RIPE
Rural Investment to Protect our Environment

Quantifying Total Public Benefits from Climate-Smart Practices
RIPE Methodology & Data Sources

Shared with USDA on September 8, 2022

This document includes the methodology and citations for quantifying the combined public benefits of climate-smart agricultural practices. We hope this is helpful to USDA and we welcome feedback from USDA on improving the methodology and data sources.

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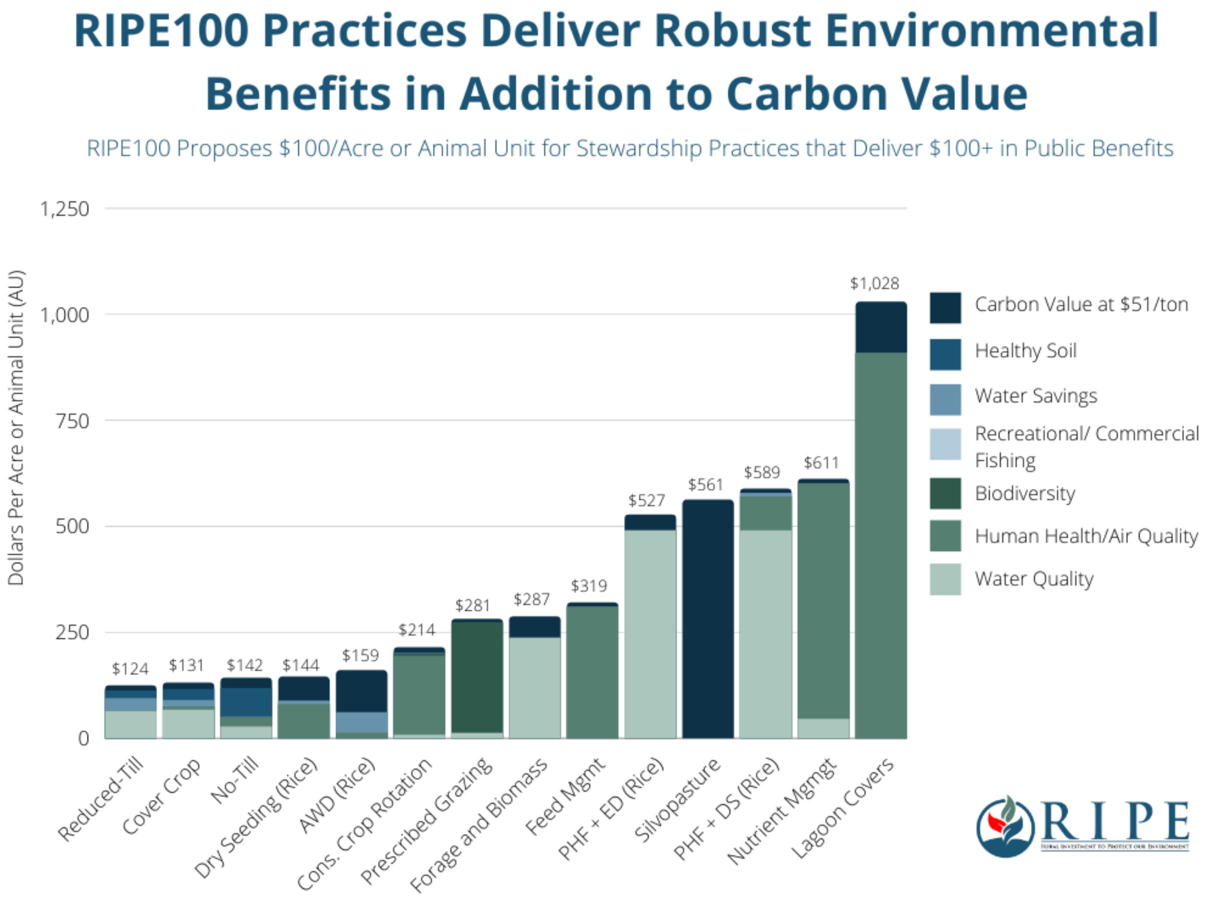
Graphic Summary of Public Benefits



Key Takeaways from Findings

- **Climate Smart Ag Delivers in the Range of a 9:1 Benefit Cost Ratio.**
- **17x More Public Benefit Than Climate Alone**, so Benefit-Cost Ratios should include these public benefits.
- **GHG Value is Less than the Cost of the Practice** (except AWD rice).
- **USDA Should Consider Adding Practices:** feed management, dry seeding rice, winter flooding w/ early drainage or dry seeding rice
  - **Rice practices support wildlife significantly**
- **Challenge of significant variability can be addressed practically with a price floor model, since data consistently finds credible case for $100 range**
- **RIPE welcomes feedback from USDA on methodology to be more helpful**

Methodology

All Figures are Intended to Provide Sense of Scale. The goal of this research is not to provide an exhaustive nor technically precise academic study but rather to provide a broader context of the stacked environmental values of climate-smart practices. We welcome technical experts contributing refinements on the issues we present.

Ecosystem Service Values are Additional to Farmer's Private Economic Gains. "Ecosystem services" refer to the direct and indirect contributions of ecosystems to human well-being and subsistence. Ecosystem valuation is an approach to assign monetary values to an ecosystem and its key ecosystem goods and services, generally referred to as Ecosystem Service Value (ESV). The private economic value that a farmer gains from producing food or avoiding costs is not included in RIPE's methodology for quantifying ESV, because our goal is to identify an appropriate level of public funding for public services. We did not include recreational value in order to focus on environmental value, but that should be considered in future work as it is a pubic value beyond the farmers' private gain, it is well-studied, and widely supported in Congress as a

High Variability Addressed by Using Meta-Study, Averages, and Means. The field of ecosystem service analysis has been around for decades and one factor it confronts is that the environmental impacts vary significantly depending on the location, weather, timing, and methodology for translating environmental value into economic terms. To address this variability, we began with a meta-study of over 30 studies to provide an outline of the range of values. We augmented those studies based on guidance we received from our Technical Advisory Group when they believed some services needed additional research. The compiled list of values were then broken into high, low, and average values. In the situations where the average value varied significantly from the median value, we used the median value. We looked at several dozens of papers but do not claim to have looked at every study in the field.

