Valuing the Ecosystem Service Benefits from Regenerative Agriculture Practices

Farmland LP 2017 Impact Report

With funding from the
USDA Natural Resource Conservation Service (NRCS)

And technical services by
Delta Institute
&
Earth Economics

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Dear Readers,

We are excited to present our 2017 Impact Report, summarizing the social and environmental impacts of Farmland LP's two investment funds, Vital Farmland LP (Fund I) and Vital Farmland REIT, LLC (Fund II). Through these funds, Farmland LP purchases conventionally farmed land and introduces sustainable farmland management practices to generate competitive financial returns and achieve positive environmental and social impacts.

This year, we have made a significant update to the format and breadth of our impact reporting. This report is the culmination of a 2-year "Conservation Innovation Grant" received by Farmland LP from the USDA Natural Resource Conservation Service (NRCS). Implemented alongside our partners Delta Institute and Earth Economics, the objective of the grant was to more accurately quantify the ecological benefits of Farmland LP's sustainable agriculture practices using Ecosystem Service Valuation (ESV) and Greenhouse Gas (GHG) accounting models on a field-by-field basis.

The outputs of these models allow for a new, more comprehensive form of impact reporting, encompassing biophysical and, for the first time, ecosystem service value metrics. Ecosystem service value encompasses a broad spectrum of impact beyond simple biophysical values, and help us to quantify the environmental, social, and economic value that our sustainably managed farms generate, such as clean water, biodiverse pollinator habitat, and healthy soils.

The results from this work illustrate the profound impact of our management practices on the ecosystem service value provided by our farms. For example, Fund I farmland under our management generated $12.9 million in ecosystem service value since inception – a significant benefit that accrues to the surrounding communities and environment. Under a conventional management practices, these same farms would have caused $-8.5 million in ecosystem harm since inception, resulting in a total $21.4 net ecosystem service value benefit from our management as compared to conventional practices. This benefit was generated on $85 million of farmland, and is on top of the 67% net financial gain in our fund – a true double-bottom line investment return.

Farmland LP is committed to creating meaningful, lasting changes to the way farmland is managed. The sustainable farming practices we employ improve the health and wellness of people and places, the extent of which is only now able to be partially measured and summarized in this impact report. We are grateful to the USDA NRCS and our partners in helping us demonstrate the importance and benefits of implementing sustainable agriculture at scale. Your support and interest is invaluable as we continue to demonstrate the viability and importance of our work.

Sincerely,
Craig Wichner
Managing Partner

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Acknowledgements

We would like to acknowledge and thank the core team that helped to create this Impact Report, and who contributed to the completion of Farmland LP's 2015 NRCS CIG grant:

Farmland LP	**Delta Institute**	**Earth Economics**
Mark Lambert	David LeZaks	Angela Fletcher
Jason Bradford	Ryan Anderson	Kellen Hawley
Craig Wichner	Ryan Smith	

Special thanks are also due to Adam Chambers, Kari Cohen and Lindsay White from NRCS, as well as to Matthew Stermer from Colorado State University for his support in the implementation of the COMET-Farm tool.

As President Eisenhower put it, "Farming looks might easy when your plow is a pencil and you're a thousand miles from the corn field." With that in mind, we acknowledge the skilled and tireless efforts of our farm team and our farming tenants in California and Oregon, without whom none of the work discussed in this document would be possible.

Our Approach

Our farm management and operational decisions are underpinned by three core values:
Regenerative, not extractive - we seek to shift farming practices towards those that enhance soil biota, build topsoil, improve fertility, and integrate biodiversity;
Business ethics to match land ethics - we adhere to B-Corp certification standards, acting with integrity and considering the consequences of our actions for our investors, staff, and broader community;
A positive example - we seek to demonstrate a positive, replicable example of producing healthy food on healthy land with fewer external inputs while generating market-rate financial returns for our investors.
These values set the stage for the strategies we use to manage our portfolio of land, strategies we refer to collectively as regenerative agriculture. Regenerative agriculture integrates the principles of organic farming, agroecology and holistic management to counter the decline in biodiversity, rise in atmospheric carbon dioxide, loss of topsoil and water pollution caused by standard farming practices. In practice, this means growing more perennial crops, reducing external chemical inputs such as synthetic fertilizers, diversifying crop rotations, integrating livestock grazing with cropping systems, and improving or establishing functional natural areas.

As farm managers, we know that managing the land in this way drives profound environmental and ecological changes, such as increasing the carbon storage capacity of soils and establishing new populations of native pollinators. We believe these changes are just as important to measuring the success of our fund as financial results.

To describe these benefits in quantitative terms, this report presents the estimated biophysical and ecosystem service values generated by our farms. Our previous impact reports presented only the biophysical impacts of our farming practices; for example, pounds of pesticides avoided. This year, we are using ecosystem service value as an additional measure of impact. Ecosystem services are the processes and benefits provided by natural ecosystems, for example pollination of crops or purification of water. Ecosystem service *value* is the monetary representation of the value of ecosystem services to humans. It is often used to inform policy and planning decisions by estimating the economic implications of activities that have an environmental impact. In this report, we use ecosystem service value to assign an economic measure of value to impacts that cannot necessarily be measured with a biophysical metric. The presence of habitat for native pollinators, for example, doesn't have an easily quantifiable biophysical value akin to "pounds of synthetic fertilizer avoided", but we can estimate the economic impact of the presence of native pollinators to our farms and the surrounding ecosystems.

Although denominated in dollars, ecosystem service values don't appear in any financial statements, nor are they valued or compensated for in financial markets. They are, in essence, a tangible but hidden benefit that regenerative farming practices provide to the surrounding environment and community. As such, we are excited to report these values to provide context for the importance and scale of these impacts.

To quantify biophysical and ecosystem service value metrics, we have used management data from our farms and a combination of three models:

The **Ecosystem Valuation Toolkit (EVT)**, developed by Earth Economics. The EVT comprises a comprehensive database of ecosystem service values gleaned from peer reviewed articles and journals, and a set of calculators to estimate (in dollars) the ecosystem service value generated by our properties. The EVT is our primary reporting tool.

COMET-Farm, developed by the USDA Natural Resources Conservation Service (NRCS) and Colorado State University, is a GHG accounting tool that uses information on management practices together with spatially-explicit data on climate and soil conditions to estimate the carbon footprint of a farm or ranch operation. COMET-Farm provides us with field-specific estimates of, for example, annual changes in carbon stored in the soil and nitrous oxide emissions from nutrient applications.

Revised Universal Soil Loss Equation **(RUSLE)**, developed by USDA and the University of Tennessee, which estimates soil loss from sheet and rill erosion.

We used these models to generate a quantitative assessment of the ecosystem service and biophysical impacts from our farms, which we report in the following sections. We have divided this information into 5 "Impact Areas", which are further subdivided into thirteen "Impact Metrics". Definitions for each Impact Area and Metric are provided in the Appendix.

Impact Area	Impact Metric	Underlying Biophysical Metric
Social	Air Quality	Particulates, NOx
	Aesthetics	Housing prices
	Disaster Risk Reduction	Damages from flooding
	Food	For human and animal consumption
Biodiversity	Biological Control	Predators or noxious weeds
	Habitat	Areas used as habitat by wild animals
	Pollination & Seed Dispersal	Increased plant productivity
Climate & Energy	Climate Stability	Soil carbon (C), CO_2, N_2O
	Soil Formation	Soil organic matter carbon, soil quantity
Water	Water Capture, Conveyance & Supply	Water used by humans and the environment
	Water Quality	Excess nutrients or particulates in water
Soils	Soil Retention	Soil erosion
	Soil Quality	Soil nutrients

This impact report is divided into six sections:

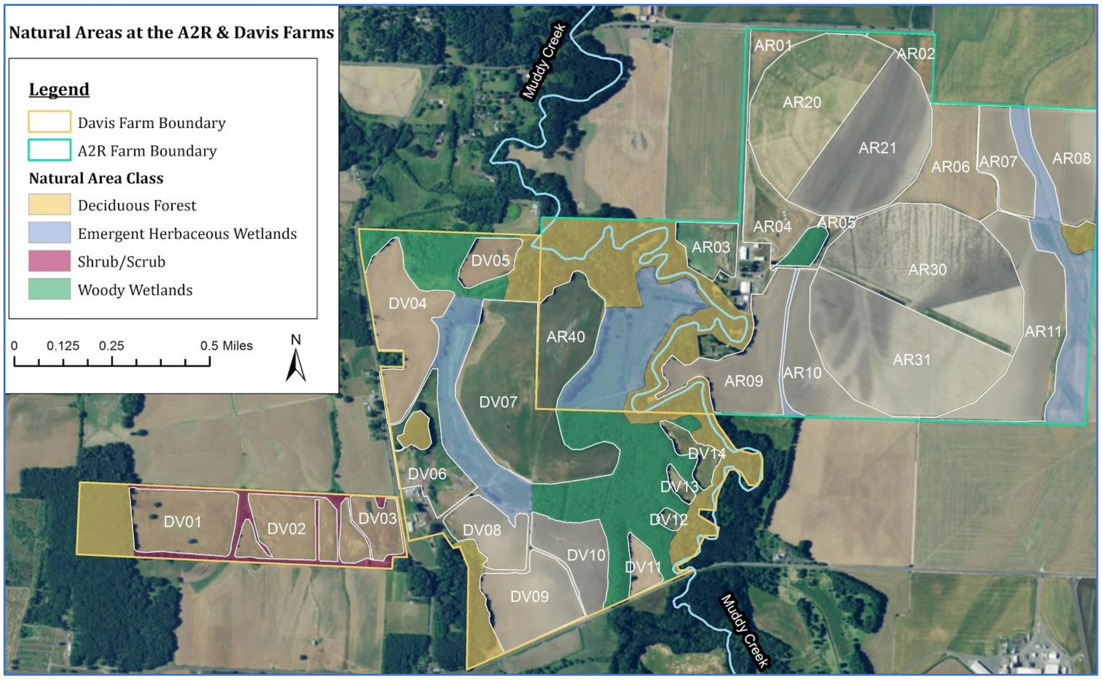
- Brief discussion on the importance, and our use, of spatially-explicit information
- Summary of our fund-level impact
- Assessment of the impacts generated across our five Impact Areas
- On-farm highlights of activities supporting specific Ecosystem Services
- An "Impact Balance Sheet" summarizing our farm-level impact data
- Appendix

Spatial Information & The EVT

The ecosystem service values we have derived from EVT for this report are given in terms of dollars per acre, and we are able to estimate the ecosystem service value impact of each acre under our management. This level of spatially-explicit (field-by-field) analysis is enabled by Farmland LP's Geographical Information System (GIS). Our GIS data set includes the bounds of every owned property and classifies areas as farmed and non-farmed (for leased farms we only included farmed areas). Farmed areas are given an identification code, assigned attributes, and key activities are tracked on each field. For example, given a particular field code, we can look up records for when organic practices were initiated, the history of crops grown, see the soil types, and whether the field is irrigated.

These field attributes and activity histories were used to model biophysical values per acre, such as whether carbon is being stored or released from soils. Biophysical values were then converted into monetary ecosystem service value (positive or negative) for a specific field. For example, a net increase in soil carbon would add imputed ecosystem service value gains (a positive number), whereas a decrease in soil carbon would show up as a loss (a negative number). Values per acre are multiplied by the field acres to generate a value for a field, and all the fields are added to generate farm level subtotals.

