitrate leaching levels varied widely across the treatments, with the highest leaching in the conventional system and the lowest levels in the poplar system (Syswerda et al., 2014). Focusing on conventional, no-till conventional and alfalfa systems we see annual pounds of N leached per acre under each system at 55.4 pounds NO3-N for conventional, 36.9 pounds NO3-N p from no-till conventional and 11.3 pounds NO3-N from alfalfa. Using alfalfa as a representative proxy of perennial forage we utilize the no-till conventional average figure to reach a conservative 25.6 pounds of N avoided being leached each year per acre. This value is likely higher under conventional systems that are not using conservation practices such as no-till, cover crops, rotations, etc.

While this study did not include grazing we assume the alfalfa's ability to reduce N leaching is appropriate for a perennial forage pasture that will often have multiple species and be periodically grazed.

From there studies assessing the social cost of nitrogen are utilized to monetize the value of the N no longer leached (Sobota et al., 2015; Schullehner et al., 2018; Ward et al., 2018; Gourevitch et al., 2018; Dodds et al., 2009).

NET GHG EMISSIONS AND CARBON SEQUESTRATION

Interest in PFG's potential climate impacts is large. The rate of SOC accumulation under well-managed grazing land can be very high during initial years, but its magnitude diminishes with time due to saturation of the soil, a process that may be determined by various environmental factors, including climate and soil type. (Franzluebbers et la., 2012). However, the permanence of the ~2270 Pg C currently stored globally in biomass and soils to 1 m is a significant concern (Fargione et al., 2018). SOC accumulation may be temporary if soil is disturbed after having sequestered carbon.

Noting this interest, initial evidence and the importance of pursuing means for reducing climate risk and supporting climate adaptation we reviewed literature around PFG and perenniality more broadly for their ability to sequester carbon as well as the whole system view of GHG emissions. Like other outcomes, the literature is not always specific to the PFG system we are interested in here, however several signals exist in varying contexts to inform a reasonable estimate for this analysis. For example, perennial crops have the potential to capture and hold large quantities of carbon as SOC, accumulating up to 0.9 metric tons carbon per ha per year in Minnesota (Paustian et al. 1997). Similarly, Follet et al. (2000) and Namken (2002) estimate that improved grassland management can increase carbon sequestration, storing an additional 0.11 tons of carbon per acre per year. More recently and in greater alignment with this analysis, Rowntree et al. (2020) find a multi-species pastured livestock system in Georgia to reduce GHG potential from a commodity production system by about 1 ton per acre per year when including additional soil C sequestered in the pasture which was converted from annual 4 crop rotation. Conant et al., (2017) also note a range of increased SOC rates for improved grazing and separately for conversion from cultivation to grasses with values ranging from .3-.9 Mg per HA per yr. Together these figures led to us utilizing the conservative 0.3 tons of CO2e avoided per acre of a PFG system.

To compare against a perennial grain system without grazing Crews and Rumsey (2017) find estimates of 0.32 to 4.2 tons per acre per year.

With our point estimate of reduced CO2e then we apply a social cost of carbon to understand the value of the CO2e avoided per acre per year. This is not a straightforward figure but we utilize a median figure from the U.S. Federal Social Cost of Carbon (2016) and the National Academies of Science Engineering and Medicine, Valuing Climate Damages (2017) - both of which estimate a value at approximately $50. This value is highly sensitive to underlying assumptions around the damages accounted for and the discount rate used for future damages. For example, other studies may suggest a value greater than $100 per ton. This variability is tested in Appendix B.

NON-MONETIZED OUTCOMES

Some impacts are not readily monetizable given that some aspects of perennial forage and grazing lack sufficient data to attach a dollar value to them. These benefits may accrue to farmers and local communities, society in general, 2nd generation (i.e. children), government, or other stakeholders as of yet not identified. However, it is important to note that where data limitations restrict the ability to monetize an outcome there may continue to be significant value not presently represented in this SROI. The numbers we have calculated in this analysis are conservative and can be considered a baseline onto which additional non-monetized outcomes can be added. Outcomes more readily monetized should not belittle the potential value of currently non-monetized outcomes.

Examples of non-monetized outcomes include:

- Increased equity of agricultural sector
- Improved land access and generational transfer
- Stability of water flows and stream flows
- Flood damage mitigation
- Yield stability in extreme conditions
- Farm property values
- Livestock health
- Changes in water quality impact due to reduction of concentrated animal feeding operations
- Increased economic development in local communities
- Improved health of farmers and families on farms
- Increased biodiversity (in terms of the value not tied to human recreation)
- Continuation of family farms
- Reduced debt loads of farmers/landowners
- Increased and improved rural - urban connections and recognition of interconnectedness
- Increased stability of food supply chains
- Improved government, industrial and commercial budgeting from improved planning ability resulting from stability of water supply and food supply
- Improved State and local government budgets and the reallocation of budgets otherwise spent on water management
- Reduced federal deficits tied to farm bill spending
- Changes in cost of risk management when appropriate insurance is not readily available
- More diversified sales channels for agricultural retailers and agribusinesses

Each of these are points of future research to strengthen this analysis and incorporate additional monetized pathways.

SOCIAL RETURN ON INVESTMENT

The SROI for this analysis takes the benefits generated by Perennial Forage and Grazing over conventionally managed annual row crops, divided by the cost to implement a PFG system. The total SROI, which includes the benefits of all stakeholders, is projected to be approximately $3.46. The farm itself is the leading beneficiary of the initiative, receiving a projected $1.30 in social value for every $1 invested in establishing a pasture and grazing system. Taxpayers are the next stakeholder category to benefit from the program, primarily through reduced surface water management and regulatory cost, improved aquatic ecosystems, reduced costs of sedimentation, and damage to waterways, road ditches, flood damage.

Table 8: SROI for each Stakeholder

Scenario: Assuming transitioning from annual cropping system with cows on site to perennial pasture well-managed grazing system

SROI - 20 acre pasture establishment and production with costs depreciated over the 20-30 year expected lifespan of fencing and water system		
Total (per acre per year)	**$3.46**	**Explanation**
Farmer and Landowner	$1.30	Reduced input application, feed purchased, machinery costs, labor costs, field repair costs; Increased long-term productivity of soil and potential grazing/forage income
Municipal Water Treatment / Municipal Taxpayers and Water Users	$0.33	Reduced drinking water treatment from turbidity; Avoided costs from undesirable odor and taste, nitrate contamination, and cancer risk
Local Community Members	$0.79	Reduced health risks from contact with surface water, protected economic activity and property values; Reduced health risks from contact with surface water improved aquatic Ecosystems; Improved health from improved air quality; Increased sustainability of local agricultural economy
State Taxpayers	$0.79	Reduced surface water management and regulatory cost; Improved aquatic ecosystems; Reduced costs of sedimentation, damage to waterways, road ditches, flood damage
Federal Taxpayers	$0.06	Reduced costs of sedimentation, damage to waterways, road ditches, flood damage
Society	$0.20	Reduced GHG emissions and climate risk; Increased land and water-based recreation

To provide some comparison between on-farm benefits and off-farm benefits, we note here the breakdown of returns.

- SROI to the farmer/landowner: *$189 in benefits divided by $145 in costs = $1.30*
- SROI to all off-farm stakeholders: *$311 in benefits divided by $145 in costs = $2.14*

It is quickly apparent that the off-farm returns are greater than the on-farm economic returns. This is important to communicate to off-farm stakeholders to help build support for cost-share programs and other funding support initiatives to promote PFG systems

OUTCOME ATTRIBUTION RATIOS

In order to estimate the SROI to each stakeholder (shown above), we must estimate the extent each outcome affects the relevant stakeholder. The table below shows how the value of each outcome (left column) is allocated to the given stakeholder (top row). Of note, the stakeholders with value assigned to them only include those with associated monetized outcomes. This stakeholder breakdown should be viewed as a preliminary estimate to note the potential scale of value to target beneficiaries.

	Farmer and Landowner	Municipal Water Treatment and Water Users	Local Community Members	State Taxpayers	Federal Taxpayers	Society	Notes
Reduced surface water treatment costs and cleanup costs		0.39		0.43	0.17		Municipal water treatment bears the cost of the cleaning the drinking water, while the State and Federal government must respond to damaged infrastructure. We will utilize the cost breakdown from Ribaudo and Hansen (2008) to assign value to stakeholders and assume surface water belongs to the state such that water impacts on road drainage ditches and irrigation ditches are costs to the state and supported by federal funding.
Reduced value of soil lost off-farm	1						So as to not double count the benefits of the soil health gains from avoided erosion as the yield benefits that support farmer net income, we assume the soil productivity protected from avoided erosion is a future net income gain, rather than a current net income gain which is what is estimated in the bottom pathway here.

	Farmer and Landowner	Municipal Water Treatment and Water Users	Local Community Members	State Taxpayers	Federal Taxpayers	Society	Notes
Revenue in Year 1 of practice adoption	1						Assumes income gains accrue to the Farm operation solely - does not take into account whether the farm is structured as a corporation. Also, income change estimates do not consider debt loads, land costs, and other outstanding liabilities that would be paid down with the additional income, thereby having little effect on the farms' tax liability.
Social cost of carbon						1	Assumes value of avoided GHG emissions accrues to global society
Reduced water treatment costs and avoided costs from undesirable odor and taste, nitrate contamination, increased colorectal, bladder, thyroid cancer risks (from nitrates)		1					The municipal water facility would bear the cost of mitigating health and taste/odor risks. If however the risk is not mitigated effectively, the risk of cancer is borne by local communities and the health care system. We will assume the costs are effectively borne by the water treatment facility.
Reduced water treatment costs - eutrophication (tied to N, but assume could include P as well to avoid double counting)			0.5	0.5			
Health care expenditures from air quality			1				
Tourism and recreation revenues - Birds, aesthetic value, human health						1	

DISCUSSION AND FUTURE RESEARCH

When projecting impacts from an agricultural system, there are always questions around data and how that data is used to monetize the outcomes for use in an SROI estimation. As has been discussed, figures in this projection are built from a combination of external literature and discussions with GLBW and their network partners.

LIMITATIONS AND UNCERTAINTIES

Our previous discussion regarding the evidence map and gap analysis has already outlined several of the limitations faced in the monetization of the costs and benefits of PFG. Here we will note more broadly the relationship between those limitations and other uncertainties that may impact the analysis should more information become available.

Uncertainties include:

- By combining literature on the individual components of the PFG system into a single holistic system, the outcomes are likely positive but not necessarily duplicative. We do not have a full understanding of the scale of benefits attributed to the full PFG system in comparison to our counterfactual used of a farm with annual row crops and confinement livestock.
- The causal argument for whether increases in net income experienced by the farmer are due to the PFG system is an area deserving of additional research.
- For effects on net income, we must assume that a well-managed system is in place, and practices are selected and adapted to farm context in the most suitable form. There continues to be uncertainty about when benefits would be realized, how long they would take to be realized, how long the benefits would last, and what factors would lead to future loss of benefits.
- The effect of weather conditions on the scale of impact from PFG practices is unclear. For example, a period of significant rainfall would lead to increased nutrient runoff avoided, increased erosion avoided, increased streamflows avoided, increased flooding of fields avoided, but we do not have a strong causal study of what the additional monetized savings would amount to.
- We do not model climate changes which may occur over the next decade and beyond (IPCC, 2014). These may result in more variation in weather conditions, larger extremes in drought severity, flood severity, temperature extremes, etc. which would all increase the value of perennial forage and pasture establishments.
- The change in effects from transitioning from confinement livestock to year round grazing is unclear at this time.
- The attribution of outcome values to specific stakeholders are potentially highly variable depending on who bears the responsibility for damages incurred as a result of poor drinking water quality, flood damage, climate risks, poor air quality, etc.
- The size of the pasture established will influence the estimated cost per acre. While we assume a 20 acre pasture averaging costs across multiple pasture shapes and forage types, it is unclear what size pasture may be most suitable on each farm adopting PFG.

Geographical specificity of impacts

We have not made an assumption on where in the Upper Midwest the PFG is adopted - although it is important to note that it will vary, as research shows how proximity to highly valued features such as water bodies can influence ecosystem service valuations. High priority areas will serve as important target areas for the cost effective support of the ecosystem services desired.

Projecting value at scale

Of note with this analysis, we do not make a claim regarding total potential value created should large numbers of acres in the Upper Midwest adopt PFG. This exclusion of scale projections is intentional and is done for 2 leading reasons.