Field-Specific Context Less Critical for National Program That is Not Environmental Trading. Quantifying the impacts from a particular location is relevant when designing an environmental quality trading program, which allows regulated entities to pollute more based on the purchase of pollution reductions from farmers. RIPE is not proposing an environmental quality trading program. Rather we propose a stand-alone federal program - such as current USDA NRCS EQIP and CSP programs - and therefore the evidence of impact can be based on broad national program-wide findings. As research improves on the farm-specific, field-level impacts, those findings will be aggregated in national studies that can deliver credible figures on typical impacts.

GHG Value May be Higher with Latest Social Cost of Carbon. In August of 2022, Resources for the Future updated its projections of the Social Cost of Carbon with a significant increase, with most research pointing to a value in the range of $200/ton of GHG. RIPE's compilation of research was done before this was released, so it uses $51/ton based on the interim 2020 federal social cost of carbon. RIPE will work to update these figures with the latest information by November 2022. While this higher level will make a difference in the total value, it is not a big enough difference to overcome the cost-share challenge for most climate-smart practices from the perspective of only compensating producers for the GHG value.

We welcome suggestions for improving methodology. We welcome input from technical experts who can refine and improve our methodology. We know many values were not properly evaluated, such as biodiversity, and hope others can help fill those gaps. We expect the technical limitations of our work will be resolved in future rounds of policy discussions, when additional research resources from USDA and others can help refine the methodology. RIPE's mission is not to provide the definitive technical answer to the stacked ecosystem service value, but rather to advance a policy dialogue around fairly compensating farmers in the general direction of stacked ecosystem service values. We expect that work being done by the Ecosystem Service Market Consortium and others will provide invaluable contributions to refining the figures as that research becomes available. **The existing research demonstrates the value the public can derive from compensating farmers fairly for stewardship practices is in the order of magnitude of $100-700/acre or AU** We offer this methodology as an example of the technical analysis that can be done to support a policy design with these principles. We expect other actors will improve upon this methodology, and for future policy payment designs to reflect the latest scientific findings.

List of Practices and Total Public Values

The order of practices below follows the order of the NRCSClimate-Smart Agriculture and Forestry Mitigation Activities List (February 2022). RIPE also includes the following practices that demonstrate public benefits over $100/acre: feed management, dry seeding (rice), post-harvest flood with dry seeding (rice), and post-harvest flood with early drainage (rice). RIPE staff continuously analyze more practices and update the list regularly through its newsletter and website. We welcome the opportunity to share updates with the USDA staff, whenever it would be helpful.

Conservation Crop Rotation ($214/acre)
Residue and Tillage Management, No-Till ($142/acre)
Cover Crop ($131/acre)
Residue and Tillage Management, Reduced Till ($124/acre)
Filter Strip ($2,548/acre)
Nutrient Management ($611/acre)
Lagoon Cover/Anaerobic Digester ($1,008-$1,089/animal unit)
Forage and Biomass Planting ($287/acre)
Prescribed Grazing ($281/acre)
Silvopasture ($561+/acre)
Riparian Herbaceous Cover ($1,782/acre)
Riparian Forest Buffer ($4,430/acre)
Irrigation Water Management (Alternate Wetting and Drying) ($159/acre)
Dry Seeding, Rice (CARB Protocol)- *regionally specific* ($144/acre)
Post-Harvest Flood with Early Drainage, Rice (CARB Protocol) ($527/acre)
Post-Harvest Flood with Dry Seeding, Rice (CARB Protocol) - *regionally specific* ($589/acre)
Feed Management ($172-$705/animal unit)

Data for Each Practice

Conservation Crop Rotation

Ecosystem Service	$/Acre/Year	Citation
GHG Mitigation (at $51/tonne CO2e)	$12	The USDA COMET-Planner tool demonstrates that conservation crop rotation reduces GHG emissions by a national average of 0.23 tonnes CO2e per acre. At a value of $51 per tonne CO2e, the public benefit is $12 per acre.
Reduced Soil Erosion (water quality benefits)	$9	The average sheet and rill erosion rate on cropland in the United States equals 2.67 tons of soil per acre (USDA, Cropland Soil Erosion, 2017). According to "Cropping System Diversity Effects on Nutrient Discharge, Soil Erosion, and Agronomic Performance," (Hunt et al., *Environ. Sci. Technol.*, 2019), longer crop rotations reduce soil erosion by an average of 50%. Applying this 50% reduction to the average national erosion rate equals 1.33 tons of soil saved per acre. The water quality value of reduced sheet and rill soil erosion is $7 per ton of soil in 2022 dollars (Final Benefit-Cost Analysis for the Environmental Quality Incentives