Ecosystem services occur on non-farmed areas as well, so we have also mapped natural areas, such as wetlands and forests, and generated ecosystem service values corresponding to the ecological system and its size. For example, a forest will support bat and bird populations that will consume crop pests, leading to higher crop yields. The total value of Ecosystem Services from a farm is therefore a combination of farmed and non-farmed area contributions.



A map of Davis (Fund 2) and A2R (Fund 1) farms, indicating farmed fields and natural areas

Fund-Level Ecosystem Service Values

This section summarizes our fund-level impacts, with ecosystem service values provided for both farmed as well as non-farmed areas. A more detailed, property-by-property dataset has been included in the Impact Balance Sheet section.

For farmed fields, ecosystem service values were calculated using historical management data (crop type, tillage, soil type, organic status, etc.) for each field since the acquisition date. To provide a comparative baseline, we have also calculated ecosystem service values from these same farmed fields under a baseline scenario that assumes conventional management practices and crop types common to the local area. We believe that the use of a conventional baseline is important to provide context for how ecosystem services accrue from Farmland LP's regenerative practices as compared to conventional agricultural management practices. Every effort has been made to model what we believe are the most appropriate conventional management practices but acknowledge that, as with any modeled approach, assumptions are required that likely oversimplify reality. Still, we find this comparison to be a compelling argument in favor of the ecosystem value benefits of regenerative agriculture.

We have also calculated ecosystem service values of non-farmed and naturally managed areas within our property boundaries. These areas contribute a significant amount of overall ecosystem service value. We seek to manage non-farmed areas as sustainable as possible, and in some cases, have implemented restoration and conservation projects within these areas. However, have not provided a conventional baseline for non-farmed ecosystem service values as it is difficult to make a baseline assumption about how these areas would be managed under a "conventional" management regime.

Summary of Impacts

Fund I, inception through 2017:

- Total ESV generated (farmed & non-farmed areas): **$46.0m**
- Total ESV of farmed fields under our management: **$12.9m, or $2,261/acre**
- Annual ESV created by farmed fields under our management: **$1.6m/year**
- Total ESV damage under a baseline of conventional management: **-$8.5m, or -$1,500/acre**
- Net ESV benefit under our management: **$21.4m, or $3,762/acre**
- Total ESV generated by Fund's non-farmed areas**: $33.1m, or $150k/acre**

Fund II, inception through 2017:

- Total ESV generated (farmed & non-farmed areas): **$28.2m**
- Total ESV of farmed fields under our management: **$2.4m, or $269/acre**
- Annual ESV created by farmed fields under our management: **$616k/year**
- Total ESV damage under a baseline of conventional management: **-$1.9m, or -$373/acre**
- Net ESV benefit under our management: **$4.4m, or $841/acre**
- Total ESV generated by Fund's non-farmed areas**: $25.8m, or $68k/acre**

Fund I Tables

ESV by Farm & Comparison to Conventional Management

Fund I Farms	Acres	ESV Under FLP Management			ESV Under Conventional Management	FLP Net ESV
		Total ESV	*Avg. Per Acre*	*Per Acre/Year*		
A2R	516	$2,828,380	*$5,485*	*$914*	($276,491)	$3,104,871
Brentwood Creek	1,114	$3,822,263	*$3,431*	*$686*	($1,655,518)	$5,477,781
Brentwood Creek-Adobe	350	$255,391	*$730*	*$182*	($477,109)	$732,500
Burns	3,500	$4,355,350	*$1,244*	*$311*	($6,074,980)	$10,430,330
Fern Road	137	$998,994	*$7,293*	*$912*	($57,035)	$1,056,029
Wattenpaugh	89	$642,157	*$7,243*	*$1,035*	($21,892)	$664,049
Total Farmed Fields	**5,705**	**$12,902,535**			**($8,563,026)**	**$21,465,560**
A2R	157	$19,088,063	*$121,233*	*$20,205*	N/A	N/A
Brentwood Creek	1	$115,292	*$115,292*	*$19,215*	N/A	N/A
Brentwood Creek-Adobe	0	$0	*$0*	*$0*	N/A	N/A
Burns	109	$10,488,183	*$96,222*	*$16,037*	N/A	N/A
Fern Road	15	$2,300,958	*$153,705*	*$25,617*	N/A	N/A
Wattenpaugh	23	$1,131,067	*$48,171*	*$8,029*	N/A	N/A
Total Non-Farmed Areas	**306**	**$33,123,563**			**N/A**	**N/A**
Fund I Total	**6,011**	**$46,026,098**			**($8,563,026)**	**$21,465,560**

ESV of Farmed Fields by Impact Metric – Comparison of FLP to Conventional Mgt.

Impact Metric	FLP Management	Conventional Management	Net ESV Benefit of Farmland LP Mgt.
Aesthetic Information	$5,209,596	$5,218,855	$(9,259)
Air Quality	$(4,268,877)	$(9,196,905)	$4,928,028
Biological Control	$196,504	$-	$196,504
Climate Stability	$113,410	$260,243	$(146,834)
Disaster Risk Reduction*	$-	$-	$-
Food	$134,609	$-	$134,609
Habitat	$10,185,092	$-	$10,185,092
Pollination & Seed Dispersal	$-	$-	$-
Soil Formation	$83,398	$-	$83,398
Soil Quality	$540,978	$(2,869,885)	$3,410,863
Soil Retention	$1,133,546	$(1,174,066)	$2,307,612
Water Capture, Conveyance & Supply*	$-	$-	$-
Water Quality	$(425,721)	$(801,268)	$375,547
Total ESV	**$12,902,535**	**$(8,563,026)**	**$21,465,560**

*Disaster Risk Reduction & Water Capture, Conveyance and Supply are applicable to non-farmed areas only

ESV Total of Farmed and Non-Farmed Areas by Impact Metric

Impact Metric	Farmed Fields	Non-Farmed Areas	Total Benefit
Aesthetic Information	$5,209,596	$61,861	$5,271,457
Air Quality	$(4,268,877)	$19,045	($4,249,832)
Biological Control	$196,504	$30,641	$227,145
Climate Stability	$113,410	$106,841	$220,251
Disaster Risk Reduction	$-	$1,970,103	$1,970,103
Food	$134,609	$-	$134,609
Habitat	$10,185,092	$24,209,384	$34,394,476
Pollination & Seed Dispersal		$478,279	$478,279
Soil Formation	$83,398	$4,837	$88,235
Soil Quality	$540,978	$-	$540,978
Soil Retention	$1,133,546	$5,797	$1,139,343
Water Capture, Conveyance & Supply	$-	$400,111	$400,111
Water Quality	$(425,721)	$5,836,664	$5,410,943
Total ESV	**$12,902,535**	$33,123,563	$46,026,098

Fund II Tables

ESV by Farm & Comparison to Conventional Management

Fund II Farms	Acres	ESV Under FLP Management			ESV Under Conventional Management	Total FLP Net ESV
		Total	*Per Acre*	*Per Acre/Year*		
Davis	270	$1,014,319	*$3,755*	*$939*	($143,788)	$1,158,108
Kennel	115	($83,842)	*($729)*	*($182)*	($43,773)	($40,069)
Kester	541	$703,402	*$1,299*	*$325*	($172,461)	$875,863
Massey Wells	506	$448,069	*$885*	*$221*	($205,243)	$653,312
Mulkey	173	($141,667)	*($820)*	*($205)*	($69,207)	($72,459)
Nut	231	($16,224)	*($70)*	*($18)*	($93,517)	$77,293
Olsen	274	($223,524)	*($815)*	*($204)*	($109,632)	($113,892)
Robison	365	$532,195	*$1,456*	*$364*	($114,757)	$646,953
Suver	61	($52,144)	*($856)*	*($214)*	($22,129)	($30,015)
Todd	83	($9,662)	*($116)*	*($29)*	($32,059)	$22,397
Total Owned Farms	**2,621**	**$2,170,925**			**($1,006,567)**	**$3,177,492**
Auer	325	($148,229)	($457)	($114)	($113,673)	($34,556)
Baker	69	($1,058)	($15)	($4)	($20,631)	$19,573
Blair	73	($12,965)	($178)	($44)	($23,051)	$10,086
Boyer	22	$2,115	$97	$24	($7,629)	$9,743
Buerge	82	($12,263)	($150)	($38)	($25,901)	$13,638
Clem	123	($18,925)	($154)	($38)	($40,450)	$21,525

Coleman	5	$2,692	$575	$144	($2,792)	$5,484
Cornelius	75	$190,362	$2,553	$638	($40,265)	$230,628
Fry	196	$338,012	$1,728	$432	($71,306)	$409,318
Howard	28	$129,629	$4,667	$1,167	($19,841)	$149,470
Kelso Trust	60	$748	$12	$3	($19,526)	$20,274
Lubbers	79	$61,480	$779	$195	($30,866)	$92,346
Maple Grove	151	($8,781)	($58)	($15)	($49,888)	$41,107
Mathany	212	($205,567)	($971)	($243)	($87,023)	($118,544)
Pope Airlie	155	($35,777)	($231)	($58)	($51,778)	$16,001
Pope Poppitz	126	($14,116)	($112)	($28)	($45,388)	$31,272
Pope Suver	328	($141,815)	($432)	($108)	($121,639)	($20,176)
Rainwater	18	($25,749)	($1,401)	($350)	($6,148)	($19,601)
Silverdome	160	($41,134)	($257)	($64)	($53,132)	$11,998
Simila	67	$122,843	$1,829	$457	($21,291)	$144,134
Swan	56	$19,336	$345	$86	($21,111)	$40,447
Underwood	229	93,692	$410	$102	($80,767)	$174,459
Total Leased Farms	**2,637**	**$294,531**			**($954,098)**	**$1,248,628**
Davis	194	$19,271,212	*$99,213*	*$24,834*	*N/A*	*N/A*
Kennel	2	$71,837	*$33,258*	*$8,980*	*N/A*	*N/A*
Kester	51	$2,559,082	*$49,865*	*$12,545*	*N/A*	*N/A*
Massey Wells	74	$1,112,831	*$15,071*	*$3,760*	*N/A*	*N/A*
Mulkey	11	$348,675	*$30,938*	*$7,924*	*N/A*	*N/A*
Nut	13	$127,112	*$10,112*	*$2,444*	*N/A*	*N/A*
Olsen	6	$366,831	*$66,697*	*$15,285*	*N/A*	*N/A*
Robison	21	$1,787,277	*$86,761*	*$21,277*	*N/A*	*N/A*
Todd	5	$171,611	*$33,258*	*$8,581*	*N/A*	*N/A*
Total Non-Farmed Areas	**377**	**$25,816,468**			**N/A**	**N/A**
Fund II Total	**5,635**	**28,281,923**			**-1,960,665**	**4,426,120**

ESV of Farmed Fields by Impact Metric – Comparison of FLP to Conventional Mgt.