1. Benefits per acre will vary throughout the Upper Midwest. For those first acres converted to PFG (beyond those already having well-managed PFG), each will have a different SROI. We would expect those acres in high priority areas of the Watershed to have higher SROIs - likely at or above those values communicated in the visualization. This may include those acres adjacent to waterways and water bodies, those with higher degree of slope and/or more prone to erosion, those located near heavily recreated water bodies, etc. However, in other areas that may be drier, further from surface water, we would expect the SROI to be somewhat lower, as they will have less nutrient runoff and sedimentation that reaches surface water bodies where large costs of eutrophication may occur downstream. As a result, we cannot reasonably take the per acre estimate and multiply it by the number of acres of annual row crops targeted for transitioning to PFG and suggest that is the total value "on the table".
2. We do not have an understanding of the marginal benefit curve specific to the Upper Midwest watershed. While we have signals that higher priority areas within the watershed would lead to greater impacts and as a result, potentially higher valuations, at a certain point of practice-adoption even within the high priority areas, the off-farm impacts from additional acres converted to PFG will be reduced (although on-farm economic benefits will continue to accrue). After a certain level of adoption, the rate of water quality improvement, for example, will begin to slow as acres are converted until a threshold is reached such that further PFG adoption will not measurably impact water quality. This means that after a certain point in time the SROI for each additional acre adopting PFG will decline, however we do not know the extent this decline may occur. Other benefits such as on-farm economics and carbon sequestration are not expected to decline, however, as more acres adopt PFG. This means that there is still a persuasive value proposition in place regardless of the scale of adoption, as the combined on-farm benefits, carbon sequestration, air quality and recreation benefits total approximately $210 per acre, greatly surpassing the estimated $145 per acre of costs.

Noting the previously described limitations, we include the table below to highlight what potential benefits could be at different scales. Smaller scales and effective targeting of practices are more likely to achieve high ecosystem service benefits.

Table 9: Preliminary projected benefits - across multiple scales

SCALE	Economic benefits (per year)	Social and Environmental Benefits (per year)	Total Benefits (per year)	Net Benefits (per year)
10 acres of pasture	$1,620	$3,380	$5,000	$3,550
20 acres of pasture	$3,240	$6,760	$10,000	$7,100
40 acres of pasture	$6,480	$13,520	$20,000	$14,200
5% of existing corn/ soybean acreage in MN (700,000 acres	$113.4 million	$236.6 million	$350 million	$248.5 million
5% of existing row crop acreage in MN, WI, IA (2 million)	$332.1 million	$676 million	$999 million	$711 million

Note: depending on the size of the pasture being established, there are some economies of scale that come from a larger pasture, such that the per acre cost of a single 40 acre pasture is slightly lower than that of a 20 acre pasture. The projections in Table 8 above do not account for this potential variation.

CONSERVATIVE TRUMPING RULES

Where monetized pathways lead to the same category of outcome (i.e. improved surface water quality from both reduced nitrogen runoff and reduced phosphorus runoff, etc.) we take the largest valued pathway to be the one utilized in the SROI calculation. This is to avoid risk of double counting gains made and be sure to not overclaim impact generated. With new research however, we may learn that this approach has been overly conservative

MONETIZING ENVIRONMENTAL SERVICES

Context for Benefits transfer

Studies that attempt to value changes in agricultural practices are often partially developed and lack sufficient transferability to other fields given the context-specific features of farms. While this is a limitation, the practice of transferring benefits estimated in a different context, and adjusting them to the context of interest is a common practice for understanding environmental impacts. It is such an approach that is often utilized by the NRCS and EPA to create initial understandings of the scale of value being protected due to regulation. Our own benefits transfer incorporated studies utilizing market-based pricing, avoided cost methods, and revealed preferences. This included consumptive value (e.g. drinking water that is now not available to others) as well as non-consumptive value (e.g. boating which derives value from the surface water but has not removed it from use). Other types of value not included in those studies referenced but of relevance for comparison are bequest value (value of passing on ecosystem value), existence value (the value of knowing something exists even if not used), and option value (valuing an asset in case you would like to use it in the future). While many water bodies in Minnesota, Wisconsin and other Midwest States are popular recreation destinations, we did not reference a study utilizing a travel-cost method which would consider the distances traveled to enjoy the water body, although this may be a useful method for future use.

While there are data limitations for this type of SROI analysis, it is important to begin the valuation process, knowing that there is likely more value being created beyond that monetized here. Not including an estimate of the value of PFG due to incomplete information risks belittling the importance of those outcomes that are still being studied. Our ability to attach monetized value to a range of environmental and social outcomes brings environmental and social issues to a level alongside the more easily recognized economic impacts from drought, flood damage, and new water treatment plants.

Although monetization of impact is not always the end goal, it is a part of a broader goal to increase the recognized value of social and environmental impacts. The estimation is important because valuation of ecosystem services is happening - whether it be an explicit dollar value or an indirect consideration of water quality. This analysis should fit into the decision making and valuation in the Upper Midwest around agriculture systems and their sustainability.

Costanza et al. (2017) address this in more detail:

> "To value or not to value: That is NOT the question - Even without any subsequent valuation, the very process of listing all the services derived from an ecosystem can help ensure their recognition in public policy...However, valuation is often useful, because many decisions involve trade-offs between ranges of things that affect human wellbeing differently. In these cases, we do not really have a choice. The decisions we make as a society about ecosystems imply valuations (although not necessarily expressed in monetary terms). We can choose to make these valuations explicit or not...being more explicit about the value of [ecosystem services] can help society make better decisions in the many cases in which trade-offs exist."

This analysis is not designed to obfuscate the critical research that has been conducted and continues to be developed by GLBW, its network partners and ecological economists around the world. The complexity and importance of their research is profound and essential to future understanding of value creation and the essential role of ecosystems to human well-being.

Market Development and Behavioral Insights

PFG, CLC and ecosystem service market development will likely require incorporation of behavioral insights. Targeting non-economic motives for behavior change appear meaningful, as findings in the literature note tendencies for conservation practice adoption. For example, the Working Group members note that the farmers who want to adopt a new practice will figure out how to do it. For those who are not inclined to adopt the practice - it may be as much a mental barrier as it is a financial one. This may mean meeting farmers where they are at in their understanding and interest in sustainable practices. For example, for many farmers the first step of their journey may be using cover crops which could then lead to grazing cover crops, and finally grazing more year round with perennial forage. For those entities focused on the near term adoption of PFG, their starting point may be 1) working with those farmers with land and livestock already in place who have not yet put in place a perennial grazing system or 2) facilitating the grazing exchanges to link together crop farmers without livestock and livestock farmers without enough land.

External research notes other insights that are worth addressing in market development efforts:

- "Three farmer traits—the belief that their production could benefit from nature, their years of prior experience, and the availability of suitable equipment—were collectively the best predictor of farmers' willingness to shift land into the more complex cropping systems associated with reduced chemical inputs." (Robertson et al., 2014)
- "Farmers more frequently implement conservation practices to control pollutants they can see." (Osmond et al., 2012)
- "Farmers tend to abandon and discontinue management practices (e.g., nutrient management) more frequently than structural practices (e.g., terraces)." (Osmond et al., 2012)
- "Farmers often view routine nutrient applications as a way to avoid risk." (Osmond et al., 2012)
- Social networks and farmer to farmer knowledge sharing are important features of agricultural practice adoption (Chavas and Nauges, 2020).
- "The impact of social networks is weaker when the profitability of the technology or practice depends on characteristics that vary across farms (e.g. soil quality). Learning from others is made even more difficult if those important characteristics that condition the outcome of a new technology or practice are not easily observable. In this case, learning by doing may be a more important driver of farmers' adoption decisions than learning from others." (Chavas and Nauges, 2020)

Behavioral insights for consideration

Based on the above findings noted in the literature, there are a series of behavioral tools that may support increased PFG adoption and in some cases may already be implemented by partner organizations. These include:

- Recognition of loss aversion - people want to protect what they have over gaining more. This may include framing communication to be about protecting a farm's operations for years to come and generations to come.
- Comparisons against peers. People often want to outperform peers and focusing on the gains made from PFG vs. conventional practices may support this. In some cases the gains to focus on may not be financial.
- Nudging with the 'how' along with the 'what' of the PFG recommendations. When communicating with stakeholders, make recommendations for PFG adoption as actionable as possible, and minimize the additional leg work the stakeholder may need to do to change behaviors. This applies to all stakeholders, not just farmers/landowners.
- Hyperbolic discounting (reality of human decision making) vs. exponential discounting ("rational" economic decision making) is a common limitation. People tend to place too large a value on a dollar today compared to a dollar tomorrow, even if we know there is a reliable return on investment accompanying the later payment. Case studies that address the first couple years of PFG practice adoption will be important to mitigate the perceived risk of PFG and support long-term investment.

Impact considerations

During our literature review, we noted a summary of considerations made by Fox et al. (2016) to make sure the changes to agricultural practices with the intent of improving water quality, result in the intended changes. These include:

1. Making sure conservation practices are targeted in high priority areas. While this point is already widely recognized, as other

stakeholders become engaged it will be important to keep this focus.

2. Recognizing the potential delay in when water quality benefits are realized. In some cases, it may be that significant benefits are not realized until multiple years later, for example when an extreme rainfall event occurs which has risks that are largely mitigated due to PFG systems. It is likely that the flow of benefits, both on and off-farm is not steady and predictable but will fluctuate as weather and climatic conditions place different pressures on the soil and crops. Thus it should not be the expectation that benefits will immediately begin to accrue to all stakeholders immediately and simultaneously.
3. Cropping practices designed to limit erosion and nutrient runoff will not lead to dramatic results if other obstacles such as widespread streambank erosion are not also considered. PFG system adoption is not the only tool for managing agricultural impacts but does appear to be an important tool in the toolkit.

Future Research

Much of the previous discussion addresses future research needs. Rather than recount those points we will briefly outline here additional research questions identified by the GLBW network partners that are important to address and may build from this analysis.

- What amount of PFG or more broadly, CLC, is needed to achieve local water quality targets or regional climate targets?
- What social behavior target is necessary to achieve that adoption level?
- What policy and program activity will induce that behavior willingness and ability?
- How much do regional differences matter in terms of the environmental services generated from PFG and CLC?
- How much does farm size influence the economics of PFG? Would farm size be a characteristic to consider when targeting educational efforts?

TAKEAWAYS AND RECOMMENDATIONS

Facilitating the adoption of PFG systems around the Upper Midwest can support improved water quality, reduced risk to drinking water, improved air quality and wildlife habitat, and likely climate risk mitigation. **Based on this analysis, with a conservative framing to manage data limitations, the PFG system has a positive social return on investment.**

KEY PERFORMANCE INDICATORS

The KPIs in Table 9 are recommended for future tracking of PFG systems. Scale KPIs are outputs and sub-sets of outputs that can be used to understand the scale of impact of PFG systems. Quality KPIs are the maximization of benefits generated on those acres that adopt a PFG system.

Of note, these figures do not have to be an annual figure, and instead could simply reflect 1) the present state and 2) the direction pursued. Target columns are noted to help guide program planning as these cells may be filled in as programs are being developed, implemented, and grown.

Table 10: Key Performance Indicators for PFG

SCALE KPIS	TARGET	QUALITY KPIS	TARGET
# of acres or farms implementing PFG strategies		**Annual rate of adoption of practices in acres**	
# of farmers participating in grazing exchanges		**Proportional Reduction in N and P leached, runoff and soil erosion per field**	
Pounds of N, P and Soil prevented from erosion		**CO2e sequestered per acre**	
Tons of CO2e sequestered		**% of PFG strategies in high priority areas of watershed**	
Pounds N, P leached		**% of farms with PFG strategies reporting net income gains over time**	
Proportional reduction in streamflows during heavy rainfall events			
Proportional increase in soil health			

In addition to the above indicators specific to PFG, Table 10 below acknowledges broader community indicators of which increased adoption of PFG systems will seek to address. These may be referenced in communities around the Upper Midwest and tailored to topics of particular interest to each community.

Table 11: Sampling of Community Indicators

SCALE	QUALITY
# family farms	Annual Municipal water treatment costs per person
Change in Property values within and downstream Watershed	Average annual pm2.5 level
Number of fish kills	Annual maintenance costs of municipal water treatment infrastructure
Existence and recurrence of taste and odor issues in drinking water supply	Quality of fishing and recreation on surrounding water bodies
Number of algal blooms and their size, duration	Proportion of farms that are family operated and BIPOC owned
Days with dust clouds	Average debt burden of each farm
Annual infrastructure repair costs	Average dependence on federal subsidies
# of BIPOC farmers	

IMPACT COMMUNICATION

Why identify the United Nations Sustainable Development Goals?

These are the blueprint, established by the United Nations, to achieve a better and more sustainable future for all and include 17 distinct goals. They serve as an easily recognizable marker of agreed upon impact areas for stakeholders. See pages below for the SDGs that GLBW and CLC strategies align with.

Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Target 2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality

Indicator 2.4.1 Proportion of agricultural area under productive and sustainable agriculture

Target 2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries

Goal 3: Good Health and Wellbeing

Target 3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

Goal 6: Ensure availability and sustainable management of water and sanitation for all

Target 6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Target 9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending

Goal 10. Reduce inequality within and among countries

Target 10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status

Goal 13: Take urgent action to combat climate change and its impacts*

Target 13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Target 15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

Target 15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

Target 15.A Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems

17 PARTNERSHIPS FOR THE GOALS

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

Target 17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships

For more information on UN SDGs: un.org/sustainabledevelopment

Why use the Impact Management Project Five Dimensions of Impact?