		Program (EQIP), NRCS, 2010). 1.33 tons of soil per acre multiplied by $7 per ton equals $9 per acre.
Biodiversity	$5	Conservation crop rotation reduces required herbicide application by an average of 0.54 kg per acre (Hunt et al., "Reducing Freshwater Toxicity while Maintaining Weed Control, Profits, And Productivity: Effects of Increased Crop Rotation Diversity and Reduced Herbicide Usage," *Environ. Sci. Technol.*, 2017). Reducing herbicide or pesticide use provides biodiversity benefits valued at $10 per kg of herbicide in 2022 dollars (D. Pimentel. "Environmental and Economic Costs of the Application of Pesticides Primarily in the United States," *Environment, Development, and Sustainability*, 2005). 0.54 kg of herbicide per acre multiplied by $10 per kg equals $5.40 per acre.
Air Quality/Public Health	$185	This estimate averages a high-end and a low-end value of reduced ammonia emissions: High-end: Conservation crop rotation reduces fertilizer usage by 50% (Hunt, et al. "Fossil Energy Use, Climate Change Impacts, and Air Quality-Related Human Health Damages of Conventional and Diversified Cropping Systems in Iowa, USA," *Environ. Sci. Technol.*, 2020). The baseline nitrogen application averages of 84.5 pounds of nitrogen per acre for continuous corn, cotton, soy, or wheat (USDA NASS Agricultural Chemical Use Program, 2021). Converting nitrogen to emitted ammonia yields an average of 50 pounds NH3 reduced per acre (Goebbes et al., 2003; Mikkelsen, 2009; Dari et al., 2019; Jones et al., 2020). A 50% reduction equals 8.5 pounds of ammonia per acre. The human health cost of ammonia is $27 per pound (Heo, et al. "Public Health Costs of Primary PM2.5 and Inorganic PM2.5 Precursor Emissions in the United States," *Environ. Sci. Technol.*, 2016). 8.5 pounds of ammonia per acre multiplied by $27 per pound equals $229.50 per acre. Low-end: In "Fossil Energy Use, Climate Change Impacts, and Air Quality-Related Human Health Damages of Conventional and Diversified Cropping Systems in Iowa, USA," Hunt, et al. (2020) find that diversified crop rotations provide an average value of $140 per acre in air quality benefits due to reduced nitrogen fertilizer use.

Soil Quality	$3	The average sheet and rill erosion rate on cropland in the United States equals 2.67 tons of soil per acre (USDA, Cropland Soil Erosion, 2017). According to "Cropping System Diversity Effects on Nutrient Discharge, Soil Erosion, and Agronomic Performance," (Hunt et al., *Environ. Sci. Technol.*, 2019), longer crop rotations reduce soil erosion by an average of 50%. Applying this 50% reduction to the average national erosion rate equals 1.33 tons per acre. Reduced erosion provides $2 per ton of soil in soil quality benefits ("Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP)," NRCS, 2010).
Total	$214	

Residue and Tillage Management, No-Till

Ecosystem Service	**$/Acre/Year**	**Citation**
GHG Mitigation (at $51/tonne CO2e)	$24	According to the USDA COMET-Planner tool, the national average GHG value of no-till is 0.46 tonnes per acre. At a value of $51 per tonne CO2e, the public benefit value is $24 per acre.
Air Quality	$22	Pimentel et. al. "Environmental and Economic Costs of Soil Erosion and Conservation Benefits." Science. Vol 267, Issue 5201, pages 1117-1123. 1995. Addresses wind erosion and associated health issues.
Water Quality	$28	Pimentel et. al. "Environmental and Economic Costs of Soil Erosion and Conservation Benefits." Science. Vol 267, Issue 5201, pages 1117-1123. 1995. Includes a table that compares different agricultural practices and their water runoff.
Healthy Soil	$68	Soil nutrients: Pimentel et. al. "Environmental and Economic Costs of Soil Erosion and Conservation Benefits." Science. Vol 267, Issue 5201, pages 1117-1123. 1995. Assumes a cost of $3 per ton of soil for nutrients. This was updated to 2022 dollars and used as a multiplier for values on no-till. Soil conservation: In "Environmental and Economic Costs of Soil Erosion and Conservation Benefits," Pimentel et. al (1995) stated that, "In the United States, an estimated 4,000,000,000 tons of soil are lost every year" on cropland. The study estimated the economic cost of specific types of erosion. In Land Econommics""The Value of

		the Reservoir Services Gained with Soil Conservation," Hansen and Hellerstein (2007) estimate the costs of erosion, stating that "a one-ton reduction in soil erosion provides benefits ranging from zero to $1.38 (in 2007 dollars)." Values were converted to 2022 dollars.
Total	**$142**	

Cover Crops

Ecosystem Service	**$/Acre/Year**	**Citation**
GHG Mitigation (at $51/tonne CO2e)	$15	The USDA COMET-Planner shows that cover crops provide a national average greenhouse gas value of 0.29 tonnes per acre. At $51 per tonne of CO2e, the public benefit value equals $15 per acre.
Water Quality	$67	According to the Sustainable Agriculture Research and Education (SARE) report "Cover Crops Improve Soil Conditions and Prevent Pollution," (2015), cover crops reduce soil erosion by 20.8 tons per acre on conventional-till fields, 6.5 tons per acre on reduced-till fields and 1.2 tons per acre on no-till fields, or an average of 9.5 tons per acre. In "Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP)," NRCS (2010) values the water quality benefits of reduced soil erosion at $7 per ton in 2022 dollars. Multiplying the average erosion reduction rate of 9.5 tons of soil per acre by $7 per ton of soil yields a water quality value of $67 per acre.
Air Quality	$8	NRCS's report, "Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP)" (NRCS, 2010) identified benefits and their transfer values from EQIP practices and identified which stewardship practices led to different categories of benefits. Cover crops were identified as a practice that led to improvements in "sheet and rill water erosion, and air quality." The air quality value identified in this report was $5.71 per acre per year, which was converted to 2022 dollars.
Healthy Soil	$26	This number is an average taken from two papers: Pimentel, et al. "Environmental and Economic Costs of Soil Erosion and Conservation Benefits." Science, Vol 267, Issue 5201, 24 Feb. 1995, pages 1117-1123., doi:10.1126/science.267.5201.1117.; and USDA/NRCS, Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP), May 10, 2010. The USDA article valued the reduction of loss of nutrients from

		planting cover crops at $2 per ton of soil in 2022 dollars. This figure was multiplied by the average cover crop soil erosion reduction of 9.5 tons of soil (SARE). Pimentel, et al. calculated a cost of $3 per ton of soil for nutrients, which was converted into $32 per acre per year in 2022 dollars.
Water Savings	$15	In the economic tool "Cover Crop Economics" version 3.1, USDA lists a 5.41 acre-inch water efficiency gain per year with the use of cover crops, which is valued at $10.30 per acre in 2007 dollars. Updating this value to 2022 dollars yields a water conservation value of $15 per acre.
Total	**$131**	