	FLP Management		Conventional Management		Net Benefit of Farmland LP Management
Impact Metric	Owned	Leased	Owned	Leased	
Aesthetic Information	$1,436,631	$1,432,475	$1,443,379	$1,432,481	$(6,755)
Air Quality	$(1,670,823)	$(1,889,748)	$(2,646,873)	$(2,621,551)	$1,707,854
Biological Control	$36,650	$24,139	$-	$-	$60,789
Climate Stability	$182,359	$42,994	$513,210	$548,668	$(836,525)
Disaster Risk Reduction	$-	$-	$-	$-	$-
Food	$9,590	$2,403	$-	$-	$11,993
Habitat	$1,604,747	$501,511	$-	$-	$2,106,258
Pollination & Seed Dispersal	$-	$-	$-	$-	$-
Soil Formation	$20,564	$5,743	$-	$-	$26,307
Soil Quality	$648,146	$526,195	$605,811	$600,015	$(31,485)
Soil Retention	$125,802	$(59,937)	$(401,665)	$(397,904)	$865,434
Water Capture, Conveyance & Supply	$-	$-	$-	$-	$-
Water Quality	$(222,741)	$(291,244)	$(520,431)	$(515,812)	$522,258
Total ESV	**$2,170,925**	**$294,531**	**$(1,006,567)**	**$(954,098)**	**$4,426,120**

ESV Total of Farmed & Non-Farmed Areas by Impact Metric

Impact Metric	Farmed Fields	Non-Farmed Areas	Total Benefit
Aesthetic Information	$2,869,106	$71,386	$71,386
Air Quality	($3,560,571)	$21,110	$21,110
Biological Control	$60,789	$11,683	$11,683
Climate Stability	$225,353	$110,272	$110,272
Disaster Risk Reduction	$0	$2,321,750	$2,321,750
Food	$11,993	$-	$-
Habitat	$2,106,258	$15,796,457	$15,796,457
Pollination & Seed Dispersal	$0	$293,203	$293,203
Soil Formation	$26,307	$4,273	$4,273
Soil Quality	$1,174,341	$-	$-
Soil Retention	$65,865	$5,696	$5,696
Water Capture, Conveyance & Supply	$0	$450,837	$450,837
Water Quality	($513,985)	$6,729,801	$6,729,801
Total ESV	**$2,869,106**	**$25,816,468**	**28,281,923**

Overview of Farmland LP's Impact Areas

In this section, we define our five Impact Areas: Biodiversity, Soils, Water, Carbon & Climate, and Social Value. We separate these Impact Areas into five distinct categories for ease of discussion, but acknowledge that there is significant overlap between each in a well-functioning agricultural system.

Biodiversity

Biodiversity refers to the variety of living organisms in a given environment. It can be viewed at many levels of organization, each of which contribute to key functions of the agricultural ecosystem. Our management system promotes biodiversity at three levels:

Diversity of soil biota. Healthy soils are alive with a diversity of soil biota, a living ecosystem that supports and sustains plant life. The soil biota on conventional farms tends to be dominated by bacteria as these organisms are most able to tolerate or rebound from applications synthetic fertilizers and pesticides as well as tillage. Bacterially-dominated soils lose organic matter over time and become compacted. By contrast, soils in our rotational management program (long periods in pasture without tillage and only organic fertilizers) develop a complex soil biota. The growth of fungal, protozoan and macro-organism populations, such as beetles, spiders, and earthworms, creates soil organic matter that promotes healthy functions, including high water holding capacity, high rates of water infiltration, good aggregate stability, and low bulk density.

A swallowtail butterfly pollinates an organic Phacelia in

Diversity of crops grown on our farms. We seek to avoid the repeated planting of one family of cash crops on a field in successive years. At a landscape level, we desire a mosaic of crops within a single farm. These practices tend to decrease the risk of pest and disease pressure and promote population stability of regulating and service species, such as bees, birds, spiders, etc.

Diversity of plant and animal species within our property boundaries and in the surrounding ecosystem. Our property boundaries often encompass areas not suitable for farming, such as river channels, wetlands and forest slopes – these areas provide habitats that support biodiversity. Wild animals in these habitats often interact with organisms on our fields. In some cases, we object to these interactions, such as coyotes eating lambs, while in other cases we approve, such as bumblebees pollinating our crops. Farms with adjacent habitat tend to have lower pest pressures and better pollination rates for certain crops. Overall, we seek to integrate and promote biodiversity within and surrounding our farms by protecting natural areas and, in some cases, creating habitats.

Soils

There are both environmental and business reasons to conserve and restore soil on our farm fields. From an environmental perspective, good soil management can prevent air and water pollution, and sequester atmospheric carbon. From a business perspective, healthier soils lead to healthier crops, higher yields, and lower costs, typically resulting in increased profits.

Our primary method for conserving and restoring soil is to mimic grasslands during the pasture phase of our crop rotation. This rotation strategy removes land from tillage by sowing a multi-species pasture with an expected 3 to 5-year lifespan. As described in the Biodiversity section, allowing diverse soil biota to thrive builds soil organic matter, which positively impacts key attributes of soil health. An important practice to help ensure a thriving soil biota once fields are rotated out of pasture is to utilize cover crops. These are plants grown between cash crops to prevent erosion, compete against weeds, build stores of nitrogen, and maintain levels of organic matter.

A key indicator of soil health are mycorrhizal fungi. These fungi form a symbiotic relationship with crops whereby the fungi access remote nutrients and water and make them available in exchange for energy produced by the plants. The unique biochemical properties of fungi, such as the molecule glomalin, contribute greatly to soil function by forming stable aggregates and organic matter fractions that resist decay and compaction and promote infiltration and storage of water.

Oregon pasture soil. A Soil Carbon Coalition study found that after a few years in pasture, the infiltration rate on this soil was about 6 inches/hr. By contrast, a recently tilled conventional field ready for corn, measured only 1 inch of water infiltration per hour.

Water

Our farming practices – specifically perennial pasture, crop rotation, planting cover crops, and avoiding synthetic pesticides and fertilizers - increase the biodiversity and organic matter content of our soils. Functionally, this creates channels for air and water movement, resists compaction, and allows for soil organisms to breakdown potential water contaminants in runoff. Soils high in soil organic matter allow water to move into the soil profile more quickly, filter and store water well, and release it slowly between rain and irrigation events. In addition to overuse, fresh water supplies are often degraded from pollutants that run off of farm fields, affecting both local and downstream surface and groundwater sources.

By setting up our farming system to have higher water retention and infiltration rates, we decrease the amount of irrigation water required as compared to unhealthy or conventionally managed soils. Lower irrigation requirements reduce the need to pump water out of rivers and aquifers, both lowering operational costs and leaving more for others. And the water we leave for others is made clean by health soils that have been weaned of highly soluble fertilizers and pesticides that often pollute local and downstream water sources.

Carbon & Climate

Our atmosphere currently has too much carbon while our soils, due to historically degrading farming practices, has too little. In agricultural settings, management practices determine whether carbon is being added or lost in the soil.

At the farm level, we are eager to increase soil carbon levels, which benefit us directly through the improvements in soil and water dynamics previously discussed. Simultaneously, through the creation and storage of soil organic matter, we are able to pull carbon out of the atmosphere and sequester it in the soils on our farms. Similarly, we seek to achieve a reduction in carbon emissions by reducing the amount of tillage events on our fields, which disturb soils and can release the carbon stored there.

To review, practices contributing to an increase in soil carbon include: minimizing soil disturbance from tillage, maintaining continuous plant cover from perennial crops such as pasture, cover cropping between cash crop seasons to keep soils covered as many days of the year as possible, keeping residual plant material such as straw on fields, and not using synthetic nitrogen fertilizers that tend to allow bacteria to consume organic matter. Even after rotating into organic annual crops that do require significant tillage, some of the sequestered carbon is protected in deep soil layers where the roots of long-lived, perennial plants and associated mycorrhizal fungi developed. This report also considers on-farm emissions of nitrous oxide (N_2O), a potent greenhouse gas and ozone-depleting substance, which we seek to minimize through the incorporation of organic amendments, use of nitrogen-fixing cover crops, and including legume seed in pasture establishment mixes. However, due to large uncertainties in the current estimation method used by COMET-Farm, N_2O totals are not included in our impact metrics at this time. COMET-Farm also quantifies CO_2 emissions from adding lime and applying urea-based fertilizers, but both are excluded from our metrics due to their minimal effect on farm-level totals.

Social Value

Just as biodiversity, soil, water and carbon are part of an interacting system on the farm, farmland is part of the broader landscape in which people live. Practices on the farm, therefore, have consequences off the farm. Our farmland management practices were designed with an awareness of the larger system in which farms exist and aimed to yield positive externalities. We are pleased to provide a quantification of these societal benefits for the first time via this impact report.

Farms are normally paid for the food, fiber and biomass they produce. The effects, positive or negative, of the production of these goods on water and air quality, natural hazard risks (e.g. flooding), and aesthetic experiences are often not priced into the cost of these goods. Because these externalities are not captured on a farm balance sheet or income statement, there has been little financial to invest the thought, time or money into improving outcomes. Fortunately, farmers, food processors, and food consumers are becoming increasingly aware of these uncaptured externalities, which we can see partially reflected in food consumer's willingness to pay more for products grown in sustainable and regenerative ways. There is still significant work to be done to ensure that responsible members of the food production and consumption chain understand these impacts and align the production and purchasing decisions accordingly.

Ecosystem Service Highlights from the Farm

In this section, we provide examples from our farms of how Farmland LP supports important ecosystem services, providing tangible real-life supplements to the overview of ecosystem service values presented in this report.

Food

Food is an ecosystem service that doesn't require much explanation; farms grow food, which is essential to human survival. Food provision is the most essential ecosystem service provided by agricultural land.

With the exception of perennial pasture for livestock grazing, most of the crops on our farms are annual plants that complete their life cycle within a 3-9-month period. Annual crops comprise the bulk of the food grown and calories consumed around the world. These crops typically require clearing and tilling before replanting, resulting in erosion, loss of soil carbon and disturbance to microorganisms. Perennial crops, do not require annual replanting, thereby reducing erosion and building soil carbon. The EVT clearly shows how ecosystem service value declines in fields being farmed with annual crops, primarily due the impacts of tillage.

Emerging Kernza seedlings. A perennial grain, Kernza may enable us to grow a food crop without tillage after establishment

In an effort to expand our production of perennial food crops we partnered with Plovgh in 2017 to plant Kernza, a perennial grain developed by the Land Institute on 26 acres in Oregon. Kernza is a relative of annual wheat, and can be used in many of the same applications including beer, pasta and bread, while offering the ecological benefits of a perennial crop. We are hopeful that we will find agronomic and financial success with Kernza so that we can expand the acreage of perennials in our crop rotation and provide additional Kernza supply to organizations like Patagonia Provisions and Cascadian Farms that are already incorporating it into their products.

Habitat

It is rare to find anything like a mono-cropped field in a natural setting. Most plant communities include many species and provide a wide variety of resources for a diversity of animals. Large fields of one species are convenient for us to manage agriculturally, but create risk in concentrating a food source for potential pests. In natural settings, a diverse plant community flowers over an extended period, which feeds pollinators evenly over a year. Crops that require pollination can have significantly reduced yields if there are not enough pollinators present during flowering.

Organic farms are required to devise and implement biodiversity plans that, over time, increase ecosystem services such as pollination and predation through improvements in habitats. A few of our farms have extensive natural areas adjacent to fields and an impressive flow of insects, spiders, birds, and bats can be seen moving between crops, forests and wetlands. Other farms are largely devoid of habitat, or habitat needs to be more evenly distributed to spread the benefits of species interactions more thoroughly.

For example, with the assistance of USDA funding, we installed 2,700 feet of hedgerows along the edge of several fields at Brentwood Creek Farm in California. The need to increase habitat on this farm was obvious when we first began stewarding the property. Historic crops such as alfalfa, corn and asparagus do not require insect pollination, and conventional farmers were comfortable using a suite of pesticides to take care of problems. We looked ahead a few years to the land becoming organic and rotating into vegetables, noting that biological control of pests and pollination of crops might be insufficient without more beneficial species adjacent to fields.