The Impact Management Project (IMP) is a community of 2,000+ organizations building consensus on how to measure, compare and report impact on environmental and social issues. The IMP community has developed a set of 5 dimensions of impact in order to help build consensus and a common language when organizations and investors discuss their impact. This has been a rapidly growing field, and future alignment of GLBW's and CLC's impact with the 5 dimensions could help attract additional investment as CLC strategies and GLBW network partner initiatives are developed.

Table 12. Details for the Five Dimensions of Impact

Impact Dimension	Impact Questions Each Dimension Seeks to Answer
WHAT	• What outcome occurs in period? • How important is the outcome to the people (or planet) experiencing it?
WHO	• Who experiences the outcome? • How under served are the affected stakeholders in relation to the outcome?
HOW MUCH	• How much of the outcome occurs--across scale, depth and duration?
CONTRIBUTIONS	• What is the enterprise's contribution to the outcome accounting for what would have happened anyway?
IMPACT RISK MITIGATION	• What is the risk to the people and planet that impact does not occur as expected?

IMPACT MANAGEMENT PROJECT

Table 13. Continuous Living Cover (CLC) Five Dimensions of Impact

Continuous Living Cover FIVE DIMENSIONS OF IMPACT

IMPACT MANAGEMENT PROJECT

WHAT: CLC cropping strategies and the perennialization of the agricultural landscape produce food, feed, fuel and fiber and deliver environmental and socioeconomic benefits, including soil health, biodiversity, climate change resilience, quality of life, and equitable access/support for all farmers.

WHO: Midwest farmers; local, downstream, and regional communities and ecosystems; global climate.

HOW MUCH: Environmental and ecological improvements are provided while perennial practices are implemented. Farmer incomes streams are diversified and stabilized, mitgitating weather and market crises. Ecological and socioeconomic benefits accrue on individual farms, across communities, and at a landscape level.

CONTRIBUTION: CLC and perennial cropping strategies offer longer growing seasons, deeper roots, improved soil health and water quality, more resilient ecosystems, and varied market opportunities over annual monocropping production systems.

IMPACT RISK MITIGATION: Farmers can adopt CLC cropping strategies in a variety of ways; various on-ramps offer flexibility and expanded accessibility; a network approach informed by multiple sectors de-risks investment in adoption and supportive infrastructure.

Appendix A: SUPPLEMENTARY ANALYSIS

The following scenarios are developed to test the sensitivity of the SROI estimation to some of our key assumptions.

SENSITIVITY ANALYSIS: VARIATION IN COSTS AND BENEFITS WITHOUT SPECIFICITY TO A GIVEN ASSUMPTION

The following scenarios are developed to test the sensitivity of the SROI estimation to a simultaneous change in costs and benefits without specificity to a given assumption. The following table shows how the SROI could change given a 50% increase or decrease in costs and benefits. We see that in all scenarios, even with a 50% decrease in benefits and a 50% increase in costs, the SROI remains greater than $1.

Table A1: Perennial Forage and Grazing SROI Sensitivity

SROI Sensitivity		% change in benefits										
		-50%	-40%	-30%	-20%	-10%	0	10%	20%	30%	40%	50%
% change in costs	-50%	$3.46	$4.15	$4.84	$5.53	$6.22	$6.92	$7.61	$8.30	$8.99	$9.68	$10.37
	-40%	$2.88	$3.46	$4.03	$4.61	$5.19	$5.76	$6.34	$6.92	$7.49	$8.07	$8.64
	-30%	$2.47	$2.96	$3.46	$3.95	$4.45	$4.94	$5.43	$5.93	$6.42	$6.92	$7.41
	-20%	$2.16	$2.59	$3.03	$3.46	$3.89	$4.32	$4.75	$5.19	$5.62	$6.05	$6.48
	-10%	$1.92	$2.31	$2.69	$3.07	$3.46	$3.84	$4.23	$4.61	$4.99	$5.38	$5.76
	0%	$1.73	$2.07	$2.42	$2.77	$3.11	$3.46	$3.80	$4.15	$4.50	$4.84	$5.19
	10%	$1.57	$1.89	$2.20	$2.51	$2.83	$3.14	$3.46	$3.77	$4.09	$4.40	$4.72
	20%	$1.44	$1.73	$2.02	$2.31	$2.59	$2.88	$3.17	$3.46	$3.75	$4.03	$4.32
	30%	$1.33	$1.60	$1.86	$2.13	$2.39	$2.66	$2.93	$3.19	$3.46	$3.72	$3.99
	40%	$1.23	$1.48	$1.73	$1.98	$2.22	$2.47	$2.72	$2.96	$3.21	$3.46	$3.70
	50%	$1.15	$1.38	$1.61	$1.84	$2.07	$2.31	$2.54	$2.77	$3.00	$3.23	$3.46

SENSITIVITY SCENARIOS

Farmer net income with opportunity cost

While the scenario described in the body of this analysis did not include opportunity cost associated with annual row crops such as a corn and soybeans, when we incorporate a range of values based on partial enterprise budget returns over the past 10 years for corn and soybeans (from FINBIN) we see returns ranging from $0 - $300 per acre.

When we put these values up against the returns projected from the perennial forage and grazing system of $162 per acre, the benefit to the farm ranges from -$138 to $162 per acre. This range reflects the range of market conditions corn and soybeans have gone through over the past 10 years. Beef and dairy markets being served by the cows grazing on the pasture will vary as well but this range provides a snapshot of the types of returns for a farm when accounting for opportunity cost.

When we include this range of net income values alongside the other social and environmental benefits of PFG, the total benefits range from $200 - $500 per acre per year. Compared to the still constant $145 in pasture establishment and grazing system costs estimated per acre per year, the resulting SROI is $1.37 - $3.46. Thus even when accounting for large opportunity costs associated with heavily subsidized annual row crops, when taking a bigger view of the social and environmental returns, the projected SROI is still greater than 1. **While the business case may not always be in place for the farm to make the switch to PFG on their own, the returns experienced by other stakeholders are sufficient to more than offset the costs borne by the farm.** When the opportunity cost is large for the farm, there is a need for coordination of the stakeholders to understand the benefits they could receive from PFG and then pooling resources based on these benefits to compensate the farm for implementing PFG.

Carbon sequestration variability

The potential for carbon sequestration and broader GHG emissions potentials for perennials are a hot topic for discussion. There are many studies that have been conducted and underway to better understand the amount of carbon potentially stored, the amount of methane emissions potentially avoided, among other GHGs. While this analysis uses a point estimate for communication purposes, the reality is a moving target.

To help show the variability of the valuation of the reduction in GHG emissions pathway, we outline two sensitivity tests: 1) variability in the value per ton of CO_2e and 2) variability in the amount of GHG emissions avoided/sequestered due to PFG strategies.

Along the first dimension, the value per ton of CO_2e, we utilize the social cost of carbon. This however is not a precise figure either. The generally accepted value of $50 per ton is what is utilized in the body of the analysis but figures range from $1 - several hundred dollars. A recent publication noting the need for a lower discount rate estimated an appropriate social cost of carbon to be $125 per ton (Carleton and Greenstone, 2021). With this higher value our point estimate of $15 per acre rises to $37.50 per acre. This adjustment boosts the total SROI from $3.46 to $3.60.

Along the second dimension, the amount of GHG emissions avoided and carbon sequestered as a result of PFG strategies, we utilized a conservative value in the body of the analysis at approximately 0.3 tons per acre. The literature notes the potential variability in this figure as well as the eventual reduction over time with the largest amounts of carbon sequestration occurring in the first few years after transitioning to perennials.

As a lower bound for this analysis, data indicate that an additional 0.11 tons of carbon per acre per year is sequestered from improved grassland management practices, of which PFG would fall into (Follett, et al. 2000; Namken 2002). More recently Rowntree et al. (2020) found a multi-species pastured livestock system in Georgia to reduce GHG potential from a commodity production system by about 1 ton per acre per year when including additional soil C sequestered in the pasture which was converted from annual 4 crop rotation. Other estimates have shown higher values for carbon sequestered from perennial grains - up to 4 tons per acre per year in some cases (Crews and Rumsey, 2017). Noting our range of 0.1 to 1 ton per acre this results in a benefit of \$5-\$50 per acre per year when using a \$50 / ton of CO2e social cost of carbon.

Water quality variability

There were multiple potential pathways to estimate the value of improved water quality. The pathway utilized in the body of this analysis represented the one that utilized the highest level of evidence as well as the most direct pathway to the monetized value. Given the importance of this outcome and the amount of studies on the subject we compared our initial estimation against a secondary approach to see how the resulting valuations may differ. Within the second approach more steps are needed to get to a valuation - linking the reduced nutrient loss from forage (Francesconi et al., 2015) to the typical percentage nutrient loss from a monoculture row crop (Doane et al., 2016) to the amount of nutrient applied to a monoculture row crop (Davis et al., 2012). Using this approach we reach a value of approximately \$125 per acre in water quality benefits. This is in comparison to the higher level evidence pathway which reached a valuation of \$217 per acre in water quality benefits.

Livestock integration with cover crops and annuals as opposed to perennials

Given that livestock integration with cover crops requires less of a transition it is expected that larger initial net income gains may be possible. Indeed research from SARE (2019) and Tobin et al. (2020) project such gains, and in particular note how the gains may grow over time. Tobin et al. (2020) project net income benefits to be \$43.61 per acre in the second year after adoption. "In the long term, we expect economic profit will increase even more, as a cover crop will increase water holding capacity, which will reduce the yield risk during the drought season. Furthermore, an increase in SOM in the long term will reduce the need for N fertilizer application, which can add further to the reduced costs.)"

Similarly, Carr et al. (2005) in North Dakota averaged a \$65/acre return to labor and management in an integrated system compared to negative values for grain crops alone. Economic performance of the farm can be enhanced when producers feed their forage crop standing or windrowed, graze or bale the excess crop for winter-feeding, or store for later sale.

Table A2: Projected Net Income increases with integrated livestock into an annual cover cropping system (Source: Estimates derived from SARE, 2019.)

		Years after implementation and continued use of practice (net income per acre per year)				
Location	Practice	1	2	3	4	5
Midwest - Corn belt	cover crops with integrated grazing, normal weather year, corn as cash crop	\$17.87	\$34.26	\$50.65	\$58.89	\$67.13

Appendix B: MONETIZED PATHWAYS

Table B1. Projected Monetized Outcomes

OUTCOMES			MARGINAL BENEFIT PER ACRE PER YEAR
Water quality - sedimentation avoided from perennial forage	Avoided soil erosion from water	Reduced surface water treatment costs and cleanup costs	$47
	Avoided soil erosion from water	Reduced value of soil lost off-farm	$27
Income from perennial forage AND grazing	Increased economic benefits (adding partial enterprise budget net income gains on top of the estimated costs above)	Year 1 of practice adoption (economic benefits are expected to increase in future years although there is uncertainty in this outcome)	$162
Carbon from perennials (informed by effects of grazing)	Reduced GHG emissions	Social cost of carbon	$15
Water quality - nutrients avoided from perennial forage	Reduced nutrient runoff/leached in surface and ground water - Estimation process #1	Reduced water treatment costs and avoided costs from undesirable odor and taste, nitrate contamination, increased colorectal, bladder, thyroid cancer risks (from nitrates)	$28
		Reduced costs from lost recreation value, endangered species value	$2
		Reduced costs from eutrophication	$187
Air quality	Reduced health care expenditures from air quality		$20
Recreation from wildlife, aesthetics, etc. from perennial forage AND grazing	Tourism and recreation revenues - Birds, aesthetic value, human health		$13
Total			**$502**

Water quality - sedimentation avoided from perennial forage

AVOIDED SOIL EROSION FROM WATER - REDUCED SURFACE TREATMENT COSTS AND CLEAN UP COSTS

EFFECT SIZE - 1

Francesconi et al. (2015) demonstrated that cover crops and forage were most successful at reducing sediment and nutrient loss (56% to 88% and 28% to 91%, respectively) in an Ohio watershed and that, compared to single practices, two and three practices resulted in greater sediment and nutrient reductions.

0.88

EFFECT SIZE - 2

In the corn belt, lake states and northern plains, NRCS reports in 2007 average erosion per acre of 3.9, 2.3 and 2.0 tons per acre per year from water erosion alone (not including wind). https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/nra/nri/?cid=nrcs143_013656 We assume 3 tons per acre per year for the Midwest.

3

COST

Reduced Water Treatment Costs from sedimentation; Reduced costs of erosion to various stakeholders (Hansen and Ribaudo, 2008; 0.41; EQIP, 2009) USDA/NRCS studies also estimated a per-ton benefit of $4.93 per acre for improved water quality benefits. Pratt et al., 2013 and USDA 2011 notes value separately: the on-site value of soil erosion is $10.17/ton, which accounts for soil nutrients and contribution to yield as well as water, and the off-site value of soil erosion is estimated at $17.99/ton accounting for water sedimentation and nutrient runoff costs (U.S. Department of Agriculture, 2011) - this figure was estimated with much lower rates of erosion however, suggesting that marginal benefit increases in contexts that may highly value remaining soil. (Pratt et al., 2013; USDA, 2011) In comparison, one USDA Economic Research Service reported that, “The county level sums of the water-erosion benefit estimations range from $1.70 to $18.24 per ton”. (pg. 21, Hansen and Ribaudo) The figures generated by Pratt et al., (2013) and USDA (2011) are utilized to note the potential value of strategic placement of perennial forage acres.