Residue and Tillage Management, Reduced-Till

Ecosystem Service	$/Acre/Year	Citation
GHG Mitigation ($51/tonne CO2e)	$12	The USDA COMET-Planner tool shows that reduced-tillage provides a GHG reduction benefit equal to 0.23 tonnes CO2e per acre. At $51 per tonne, this is equal to $12/acre.
Water Conservation	$30	According to Pimentel, et al. (1995), reduced-till vs. conventional-till corn conserved water at a rate of 1.5 cm per ha. The cost of replacement listed for water runoff equals $2.5 per mm in 1995$. The value per hectare of reduced tillage is thus $37.50 per hectare (water runoff, 1995 $). $37.50 per hectare (1995) = $30 per acre (2022). Pimentel et. al. "Environmental and Economic Costs of Soil Erosion and Conservation Benefits." Science. Vol 267, Issue 5201, pages 1117-1123. 1995
Water Quality	$64	A USDA study, "Erosion from Reduced-Till Cotton" (Mutchler, et al.), finds that no-till cotton reduced soil loss due to erosion by an average of 20.4 tons per acre compared to conventional-till cotton. Another USDA study, "How Tillage Affects Soil Erosion and Runoff" (Rust & Williams, 2009), found that seasonal-till cotton reduced soil loss by 4.98 tons per acre per year. Averaging these values yields 12.7 tons of soil per acre per year. In "Environmental and Economic Costs of Soil Erosion and Conservation Benefits," Pimentel et al. (1991) find the soil conservation values of reduced-till corn, soy and wheat to be: 5.3 tons per acre, 10.2 tons per acre, and 8.2 tons per acre, respectively. Averaging the soil conservation values for cotton, corn, soy and wheat yields a value of 9.1 tons of soil per acre.In "Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP)," NRCS (2010) values the water

		quality benefits from reduced soil erosion at $7 per ton of soil per year in 2022 dollars. $7 per ton of soil multiplied by 9.1 tons per acre equals $64/acre.
Soil Quality	$18	In “Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP),” NRCS (2010) values the soil quality benefits from reduced soil erosion at $2 per ton of soil per year in 2022 dollars. $2 per ton of soil multiplied by 9.1 tons per acre equals $18/acre.
Total	**$124**	

Filter Strip

Ecosystem Service	$/Acre/Year	Citation
GHG Mitigation (at $51/tonne CO2e)	$43	The USDA COMET-Planner tool shows that filter strips provide a a GHG reduction benefit equal to 0.84 tonnes CO2e per acre. At $51 per tonne, this is equal to $43 per acre.
Air Quality Benefits (Human Health)	$67	The Economic Value of Riparian Buffers in the Delaware River Basin. Report prepared by ECONorthwest for the Delaware Riverkeeper Network. 2018. https://www.delawareriverkeeper.org/sites/default/files/Riparian%20B enefits%20ECONW%200818.pdf
Soil Conservation	$2,438	The Economic Value of Riparian Buffers in the Delaware River Basin. Report prepared by ECONorthwest for the Delaware Riverkeeper Network. 2018. https://www.delawareriverkeeper.org/sites/default/files/Riparian%20B enefits%20ECONW%200818.pdf
Total	**$2,548**	

Nutrient Management - Improved Land Application

Ecosystem Service	$/Acre/Year	Citation
GHG Mitigation (at $51/tonne CO2e)	$11	The Duke University report “Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States: A Synthesis of the Literature” (Eagle et al., 2012) estimates that improved land manure application can reduce N2O emissions by an average of 0.32 tonnes per acre. *Farming for Our Future* (Rosenberg & Lehner, 2021) reports that improved synthetic fertilizer management can reduce GHG emissions by 0.11 tonnes per acre.

		The average of these estimates yields a value of 0.22 tonnes per acre. At $51 per tonne CO2e, this average benefit is valued at $11 per acre.
Air Quality Benefits (Human Health)	$554	A number of studies demonstrate that closed-slot manure injection typically reduced ammonia emission by up to over 90% (e.g., Thompson et. al. 1987, Weslien et al. 1998, Hansen et al. 2003, Webb et al. 2010, Pote et al. 2011, Dell et al. 2012, Carozzi et al. 2013, and Kulesza et al. 2014). Annually, incorporation and injection can reduce ammonia emissions by 6 to 13 kg NH3 per acre (Powell, et al., "Dairy slurry application method impacts ammonia emission and nitrate in no-till corn silage," *USDA-ARS*, 2011). The public cost of ammonia is $54,900 per ton NH3 in 2022 dollars (Heo, et al. "Public Health Costs of Primary PM2.5 and Inorganic PM2.5 Precursor Emissions in the United States," *Environ. Sci. Technol.*, 2016).
Water Quality Benefits	$46	A long-term study conducted by Iowa State University researchers found that reduced poultry manure application rates reduced nitrate loss to water sources by nearly 10 kg per ha per year, or 4.02 kg per acre per year (Nguyen et al., "Long-Term Effects of Poultry Manure Application on Nitrate Leaching in Tile Drain Water," *American Society of Agricultural and Biological Engineers*, 2013). Incorporation and injection are found to reduce N loading by an average of 10% in the Chesapeake Bay (Chesapeake Bay Program, "Manure Incorporation and Injection Practices For Use in Phase 6.0 of the Chesapeake Bay Program Watershed Model" 2016). Manure land application on average loses 486 kg of nitrate per ha per year, or 197 kg per acre per year, to water sources (UC Davis, "Nitrogen Sources and Loading Groundwater," 2012). At 10% reduction would equate to 19.7 kg per acre per year in reduced nitrate pollution. The average of 4.02 kg nitrate per acre and 19.7 kg nitrate per acre is 11.86 kg per acre. In "The Social Costs of Nitrogen," Keeler et al. (2016) found the social cost of nitrogen pollution in water to be on average $0.01 per kg nitrate, based on water treatment costs.* In "Final Report - Low Cost Retrofits for Nitrogen Removal at Wastewater Treatment Plants in the Upper Long Island Sound