It has been incredible to watch the small planted shrubs grow and fill in the hedge. The blooms are now prolific and the insect diversity impressive. In terms of Ecosystem Services Values, one acre of native shrub land is worth over $19,000 per year.

The hedgerows at Brentwood Creek Farm are newly installed habitats designed to provide for the needs of pollinators and predators on crop pests.

Scientific and Educational Value

The fertile Willamette Valley, nestled between the foothills of the snowy Cascade Mountains and the temperate rainforests of the Coast Range, contains a variety of ecological systems. Some examples of native habitats, including oak woodland, riparian forest and shrubland, and wet prairie, can be found along the Muddy Creek corridor as it passes through Davis (Fund 2) and A2R Farms (Fund 1) south of Corvallis. The wet prairie has attracted significant interest from scientists and conservation practitioners as this ecological system is now so rare, and this site includes some key populations of threatened and regionally endemic plant species.

***Left**: The Muddy Creek corridor shared by Davis and A2R Farms includes wet prairie, riparian and oak forests. In this picture, camas, buttercup and popcorn flowers are blooming in the prairie with majestic oaks in the background.*

***Right:** The Willamette daisy, Erigeron decumbens, is one of the most endangered plant species in the area and a sizeable population lives*

Invasive species were over-taking much of the rare plant populations when we began managing these farms. The U.S. Fish and Wildlife Service funded a project through Institute for Applied Ecology (IAE) to study the effects of managed grazing on wet prairie recovery. Through grazing, we were able to dramatically reduce the abundance of reed canary grass and the native wildflowers returned with a flourish. Visitors from Washington D.C. were very impressed and perhaps now more open to using grazing instead of relying so much on mowing and herbicides in vegetation management.

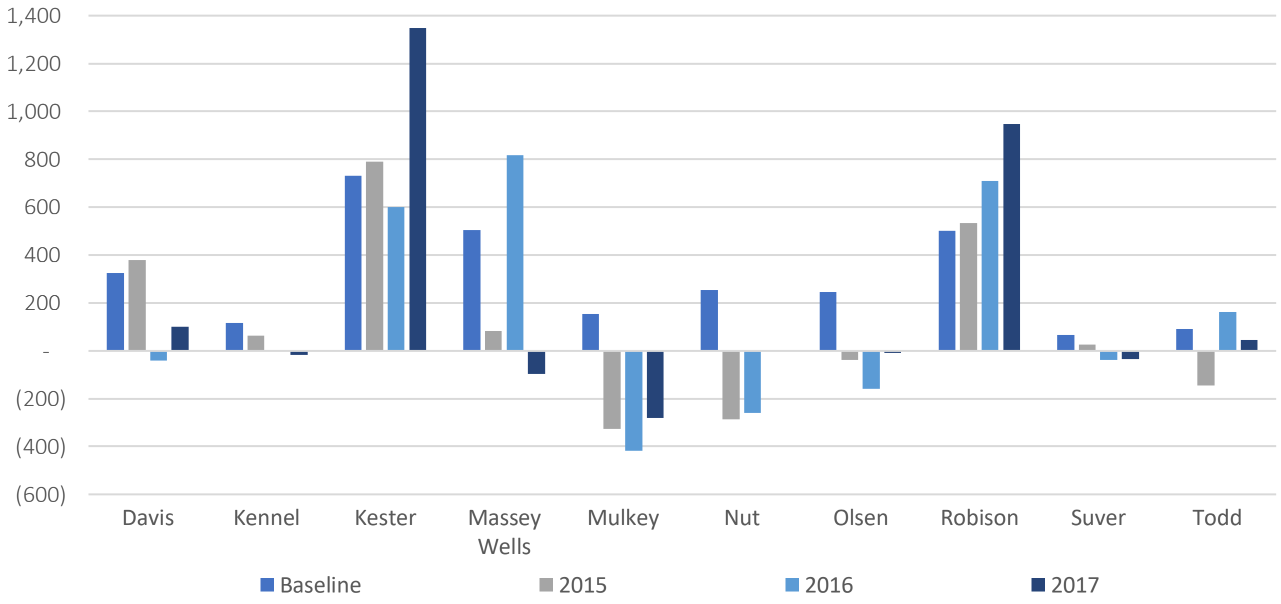
Our partnership with IAE continues and they have secured funds to continue habitat improvements and research on grazing. We are honored to be stewards of these 200 acres of a semi-wild place, which is viewed as a living museum of sorts, a "reference site" for what much of the Willamette Valley may once have looked like, while at the same time being a place of dynamism and inspiration.

Carbon and Climate

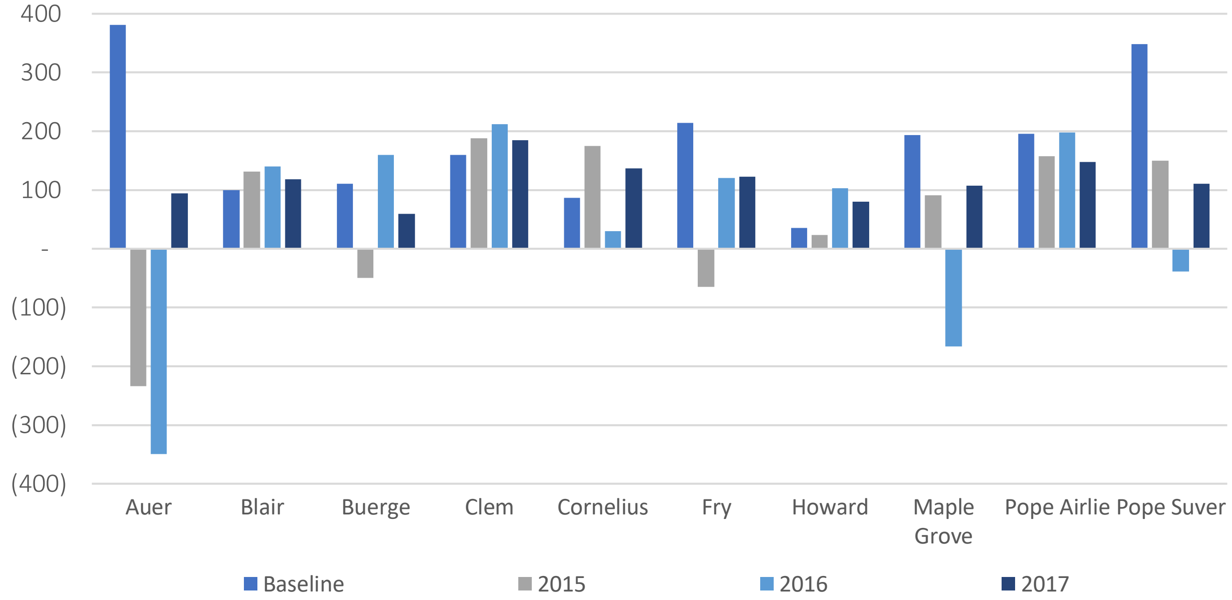
Working with NRCS and Colorado State University, Delta Institute translated our Oregon farm management records into the COMET-Farm tool to estimate the change in carbon stocks attributable to each farm. The charts below show the total carbon sequestered (positive) or emitted (negative) from all Fund 2 owned farms, as well as a selection of leased Fund 2 properties. An average annual baseline is provided for comparison. The dollar-equivalent ecosystem service values derived from this data have been integrated into ESV data provided in the Impact Balance Sheet section.

We know the field history of each farm and are able to interpret the farm-level results. Farms with significant tillage events lost soil carbon according to COMET. Our management results were below baseline for certain farms (e.g., Mulkey, Auer) because in the Willamette Valley many fields are in perennial grass seed crops most years. Our portfolio in Fund 2 had a large number of older grass seed fields in 2015 that were tilled and replaced during 2016 and 2017, yielding a pulse of carbon loss. Other farms did well as compared to baseline (e.g., Kester, Robison) because they went into pasture or were kept in perennial seed crops.

Annual Changes in Carbon Stocks for Fund 2 Owned Farms (tons CO2e)



Annual Changes in Carbon Stocks for Select Fund 2 Leased Farms (tons CO2e)



Impact Balance Sheet

The following tables show ESV by Impact Metric for each property. Values are included for owned and leased farms under Farmland LP management (no conventional baseline is presented), as well as non-farmed areas. This data is a summary of the field-by-field ESV outputs. Similar to the financial statements we produce as fund managers, these tables are intended to provide a representation of the relative value (in this case ecosystem service value) that each property contributes to the funds overall "ESV" return, and gives a perspective as to what ecosystem services are enhanced or damaged by our farming practices.

Fund 1 – Detail of Ecosystem Service Value by Property

Property Name	Total ESV	Aesthetic Information	Air Quality	Biological Control	Climate Stability	Disaster Risk Reduction	Food
A2R	**$2,828,380**	$548,778	($348,571)	$53,305	$89,163	$0	$5,186
Brentwood Creek	**$3,822,263**	$949,770	($388,069)	$46,624	$0	$0	$38,501
Brentwood Creek-Adobe	**$255,391**	$248,707	($217,018)	$3,784	$0	$0	$3,401
Burns	**$4,355,350**	$3,166,841	($3,292,878)	$74,532	$0	$0	$70,962
Fern Road	**$998,994**	$194,565	($20,335)	$11,634	$22,796	$0	$10,079
Wattenpaugh	**$642,157**	$100,935	($2,006)	$6,625	$1,451	$0	$6,480

Property Name	Habitat	Pollination & Seed Dispersal	Soil Formation	Soil Quality	Soil Retention	Water Quality	Water Capture, Conveyance & Supply
A2R	$1,711,873	$0	$9,473	$689,938	$114,186	($44,951)	$0
Brentwood Creek	$2,589,240	$0	$22,439	$290,385	$323,745	($50,372)	$0
Brentwood Creek-Adobe	$164,861	$0	$1,925	$105,062	($8,817)	($46,514)	$0
Burns	$4,694,893	$0	$40,193	($671,155)	$551,038	($279,076)	$0
Fern Road	$595,498	$0	$5,739	$92,383	$90,585	($3,950)	$0
Wattenpaugh	$428,727	$0	$3,629	$34,365	$62,809	($858)	$0

Fund 1 – Detail of Ecosystem Service Value by Property, Non-Farmed Areas

Property Name	Total ESV	Aesthetic Information	Air Quality	Biological Control	Climate Stability	Disaster Risk Reduction	Food
A2R	**$19,088,065**	$55,551	$14,289	$3,538	$74,363	$1,821,240	$0
Brentwood Creek	**$115,291**	$0	$6	$228	$117	$0	$0
Brentwood Creek-Adobe	**$0**	$0	$0	$0	$0	$0	$0
Burns	**$10,488,183**	$0	$546	$20,751	$10,648	$0	$0
Fern Road	**$2,300,959**	$0	$120	$4,552	$2,336	$0	$0
Wattenpaugh	**$1,131,065**	$6,310	$4,084	$1,572	$19,377	$148,863	$0