$17.99

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

$47.49

Water quality - sedimentation avoided from perennial forage

AVOIDED SOIL EROSION FROM WATER - REDUCED SURFACE TREATMENT COSTS AND CLEAN UP COSTS

CONTINUED

Additional Notes

Soil Erosion: Improved grazing management reduces average soil erosion 0.69 ton per acre per year (Spaeth 2000). Additional erosion reductions result if GRP prevents grassland conversion to cropland. (NRCS- GRP, 2010). On average, cover crops reduced sediment losses from erosion by 20.8 tons per acre on conventional-till fields, 6.5 tons per acre on reduced-till fields and 1.2 tons per acre on no-till fields. Averages 9.5 across tillage systems.(SARE, 2019).

"By 2007 erosion in Iowa had decreased to 5.1 tons per acre [per year]. For the entire United States, erosion rates dropped from 4.0 tons to 2.7 tons per cropland acre over the same time period." (USDA/NRCS, 2). Tegtmeier and Duffy estimated the external costs of agricultural production in the United States (primarily erosion related) to range from $14.09 to $45.68 in 2002 dollars. (Tegtmeier and Duffy). USDA/NRCS studies reported that each ton of soil eroded contained the equivalent of 2.32 pounds of nitrogen and 1 pound of phosphorus. The estimated costs per pound for nitrogen and phosphorus in 2012 were $.63 and $.64, respectively. (Duffy) Using these estimates, the cost to the farmer in lost fertilizer value alone is $2.10 per ton of soil loss. The USDA study estimated that for soils in the EQIP program, soil erosion was reduced by 8.6 tons per acre; assuming $2.10 fertilizer value per ton of soil lost, enrollment in the EQIP program saves the farmer $18.06 per acre. USDA/NRCS studies also estimated a per-ton benefit of $4.93 per acre for improved water quality benefits. The 8.6 ton per acre soil saving would result in a savings of $42.40 per acre for water quality improvement. . . The studies presented a methodology that, by their own admission, had problems and was very site specific to calculate. One USDA Economic Research Service reported that, "The county level sums of the water-erosion benefit estimations range from $1.70 to $18.24 per ton". (pg. 21, Hansen and Ribaudo). Notice that erosion can decrease the value of the land anywhere from 3 to 17 percent depending on the soil map unit. The average loss in value for all counties is 4.9 percent ($339) (Duffy, 2012)

USDA/NRCS studies reported that each ton of soil eroded contained the equivalent of 2.32 pounds of nitrogen and 1 pound of phosphorus. The estimated costs per pound for nitrogen and phosphorus in 2012 were $.63 and $.64, respectively. (Duffy) Using these estimates, the cost to the farmer in lost fertilizer value alone is $2.10 per ton of soil loss. The USDA study estimated that for soils in the EQIP program, soil erosion was reduced by 8.6 tons per acre; assuming $2.10 fertilizer value per ton of soil lost, enrollment in the EQIP program saves the farmer $18.06 per acre.

Water quality - sedimentation avoided from perennial forage

AVOIDED SOIL EROSION FROM WATER - REDUCED VALUE OF SOIL LOST OFF-FARM

EFFECT SIZE - 1

Francesconi et al. (2015) demonstrated that cover crops and forage were most successful at reducing sediment and nutrient loss (56% to 88% and 28% to 91%, respectively) in an Ohio watershed and that, compared to single practices, two and three practices resulted in greater sediment and nutrient reductions.

0.88

EFFECT SIZE - 2

In the corn belt, lake states and northern plains, NRCS reports in 2007 average erosion per acre of 3.9, 2.3 and 2.0 tons per acre per year from water erosion alone (not including wind). https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/nra/nri/?cid=nrcs143_013656 If we say 3 tons per acre per year for the Midwest.

3

COST

Reduced Water Treatment Costs from sedimentation; Reduced costs of erosion to various stakeholders (Hansen and Ribaudo, 2008; 0.41; EQIP, 2009) USDA/NRCS studies also estimated a per-ton benefit of $4.93 per acre for improved water quality benefits. Pratt et al., 2013 and USDA 2011 notes value separately: the on-site value of soil erosion is $10.17/ton, which accounts for soil nutrients and contribution to yield as well as water, and the off-site value of soil erosion is estimated at $17.99/ton accounting for water sedimentation and nutrient runoff costs (U.S. Department of Agriculture, 2011) - this figure was estimated with much lower rates of erosion however, suggesting that marginal benefit increases in contexts that may highly value remaining soil. (Pratt et al., 2013; USDA, 2011) In comparison, one USDA Economic Research Service reported that, “The county level sums of the water-erosion benefit estimations range from $1.70 to $18.24 per ton”. (pg. 21, Hansen and Ribaudo) The figures generated by Pratt et al., (2013) and USDA (2011) are utilized to note the potential value of strategic placement of perennial forage acres.

$10.17

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

$26.85

Green Lands Blue Waters IN PARTNERSHIP WITH ECOTONE ANALYTICS

Income from perennial forage and grazing

INCREASED NET INCOME - YEAR 1 OF PRACTICE ADOPTION

COST

The economic analysis showed that implementing Integrated crop-livestock systems “ICLS” increased the profit of the farm by \$17.23 ac−1 in the first year and \$43.61 ac−1 in the second year. . . (As the fence wire, post, energizer and water tank costs could last for at least 10 years, the costs of these elements will drop to 0 in the 2nd year, which will further boost the net effect to \$43.61 ac−1. In the long term, we expect economic profit will increase even more, as a cover crop will increase water holding capacity, which will reduce the yield risk during the drought season. Furthermore, an increase in SOM in the long term will reduce the need for N fertilizer application, which can add further to the reduced costs.) (Tobin et al., 2020 - South Dakota study with cover crops). SARE (2019) also notes year 1 net income of approximately \$18 per acre for livestock integration with cover crops on a corn cash crop. While these studies are focused on grazing cover crops - we assume the net benefit from integrating livestock is at least as large on a perennial pasture as it is on annual cover crops field. Boody et al., 2005 also estimate net income for a whole farm that has partially adopted rotational grazingn with perennials - with net incomes ranging from \$12 - \$105 per acre for the whole farm. This supports our conservative framing at about \$17-18 per acre.

\$17.23

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

\$17.23

Carbon from perennials (informed by effects of grazing)

REDUCED GHG EMISSIONS - SOCIAL COST OF CARBON

EFFECT SIZE - 3

Perennial crops have the potential to capture and hold large quantities of carbon as SOC, accumulating up to 0.9 metric tons carbon per ha per year in Minnesota (Paustian et al. 1997) = .99 US tons. Carbon Sequestration: Improved grassland management can increase carbon sequestration. Data indicate that an additional 0.11 tons of carbon per acre per year is sequestered (Follett, et al. 2000; Namken 2002). We present calculations that estimate potential soil organic carbon accumulation rates in fields converted from annual to perennial grains of between 0.13 and 1.70 t ha−1 year−1 (equates to .32 - 4.2 tons per acre per year). (Crews and Rumsey, 2017). More recently Rowntree et al. (2020) find a multi-species pastured livestock system in Georgia to reduce GHG potential from a commodity production system by about 1 ton per acre per year when including additional soil C sequestered in the pasture which was converted from annual 4 crop rotation. Conant et al., (2017) note a range of increased SOC rates for improved grazing and separately for conversion from cultivation to grasses with values ranging from .3-.9 Mg per HA per yr.

0.3

COST

Social Cost of Carbon - $50 per ton (EDF, 2020, U.S. Federal Social Cost of Carbon, 2016; National Academies of Science Engineering and Medicine, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide (The National Academies Press, 2017).)

$50

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

$15

Water quality - nutrients avoided from perennial forage

REDUCED NUTRIENT RUNOFF/LEACHED IN SURFACE AND GROUND WATER - ESTIMATION PROCESS #1 - REDUCED WATER TREATMENT COSTS - AVOIDED COSTS FROM UNDESIREABLE ODOR AND TASTE, NITRATE CONTAMINATION INCREASED COLON CANCER RISK (FROM NITRATES)

EFFECT SIZE - 3

Nitrate leaching levels varied widely across the treatments, with the highest leaching in the conventional system(62.2 ± 9.4 kg NO3−−N ha−1y−1) and the lowest levels in the poplar system (0.1 ± 0.0 kg NO3−−N ha−1y−1). Alfalfa came in at 12.7 +/- 1.83 kg NO3−−N ha−1y−1. No-till conventional was 41.4 kg NO#-N ha-1 y-1. (Syswerda et al., 2014) This equates to 55.4 pounds NO3-N per acre per year for conventional, 36.9 pounds NO3-N per acre per year from no-till conventional and 11.3 pounds NO3-N per acre per year from alfalfa - a representative proxy of perennial forage. This is a reduction in leaching of N per year per acre of 25.6 pounds between no-till and alfalfa.

25.6

COST

$/kg of N leached drinking water: undesirable odor and taste ($.14), nitrate contamination ($.54), colon cancer risk ($1.76) = $2.44 per Kg = $1.11 per pound. Total surface water and drinking water costs of $18.72 median or $9.06 conservative per kg of N leached. Equates to $8.50 and $4.12 per pound of N avoided. (Sobota et al., 2015) This figure is likely conservative for high-priority acres in the Midwest based on Gourevitch et al., 2018 estimations for corn belt states. Compton et al., 2011 - note varying costs of N leached between $2 and $56 per kg of N depending on context.

$1.11

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

$28.42

Additional Notes

In the Marsden Farm cropping systems experiment, lengthening a simple corn–soybean rotation with small grain and forage crops and recycling nutrients and carbon in the form of manure allowed for 76–84% reductions in the use of synthetic N fertilizer, 85–89% reductions in the use of herbicides and 41–56% reductions in the use of fossil energy, while increasing corn yield 3–5%, increasing soybean yield 9–12%, and maintaining equivalent returns to land and management on a whole rotation basis (Table 1). (Liebman et al., 2013)

Water quality - nutrients avoided from perennial forage

REDUCED NUTRIENT RUNOFF/LEACHED IN SURFACE AND GROUND WATER - ESTIMATION PROCESS #1 - REDUCED WATER TREATMENT COSTS - AVOIDED COSTS FROM UNDESIREABLE ODOR AND TASTE, NITRATE CONTAMINATION, INCREASED COLON CANCER RISK (FROM NITRATES)

CONTINUED

Additional Notes

Costs of N leached (Sobota et al., 2015; Gourevitch et al., 2018; Tang et al., 2018; Keller and Polasky, 2014)

At the end of the growing season the NO3-N concentrations below root zones (3.0–3.2 m) were 24% lower ($p = 0.0459$; $n = 3$) in perennial plots than in annual no-tillage plots. Even with the use of modern no-tillage practices, annual crop cover decreased ROC stocks, negatively impacted soil food webs (DuPont et al., this issue) and resulted in greater losses of N below rooting zones. (Glover et al., 2010)

Water quality - nutrients avoided from perennial forage

REDUCED NUTRIENT RUNOFF/LEACHED IN SURFACE AND GROUND WATER - ESTIMATION PROCESS #1 - REDUCED COSTS FROM LOST RECREATION VALUE, ENDANGERED SPECIES VALUE

This pathway is trumped given the overlap in value creation of this pathway and the pathway that monetizes the value of recreation supported by pasture establishment and well-managed grazing systems.

Water quality - nutrients avoided from perennial forage

REDUCED NUTRIENT RUNOFF/LEACHED IN SURFACE AND GROUND WATER - ESTIMATION PROCESS #1 - REDUCED COSTS FROM EUTROPHICATION

EFFECT SIZE - 1

Nitrate leaching levels varied widely across the treatments, with the highest leaching in the conventional system(62.2 ± 9.4 kg NO3−−N ha−1y−1) and the lowest levels in the poplar system (0.1 ± 0.0 kg NO3−−N ha−1y−1). Alfalfa came in at 12.7 +/- 1.83 kg NO3−−N ha−1y−1. No-till conventional was 41.4 kg NO#-N ha-1 y-1. (Syswerda et al., 2014) This equates to 55.4 pounds NO3-N per acre per year for conventional, 36.9 pounds NO3-N per acre per year from no-till conventional and 11.3 pounds NO3-N per acre per year from alfalfa - a representative proxy of perennial forage. This is a reduction in leaching of N per year per acre of 25.6 pounds between no-till and alfalfa.

25.6

COST

Increased eutrophication ($16.10 or $6.44 for low end) = $16.10 per kg = $7.32 per pound (Sobota et al., 2015) This figure is likely conservative for high-priority acres in the Midwest based on Gourevitch et al., 2018 estimations for corn belt states. Keeler et al., 2016, also note the importance of local context as N social cost can vary widely - strengthening importance of targeting high-priority acres.