		Watershed" (2015) the Long Island Sound Study found that nitrate removal costs an average of $7.71 per kg of nitrate in 2022 dollars, amortized over ten years. Similarly, the EPA cited a cost of $8.82 per pound of nitrate removal in stormwater runoff (EPA, "A Compilation of Cost Data Associated with the Impacts and Control of Nutrient Pollution," 2015). The average of $7.71 per kg of nitrate and $0.01 per kg of nitrate is $3.86 per kg. 23.72 kg of nitrate per acre multiplied by $3.86 per kg of nitrate equals a total value of $45.77 per acre. *This is a low-end estimate and excludes potential health, recreational, or aesthetic values. More comprehensive estimates of the public cost of Nitrate in water sources would yield a higher water quality value for nutrient management.
Total	**$611**	

Lagoon Covers - Swine

Ecosystem Service	$/Animal Unit/Year	Citation
GHG Mitigation (at $51/tonne CO2e)	$138	The average uncovered emissions from a swine waste lagoon are 31kg per m3 per year. At 45 m3 required per AU, the baseline emissions are 1,395kg methane per AU per year (Kupper et. al., 2020). Kupper et al. (2020) determined that lagoon covers* reduce CH4 emissions by 8%. At an 8% reduction, implementing a cover reduces emissions by 111 kg per AU per year. When converted to CO2e per AU and converted to tonnes, the reduction is 2.7 tonnes per AU. At a value of $51 per tonne CO2e, the benefit is $138. *Cover types for which there was available methane data: lid (wood or concrete), plastic film, plastic fabrics, expanded clay, expanded polystyrene, plastic tiles, peat, straw cover, and vegetable oil.

Air Quality/ Human Health Benefits	$870	A covered lagoon saves 9lbs of ammonia from storage-related loss per head of swine ("Managing Manure to Improve Air and Water Quality," USDA ERS, 2005). Divided by 0.4 for animal unit conversion yields a value of 22.5lbs per AU. The public cost of ammonia emissions in the United States is $54,900 per ton NH3 (Heo et al., 2016), resulting in a per-animal unit benefit of $607. In "Ammonia and greenhouse gas emissions from slurry storage - A review," Kupper et al. (2020) determine that swine lagoon covers* tend to reduce ammonia emissions by an average of 71% compared to uncovered lagoons. The data suggests that covering lagoons reduces ammonia by 42 pounds per animal unit. Multiplied by $27 per lb ammonia is $1,134 per AU (Kupper et. al. 2020). The average of $607 per AU per yr and $1,134 per AU per yr equals $870 per AU per yr. *Cover types for which there was available ammonia data: lid (wood or concrete), tent covering, plastic film, plastic fabrics, expanded clay, expanded polystyrene, plastic tiles, peat, straw cover, and vegetable oil.
Total	**$1,008**	

Lagoon Covers - Dairy

Ecosystem Service	$/Animal Unit/Year	Citation
Methane emissions mitigation (at $51/tonne CO2e)	$61	In "Ammonia and greenhouse gas emissions from slurry storage - A review," Kupper et al. (2020) find that uncovered dairy lagoons emit 8.3 kg methane per m3 per year. Assuming 46 m3 per animal unit, methane emissions total 381 kg per animal unit per year. Assuming a 13% reduction in methane emissions from implementing a cover,* as per Kupper et al., emissions reductions total 50 kg per AU per year. Converting to tonnes of CO2e yields a value of 1.2 tonnes CO2e per AU per year. At $51 per tonne CO2e, the value of implementing a cover is $61 per AU per year. *Cover types for which there was available methane data: lid (wood or concrete), plastic fabrics, expanded clay, straw cover, and vegetable oil.

Carbon dioxide emissions mitigation (at $51/tonne CO2e)	$10	Kupper et. al. (2020) find that an uncovered dairy lagoon emits 58 kg per m2 per year, which equals 2.26 tonnes CO2e per animal unit per year if assuming 39 m2 per animal unit. Assuming that a lagoon cover* reduces CO2 emissions by 9% (Kupper et. al. 2020), the cover will reduce CO2 emissions by an average of 0.2 tonnes CO2 per AU per year when standardized. The benefit, at $51 per tonne, totals $10 per AU per year. *Cover types for which there was available CO2 data: plastic fabrics, expanded clay, straw cover, and vegetable oil.
Air Quality/ Human Health Benefits	$1,018	In "Ammonia and greenhouse gas emissions from slurry storage - A review," Kupper et. al. 2020 find that storage covers* on dairy waste lagoons tend to reduce ammonia emissions by an average of 75%. The average ammonia emissions from a dairy waste lagoon total 43 kg per animal unit per yr. A 75% reduction equals 71lbs per head per year. The public health cost of ammonia emissions in the United States is $54,900 per ton NH3 (Heo et al. 2016), resulting in a per-animal unit benefit of $1,917. In "Measurement of Atmospheric Ammonia, Methane, and Nitrous Oxide at a Concentrated Dairy Production Facility in Southern Idaho Using Open‑path Ftir Spectrometry," Bjorneberg et al. (2009) found that a waste lagoon on a dairy farm emitted 7.25kg of ammonia per day. When adjusted for an annual rate and divided by the herd size, emissions equal 3.7kg per head per year. At a 75% reduction rate from implementing a cover, the emissions reduce by 4.46lbs per AU per yr, creating a benefit of $120 per AU per yr. The average of $1,917 per AU per year and $120 per AU per year equals $1,018 per AU per year. *Cover types for which there was available ammonia data: lid (wood or concrete), tent covering, plastic film, plastic fabrics, expanded clay, plastic tiles, peat, straw cover, and vegetable oil.
Total	**$1,089**	