Property Name	Habitat	Pollination & Seed Dispersal	Soil Formation	Soil Quality	Soil Retention	Water Quality	Water Capture, Conveyance & Supply
A2R	$11,003,171	$144,723	$2,699	$0	$756	$5,589,727	$378,008
Brentwood Creek	$112,353	$2,539	$12	$0	$36	$0	$0
Brentwood Creek-Adobe	$0	$0	$0	$0	$0	$0	$0
Burns	$10,220,880	$230,990	$1,092	$0	$3,276	$0	$0
Fern Road	$2,242,316	$50,676	$240	$0	$719	$0	$0
Wattenpaugh	$630,664	$49,351	$794	$0	$1,010	$246,937	$22,103

Fund 2 - Detail of Ecosystem Service Value by Property, Owned Farms

Property Name	Total ESV	Aesthetic Information	Air Quality	Biological Control	Climate Stability	Disaster Risk Reduction	Food
Davis	**($126,325)**	$185,010	($81,936)	$12,435	$19,752	$0	$4,799
Kennel	**($7,076)**	$61,270	($112,357)	$0	$1,949	$0	$0
Kester	**($30,439)**	$288,216	($312,806)	$9,142	$122,757	$0	$0
Massey Wells	**$4,747**	$269,654	($168,358)	$5,758	$27,580	$0	$4,349
Mulkey	**($19,860)**	$92,014	($185,054)	$0	($45,936)	$0	$0
Nut	**($45,133)**	$123,115	($152,619)	$3,027	($32,729)	$0	$443
Olsen	**$2,743**	$146,014	($360,336)	$0	($9,196)	$0	$0
Robison	**$175,046**	$194,581	($185,501)	$6,162	$98,142	$0	$0
Suver	**$329,989**	$32,439	($56,587)	$126	($2,181)	$0	$0
Todd	**$120,357**	$44,322	($55,272)	$0	$2,221	$0	$0

Property Name	Habitat	Pollination & Seed Dispersal	Soil Formation	Soil Quality	Soil Retention	Water Quality	Water Capture, Conveyance & Supply
Davis	$700,177	$0	$3,833	$126,965	$59,745	($16,460)	$0
Kennel	$0	$0	$0	($21,509)	($1,753)	($11,443)	$0
Kester	$359,085	$0	$3,039	$249,040	$41,048	($56,118)	$0
Massey Wells	$224,967	$0	$7,007	$82,972	$34,115	($39,974)	$0
Mulkey	$0	$0	$958	$19,730	($14,731)	($8,648)	$0
Nut	$29,256	$0	$1,447	$32,014	($7,340)	($12,836)	$0
Olsen	$0	$0	$1,382	$34,541	($9,152)	($26,777)	$0
Robison	$291,262	$0	$2,465	$130,133	$29,453	($34,501)	$0
Suver	$0	$0	$21	($21,149)	($861)	($3,952)	$0

Fund 2 - Detail of Ecosystem Service Value by Property, Leased Farms

Property Name	Total ESV	Aesthetic Information	Air Quality	Biological Control	Climate Stability	Disaster Risk Reduction	Food
Auer	**($148,229)**	$172,820	($220,409)	$0	($21,900)	$0	$0
Baker	**($1,057)**	$36,672	($46,632)	$0	$6,019	$0	$0
Blair	**($12,963)**	$38,791	($71,133)	$0	$17,473	$0	$0
Boyer	**$2,118**	$11,636	($14,394)	$1,730	($2,631)	$0	$0
Buerge	**($12,259)**	$43,400	($91,539)	$3,321	$7,598	$0	$0
Clem	**($18,920)**	$65,611	($121,247)	$716	$26,207	$0	$0
Coleman	**$2,698**	$2,494	$0	$0	($51)	$0	$0
Cornelius	**$190,063**	$52,946	($33,645)	$4,135	$15,316	$0	$306
Fry	**$338,020**	$104,147	($72,242)	$5,157	$8,025	$0	$0
Howard	**$129,638**	$30,220	($10,731)	$1,979	$9,275	$0	$0
Kelso Trust	**$758**	$31,950	($50,741)	$519	$2,412	$0	$0
Lubbers	**$60,915**	$42,021	($32,942)	$1,472	($20,813)	$0	$576
Maple Grove	**($8,769)**	$80,294	($78,068)	$0	$1,413	$0	$0
Mathany	**($205,554)**	$112,667	($202,913)	$0	($17,227)	$0	$0
Pope Airlie	**($35,763)**	$82,427	($151,155)	$0	$22,566	$0	$0
Pope Poppitz	**($14,101)**	$67,218	($58,850)	$0	($10,130)	$0	$0
Pope Suver	**($141,799)**	$174,840	($288,398)	$0	$9,934	$0	$0
Rainwater	**($25,732)**	$9,789	($32,390)	$0	($3,604)	$0	$0
Silverdome	**($41,116)**	$85,125	($135,433)	$0	$16,698	$0	$0
Simila	**$122,862**	$35,757	($28,152)	$1,520	$10,443	$0	$0
Swan	**$19,356**	$29,851	($8,551)	$395	($8,612)	$0	$0
Underwood	**$92,192**	$121,803	($140,188)	$3,197	($25,413)	$0	$1,521

Property Name	Habitat	Pollination & Seed Dispersal	Soil Formation	Soil Quality	Soil Retention	Water Quality	Water Capture, Conveyance & Supply
Auer	$0	$0	$0	($33,105)	($14,916)	($30,721)	$0
Baker	$91	$0	$320	$11,240	$497	($9,265)	$0
Blair	$0	$0	$0	$18,179	($3,477)	($12,797)	$0
Boyer	$0	$0	$136	$7,839	($1,593)	($608)	$0
Buerge	$0	$0	$464	$37,731	($6,218)	($7,020)	$0

Clem	$0	$0	$62	$32,322	($2,268)	($20,328)	$0
Coleman	$0	$0	$98	$432	$28	($309)	$0
Cornelius	$40,502	$0	$201	$121,108	($4,955)	($5,551)	$0
Fry	$193,582	$0	$1,713	$93,297	$17,049	($12,714)	$0
Howard	$54,688	$0	$487	$39,196	$6,349	($1,833)	$0
Kelso Trust	$0	$0	$0	$30,347	($4,578)	($9,162)	$0
Lubbers	$38,083	$0	$322	$41,592	($2,043)	($6,788)	$0
Maple Grove	$0	$0	$0	$18,348	($11,042)	($19,725)	$0
Mathany	$0	$0	$0	($77,999)	($5,321)	($14,775)	$0
Pope Airlie	$0	$0	$0	$39,786	($2,931)	($26,470)	$0
Pope Poppitz	$0	$0	$0	$13,470	($9,899)	($15,925)	$0
Pope Suver	$0	$0	$0	$9,270	($5,520)	($41,941)	$0
Rainwater	$0	$0	$184	$2,042	($361)	($1,408)	$0
Silverdome	$0	$0	$0	$33,258	($14,354)	($26,428)	$0
Simila	$73,942	$0	$626	$26,173	$7,814	($5,279)	$0
Swan	$0	$0	$0	$12,342	($3,483)	($2,606)	$0
Underwood	$100,623	$0	$1,131	$49,333	$1,281	($19,593)	$0

Fund 2 - Detail of Ecosystem Service Value by Property, Non-Farmed Areas

Property Name	Total ESV	Aesthetic Information	Air Quality	Biological Control	Climate Stability	Disaster Risk Reduction	Food
Davis	**$19,271,211**	$46,729	$7,684	$4,132	$44,676	$1,657,012	$0
Kennel	**$71,838**	$376	$0	$94	$165	$25,836	$0
Kester	**$2,559,081**	$6,500	$2,330	$1,799	$12,044	$195,294	$0
Massey Wells	**$1,112,831**	$7,580	$5,830	$2,410	$27,382	$149,978	$0
Mulkey	**$348,674**	$632	$563	$755	$2,827	$9,781	$0
Nut	**$127,113**	$1,254	$1,089	$382	$5,040	$19,425	$0
Olsen	**$366,832**	$4,241	$3,452	$1,107	$16,031	$79,380	$0
Robison	**$1,787,276**	$3,176	$162	$780	$1,712	$123,325	$0
Suver	**$171,612**	$898	$0	$224	$395	$61,719	$0
Todd	**$19,271,211**	$46,729	$7,684	$4,132	$44,676	$1,657,012	$0

Property Name	Habitat	Pollination & Seed Dispersal	Soil Formation	Soil Quality	Soil Retention	Water Quality	Water Capture, Conveyance & Supply
Davis	$11,679,813	$102,201	$1,558	$0	$864	$5,377,460	$349,082
Kennel	$0	$2,741	$0	$0	$726	$41,900	$0
Kester	$1,705,711	$36,974	$499	$0	$301	$557,830	$39,799
Massey Wells	$666,550	$71,410	$1,143	$0	$1,105	$158,549	$20,894
Mulkey	$315,329	$12,441	$135	$0	$117	$4,515	$1,579
Nut	$75,295	$12,257	$211	$0	$57	$8,967	$3,136
Olsen	$155,272	$38,900	$661	$0	$651	$57,180	$9,957
Robison	$1,198,487	$9,731	$66	$0	$141	$423,306	$26,390
Todd	$0	$6,548	$0	$0	$1,734	$100,094	$0
Davis	$11,679,813	$102,201	$1,558	$0	$864	$5,377,460	$349,082
Kennel	$0	$2,741	$0	$0	$726	$41,900	$0

Appendix

Our Methods for Estimating Impact

To create this report, we have used a model-based approach to impact measurement rather than one that relies only or partially on field-based data collection. The modeled approach provides a cost-effective means of quantifying the suite of benefits accruing from our farmland. Ultimately, we hope to supplement the data in this report with field-based data and measurements, which will give a more accurate representation of important biophysical data like soil carbon. However, a model such as EVT is the best way to estimate ecosystem service value short of sampling each acre. A detailed description of the models used follows.

Ecosystem Valuation Toolkit (EVT)

The value of the ecosystem services generated by our land and farming practices was calculated using the Ecosystem Valuation Toolkit (EVT) developed by Earth Economics. EVT is a comprehensive, searchable database containing thousands of ecosystem service values derived from peer-reviewed academic journals. EVT enables users to quickly and reliably generate ecosystem service values for virtually any location and ecosystem in the world. Values from the EVT have been used in cases around the world: providing justification for real changes in land use and financial investment; clarifying full losses for disaster declaration or legal action; making a compelling argument to voters and policymakers, resulting in policy impacts at multiple scales; and in many other cases. For the CIG grant, more than 40 peer-reviewed articles were imported into EVT to help determine the ecosystem service value generated by Farmland LP's farms and management practices.

The values in EVT are in turn used by Earth Economics' "Simple, Effective Resource for Valuing Ecosystem Services" (SERVES) tool to generate per-acre benefit transfer values and dollar figures across a wide range of ecosystem services. The output of the SERVES/EVT modeling is ecosystem service valuation data for our 13 Impact Areas.

COMET-Farm

COMET-Farm is a free, web-based tool developed by the USDA NRCS and Colorado State University to estimate the carbon footprint of a farm or ranch operation. The tool uses property-specific information about management practices together with spatially-explicit data on climate and soil conditions from USDA databases to run a series of models for each potential source of greenhouse gas emissions within a farm. For example, COMET uses annual data on crop or pasture management practices starting, including cropping sequence and approximate planting and harvest date; type of grazing system (for pasture or range areas), type of tillage system; rate, timing, type and application method for fertilizer and manure applications; irrigation method and application rate, and residue management. The platform uses the DayCent dynamic model to calculate the GHG impacts of this set of management practices, the same model used in the official U.S. National Greenhouse Gas Inventory.