$7.32

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

$187.39

Water quality - nutrients avoided from perennial forage

REDUCED NUTRIENT RUNOFF IN WATER ESTIMATION PROCESS #2 - REDUCED WATER TREATMENT COSTS - AVOIDED COSTS FROM UNDESIREABLE ODOR AND TASTE, NITRATE CONTAMINATION, INCREASED COLON CANCER RISK (FROM NITRATES)

EFFECT SIZE - 1

Francesconi et al. (2015) demonstrated that cover crops and forage were most successful at reducing sediment and nutrient loss (56% to 88% and 28% to 91%, respectively) in an Ohio watershed and that, compared to single practices, two and three practices resulted in greater sediment and nutrient reductions.

0.91

EFFECT SIZE - 2

About 25% of N is leached on average (mono-culture figure) (Doane et al., 2016)

0.25

EFFECT SIZE - 3

65 lbs/N per acre of wheat as median (between corn and soybeans USDA national average) https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0047149

65

COST

$/kg of N leached drinking water: undesirable odor and taste ($.14), nitrate contamination ($.54), colon cancer risk ($1.76) = $2.44 per Kg = $1.11 per pound. Total surface water and drinking water costs of $18.72 median or $9.06 conservative per kg of N leached. Equates to $8.50 and $4.12 per pound of N avoided. (Sobota et al., 2015) This figure is likely conservative for high-priority acres in the Midwest based on Gourevitch et al., 2018 estimations for corn belt states. Compton et al., 2011 - note varying costs of N leached between $2 and $56 per kg of N depending on context.

$1.11

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

$16.41

This pathway is trumped given the overlap in value creation of this pathway and the pathway that monetizes the value of water quality - nutrients avoided from perennial forage and grazing systems.

Water quality - nutrients avoided from perennial forage

REDUCED NUTRIENT RUNOFF IN WATER ESTIMATION PROCESS #2 - REDUCED COSTS FROM LOST RECREATION VALUE, ENDANGERED SPECIES VALUE

EFFECT SIZE - 1	Francesconi et al. (2015) demonstrated that cover crops and forage were most successful at reducing sediment and nutrient loss (56% to 88% and 28% to 91%, respectively) in an Ohio watershed and that, compared to single practices, two and three practices resulted in greater sediment and nutrient reductions. **0.91**
EFFECT SIZE - 2	About 25% of N is leached on average (mono-culture figure) (Doane et al., 2016) **0.25**
EFFECT SIZE - 3	65 lbs/N per acre of wheat as median (between corn and soybeans USDA national average) https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0047149 **65**
COST	Loss of recreational use ($.17), loss of endangered species and wildlife ($.01) = $0.18 per Kg = $0.08 per pound (Sobota et al., 2015) This figure is likely conservative for high-priority acres in the Midwest based on Gourevitch et al., 2018 estimations for corn belt states. **$0.08**
PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR	**$1.18**

This pathway is trumped given the overlap in value creation of this pathway and the pathway that monetizes the value of water quality - nutrients avoided from perennial forage and grazing systems.

Water quality - nutrients avoided from perennial forage

REDUCED NUTRIENT RUNOFF IN WATER ESTIMATION PROCESS #2 - REDUCED COSTS FROM EUTROPHICATION

EFFECT SIZE - 1

Francesconi et al. (2015) demonstrated that cover crops and forage were most successful at reducing sediment and nutrient loss (56% to 88% and 28% to 91%, respectively) in an Ohio watershed and that, compared to single practices, two and three practices resulted in greater sediment and nutrient reductions.

0.91

EFFECT SIZE - 1

About 25% of N is leached on average (mono-culture figure) (Doane et al., 2016)

0.25

EFFECT SIZE - 3

65 lbs/N per acre of wheat as median (between corn and soybeans USDA national average) https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0047149

65

COST

Increased eutrophication ($16.10 or $6.44 for low end) = $16.10 per kg = $7.32 per pound (Sobota et al., 2015) This figure is likely conservative for high-priority acres in the Midwest based on Gourevitch et al., 2018 estimations for corn belt states. Keeler et al., 2016, also note the importance of local context as N social cost can vary widely - strengthening importance of targeting high-priority acres.

$7.32

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

$108.24

This pathway is trumped given the overlap in value creation of this pathway and the pathway that monetizes the value of water quality - nutrients avoided from perennial forage and grazing systems.

Air Quality

Health care expenditures from air quality

EFFECT SIZE - 1

In the corn belt, lake states and northern plains, NRCS reports in 2007 average erosion per acre of .2, 2.3 and 2.7 tons per acre per year from wind erosion alone (not including wind). https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/nra/nri/?cid=nrcs143_013656 We can conservatively say 1.5 tons

1.5

EFFECT SIZE - 2

For the entire rotation, soil erosion by wind was lowered by at least 20% by including a perennial cropping phase on sandy soils (Padbury and Stushnoff, 2000). (from Ruselle et al., 2007)

0.2

EFFECT SIZE - 3

USDA/NRCS studies reported that each ton of soil eroded contained the equivalent of 2.32 pounds of nitrogen and 1 pound of phosphorus. (Duffy 2012)

2.32

COST

Health care expenditures from air quality (Sobota et al., 2015; Gourevitch et al., 2018). From atmospheric NOx: Increased incidence of respiratory disease. Low value of $13 / kgN equates to $28.6 per lb of N (Birch et al, 2011; van Grinsven et al, 2013; Sobota et al., 2015) Due to differing assumptions and model structures, the valuation outputs for the same category of damage costs vary by orders of magnitude. The median cost of damages from exposure to PM2.5 ranges from $0.28 to $1.49 per kg N between models A1 and A2. (Gourevitch et al., 2018 - Context: Minnesota corn fields). NRCS, 2009 also estimates reduced cost of maintaining equipment, reduced damages to nonfarm machinery, and adverse health effects $ 5.71 acre/year using conservation practices.

$29

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

$20

Recreation from wildlife, aesthetics, etc. from perennial forage and grazing

TOURISM AND RECREATION REVENUES - BIRDS, AESTHETIC VALUE, HUMAN HEALTH

COST

This analysis of the annual benefits from improved wildlife habitat started with the two components of the CRP study: improved wildlife viewing ($10.02 per acre) and improved pheasant hunting ($2.36 per acre). These combined benefit estimates ($12.38) were reduced 25 percent (to $9.29 per acre) to account for factors such as expected lower per-acre benefits on GRP working lands than on CRP retired lands, different spatial proximity of GRP lands than CRP lands, longer contract length, etc. Adjusting the value from 2002 to 2007, the resulting benefit from GRP is $10.65 per acre. (NRCS - GRP, 2010) In 2020 dollars this equates to $13.37

$13.37

PROJECTED MARGINAL BENEFIT PER ACRE PER YEAR

$13.37

Additional Notes

Our results suggest that cattle grazing can positively influence the abundance of some grassland bird species but annual variation in weather patterns can influence community composition at sites regardless of management decisions. (Ahlering and Merkord, 2017)

The Conservation Reserve Program is estimated to provide annual wildlife-related benefits of $30 per acre (USDA, FSA 2003).

Water quantity from perennial forage and grazing

WATER INFILTRATION PATHWAY: WATER STORED ON FIELD - YIELD STABILITY SUPPORTED - FLOOD RISK

EFFECT SIZE - 1

Continuous living cover significantly increased total porosity (8.0 ± 2.2%) and the water retained at field capacity (9.3 ± 2.7%). There was some evidence indicating improved effects in relatively drier environments (<900 mm annual rainfall) and in regions with sandier soils. Experiments in regions with relatively less rainfall (<900 mm) had a significant improvement in total porosity with continuous living cover (11.1 ± 3.2%, n = 16 from 8 studies), as did those without livestock included (10.5 ± 2.6%, n = 28 from 10 studies). In studies that did include livestock on treatment plots, there was a small but significant reduction in porosity (−5.4 ± 2.5%, n = 18 from 7 studies). Basche, Andrea & DeLonge, Marcia. (2017).

EFFECT SIZE - 2

Higher water infiltration rates could be the most important ecological benefit from improved grazing land management. Infiltration is determined by soil structure, amount of cover, and type of cover. Higher water infiltration rates improve forage production and site ecology and contribute to the recharge of underground aquifers and above-ground springs.
Before and after infiltration rates for six different regions including pasture lands were used to calculate a weighted average of 2.58 acre-inches per year (Spaeth 2000; Namken 2002.) (NRCS, 2010)

EFFECT SIZE - 3

Over seasons and years, mean percentages of applied rainfall lost from paddocks that were grazed by continuous or rotational grazing to a 2-inch residual height or harvested for hay and grazed as stockpiled forage (19.6 %) were greater than paddocks that were not grazed or grazed by rotational stocking to a residual height of 4 inches (9.6 %). A 10 percentage point reduction in lost rainwater in Iowa. (Isenhart et al., 2006)

Additional Notes

We found that in 81.9% of all cases, responses of infiltration rates to identified management treatments (response ratios) were above zero, with infiltration rates increasing by 59.3 ± 7.3%. Mean response ratios from unique management categories were not significantly different, although the effect of extended rest (67.9 ± 8.5%, n = 140 from 31 experiments) was slightly higher than from reducing stocking rates (42.0 ± 10.8%; n = 63 from 17 experiments) or adding complexity (34.0 ± 14.1%, n = 17 from 11 experiments). (Basche and DeLonge, 2018).

We have limited comparisons for annual crops and no grazing converted to perennial forage and grazing. It appears that grazing reduces porosity but not necessarily when switching from annuals to perennials at the same time. The question then is how much of an improvement is made. We also know that well managed grazing improves infiltration over poorly managed grazing. We may be able to use improved grazing as a proxy noting that if the fields are uncovered in winter we are likely making a similar improvement.

Appendix C: LEVELS OF EVIDENCE and BIBLIOGRAPHY

Table C1: Levels of Evidence of Causality – Ranked from highest to lowest, 1 to 7

1	Evidence from a systematic review or meta-analysis of all relevant RCTs (randomized controlled trial) or evidence-based clinical practice guidelines based on systematic reviews of RCTs or three or more RCTs of good quality that have similar results.
2	Evidence obtained from at least one well-designed RCT (e.g. large multi-site RCT).
3	Evidence obtained from well-designed controlled trials without randomization (i.e. quasi-experimental).
4	Evidence from well-designed case-control or cohort studies.
5	Evidence from systematic reviews of descriptive and qualitative studies (meta-synthesis).
6	Evidence from a single descriptive or qualitative study.
7	Evidence from the opinion of authorities and/or reports of expert committees.

In the table on the following page, specific sources referenced or whose figures were directly used, are included. Each study is ranked by its level of evidence and includes its relevant finding. This helps to communicate the relative strength of the findings estimated and used. Whenever possible, the highest level of evidence is utilized.

Level of Evidence	Study	Relevant Finding
Level 1 Evidence: Meta-analysis of RCTs	Basche, A. & DeLonge, M. (2017). The Impact of Continuous Living Cover on Soil Hydrologic Properties: A Meta-Analysis. Soil Science Society of America Journal. 81. 10.2136/sssaj2017.03.0077.	CLC significantly increased soil porosity and water retained
	Basche, A.D., DeLonge, M.S. (2019). Comparing infiltration rates in soils managed with conventional and alternative farming methods: A meta-analysis. PLoS ONE 14(9): e0215702. https://doi.org/10.1371/journal.pone.0215702	Perennials had large increases in infiltration rates over crop rotations alone
	Cates, A. M., G. R. Sanford, L. W. Good, & R. D. Jackson. (2018). What do we know about cover crop efficacy in the North Central United States? Journal of Soil and Water Conservation, 73: 153A-157A.	Cover crops can increase SOM although costs and benefits can vary by case
	DeLonge, M., & Basche, A. (2018). Managing grazing lands to improve soils and promote climate change adaptation and mitigation: A global synthesis. Renewable Agriculture and Food Systems, 33(3): 267-278. doi:10.1017/S1742170517000588	Grazing management practices can influence infiltration rates and Soil Carbon
	Tamburini, G., Bommarco, R., Wanger, T.C., Kremen, C., van der Heijden, M.G.A., Liebman, M. & Hallin, S. (2020). Agricultural diversification promotes multiple ecosystem services without compromising yield. Science Advance, 6(45).	Agricultural diversification promotes multiple ecosystem services without compromising yield
Level 2 Evidence: Randomized Controlled Trials	Basche, A.D., Kaspar, T.K., Archontoulis, S.A., Jaynes, D.B., Parkin, T.B., Sauer, T.S., Miguez, F.E. (2016). Soil water improvements with the long-term use of a cover crop. Agricultural Water Management, 172: 40-50. doi 10.1016/j.agwat.2016.04.006	Cover crops can boost water storage
	Culman, S., Snapp, S., Ollenburger, M., Basso, B. & DeHaan, L. (2013). Soil and Water Quality Rapidly Responds to the Perennial Grain Kernza Wheatgrass. Agronomy Journal, 105: 735–744. doi: 10.2134/agronj2012.0273.	Perennial kernza reduced NO3 leaching by 86% compared to wheat
	Davis, A.S., J.D. Hill, C.A. Chase, A.M. Johanns, & M. Liebman. (2012). Increasing Cropping system diversity balances productivity, profitability and environmental health. PLoS ONE 7(10): e47149. doi:10.1371/journal.pone.0047149.	Increasing Cropping system diversity balances productivity, profitability and environmental health.
	de Oliveira, G., Brusnell, N.A., Sutherlin, C.E., Crews, T.E. & DeHaan, L.R. (2018). Energy, Water and Carbon exchange over a perennial Kernza wheatgrass crop. Agriculture and Forest Meteorology, 249: 120-137.	Kernza has high water use efficiency and acts a carbon sink
	Gelfand, I., S. K. Hamilton, A. N. Kravchenko, R. D. Jackson, K. D. Thelen, and G. P. Robertson. (2020). Empirical evidence for the potential climate benefits of decarbonizing light vehicle transport in the U.S. with bioenergy from purpose-grown biomass with and without BECCS. Environmental Science & Technology 54:2961-2974.	Bioenergy yield by feedstock type can vary considerably