Forage and Biomass Planting

Ecosystem Service	$/Acre/Year	Citation
GHG mitigation (at $51/tonne CO2e)	$50	The USDA COMET-Planner Tool shows a national average GHG value of 0.95 tonnes CO2e per acre of forage and biomass

		planting. 0.97 tonnes CO2e per acre multiplied by $51 per tonne CO2e equals $50 per acre.
Water Quality - Nitrate Reduction	$235	Ribaudo et al. 2005 valued Nitrate reduction at $41.38 in 2020 dollars. Nitrate reduction for the Indian Creek Watershed was valued at $5.87 million. Mishra et.al., 2019, Valuation of Ecosystem Services in Alternative Bioenergy Landscape Scenarios. GCB-Bioenergy., Vol 11, Issue 6, pp. 748-762 https://doi.org/10.1111/gcbb.12602
Water Quality - Sediment Reduction	$2	Hansen and Ribaudo valued sediment reduction to be $4.69 per Mg in 2020 dollars. Mishra et.al., 2019, Valuation of Ecosystem Services in Alternative Bioenergy Landscape Scenarios. GCB-Bioenergy., Vol 11, Issue 6, pp. 748-762
Total	**$287**	

Prescribed Grazing

Ecosystem Service	**$/Acre/Year**	**Citation**
GHG Mitigation (at $51/tonne CO2e)	$8	The USDA COMET-Planner Tool shows a national average GHG value of 0.035 tonnes CO2e per acre of prescribed grazing. The high value was developed from Conant et al (2017)'s global meta-analysis, "Grassland management impacts on soil carbon stocks: a new synthesis," and estimation that the average sequestration rates for grazing were 0.28 Mg CO2e ha−1. The average value is 0.16 tonnes CO2e per acre per year.
Water Quality	$13	Follet et al.'s 2000 book, *The potential of US grazinglands to sequester carbon and mitigate the greenhouse effect*, cites that per USDA-NRI, in 1992 approximately 73.75% of grazing land erosion was due to water. A 2018 meta-study on rotational grazing (DeLonge, M., & Basche, A., "Managing grazing lands to improve soils and promote climate change adaptation and mitigation: a global synthesis," *Renewable Agriculture and Food Systems,* 2018) found that over 81.9% of reviewed rotational grazing studies identified infiltration rates increasing by 59.3 ± 7.3%; assuming approximately a 48.58% infiltration rate increase on average for new rotational grazing projects, an infiltration rate equal to total rainfall less any runoff, and a linear relationship between increased runoff and increased water erosion, this would overall decrease water erosion by approximately 51.42%.

		If the on-site and off-site costs are summed, erosion in general cost the United States a total of about $196 per ha in 1995 per the study "Environmental and Economic Costs of Soil Erosion and Conservation Benefits" (Pimentel, et al., 1995) of which 6 of 23 total tons per ha lost per year (26.08%) is from grazed lands ($51.13 total). If $37.71 per ha is due to water per Follet et al.'s 73.75% figure, water erosion would account for $15.26 per acre per year; associating that with the figure from DeLonge & Basche (2018) would roughly halve it to reach a $7.41 benefit from implementing the practice. Adjusted for inflation, this would equal $13.27 in 2021.
Biodiversity	$260	*Low Value* In the 2021 Rockefeller Foundation report "The True Cost of Food," pasture and rangeland in minimal use is defined as "Pasture with minimal input of fertilizer and pesticide, and with low stock density (not high enough to cause significant disturbance or to stop regeneration of vegetation)." Light use is defined as "Light Pasture either with significant input of fertilizer or pesticide, or with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation)." Intense use is defined as "Intense Pasture with significant input of fertilizer or pesticide, and with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation)." Each use level is associated with a coefficient of biodiversity impact (0.2, 0.4 and 0.7 respectively). The report proposes a whole-US monetization factor for the ecosystem service value provided by a higher degree of biodiversity, based on the True Price Foundation's estimation of the cost of "acidification, ecotoxicity, photochemical oxidant formation, nitrogen deposition, freshwater and marine eutrophication and ozone depleting emissions... opportunity cost of land use as opposed to the value of nature... valued using restoration costs, which uses loss of biodiversity as [potentially disappeared fractions of species per square meter per year] as an endpoint indicator." Numbers from U.S. land within each biome were averaged. Using this provided value, RIPE defined prescribed grazing as a move from "intense pasture" (which both uses fertilizers and disturbs forage) to "light pasture" (which may still use fertilizer but optimizes for maximum forage) to calculate the value in ecosystem services of the transition.

		High Value Though biodiversity studies and valuations are uncommon, high/low values can be obtained from the report itself by assuming both the lowest and highest possible benefits (a move from "intense pasture" to "minimal pasture") for carbon sequestration, for a value of $325.97 per acre.
Total	**$281**	

Silvopasture

Ecosystem Service	**$/Acre/Year**	**Citation**
GHG Mitigation (at $51/tonne CO2e)	$561	USDA COMET-Planner estimates a national average silvopasture GHG reduction value of 11 tonnes per acre. The value of CO2e mitigation is estimated at $51 per tonne.
*Silvopasture likely provides additional wildlife and water quality benefits that have not been quantified.		

Riparian Herbaceous Cover

Ecosystem Service	**$/Acre/Year**	**Citation**
GHG Mitigation (at $51/tonne CO2e)	$51	The USDA COMET-Planner tool demonstrates the average national level of GHG sequestration from riparian herbaceous covers equals 1 tonne CO2e per acre. At a value of $51 per tonne CO2e, the public benefit is $51 per acre.
Nutrient Retention	$31	Hui Xu, May Wu, and Miae Ha (2018). Recognizing economic value in multifunctional buffers in the lower Mississippi river basin in *Biofuels, Bioproducts and Biorefining,* published by Society of Chemical Industry and John Wiley & Sons, Ltd. This study values the nutrient retention from switchgrass buffers at $69 per ha, which is $27.4 per acre. This is $31 in 2021 dollars.
Water Quality - Sediment Reduction	$48	Herbaceous buffers reduced sediment loss by 0.8 tons per acre in the Mississippi Delta (1). Forest buffers provide a value of $12 per acre by reducing sediment by .2 tons (2). Therefore, the value of sediment reduction totals around $60 per ton. Multiplied by .8 tons, the value for herbaceous buffers totals $48 per ton. Sources: 1) Rempel, A. & Buckely, M. "The Economic Value of Riparian Buffers in the