Revised Universal Soil Loss Equation (RUSLE)

RUSLE is an online tool developed by USDA to estimate rates of soil erosion. It has been used extensively by government and planning agencies to assess and inventory erosion to assist in public policy development and as a regulatory and conservation planning tool. RUSLE can model erosion from multiple land-use types, including cropland, forestland, rangeland, construction sites, mined land, etc. We have used RUSLE to estimate the degree of soil erosion caused by Farmland LP's practices as compared to conventionally managed farming operations.

A Framework for Assessing Ecosystem Services

Considerable progress has been made over the past decade to systematically link functioning ecosystems with human well-being. Although it is well recognized that further research and refinement is needed, this progress has provided a key conceptual framework for valuing natural capital and its related ecosystem goods and services.

Earth Economics has adapted previous ecosystem service descriptions to develop a framework that best articulates and values the vast array of critical services and benefits that natural capital provides. Under this framework, the four categories of nature's goods and services, now commonly accepted in the field of ecological economics, are as follows:

- Provisioning goods and services provide physical materials and energy for society that vary according to the ecosystems in which they are found. Forests produce lumber, while agricultural lands supply food and rivers provide drinking water.
- Regulating services are benefits obtained from the natural control of ecosystem processes. Intact ecosystems keep disease organisms in check, maintain water quality, control soil erosion or accumulation, and regulate climate.
- Supporting services include primary productivity (natural plant growth) and nutrient cycling (nitrogen, phosphorus, and carbon cycles). These services are the basis of the vast majority of food webs and life on the planet.
- Information services are functions that allow humans to interact meaningfully with nature. These services include providing spiritually significant species and natural areas, natural places for recreation, and opportunities for scientific research and education.

The table below defines the four categories and 21 distinct natural services of Earth Economics' framework, thirteen of which have been estimated for this report.

Service	Economic Benefit to People	FLP Impact Area
	Provisioning	
Energy and Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy	
Food	Producing crops, fish, game, and fruits	X
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms	
Ornamental Resources	Providing resources for clothing, jewelry, handicraft, worship, and decoration	
Water Storage	Providing long-term reserves of usable water via storage in lakes, ponds, aquifers, and soil moisture	
	Regulating	
Air Quality	Providing clean, breathable air	X
Biological Control	Providing pest, weed, and disease control	X
Climate Stability	Supporting a stable climate at global and local levels through carbon sequestration and other processes	X
Disaster Risk Reduction	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts	X

Pollination and Seed Dispersal	Pollinating wild and domestic plant species via wind, insects, birds, or other animals	X
Soil Formation	Accumulating soils (e.g. via plant matter decomposition or sediment deposition in riparian/coastal systems) for agricultural and ecosystem integrity	X
Soil Quality	Maintaining soil fertility and capacity to process waste inputs (bioremediation)	X
Soil Retention	Retaining arable land, slope stability, and coastal integrity	X
Water Quality	Removing water pollutants via soil filtration and transformation by vegetation and microbial communities	X
Water Capture, Conveyance, and Supply	Regulating the rate of water flow through an environment and ensuring adequate water availability for all water users	X
Navigation	Maintaining adequate depth in a water body to sustain traffic from recreational and commercial vessels	
Supporting		
Habitat	Providing shelter, promoting growth of species, and maintaining biological diversity	X
Information		
Aesthetic Information	Enjoying and appreciating the scenery, sounds, and smells of nature	X
Cultural Value	Providing opportunities for communities to use lands with spiritual, religious, and historic importance	
Science and Education	Using natural systems for education and scientific research	
Recreation and Tourism	Experiencing the natural world and enjoying outdoor activities	

Compiled from Daly and Farley 2004, de Groot 2002, and TEEB 2009.

Valuing Nature's Services and Accounting for Natural Capital

Understanding and accounting for the value of natural capital assets and the ecosystem services they provide can reveal the economic benefits of investment in natural capital. Natural systems have only recently begun to be viewed as economic assets that provide economically valuable goods and services. Yet when these valuable goods and services are lost, people are more susceptible to disasters such as flooding, and they face costly expenditures to replace lost services, like water quality. When the ecosystem services nature previously provided for free are damaged or lost, they must be replaced by costly, taxpayer-funded built structures. Developing in a watershed without taking natural infrastructure into account can inhibit or even destroy natural flood protection, which in turn requires replacing natural protective services with pipes or other infrastructure. In some cases, lost ecosystem goods and services are irreplaceable.

Throughout economic history, it has been necessary to develop new means of measuring economic contributing factors. In 1930, nations lacked measures of gross domestic product (GDP), unemployment, inflation, consumer spending, and money supply. Benefit-cost analysis and rate of return calculations were initiated after the 1930s to examine and compare government investments in built capital assets such as roads, power plants, factories, and dams. Private companies have relied on increasingly sophisticated approaches to calculating the expected rate of return on investments. As these examples demonstrate, both private and public decision makers were investment blind without the basic economic measures and tools which are now widely accepted and expected in guiding the vast scale of investment in today's economy.

We believe it's time that that valuation of natural capital assets and ecosystem services became a part of investment planning. Just as understanding the condition, production capacity, and value of built assets was important to economic progress in the 1900s, so too can valuing and accounting for natural capital assets and the ecosystem services they provide better inform investments in the 21st century. The benefits of ecosystem goods and services are similar to the economic benefits typically valued in the economy, such as the services and outputs of skilled workers, buildings and infrastructure.

Many ecosystem goods, like food and water, are already valued and sold in markets. Some ecosystem services, however, are not amenable to markets and have not traditionally been valued, even though they provide vast economic value. Flood protection and climate stability are prime examples of ecosystem services that provide vast value and yet go largely unvalued within traditional accounting. To illustrate, when the flood protection services of a watershed are lost, economic damages from floods can include job losses, infrastructure repairs, reconstruction and restoration costs, property damages, and deaths.

Conversely, when investments are made to protect and support these services, local economies are more stable and less prone to the sudden need for burdensome expenditures on disaster mitigation. For example, during Superstorm Sandy, New York City's Catskills Watershed provided naturally filtered, clean, gravity-fed water with virtually no interruption in service. Previous efforts to protect and restore the watershed played a role in minimizing disruption. In contrast, New Jersey's damaged pumps, filtration plants, and contaminated intakes left much of New Jersey without potable water for weeks after the storm and with a $2.6 billion tab for water infrastructure repair. In addition to the economic value associated with these avoided costs, natural capital such as healthy watersheds provide a myriad of other services, including water supply, carbon sequestration, water filtration, biodiversity, and more. All ecosystem services provide additive economic value locally, regionally, and globally.

Today, economic methods are available to value natural capital and many non-market ecosystem services. When valued in dollars, these services can be incorporated into a number of economic tools, including benefit-cost analysis, accounting, environmental impact statements, asset management plans, conservation prioritization, and return on investment calculations. Inclusion of these values ultimately strengthens decision-making. When natural capital assets and ecosystem services are not considered in economic analysis, they are effectively valued at zero, which can lead to inefficient capital investments, higher incurred costs, and poor asset management.

In summary, natural capital provides what we need to survive. Without healthy natural capital, many of the services that we freely receive could not exist. Once lost, these services must be replaced with costly built capital solutions, which are often less resilient and shorter-lived. When we lose natural capital, we also lose the economic goods and services it provides.

Ecosystem Service Valuation Limitations

Valuation exercises have limitations that must be noted, yet these limitations should not detract from the core finding that ecosystems produce significant economic value for society. Benefit transfer analyses such as the one employed for this impact report estimate the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. Some arguments against benefit transfer include:

- Every ecosystem is unique; per-acre values derived from another location may be irrelevant to the ecosystems being studied.
- Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value is expected to increase and vice versa.
- To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of exchange value. We cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income account aggregates and not exchange values. These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates.

Proponents of the above arguments recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location. This method only uses data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. The size and landscape complexity of most ecosystems makes this approach to valuation extremely difficult and costly. Responses to the above critiques can be summarized as follows:

- While every wetland, forest or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts, such as in the development of economic statistics such as Gross Domestic or Gross State Product.
- As employed here, the prior studies upon which we based our calculations encompass a wide variety of time periods, geographic areas, investigators and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low." Also, only limited sensitivity analyses were performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels ("comps"): even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.
- The objection to the absence of an imaginary exchange transaction was made in response to the study by Costanzo et al. of the value of all of the world's ecosystems. Leaving that debate aside, one can conceive of an exchange transaction in which, for example, all or a large portion of a watershed might be sold for development, so that the basic technical requirement of an economic value reflecting the exchange value could be satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale – a purpose that is more analogous to national income accounting than to estimating exchange values.

The presentation of our study results clearly displays the range of values and their distribution. The final estimates are not precise; however, it is better to provide estimates than to assume that ecosystem services have zero value or even infinite value. Pragmatically, in estimating the value of ecosystem services, it is better to be approximately right than precisely wrong.

Annotated Bibliography of Studies Used to Calculate Ecosystem Service Values in EVT

Beasley, S. D., Workman, W. G., Williams, N. A. 1986. Non-Market Valuation of Open Space and Other Amenities Associated with Retention of Lands in Agricultural Use: The Matanuska-Susitna Valley of Southcentral Alaska-A Case Study. University of Alaska-Fairbanks.
This study investigates people's willingness to pay to preserve open space used for farming. The Matanuska-Susitna valley is a rapidly growing area in Southcentral Alaska, where development pressure is increasing for open space. A contingent valuation survey shows that Matanuska-Susitna residents place significant social value on the existence of farmland, worth upwards of $100 million.

Brander, L. M., Brouwer, R., Wagtendonk, A. 2013. Economic valuation of regulating services provided by wetlands in agricultural landscapes: A meta-analysis. Ecological Engineering 56: 89-96.
The authors conduct a meta-analysis of valuation literature assessing flood control, water supply, and nutrient cycling provided by wetlands in agricultural landscapes. The meta-analysis consisted of 66 values from the United States and Europe.

Costanza, R., dArge, R., de Groot, R. S., Farber, S. C., Grasso, M., Hannon, B., Limburg, K., Naeem, S., Oneill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., vandenBelt, M., Paruelo, J., Raskin, R. G., Sutton, P., Van Den Belt, J. M. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 1-11.
The authors estimate the total economic value of the world's ecosystem services and natural capital, finding a value to be between US$16-54 trillion per year, with an average of US$33 trillion per year. Values for 17 ecosystem services are given.

Delfino, K., Skuja, M., Albers, D. 2007. Economic Oasis: Revealing the True Value of the Mojave Desert.
There is often a lack of appreciation for all the benefits the Mojave Desert provides. The Mojave offers immense economic benefit, including raising property values, contributing to national security, as well as providing unique environmental and cultural assets. This report highlights these benefits through a variety of primary and secondary methods.

DeLonge, M.S., Ryals, R., Silver, W. 2013. A Lifecycle Model to Evaluate Carbon Sequestration Potential and Greenhouse Gas Dynamics of Managed Grasslands. Ecosystems 16: 962-979.
This study investigates the opportunities for climate change mitigation on grasslands in California. Models were constructed which calculated the net emissions over a 3-year period. Results show that compost amendments may result in significant offsets to greenhouse gas emissions across a broad range of environmental and management conditions.

Donovan, G., Butry., D. 2010. Trees in the city: Valuing street trees in Portland, Oregon. Landscape and Urban Planning: 94(2): 77-83.
A hedonic model estimates the value street trees bring to sale prices of houses in Portland, Oregon. Street trees are shown to increase sales prices and also reduce the amount of time houses spend on the market. Street tree benefits also spill over to neighboring houses.