Level of Evidence	Study	Relevant Finding
Level 2 Evidence: Randomized Controlled Trials	Gelfand, I., Shcherbak, I., Millar, N., Kravchenko, A.N. and Robertson, G.P. (2016). Long-term nitrous oxide fluxes in annual and perennial agricultural and unmanaged ecosystems in the upper Midwest USA. Glob Change Biol, 22: 3594-3607. doi:10.1111/gcb.13426	N2O emissions were higher from annual grain and N-fixing cropping systems than from nonleguminous perennial cropping systems
	Gesch, R.W. & Johnson, J.M.-F. (2015). Water Use in Camelina–Soybean Dual Cropping Systems. Agronomy Journal, 107: 1098-1104. doi:10.2134/agronj14.0626	Winter camelina can be effectively dual cropped with soybean
	Gesch, R.W., Archer, D.W. and Berti, M.T. (2014). Dual Cropping Winter Camelina with Soybean in the Northern Corn Belt. Agronomy Journal, 106: 1735-1745. doi:10.2134/agronj14.0215	Winter Camelina increased costs but also included additional income to offset the costs
	Hummel, A. Dalman, N., Liu, R. & Garcia y Garcia, A. (2017). Mitigating Water Loss in Soybean-Corn Rotations with Winter Cover Crops.	Winter cover crops can reduce water loss
	Jungers, J.M., DeHaan, L.H., Mulla, D.J., Sheaffer, C.C. & Wyse, D.L. (2019). Reduced nitrate leaching in perennial grain crop compared to maize in the Upper Midwest, USA. Agriculture, Ecosystems and Environment, 272: 63-73.	Intermediate wheatgrass significantly reduced nitrate leaching compared to maize
	Liebman, M., M.J. Helmers, L.A. Schulte C., & A. Chase. (2013). Using biodiversity to link agricultural productivity with environmental quality: Results from three field experiments in Iowa. Renewable Agriculture and Food Systems, 28(2): 115–128.	Crop diversity and rotations can boost yields and reduce costs
	Ott, M., Eberle, C., Thom, M., Archer, D., Forcella, F., Gesch, R. & Wyse, D. (2019). Economics and Agronomics of Relay-Cropping Pennycress and Camelina with Soybean in Minnesota. Agronomy Journal. 111. 10.2134/agronj2018.04.0277.	The extra effort in growing pennycress may be worthwhile in some years
	Pimentel, D., Hepperly, P., Hanson, J., Douds, D., Seidel, R. (2005). Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems. BioScience 55(7): 573-582.	Organic practices reduce water runoff
	Randall, G.W. & M.J. Gross. (2008). Nitrate losses to surface water through subsurface tile drainage. In: Nitrogen in the Environment: Sources, Problems, and Management, (Ed.) J.L. Hatfield and R.F. Follett. Elsevier Sciences B.V: 145-175.	Tile drainage and annual crops together increase likelihood of NO3 losses
	Sanford, G. R., J. L. Posner, R. D. Jackson, C. J. Kucharik, J. L. Hedtcke, and T.-L. Lin. (2012). Soil carbon lost from Mollisols of the North Central U.S.A. with 20 years of agricultural best management practices. Agriculture, Ecosystems & Environment 162:68-76.	Perennial crops reduced SOC loss but did not support gains in carbon sequestration

Level of Evidence	Study	Relevant Finding
Level 2 Evidence: Randomized Controlled Trials	Schulte, L. A., J. Niemi, M. J. Helmers, M. Liebman, J. G. Arbuckle, D. E. James, R. K. Kolka, M. E. O'Neal, M. D. Tomer, J. C. Tyndall, H. Asbjornsen, P. Drobney, J. Neal, G. Van Ryswyk, and C. Witte. (2017). Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn-soybean croplands. Proceedings of the National Academy of Sciences 114:11247-11252.	Prairie strips reduced total water runoff from catchments by 37%, resulting in retention of 20 times more soil and 4.3 times more phosphorus
	Skinner, R.H. and Dell, C.J. (2016), Yield and Soil Carbon Sequestration in Grazed Pastures Sown with Two or Five Forage Species. Crop Science, 56: 2035-2044. doi:10.2135/cropsci2015.11.0711	Reference for increased carbon sequestration from livestock integrations
	Snapp, S. S., Gentry, L. E., Harwood, R. (2010). Management intensity - not biodiversity - the driver of ecosystem services in a long-term row crop experiment. Agriculture, Ecosystems and Environment 138: 242-248.	Management intensity can drive ecosystem services
	Syswerda, S. P., Robertson, G. P. (2014). Ecosystem services along a management gradient in Michigan (USA) cropping systems. Agriculture, Ecosystems and Environment 189(0): 28-35.	Management systems have large effects on ecosystem services
	Tobin, C. , Singh, S. , Kumar, S. , Wang, T. and Sexton, P. (2020) Demonstrating Short-Term Impacts of Grazing and Cover Crops on Soil Health and Economic Benefits in an Integrated Crop-Livestock System in South Dakota. Open Journal of Soil Science, 10, 109-136. doi: 10.4236/ojss.2020.103006.	Net income changes from livestock integration; reference for changes in bulk density
	Tomer, M.D. & M. Liebman. (2013). Nutrients in soil water under three rotational cropping systems, Iowa, USA. Agriculture, Ecosystems and Environment 180: 105-114.	More crop rotations is associated with reduced NO3-N concentrations
	Turner, R.E. (2020). Reference List draft paper in progress. Manuscript in preparation.	Diversification of crops can boost profits and increase carbon storage
	von Haden, A.C. & Dornbush, M.E. (2017). Ecosystem carbon pools, fluxes, and balances within mature tallgrass prairie restorations. Restoration Ecology, 25(4): 549-558.	Tallgrass prairie restorations can quickly accrue organic C in soil and biomass
Level 3 Evidence: Quasi-experimental Analysis	Ahlering, M.A. and Merkord, C.L. (2016). Cattle grazing and grassland birds in the northern tallgrass prairie. Jour. Wild. Mgmt., 80: 643-654. doi:10.1002/jwmg.1049	Birds can benefit from grazing intensity
	Asbjornsen, H., Hernandez-Santana, V., Liebman, M., Bayala, J., Chen, J., Helmers, M., . . . Schulte, L. (2014). Targeting perennial vegetation in agricultural landscapes for enhancing ecosystem services. Renewable Agriculture and Food Systems, 29(2), 101-125. doi:10.1017/S1742170512000385	Reestablishment of perennial grasslands on former agricultural lands could rebuild soil organic C pools to levels equivalent to unplowed native prairie within 55–75 years

Level of Evidence	Study	Relevant Finding
Level 3 Evidence: Quasi-experimental Analysis	Berti, M., Johnson, B., Ripplinger, D., Gesch, R. & Aponte, A. (2017). Environmental impact assessment of double- and relay-cropping with winter camelina in the northern Great Plains, USA. Agricultural Systems, 156: 1-12.	There is reduced erosion but increased emissions from double or relay cropping with winter camelina
	Dinnes, D.L., Karlen, D.L., Jaynes, D.B., Kaspar, T.C., Hatfield, J.L., Colvin, T.S. and Cambardella, C.A. (2002), Nitrogen Management Strategies to Reduce Nitrate Leaching in Tile-Drained Midwestern Soils. Agron. J., 94: 153-171. https://doi.org/10.2134/agronj2002.1530	70% of NO3 leached comes from less than 30% of the field
	Glover, J.D. et al. (2010a). Harvested perennial grasslands provide ecological benchmarks for agricultural sustainability. Agriculture, Ecosystems and Environment 137: 3–12.	Perennials have a series of positive environmental benefits
	Glover, J.D. et al. (2010b). Increased food and ecosystem security via perennial grains. Science 328: 1638–1639. doi:10.1126/science.1188761	Perennial grains provide many ecosystem services
	Leopold Center for Sustainable Agriculture & Iowa Cattleman's Association. (2006). Final Report: Impacts of Managed Grazing on Stream Ecology and Water Quality.	Maintaining adequate forage cover boosts stream ecology
	Meehan, T. D., Gratton, C., Diehl, E., Hunt, N. D., Mooney, D. F., Ventura, S. J., Barham, B. L. & R. D. Jackson. (2013). Ecosystem-service tradeoffs associated with switching from annual to perennial energy crops in riparian zones of the US Midwest. PLoS One 8:e80093	Perennial grass production reduced incomes but increased ecosystem services relative to continuous corn
	Morandin, L. A., Long, R. F., Kremen, C. (2016). Pest Control and Pollination Cost-Benefit Analysis of Hedgerow Restoration in a Simplified Agricultural Landscape. Journal of Economic Entomology 109(3): 1020-1027.	Hedgerows can boost pollination and profitability
	Moriasi, D.N., Duriancik, L.F., Sadler, E.J., Tsegaye, T., Steiner, J.L., Locke, M.A., Strickland, T.C., & Osmond, D.L. (2020). Quantifying the impacts of the Conservation Effects Assessment Project watershed assessments: The first fifteen years. Journal of Soil and Water Conservation, 75(3): 57A-74A; DOI: 10.2489/jswc.75.3.57A	Forage can reduce sediment and nutrient loss compared to row crops by upwards of 90%
	Phillips, R. L., M. R. Eken, and M. S. West. (2015). Soil Organic Carbon Beneath Croplands and Re-established Grasslands in the North Dakota Prairie Pothole Region. Environmental Management 55:1191-1199.	CRP grasslands boost SOC
	Rowntree, J., Ryals, R., DeLonge, M., Teague, W.R., Chiavegato, M., Byck, P., Wang, T. & Xu, S. (2016). Potential mitigation of midwest grass-finished beef production emissions with soil carbon sequestration in the United States of America. Future of Food: Journal of Food, Agriculture and Society, 4: 31.	Beef production in well-managed grazing systems can aid in soil carbon sequestration
	Stanley, P.L., Rowntree, J.E., Beede, D.K., DeLonge, M.S., Hamm, M.W. (2018). Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in Midwestern USA beef finishing systems. Agricultural Systems, 162: 249-258.	Emissions from the grazing system were offset completely by soil C sequestration

Level of Evidence	Study	Relevant Finding
Level 4 Evidence: Case Control/ Cohort Studies	Benbrook, C. et. al. (2010). The Organic Center. A Dairy Farm's Footprint:Evaluating the Impacts of Conventional and Organic Farming Systems.	Pasture-based dairy farms reduce methane from reduced manure lagoon usage
	Binder, S., Isbell, F, Polasky, S, Catford, J, Tilman, D. (2018). Grassland Biodiversity Can Pay. PNAS April 10, 2018 115 (15) 3876-3881	Profitability for landholders is maximized at 9-12 species
	Boehm, R. (2020). Reviving the Dead ZoneSolutions to Benefit Both Gulf Coast Fishers and Midwest Farmers. Union of Concerned Scientists.	Nitrogen runoff causes upwards of $2 billion in economic damages to the Gulf of Mexico fisheries
	Boody, G., Vondracek, B., Andow, D.A., Krinke, M., Westra, J., Zimmerman, J. & Welle, P. (2005). Multifunctional Agriculture in the United States. BioScience, 55: 27-38.	Changes in agricultural land management improve watershed quality without additional costs
	Dodds, W. K., Bouska, W. W., Eitzmann, J. L., Pilger, T. J., Pitts, K. L., Riley, A. J., ... & Thornbrugh, D. J. (2009). Eutrophication of US freshwaters: analysis of potential economic damages.	Eutrophication from Nitrogen runoff poses multiple costs
	Duffy, M. (2012). Value of Soil Erosion to the Land Owner. Iowa State University, Ames.	Soil erosion can be highly costly and is widespread
	Fargione, J. E., Bassett, S., Boucher, T., Bridgham, S. D., Conant, R. T., Cook-Patton, S. C., ... & Gu, H. (2018). Natural climate solutions for the United States. Science Advances, 4(11), eaat1869.	Grazing optimization, grassland restoration and legumes in pastures are all associated with soil carbon sequestration
	Fargione, J.E. et al. (2018). Natural Climate solutions for the United States. Science Advances, 4.	The two largest lower-cost opportunities for carbon sequestration: cover crops and improved natural forest management
	Fissore, C., Espeleta, J., Later, E.A., Hobbie, S.E. & Reich, P.B. (2009). Limited potential for terrestrial carbon sequestration to offset fossil-fuel emissions in the upper midwestern US. Frontiers in Ecology and the Environment.	Terrestrial carbon sequestration to offset foss-fuel emissions is unlikely
	Friedman, S. & Sands, L. (2019). How conservation makes dairy farms more resilient, especially in a lean agricultural economy. Environmental Defense Fund and KCoe Isom.	Conservation practices on a dairy farm are shown to be profitable
	Gourevitch, J., Keeler, B. & Ricketts, T. (2018). Determining socially optimal rates of nitrogen fertilizer application. Agriculture, Ecosystems and Environment, 254: 292-299.	Social cost of nitrogen
	Hashem Mousavi-Avval, S. & Shah, A. (2020). Techno-economic analysis of pennycress production, harvest and post-harvest logistics for renewable jet fuel: Renewable and Sustainable Energy Reviews, 123.	Pennycress has potential as a renewable jet fuel although remains expensive