		Delaware River Basin." Delaware Riverkeeper North. 2018. 2) Helmers, M.J. . Buffers and Vegetative Filter Strips. EPA. 2006.
Water Quality (Reduced Nutrient Transport)	$711	According to the report "The Economic Value of Riparian Buffers in the Delaware River Basin,"(2018) it costs $4-$58 ($5-$65 in 2022 dollars) to treat a pound of nitrogen in water. 20 to 40 pounds of nitrogen per acre per year move into shallow ground water sources under agricultural fields, according to NC State. Grass riparian buffers reduce nitrate in water by an average of 53%, or 10-21 pounds per acre per year, according to the EPA report "Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness" (Mayer et al., 2005). This results in a saved value of $44 to $1,378 per acre foot, or a mid-point of $711 per acre per year.
Flood Mitigation (wetlands)	$789	Rempel, A. & Buckely, M. "The Economic Value of Riparian Buffers in the Delaware River Basin." Delaware Riverkeeper North. 2018. This report demonstrates that wetlands, which can constitute riparian herbaceous buffers, provide flood attenuation benefits valued at $732 in 2017 dollars, or $845 in 2022 dollars.
Habitat Connectivity (pollinators)	$152	Rempel, A. & Buckely, M. "The Economic Value of Riparian Buffers in the Delaware River Basin." Delaware Riverkeeper North. 2018. This report demonstrates that protecting and restoring habitat for native pollinators can boost agricultural earnings on New Jersey tomatoes farms by $30 to $222 per acre in 2017 dollars. Averaged and converted to 2022 dollars, these values equal $152 per acre.
Total	**$1,782**	

Riparian Forest Buffer

Ecosystem Service	$/Acre/Year	Citation
GHG Mitigation (at $51/tonne CO2e)	$383	The USDA COMET-Planner demonstrates that riparian buffers reduce GHG emissions by a national average of 7.5 tons per acre. Multiplied by $51 per ton, this produces a value of $383 per acre.
Water Quality (Reduced Nutrient Transport)	$877	Rempel, A. & Buckely, M. (2018). "The Economic Value of Riparian Buffers in the Delaware River Basin." Delaware Riverkeeper North. This report lists the mid-range value of reduced nutrient delivery at $296-$1406 per acre. The mid-point of these mid-points is $851 per acre. Converted to 2022 dollars is $958 per acre.

Water Quality (Sediment Reductions)	$14	Rempel, A. & Buckely, M. "The Economic Value of Riparian Buffers in the Delaware River Basin." Delaware Riverkeeper North. 2018. This report lists the value of reduced sediment at $3-$21 per acre. The mid-point of these mid-points is $12 per acre. Converted to 2022 dollars is $14 per acre.
Drinking Water Source Protection	$3,000	Rempel, A. & Buckely, M. (2018). "The Economic Value of Riparian Buffers in the Delaware River Basin." Delaware Riverkeeper North. This report lists the value of drinking water source protection in Portland, Oregon at just under $3,000 per acre.
Air Quality (Human Health)	$6	Rempel, A. & Buckely, M. (2018). "The Economic Value of Riparian Buffers in the Delaware River Basin." Delaware Riverkeeper North. Converting riparian forest buffers to rural land produced a human health cost of $3 to $7, the midpoint of which is $5. In 2022 dollars this cost is $6.
Biodiversity	$150	Rempel, A. & Buckely, M. (2018). "The Economic Value of Riparian Buffers in the Delaware River Basin." Delaware Riverkeeper North. The value of pollination by native pollinators is $30-222 per acre, with a midpoint of $126. The value of pest control by foreign birds is listed as $7.34 per acre. Combined value of $133.34 per acre, or $150 in 2022 dollars.
Total	**$4,430**	

Alternate Wetting and Drying (Rice)

Ecosystem Service	**$/Acre/Year**	**Citation**
GHG Mitigation (at $51/tonne CO2e)	$98	The USDA study "Greenhouse Gas Emissions, Irrigation Water Use and Arsenic Concentrations; A Common Thread in Rice Water Management" by Merle, A. et al. (2014) finds that AWD in Arkansas reduces GHG emissions by 4,319 kg CO2 eq per ha. This equals 1.787 tonnes CO2e per acre. Multiplied by $51 per ton, this equals $91per acre. The study "Alternate Wetting And Drying Reduces Aquifer Withdrawal In Mississippi Rice Production Systems" by R. Lee Atwill, et al. (2020) finds that AWD reduces diesel costs by a baseline average of $83 per ha at a per liter cost of $.70. This equates to a 118L per ha diesel reduction, or 47.75 L per acres. Each liter of diesel emits .0026 tonnes of CO2 47.75 L per acre *

		.0026 tons per L equals .13 tons of CO2 per acre. Multiplied by $51 per ton of CO2, this equals $7 per acre.
Water Savings	$48	A 2014 USDA study, “Greenhouse Gas Emissions, Irrigation Water Use, and Arsenic Concentrations: A Common Thread in Rice Water Management” finds that AWD reduces water usage by 3560 m3 per ha, or 1.17 acre-feet. In the “Final Benefit-Cost Analysis for the Environmental Quality Incentives Program” (2010), NRCS values water savings at $41 per acre-foot in 2022 dollar values. $41 per acre-foot multiplied by 1.17 acre-feet equals $48 per acre.
Reduced Pesticide Runoff (water quality, human health, and biodiversity benefits)	$13	The environmental cost of pesticide application in the United States equals $19 per kg of pesticides in 2022 dollars due to reductions in water quality, biodiversity, and human health. (1). Around 0.77 kg per acre of pesticides are applied each year in California rice production (2). AWD reduces pesticide runoff by 89% or .68kg per acre (3). Multiplying .68kg per acre by the $19 per kg value totals $20 per acre. Sources: 1) D. Pimentel. “Environmental and Economic Costs of the Application of Pesticides Primarily in the United States.” Environment, Development, and Sustainability, vol. 7, 229-252. 2005. 2) California Department of Pesticide Regulation, Table 30. 3) Allen JM, Sander BO. “The Diverse Benefits of Alternate Wetting and Drying.” Los Baños, Philippines: International Rice Research Institute. 2020.
Total	**$159**	