Duffy, M. 2012. Value of Soil Erosion to the Land Owner. Iowa State University, Ames.
Soil erosion on agricultural lands remains a serious problem. Erosion incurs costs to farms, including lost fertilizer and soil carbon, to society, including increased turbidity in water, and damages to infrastructure, and to landowners in the form of decreased land value. This paper estimates the cost of soil erosion to landowners in Iowa using three different methods: change in land value due to a decrease in soil health characteristics, due to loss of yield potential, and due to soil erosion phase. On average, soil erosion decreased land values by about $340 per acre.

EcoAgriculture Partners. 2011. Farm of the Future: Working lands for ecosystem services.
The Sacramento River Ranch is a 4,000-acre farm adjacent to the Sacramento River in California that provides traditional agricultural services along with environmental mitigation credit sales to buyers in the region. The site provides habitat for salmon, insects, and birds, and has an extensive wetland on the property. Environmental credits make up more than 50% of the farm's revenue.

Endale, D. M., Potter, T. L., Strickland, T. C., Bosch, D. D. 2017. Sediment-bound total organic carbon and total organic nitrogen losses from conventional and strip tillage cropping systems. Soil & Tillage Research 171: 25-34.
Carbon and nitrogen cycles are closely linked to erosion. This paper investigates how reducing tillage erosion and runoff can reduce the loss of carbon and nitrogen in soils. The study was conducted over seven years in the southeastern United States and took soil and water samples periodically at the site. Findings show that using cover crops in rotations and reducing tillage retains more nitrogen and carbon in soil than using conventional tillage.

Fan, F., Henriksen, C. B., Porter, J. R. 2016. Valuation of ecosystem services in organic cereal crop production systems with different management practices in relation to organic matter input. Ecosystem Services 22: 117-127.
Maintaining or enhancing the benefits provided by agricultural ecosystems is one strategy to mitigate the loss of ecosystem services globally. This study estimates the economic value of ecosystem services provided by organic cereal crop production systems and compares these values across different management practices. Organic matter input was found to have a strong positive relationship with the value of non-market ecosystem services.

Gascoigne, W. R., Hoag, D., Koontz, L., Tangen, B. A., Shaffer, T. L., Gleason, R. A. 2011. Valuing ecosystem and economic services across land-use scenarios in the Prairie Pothole Region of the Dakotas, USA. Ecological Economics 70(10): 1715-1725.
The authors assess environmental and economic tradeoffs under different land-use scenarios over a 20-year period in the Prairie Pothole Region of North and South Dakota. Biophysical values and value transfer methods are combined to produce estimates of carbon sequestration, sedimentation reduction, and waterfowl production on grasslands, wetlands, and croplands. Results show that the loss of native prairie grassland results in a loss of $4 billion in terms of the three ecosystem service benefits accounted for.

Harrison, G. L. 2014. Economic Impact of Ecosystem Services Provided by Ecologically Sustainable Roadside Right of Way Vegetation Management Practices. Florida Department of Transportation.
Right-of-way greenspaces provide tremendous economic benefits, although historically it has been treated as a financial liability. Ecosystem services including carbon sequestration, runoff prevention, pollination, air quality, biological control, and aesthetics were valued using the benefit transfer method for right of way green spaces in Florida. Total ecosystem service value was

measured at up to 500 million dollars, which increases when sustainable vegetation management is used. These benefits are almost 15 times more than the cost of maintaining the green space.

Hill, B. H., Kolka, R. K., McCormick, F. H., Starry, M. A. 2014. A synoptic survey of ecosystem services from headwater catchments in the United States. Ecosystem Services 7: 106-115.
Water supply, climate regulation, and water purification are estimated for over 500 headwater stream catchments throughout the United States, covering nine different ecoregions. The combined value of these ecosystem services could be up to $30 million per year in international dollars, showing the economic importance of headwater catchments.

Hovde, B., Leitch, J. A. 1994. Valuing Prairie Potholes: Five Case Studies. North Dakota State University.
The value of wetlands has increased in recent years, with people acknowledging their economic, social, and environmental benefits. Yet, wetland degradation remains an important problem in many areas, including the Prairie Pothole region. This report estimates dollar values for flood risk reduction, soil erosion prevention, and recreation, among others. Total annual values ranged from $4 per acre to $373 per acre.

Kline, J. D., Alig, R. J., Johnson, R. L. 2000. Forest owner incentives to protect riparian habitat. Ecological Economics 33: 29-43.
Non-Industrial Private Forest (NIPF) land accounts for 36% of private timberland in Western Oregon, and plays a large role in Coho Salmon populations and habitats in this area. This study models NIPF owners' willingness to forgo timber harvest near riparian zones for 10 years. The authors use cluster analysis to group owners based on their land-use and ownership objectives. The study site covered in this survey comprises 38 counties in Oregon and Washington, all west of the Cascades. Methodology used was a randomized telephone survey of the NIPF owners. The authors found that the incentive payments necessary ranged from $38-$137/acre/year, and the probability that the NIPF owner would forgo harvest ranged from 32% to 91%.

Kurkalova, L. A., Kling, C., Zhao, J. 2001. The Subsidy for Adopting Conservation Tillage: Estimation from Observed Behavior. Center for Agricultural and Rural Development.
Due to risk and uncertainty, farmers may demand premiums for adopting conservation tillage practices. This study estimates the financial incentives of adopting conservation tillage to farmers. Results find that on average, regardless of whether or not farmers have adopted conservation tillage, conservation tillage provides a higher payoff than conventional tillage. A subsidy of approximately $3 per acre per year will likely encourage additional adoption of conservation tillage practices.

Liu, S., Liu, J., Young, C.J., Werner, J.M., Wu, Y., Li, Z., Dahal, D., Oeding, J., Schmidt, G., Sohl, T.L., Hawbaker, T.J., Sleeter, B.M. 2012. "Chapter 5: Baseline carbon storage, carbon sequestration, and greenhouse-gas fluxes in terrestrial ecosystems of the western United States". In: Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of the western united states. Zhu, Z. and Reed, B.C., eds. USGS Professional Paper 1797.
This study provides an accounting of the carbon storage amounts and percentages across various biomes and land types throughout the Western United States. The authors detail the results from their analysis of the carbon stock, carbon flux, and greenhouse gas (GHG) flux in live biomass, soil organic carbon, and dead biomass. Changing land use, land cover, and fire modeling are all taken into account. The types of land modeled, in increasing order of carbon sequestered, are agricultural lands (7%), grasslands/shrublands (30%), and forests (62%). The average net carbon

flux in terrestrial ecosystems in the Western US was estimated as -86.5 TgC/yr (a carbon sink). The western cordillera (Western US mountains), accounted for 59% of this storage.

Marie, B., Josette, G., Giles, B., Julien, T., Eric, G., Bruno, M. 2015. Nitrous oxide emission and nitrate leaching in an organic and a conventional cropping system (Seine basin, France). Agriculture, Ecosystems and Environment 213: 131-141.
The authors assess nitrogen losses from farms in France. Field measurements were taken from one organic and one conventional farming system in the same drainage basin between 2011 to 2014. On average, N20 emissions were lower in the organic system than for the conventional system. Nitrogen leaching into waterways was also lower for the organic system. The results of this study provide evidence that organic farming practices provide a lower environmental impact than conventional farming practices.

McPherson, E. G., Scott, K. I., Simpson, R. D. 1998. Estimating cost effectiveness of residential yard trees for improving air quality in Sacramento, California, using existing models. Atmospheric Environment 31(1): 75-84.
Based on the Sacramento Municipal Utility District's shade tree program, which would plant 500,000 trees, the net benefits of improved air quality are assessed under multiple scenarios. For the base case, annual net benefits of pollution uptake were about $383 per 100 trees planted. The pollutant uptake by tree species is discussed, and several benefit-cost ratios are given based on alternative scenarios.

McPherson, E. G., Simpson, R. D. 2002. A Comparison of Municipal Forest Benefits and Costs in Modesto and Santa Monica, California, USA. Urban Forestry & Urban Greening 1(2): 61-74.
The authors compare functions and values of urban tree populations in Modesto and Santa Monica, California. The annual benefits from urban trees were estimated at $2.2 million in Modesto and $805,732 in Santa Monica. For every $1 invested in park management, there was a $1.85 and $1.52 benefit in Modesto and Santa Monica, respectively. Most benefits were from the aesthetic value of trees, while the majority of costs were from pruning trees and foliage. Benefits and costs were unevenly distributed throughout each city, largely because of variation in tree sizes and growth rates, prices, residential property values, and climate.

Moore, R. G., McCarl, B. A. 1987. Off-Site Costs of Soil Erosion: A Case Study in the Willamette Valley. McCarl, Bruce A. (ed.) Western Journal of Agricultural Economics 12(1): 42-49.
This study examines the costs of sediment erosion in the Willamette Valley in Oregon. Erosion costs related to water treatment, infrastructure maintenance, and hydroelectric generation are considered. Costs due to erosion were estimated at approximately $5 million in the region. Costs of infrastructure maintenance were the highest, with water treatment costs being second highest.

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.
Adequate field edge habitats on mono-cropped farms add ecosystem benefits that may not be economically beneficial in the short term, such as water quality protection and habitat for native bees and insects. The study area was focused in California's Sacramento Valley, an area with large-scale monoculture orchards. All plants used were restored California native perennials, replacing field edges primarily composed of nonnative grasses and plants. The purpose of this study was to develop a model showcasing the cost-benefit analysis of installing field edge habitats (hedgerows). Additionally, this model gives farmers, who are often driven by economic incentives, more robust information for making choices with their land. Given a fixed cost to plant rounded up to $4,000

on a 300m hedgerow, the model predicts it would take 16 years to break even based solely on savings in insecticide, and 7 years including benefits from native bee pollination.

Pimentel, D. 1998. Economic and Environmental Benefits of Biological Diversity in the State of Maryland. Therres, Glenn D (ed.) Maryland Department of Natural Resources.
Pimentel estimates the annual economic and environmental benefits of biodiversity in Maryland for several ecosystem services including soil formation, pollination, recreation, and waste treatment. Total annual benefits of ecosystem services in the state of Maryland equal approximately $1.9 billion.

Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R., Blair, R. 1995. Environmental and economic costs of soil erosion and conservation benefits. Science 267(5201): 1117-1122.
This article describes the environmental and agricultural issues related to soil erosion. Water runoff rates are compared for conservation and agricultural uses, including an analysis of agricultural productivity. Costs due to erosion, as well as costs for erosion prevention, are compared.

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.
The use of conventional farming techniques over organic methods damages ecosystems and health, and has associated environmental and economic costs. The authors sought to compare energetic, economic, and environmental costs and efficiencies of the two farming techniques. The study summarized the Rodale Institute Farming Systems Trial in Pennsylvania from 1981-2002. The experiment divided a plot of land into three sub-plots, one for conventional farming, and two for organic farming. The organic plots had 15-20% higher groundwater volume than the conventional plot, and 0.4-0.5% higher carbon levels than the conventional plot. In other papers referenced by the authors, organic systems generally had lower yields and lower net returns, though these can be partially offset by nitrogen addition to the soil, and through premiums for organic produce at market. Additionally, fossil energy input was found to be 30% lower for the organic plots due to their lack of chemical inputs.