Level of Evidence	Study	Relevant Finding
Level 4 Evidence: Case Control/ Cohort Studies	Henderson, B. B., Gerber, P. J., Hilinski, T. E., Falcucci, A., Ojima, D. S., Salvatore, M., & Conant, R. T. (2015). Greenhouse gas mitigation potential of the world's grazing lands: Modeling soil carbon and nitrogen fluxes of mitigation practices. Agriculture, Ecosystems & Environment, 207, 91-100.	Grazing optimization, grassland restoration and legumes in pastures are all associated with soil carbon sequestration
	Hungate, B.A. et. al. (2017) The economic value of grassland species for carbon storage. Sci Adv 3:e1601880	There are diminishing economic returns to species richness
	Jha, M.K., Wolter, C.F., Schilling, K.E. & Gassman, P.W. (2010). Assessment of total maximum daily load implementation strategies for nitrate impairment of the Raccoon River, Iowa. Journal of Environmental Quality 39: 1317-1327.	Nitrate reduction strategies can be highly effective
	Krohn, B.J. & Fripp, M. (2021). A life cycle assessment of biodiesel derived from the "niche filling" energy crop camelina in the USA. Applied Energy, 92: 92-98.	Without considering land-use change the camelina scenarios emit more GHG than soybeans
	Langemeier, M. & M. O'Donnell (2020). Conventional and Organic Enterprise Net Returns. Farmdoc Daily (10): 161, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign.	Returns on conventional corn and soybeans are often low
	Leclère, D., Obersteiner, M., Barrett, M. et al. (2020). Bending the curve of terrestrial biodiversity needs an integrated strategy. Nature, 585: 551–556. https://doi.org/10.1038/s41586-020-2705-y	Increasing terrestrial biodiversity must consider food provision needs
	Ledo, A, Smith, P, Zerihun, A, et al. (2020). Changes in soil organic carbon under perennial crops. Glob Change Biol, 26: 4158– 4168. https://doi.org/10.1111/gcb.15120	Transitioning from annuals to perennials increased SOC
	Manson, S. M., Jordan, N. R., Nelson, K. C., & Brummel, R. F. (2016). Modeling the effect of social networks on adoption of multifunctional agriculture. Environmental modelling & software : with environment data news, 75, 388–401. https://doi.org/10.1016/j.envsoft.2014.09.015	Social networks are important to rotational grazing (RG) adoption but their impact is contingent on social and spatial factors
	Mathewson, P. D., Evans, S., Byrnes, T., Joos, A. & Naidenko, O. V. (2020). Health and economic impact of nitrate pollution in drinking water: a Wisconsin case study. Environmental Monitoring and Assessment, 192(11), 724. https://doi.org/10.1007/s10661-020-08652-0	Direct medical cost estimates for all nitrate-attributable adverse health outcomes range between $23 and $80 million annually in WI
	McIsaac, G.F., X. Hu. (2004). Net N Input and riverine N export from Illinois agricultural watersheds with and without extensive tile drainage. Biogeochemistry 70: 251-271.	Tile drainage system increases nitrate runoff
	Meehan, T. D., A. H. Hurlbert, and C. Gratton. (2010). Bird communities in future bioenergy landscapes of the Upper Midwest. PNAS 107:18533-18538.	Perennial bioenergy crops can boost avian richness
	Meehan, T. D., Werling, B. P., Landis, D. A., & C. Gratton. (2011). Agricultural landscape simplification and insecticide use in the Midwestern United States. PNAS 108:11500-11505.	Landscape simplification is associated with increased pesticide use

Level of Evidence	Study	Relevant Finding
Level 4 Evidence: Case Control/ Cohort Studies	Mercer, D.E., Li, X., Stainback, A. & Alavalapati, J. (2017). Chapter 4: Valuation of agroforestry services. In: Schoeneberger, Michele M.; Bentrup, Gary; Patel-Weynand, Toral, eds. Agroforestry: Enhancing resiliency in U.S. agricultural landscapes under changing conditions. Gen. Tech. Report WO-96. U.S. Department of Agriculture, Forest Service. 63-72.	Agroforestry can access other revenue streams such as hunting leases
	Minnesota Board of Water and Soil Resources. (2018). Working lands watershed restoration feasibility study and program plan.	Subsidies are often needed for CLC strategies
	Natural Resources Conservation Service. (2010). Final Benefit-Cost Analysis for the Grassland Reserve Program (GRP). United State Department of Agriculture.	Grassland management valuation is difficult but has been estimated for many ecosystem services
	Park, J.Y., Ale, S., Teague, W.R., & S.L. Dowhower (2017). Simulating hydrologic responses to alternate grazing management practices at the ranch and watershed scales. Journal of Soil and Water Conservation, 72 (2): 102-121; DOI: 10.2489/jswc.72.2.102	Utilizing multi-paddock grazing as opposed to heavy continuous can significantly reduce surface runoff and streamflow
	Pattison, I. & Lane, S.N. (2011). The link between land-use management and fluvial flood risk: A chaotic conception? Progress in Physical Geography, 36(1) 72–92.	Impact of land management activities upon flood risk at larger catchment scales has proved to be elusive
	Peterson et al. (2011). A Once and Future Gulf of Mexico Ecosystem: Recommendations for restoring a healthy and productive natural system. Pew Environmental Group.	Without the subsidies, the net farm income would often be negative
	Raff, Z., & Meyer, A. (2019). CAFOs and Surface Water Quality: Evidence from the Proliferation of Large Farms in Wisconsin. Available at SSRN 3379678.	The marginal CAFO in Wisconsin produces non-market surface water quality damages of at least $203,541 per year.
	Randall, G.W. & D.J. Mulla. (2001). Nitrate nitrogen in surface waters as influenced by climatic conditions and agricultural practices. Journal of Environmental Quality 30: 337–344.	N management systems can significantly reduce N losses
	Robertson, B. A., Doran, P. J., Loomis, L. R., Robertson, J. R. & D. W. Schemske. (2011). Perennial biomass feedstocks enhance avian diversity. GCB Bioenergy 3:235-246.	Avian richness was higher in perennial plantings with greater forb content and a more diverse vegetation structure
	Rowntree, J., Stanley, P. L., Maciel, I. C., Thorbecke, M., Rosenzweig, S. T., Hancock, D. W., & Raven, M. R. (2020). Ecosystem Impacts And Productive Capacity Of A Multi-species Pastured Livestock System. Frontiers in Sustainable Food Systems, 4, 232.	A multi-species pastured livestock can significantly reduce GHG emissions as opposed to siloed row crop production and concentrated feed lots
	Russelle, M. P., Entz, M. H., & Franzluebbers, A. J. (2007). Reconsidering integrated crop–livestock systems in North America. Agronomy Journal, 99(2), 325-334.	Reduce risk of environmental damage and increase soil carbon perennial forage and grazing

Level of Evidence	Study	Relevant Finding
Level 4 Evidence: Case Control/ Cohort Studies	Schullehner, J., Hansen, B., Thygesen, M., Pedersen, C. B., & Sigsgaard, T. (2018). Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study. International journal of cancer, 143(1), 73-79.	Nitrate in drinking water increases risk of colorectal cancer
	Shibu, J., Gold, M. & Zamora, D. (2017). Appendix A: Regional summaries: Midwest. In: Schoeneberger, Michele M.; Bentrup, Gary; Patel-Weynand, Toral, eds. Agroforestry: Enhancing resiliency in U.S. agricultural landscapes under changing conditions. Gen. Tech. Report WO-96. U.S. Department of Agriculture, Forest Service. 177-183.	Local food production can boost indirect economic activity over conventional food
	Stanley, P. L., Rowntree, J. E., Beede, D. K., DeLonge, M. S., & Hamm, M. W. (2018). Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in Midwestern USA beef finishing systems. Agricultural Systems, 162, 249-258.	Emissions from the grazing system were offset completely by soil C sequestration
	Undersander, D. & Pillsbury, B. (1999). Grazing Streamside Pastures. University of Wisconsin Extension.	Fencing costs $0.10 per foot with returns expected from improved forage quality
	Undersander, D., Temple, S., Bartlet, J., Sample, D. & Paine, L. (2000). Grassland birds: Fostering habitats using rotational grazing. University Wisconsin Extension.	Rotational grazing reduces feed, fuel, feretilizer, labor, equipment costs and provides nesting habitat
	Ward, M. H., Jones, R. R., Brender, J. D., De Kok, T. M., Weyer, P. J., Nolan, B. T., ... & 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.	Drinking water nitrate has several negative human health implications
	Zhou, X., Al-Kaisi, M. & Helmers, J. M. (2009). Cost effectiveness of conservation practices in controlling water erosion in Iowa. Soil & Tillage Research, 106: 71-78.	No-till is most beneficial in areas prone to higher water erosion
Level 5 Evidence: Systematic Review of Descriptive Studies	Blay-Palmer, A., Sonnino, R. & Custot, J. (2016). A food politics of the possible? Growing sustainable food systems through networks of knowledge. Agric Hum Values 33: 27–43. https://doi.org/10.1007/s10460-015-9592-0	Network building is one of 6 shared issues for growing sustainable food systems!
	Brainard, S. & Selosse, F. (2019). Overcoming Bottlenecks in the Midwest Hazelnut Industry: An Impact Investment Plan. Savanna Institute and Hyphae Partners.	Hazelnuts are positioned to replace soybeans in the Midwest and create climate benefits
	Chavas, J. & Nauges, C. (2020). Uncertainty, Learning, and Technology Adoptionin Agriculture. Applied Economic Perspectives and Policy, 42(1): 42-53.	Reference for methods to facilitate practice adoption
	Compton, J.E., Harrison, J.A., Dennis, R.L., Greaver, T.L., Hill, B.H., Jordan, S.J., Walker, H. and Campbell, H.V. (2011), Ecosystem services altered by human changes in the nitrogen cycle: a new perspective for US decision making. Ecology Letters, 14: 804-815. doi:10.1111/j.1461-0248.2011.01631.x	Social costs of nitrogen

Level of Evidence	Study	Relevant Finding
Level 5 Evidence: Systematic Review of Descriptive Studies	Conant, R. T., Cerri, C. E. P., Osborne, B. B., and Paustian, K. (2017). Grassland management impacts on soil carbon stocks: a new synthesis. Ecol. Appl. 27, 662–668. doi: 10.1002/eap.1473	Improved grazing management, fertilization, sowing legumes and improved grass species, irrigation, and conversion from cultivation all tend to lead to increased soil C
	Crews, T.E. & Rumsey, B.E. (2017). What Agriculture Can Learn from Native Ecosystems in Building Soil Organic Matter: A Review. Sustainability, 9, 578. https://doi.org/10.3390/su9040578	Potential soil organic carbon accumulation rates in fields converted from annual to perennial grains of between 0.13 and 1.70 t ha−1 year−1.
	Delta Institute & Earth Economics. (2017). Valuing the Ecosystem Service Benefits from Regenerative Agriculture Practices: Farmland LP 2017 Impact Report.	Large valuations of ecosystems services from agriculture practices stem from many value pathways
	Dow, K., Haywood, B.K., Kettle, N.P. et al. The role of ad hoc networks in supporting climate change adaptation: a case study from the Southeastern United States. (2013). Reg Environ Change 13, 1235–1244. https://doi.org/10.1007/s10113-013-0440-8	Networks can strengthen climate adaptation capabilities
	Feather, P., Hellerstein, D. & Hansen, L. (1999). Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP. Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 778	Reference for valuation of off-farm benefits of CRP land
	Franzluebbers, A.J., Paine, L.K., Winsten, J.R., Krome, M., Sanderson, M.A., Ogles, K. & Thompson, D. (2012). Well-managed grazing systems: A forgotten hero of conservation. Journal of Soil and Water Conservation, 67(4): 100A-104A; DOI: 10.2489/jswc.67.4.100A	Well-managed grassland can have significant environmental benefits but must overcome financial and behavioral obstacles
	Garrett, H.E., Kerley, M.S., Ladyman, K.P., Walter, W.D., Godsey, L.D., Van Sambeek, J.W., Brauer, D.K. (2004). Hardwood silvopature management in North America. Agroforestry Systems, 61: 21-33.	Tree planting can boost intergenerational equity
	Garrett, L. and Neves, B. (2016) Incentives for Ecosystem Services: Spectrum. Food and Agriculture Organization of the United Nations, Rome, Italy.	Incentive mechanisms span a spectrum of policy-driven investments to voluntary investments
	Grimsbo Jewett, J. & Schroeder, S. (2015). Continuous Living Cover Manual. Green Lands Blue Waters.	CLC can deliver simultaneous profitability, community benefits, and ecosystem services
	Hansen, L. & Ribaudo, M. (2008). Economic measures of soil conservation benefits: Regional values for policy assessment. USDA Technical Bulletin, (1922).	Costs of soil loss are large