Pimentel, D., Wilson, C., McCullum, C., Huang, J., Paulette, D., Flack, J., Tran, Q., Saltman, T., Cliff, B. 1997. Economic and Environmental Benefits of Biodiversity. BioScience 47(11): 747-756.
A coarse economic analysis is performed using existing literature. The annual economic and environmental benefit of biodiversity in the United States is approximately $300 billion, according to the authors' estimates. Values are considered for biomass and organic waste recycling, soil formation, nitrogen fixation, bioremediation of chemical pollution, genetic resources and crop and livestock yields, biotechnology, biological pest control, perennial grains, pollination, habitat and ecotourism, pharmaceuticals, and carbon sequestration.

Qiu, Z., Prato, T. 1998. Economic Evaluation of Riparian Buffers in an Agricultural Watershed. Journal of the American Water Resources Association 34(4): 877-890.
This study evaluates the economic value of riparian buffers and open space in a suburban watershed using both contingent valuation and hedonic pricing. The contingent valuation survey was distributed in the area surrounding the Dardenne Creek watershed, a suburban watershed in the St. Louis metropolitan area, to find residents' willingness to pay for adopting riparian buffers and preserving farmland in a hypothetical real estate market. The hedonic pricing model assessed actual sale prices of homes in the watershed, which was used to find the value of open space, flood

risk, and stream proximity. Residents' willingness to pay estimates were consistent with the values derived from hedonic pricing; in other words, stated preference was the same as observed preference.

Rein, F. A. 1999. An economic analysis of vegetative buffer strip implementation. Case study: Elkhorn Slough, Monterey Bay, California. Coastal Zone Management Journal 27(4): 377-390.
This study investigates the economics of implementing vegetative buffer strips as a tool to protect water quality from nonpoint pollution. It evaluates environmental costs and benefits of implementing vegetative buffer strips, both to the grower and to society as a whole, as a means of capturing non-market ecosystem values and informing decision making. Results indicate a net economic benefit to the grower for installing vegetative buffer strips within the first year, if the economic costs of erosion are considered. The installation of vegetative buffer strips also has extensive economic benefits to society, including in areas such as tourism, commercial fisheries, long-term road maintenance, and harbor protection. These results support installing vegetative buffer strips as a management strategy in an erosion-prone watershed to protect water quality and preserve soil fertility, as well as to protect economic interests. A number of policy tools to encourage the implementation of vegetative buffer strips are discussed, including tax incentives and legislative policies. Government intervention through incentive-based programs is advocated due to the economic and ecologic benefits to society.

Richardson, R. B. 2005. The Economic Benefits of California Desert Wildlands: 10 Years Since the California Desert Protection Act of 1994. The Wilderness Society.
This study focuses on over 8.5 million acres of desert wild lands and national parks of California (Inyo, San Bernardino, Riverside, and Imperial Counties), estimating the total economic value of these natural areas. Included in this area is one million acres of unprotected desert, intended to showcase the value of further land protections. As the benefits from these types of natural spaces are often hidden to traditional markets and left out of policy accounting, this estimation can help policymakers make land management decisions. The authors found the wild lands analyzed in this study to generate about $1.4 billion per year and close to 3,700 jobs in the area. In addition to this, revenue from visitors to the area generates $120 million and 3,674 jobs locally. Less quantifiable impacts, such as the benefits of added biodiversity, are not included in these estimations.

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.
This study explores an equilibrium between consumer demands for more yield at lower prices, and societal needs for a healthy and resilient environment. The experiment spanned 25 years at the Kellogg Biological station in southwest Michigan. The north central United States as a whole accounts for 80% of US corn and soybean production, and 50% of US wheat production. The primary focus in this experiment, row cropping, has led to increased yields per acre, but has also been damaging to the environment through many avenues. The authors assess the willingness of row crop farmers to manage not just for yield, but for long term ecosystem services (food/fuel, pest control, clean water, climate stabilization, and soil fertility). Supplemental to this was a survey to determine the supply side incentive needed to farm for ecosystem services, as well as consumer willingness to pay for those services.

Roy, R., Thomassin, P. J. 2016. Estimating a Natural Capital Account for Agricultural Land. CIRANO.
In calculating economic activity during a given time period, countries don't factor in the evolving value of natural capital or ecosystem services (considered externalities). For example, the cleaning

of the BP oil spill in the Gulf of Mexico generated positive economic activity, with the degradation in natural capital not accounted for. Focusing on agricultural land in the Canadian province of Québec, the authors use a hedonic pricing model to value natural capital. With regular analysis, negative impacts on farmland value, such as erosion (which an Australian study found to cost $14.3 billion over 50 years) can be accounted for and internalized.

Ryals, R., Silver, W.L. 2013. Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands. Ecological Applications 23: 46-59.
The authors investigate the effect of organic soil amendments on the greenhouse gas dynamics of managed grasslands. Field measurements were taken on two different grasslands over three years. The addition of organic soil amendments increased carbon storage in soils by 25 percent to 70 percent. Water-holding capacity also increased on each site. The authors conclude that a single application of organic likely carries these benefits much longer than the study period.

Sengupta, S., Osgood, D.E. 2003. The Value of Remoteness: a hedonic estimation of ranchette prices. Ecological Economics 44: 91-103.
In the western United States, it is common for ranches to be subdivided into smaller, recreation-oriented ranches called "ranchettes." This paper conducts a hedonic analysis of ranchettes, including remote sensing of vegetation as a variable. Results found that increased green vegetation raised sale prices of ranchettes.

Schuman, G.E., Janzen H.H., Herrick J.E. 2002. Soil carbon dynamics and potential carbon sequestration by rangelands. Environmental Pollution 116: 391-396.
Grazing lands are estimated to hold 10% to 30% of the world's soil organic carbon (C). Proper management can increase soil carbon storage between 0.1 and 0.3 MgC/ha/yr, and conversion to new grasslands can increase soil carbon up to 0.6 Mg C/ha/yr. This study seeks a further understanding of the effects of rangeland management on the carbon storage capabilities of soil. This paper summarizes the effects of several studies across North American rangelands (Colorado, Wyoming, southern Canada). Annual fires and the addition of nitrogen fertilizer to nitrogen deficient soils can both have positive effects on carbon storage (though making fertilizer produces carbon itself). Additionally, the authors contend that soil erosion affects the distribution of soil carbon, but does not result in carbon transfer to the atmosphere.

Smith, J.E., Heath, L.S., Skog, K.E., Birdsey, R.A. 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. USDA Forest Service Northeastern Research Station, General technical report NE-343.

The focus of this paper is detailing the methodology used to estimate the amount of carbon sequestered by forests and their byproducts. The study separates the continental United States into 10 regions, 51 forest types, and 6 forest ecosystem carbon pools. The analysis in this paper seeks to fully account for all carbon stored throughout the lifetime of a forest and its byproducts. For example, the authors assert that harvested wood products are often considered to be an immediate release of carbon into the atmosphere, when it may not be released for years or decades.

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.
Conducted in southwest Michigan, this study tested the principle that biodiversity plays a positive role in rain-fed cropping systems. The effects on maize production were tested using three

systems, biodiverse rotational, organic management, and conventional integrated management. The conventional management produced the highest yield of 6.1Mg/ha, the organic produced 5.1Mg/ha, and the biodiverse rotational produced 25% less but at higher quality. The organic system also maintained soil fertility, increased soil carbon 36%, and decreased nitrate-N leaching by 50%.

Swanepoel, G. D., Hadrich, J. C., Goemans, C. G. 2015. Estimating the contribution of groundwater irrigation to farmland values in Phillips County, Colorado. Journal of the ASFMRA 0: 165-178.
Focused in Phillips County, Colorado, this study uses hedonic price analysis to estimate farmland value in irrigated vs. non-irrigated plots. The data used to conduct this analysis was detailed records from 479 sales, including well depth and yield from on-site wells. The earning capacity of a plot of land also influences its price, and various market factors can put pressure on the value. The model estimated that grazing land added $183/acre to the plot value, non-irrigated added $481/acre, and irrigated added $654-$2,066/acre depending on well depth. Well depth played a role in the final value due to increasing costs to pump, with the value of an irrigated acre decreasing by $1.80 per foot of well depth.

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.
This study summarizes an experiment conducted in southwest Michigan that evaluates the effects of management intensity of eight replicated ecosystems with identical soil types. The authors goal is to develop a model to evaluate the tradeoffs between sets of ecosystem services associated with agricultural landscapes. The services accounted for are: grain yield, drainage, global warming, plant diversity, soil carbon, soil water content, nitrate leaching, and above ground primary productivity. The authors found grain yields to be positively correlated with nitrate leaching and global warming, and negatively correlated with plant diversity. At the same time, there were a range of impacts depending on management intensity that could be configured to maximize multiple ecosystem services associated with agricultural land, not just yield.

Thibodeau, F. R., Ostro, B.D. 1981. An economic analysis of wetland protection. J. Envtl. Mgmt. 19 : 72-79.
In response to several policies that offer payments for wetland preservation, this paper quantifies the economic benefits of wetlands in the Charles River Basin in Massachusetts. The paper also analyzes the legal issues associated with wetland preservation.

Torell, A., Doll, A. P. 1991. Public Land Policy and the Value of Grazing Permits. Western Journal of Agricultural Economics 16(1): 174-184.
Focused in New Mexico, this study explores the relationship between changing grazing fees and land management policy on the value of public land grazing permits. Public land permits have fallen in value relative to deeded land permits, with both uncertainty about the future of policy, and increased grazing fees playing a role. A regression model was used, comparing statistical estimates of permit values against various state and federal agency land policy. The model estimated a positive correlation between grazing fees and ranch value, with an $1 increase in the cost advantage of public land grazing resulting in an $29.81 increase in ranch value.

Wilson, S. J. 2008. Ontario's wealth, Canada's future: Appreciating the value of the Greenbelt's eco-services.
This document assesses the value of ecosystem services in Ontario's Greenbelt. Values per hectare are given for all types of land cover in the Greenbelt, as well as for each type of ecosystem service

provided by these lands. The annual value of the region's measurable non-market ecosystem services is estimated at $2.6 billion annually; an average value of $3,487 per hectare. Wetlands have the greatest values, worth an estimated $1.3 billion per year ($14,153/hectare) because of their high value for water regulation, water filtration, flood control, waste treatment, recreation, and wildlife habitat.

Wilson, S. J. 2010. Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature.
Similar to Wilson's analysis of Ontario's Greenbelt, this paper examines the ecosystem services derived from British Columbia's lower mainland. Values per hectare are provided for ten different ecosystem services, both on a per-person level and in aggregate.

Zhongwei, L. 2006. Water Quality Simulation and Economic Valuation of Riparian Land-Use Changes. University of Cincinnati.
This dissertation quantifies the ecological and economic impacts of land-use changes in riparian buffer zones on the hydrology and water quality in the Little Miami River watershed in Ohio. The replacement cost method is applied to estimate the value of riparian forest buffer zones, based on the cost of nitrogen and phosphorus removal through wastewater treatment plants.

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.
The objective of this study was to determine the effectiveness and economic benefits of selected conservation practices in sediment reduction by water erosion in major soil areas of Iowa. One farm was selected to represent the typical soil and slope gradient in each of the eight Major Land Resource Areas in Iowa. Three tillage systems (no-till, strip-till, and chisel plow tillage) and three conservation structures (grassed waterways, grass filter strips, and terrace systems) were investigated under a corn–soybean rotation using the Water Erosion Prediction Project model.