Level of Evidence	Study	Relevant Finding
Level 5 Evidence: Systematic Review of Descriptive Studies	Hilimire, K. (2011). Integrated crop/livestock agriculture in the United States: A review. Journal of Sustainable Agriculture, 35(4), 376-393.	Integrated crop/livestock agriculture could improve soil quality,increase yield, produce a diversity of foods, augment pollinator populations, aid pest management, and improve land use efficiency.
	Imerman, M. & Imerman, E. (2019). Estimation of Financial Implications Resulting from the Implementation ofFarm Conservation Practices. Regional Strategic, LTD.	Cover crops and no-till can lead to net cost savings
	Interim Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP). (2009). USDA Natural Resources Conservation Service. www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_007977.pdf	Ecosystem services of sustainable management practices have a postive return on investment
	IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.	Reference for future climate risks
	Kleppel, G. S. (2020). Do Differences in Livestock Management Practices Influence Environmental Impacts. Front. Sustain. Food Syst. 4: 141. doi: 10.3389/fsufs	Grazing management practices may prove to be a valuable tool for climate change mitigation
	Land Stewardship Project. (2013). Farm Transitions - Valuing Sustainable Practices Perennial Forages and Grazing.	Perennial forage production has a series of unique costs and benefits from other CLC strategies
	Landis, D. A. (2017). Designing Agricultural Landscapes for Biodiversity-Based Ecosystem Services. Basic and Applied Ecology, 18: 1-12.	Must redesign agricultural systems to improve ecosystem services!
	Montenegro de Wit, M. & Iles, A. (2016). Towards thick legitimacy: creating a web of legitimacy for agroecology. Element: Science of the Anthropocene, doi: 10.12952/journal.elementa.000115	CLC must bundle the threads of legitimacy
	Natural Resources Conservation Service. (2009). Interim Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP).	Valuation of various benefits from conservation practices eligible for EQIP payments
	Paine, L.K., Klemme, R.M., Undersander, D.J. & Welsh, M. (2000). Wisconsin's Grazing Networks: History, Structure, and Function. Journal Natural Resources and Life Science Education, 29: 60-67.	Grazing networks can address gaps in agricultural knowledge sharing
	Peterson, C.H. et. al. (2011). A Once and Future Gulf of Mexico Ecosystem: Recommendations for restoring a healthy and productive natural system. Pew Environment Group.	Adjusting U.S. farm policy to free up farmers to make locally appropriate decisions can reduce nutrient loss and increase perennialization.

Level of Evidence	Study	Relevant Finding
Level 5 Evidence: Systematic Review of Descriptive Studies	Piñeiro, V., Arias, J., Dürr, J. et al. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. Nat Sustain 3: 809–820. https://doi.org/10.1038/s41893-020-00617-y	Evidence mixed in terms of effective interventions for supporting sustainable agriculture practices
	Pratt, M., Tyner, W., Muth, D. & Kladivko, E. (2013). Synergies Between Cover Crops and Corn Stover Removal, Purdue University.	Cover crop economic and environmental benefits
	Robertson, G. P., Gross, K. L., Hamilton, S. K., Landis, D. A., Schmidt, T. M., Swinton, S. M., Snapp, S. S. (2014). Farming for Ecosystem Services: An Ecological Approach to Production Agriculture. BioScience 64(5): 404-415.	Consumer WTP farmers for clean water is greater than GHG reductions
	Rosenberger, Randall S.; White, Eric M.; Kline, Jeffrey D.; Cvitanovich, Claire. 2017. Recreation economic values for estimating outdoor recreation economic benefits from the National Forest System. Gen. Tech. Rep. PNW-GTR-957. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 33 p.	Recreation value estimates
	Schut, M., Leeuwis, C. & Thiele, G. (2020). Science of Scaling: Understanding and guiding the scaling of innovation for societal outcomes. Agricultural Systems, 184.	Networks are often needed to support scaling
	Sobota, D.J. et al. (2015). Cost of reactive nitrogen release from human activities to the environment in the United States. Environmental Research Letters, 10 025006	Social costs of nitrogen are large, particularly in agricultural regions
	Sollenberger, L. E., Kohmann, M. M., Dubeux, J. C. B. & M. L. Silveira. (2019). Grassland Management Affects Delivery of Regulating and Supporting Ecosystem Services. Crop Science, 59:441-459.	Well-managed grazing can reduce GHG emissions
	Spratt, E., Jordan, J., Winsten, J., Huff, P., van Schaik, C., Jewett, J. G., ... & Paine, L. (2021). Accelerating regenerative grazing to tackle farm, environmental, and societal challenges in the upper Midwest. Journal of Soil and Water Conservation, 76(1): 15A-23A.	Benefits of regenerative grazing continue to be undervalued and under-incentivized
	Sustainable Agriculture Research and Education. (2019). Cover Crop Economics Opportunities to Improve Your Bottom Line in Row Crops. SARE Ag Innovations Series Technical Bulletin.	Change in net income from cover crops; Reference for impacts of cover crops
	The Nature Conservancy. (2016). reThink Soil: A Roadmap for U.S. Soil Health A ROADMAP FOR COLLECTIVE ACTION TO SECURE THE CONSERVATION AND ECONOMIC BENEFITS OF HEALTHY SOILS.	Reference for valuation of off-farm benefits from conservation practices
	Turner, B. L., Wuellner, M., Nichols, T., Gates, R., Tedeschi, L. O., & Dunn, B. H. (2017). A systems approach to forecast agricultural land transformation and soil environmental risk from economic, policy, and cultural scenarios in the northcentral United States (2012–2062). International Journal of Agricultural Sustainability, 15(2), 102-123.	Reference for potential long-term social and economic changes from agricultural land transformation

Level of Evidence	Study	Relevant Finding
Level 5 Evidence: Systematic Review of Descriptive Studies	Van Tassel, D.L., Tesdell, O., Schlautman, B., Rubin, M.J., DeHaan, L.R., Crews, T.E. & Streit Krug, A. (2020). New Food Crop Domestication in the Age of Gene Editing: Genetic, Agronomic and Cultural Change Remain Co-evolutionarily Entangled. Front. Plant Sci. 11:789. doi: 10.3389/fpls.2020.00789	Broad-based approches to domestication can also build buy-in to use of the crop
	Wigboldus, S., Klerkx, L., Leeuwis, C, Schut, M., Muilerman, S. & Jochemsen, H.. (2016). Systemic perspectives on scaling agricultural innovations. A review. Agronomy for Sustainable Development. 36. 10.1007/s13593-016-0380-z.	There are many forms of scaling that each can experience their own stress points
Level 6 Evidence: Single Descriptive/ Qualitative Study	Crews, T., Carton, W., & Olsson, L. (2018). Is the future of agriculture perennial? Imperatives and opportunities to reinvent agriculture by shifting from annual monocultures to perennial polycultures. Global Sustainability, 1, E11. doi:10.1017/sus.2018.11	Production systems today are geared towards efficiency and cost reduction, including reduced profit to farmers
	Deloitte. (2016). Capitalizing on the shifting consumer food value equation.	Value drivers (e.g. Health, Safety, Social Impact) are influential on consumer behavior
	Held, L. (2020). Industrial Meat 101: Could Large Livestock Operations Cause the Next Pandemic? Civil Eats.	Zoonotic disease risks exist with confinement livestock
	Kivimaa, P., Hyysalo, S., Boon, W., Klerkx, L., Martiskainen, M. & Schot, J. (2019). Passing the baton: How intermediaries advance sustainability transitions in different phases. Environmental Innovation and Societal Transitions, 31.	Intermediation is paramount from predevelopment to stabilisation of a transition
	Land Institute. (2019). Perennializing Grain Crop Agriculture: A Pathway for Climate Change Mitigation & Adaption.	Investment in perennial grain crop research is dwarfed by that of annual row crops
	Minnesota Pollution Control Agency. (2020). Five-year progress report.	Efforts to reduce nitrogen loss in MN are so far insufficient
	Monast, M. (2020). Financing Resilient AgricultureHow agricultural lenders can reduce climate risk and help farmers build resilience. Environmental Defense Fund.	Existing crop insurance inhibits climate change adaptation practices
	Patel-Weynand, T., Bentrup, G., Schoeneberger, M., Haan Karel, T. & Nair, PKR. (2017). Chapter 9: Challenges and opportunities. In: Schoeneberger, Michele M.; Bentrup, Gary; Patel-Weynand, Toral, eds. 2017. Agroforestry: Enhancing resiliency in U.S. agricultural landscapes under changing conditions. Gen. Tech. Report WO-96. U.S. Department of Agriculture, Forest Service. 131-142.	Economic and ecosystem research is needed to boost agroforestry

Level of Evidence	Study	Relevant Finding
Level 6 Evidence: Single Descriptive/ Qualitative Study	Pretty, J., Attwood, S., Bawden, R., Van den Berg, H., Bharucha, Z., Dixon, J., . . . Yang, P. (2020). Assessment of the growth in social groups for sustainable agriculture and land management. Global Sustainability, 3, E23. doi:10.1017/sus.2020.19	Social capital formation can boost sustainability and farm economies
	Stevenson, G.W. & Pirog, R. (2013). Values-based food supply chains: Strategies for agri-food enterprises-of-the-middle.	Many challenges exist to create a value added supply chain - but strategies can be used to address those challenges
Level 7 Evidence: Expert Opinion or Non-impact studies	Boyd, J. & Banzhaf, S. (2006). What are ecosystem services: the need for standardized environmental accounting unit. Resources for the Future.	Reference for ecosystem service definition and valuation
	Costanza, R. et al. (2017). Twenty years of ecosystem services: How far have we come and how fardo we still need to go? Ecosystem Services, 28:1-16.	Reference for state of ecosystem service literature
	Jackson, W. (2008). The necessity and possibility of an agriculture where nature is the measure. Conservation Biology, 22(6): 1376-1377.	The farm bill has insufficient time horizons
	Keeler, B., Polasky, S., Brauman, K., Johnson, K., Finlay, J., O'Neill, A., Kovacs, K. & Dalzell, B. (2012). Linking water quality and well-being for improved assessment and valuation of ecosystem services. Proceedings of the National Academy of Sciences, 109 (45): 18619-18624.	Reference for structuring a valuation of ecosystem services
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Appendix D: GLOSSARY

Common Terms in the Ecotone Analysis	
Discount Rate	The annual rate of reduction of the value of outcomes accrued in the future, designed to account for uncertainty and the time value of money when calculating a present value
Effect Size	The change in the likelihood of a cost occurring given the program
Estimated Return	Present value of all monetized outcomes
External Data	Data not gathered by and/or studies not conducted by the program being analyzed
External Validity	The extent to which results of a given study are applicable across other contexts
Evidence Based	An approach to the program's work which is designed based on existing research and applications
Evidence Informed	An approach to the program's work which is designed with the knowledge and influence of existing research
Impact	The change in outcomes derived exclusively from the given program
Internal Data	Data gathered by the program itself
Internal Validity	The extent to which results of a given study are only applicable to the context of that study
Intermediate Outcome	The change resulting from the short-term outcome
Levels of Evidence of Causality	Level 1 = greatest level of evidence that there is a causal relationship between the variables, Level 7 = lowest level of evidence that there is a causal relationship between the variables
Logic Model	The planned methodology for accomplishing the desired change(s)
Long-term Outcome	The change resulting from the intermediate outcome
Marginal Cost	The effect size * the outcome cost. The average change in cost accrued
Monetized Outcome	An outcome which has been linked to a cost occurring event, thereby placing a dollar value on the outcome
Net Present Value (NPV)	The aggregation of benefits and costs valued in the present day given an assumed time period and discount (interest) rate
Non-monetized Outcome	The change which is not or could not be linked, due to data quality, to a cost occurring event, thereby keeping the outcome from having a dollar value placed on it
Outcome	The resulting change occurring from the program's inputs and activities
Outcome Cost	The total cost of an event occurring
Output	The product from the inputs and activities of the program (e.g. number of people served)
Present Value (PV)	A single annuitized benefit or cost (depending on the outcome) valued in the present day given an assumed time period and discount rate
Short-term outcome	The initial change generated from the program
Trumping Rules	Selecting certain outcomes over others when they are interlinked to avoid double counting

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ECOTONE ANALYTICS