Dry Seeding (Rice) - specific to California and regions south of I-10, as required by California Air Resources Board

Ecosystem Service	$/Acre/Year	Citation
GHG Mitigation (at $51/tonne CO2e)	$56	Low-end value: A 2020 report by the Environmental Defense Fund finds that replacing wet seeding with dry seeding, as approved by the California Air Resources Board, would reduce greenhouse gas emissions by 260,800 tCO2eq per year in the Sacramento Valley. NRCS demonstrates that 500,000 acres of rice are grown in this region. Therefore, dry seeding provides a GHG mitigation value of .47 tonnes CO2eq per acre. Multiplying this value by $51 per tonne CO2e equals $24 per acre. Sources:

		- Jeremy Proville, et al. “Agricultural Offset Potential in the United States.” EDF. April 2020. 1 - “Creating and Quantifying Carbon Credits from Voluntary Practices on Rice Farms in the Sacramento Valley: Accounting for Multiple Benefits for Producers and the Environment.” NRCS. 2010. High-end value: Methane: ● A 2015 study found that in California trials, dry-seeded rice reduced emissions by 149kg methane per ha compared to wet-seeded rice, or 1.5 tonnes of CO2e per acre. Multiplied by $51 per ton, this equals $77 per acre. Source: Maegan B. Simmonds, et al. “Modeling Methane and Nitrous Oxide Emissions from Direct-Seeded Rice Systems.” 2015. Nitrous Oxide: ● According to the Arkansas Rice Production Handbook, wet-seeded rice requires 25% more nitrogen fertilizer than dry-seeded rice. The handbook provides guidance for N application for dry-seeded rice at an average rate of 135 pounds N per acre or 61.23 kg N per acre. A 25% increase would thus equal 15kg N per acre. Keeler et al. (2016) find the social cost of N fertilizer to be at least $.5 per kg in each county of Minnesota due to N2O emissions. They derived this number using a SCC of $38 per metric of CO2e. Therefore, a SCC of $51 per metric of CO2e would convert $0.5 per kg of N to $.67 per kg of N. Multiplying 15kg N per acre by $.67 per kg N = $10 per acre. Sources: - Jarrod Hardke and Bob Scott. Water-Seeded Rice, “Arkansas Rice Production Handbook.” 2018. - - Trenton Roberts, et al. Soil Fertility, “Arkansas Rice Production Handbook.” 2018. - Bonnie L. Keeler, et al. “The Social Costs of Nitrogen.” 2016.
Water Savings	$9	Lunquist et al. (2015) found a mean water use reduction of 271.5 fewer cubed meters per acre, or .22 acre-feet, for dry-seeded rice

		compared to wet-seeded rice in California. NRCS values water savings at $41 per acre-foot in 2022 dollar values. Multiplying the two values equals $9 per acre. Sources: - Bruce Linquist, et al. "Water Balances and Evapotranspiration in Water- and Dry-Seeded Systems." 2016. - "Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP)." NRCS. 2010.
Air Quality (Human Health)	$79	According to the Arkansas Rice Production Handbook, wet-seeded rice requires 25% more nitrogen fertilizer than dry-seeded rice. The handbook provides guidance for N application for dry-seeded rice at an average rate of 135 pounds N per acre, or 61.23 kg N per acre. A 25% increase would thus equal 15kg N per acre. Keeler et al. (2016) estimate that the human health cost of N fertilizer in equals $4.75 per kg of N fertilizer, or $5.24 per kg N in 2021 dollars. Multiplying 15kg N per acre by $5.24 per kg equals $78.60 per acre. Sources: - Jarrod Hardke and Bob Scott. Water-Seeded Rice, "Arkansas Rice Production Handbook." 2018. - Trenton Roberts, et al. Soil Fertility, "Arkansas Rice Production Handbook." 2018. - Bonnie L. Keeler, et al. "The Social Costs of Nitrogen." *Science Advances*. 2016. Note: Additional international sources indicate increased nitrogen use efficiency for dry seeded rice compared to transplant-flooded rice (e.g., 6-26% increased NUE according to Liu et al., 2014).
Total	**$144**	

Post-Harvest Flood With Early Drainage (Rice)

Ecosystem Service	**$/Acre/Year**	**Citation**
GHG Mitigation ($51/tonne CO2e)	$37	A 2010 NRCS report indicates that winter flooding combined with midseason drainage reduces GHG emissions by 0.73 tonnes CO2e per acre compared to a baseline of only winter flooding or only residue incorporation. 0.73 metric tons CO2e per acre

		multiplied by $51 per tonne CO2e equals $37/acre. Source: "Creating and Quantifying Carbon Credits From Voluntary Practices on Rice Farms in the Sacramento Valley: Accounting for Multiple Benefits for Producers and the Environment." NRCS. 2010. www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044916.pdf
Water Quality - Reduced Herbicide (Post-Harvest Flood)	$5	A Mississippi State University report shows that post-harvest flooding reduced herbicide costs by $13.19 per acre in 1999, which equates to $24 in 2022 dollars. According to the Arkansas Rice Production Handbook, the average cost of herbicide for the region in 2001 was $69 per acre in 2022 dollars. This equates to a 32% reduction in herbicide application. Around 0.77kg per acre of pesticides are applied each year in California rice production. 32% of 0.77 equals 0.24 kg per acre. A 2005 study shows that 1 kg herbicide costs society $19 in reductions in water quality, biodiversity, and human health. $19 per kg of herbicide multiplied by 0.24 kg/acre = $5/acre. Sources: - Richard Kaminski, et al. "Winter-Flooded Rice Fields Provide Waterfowl Habitat and Agricultural Values." Mississippi State University. 1999. www.fwrc.msstate.edu/pubs/ricefields.pdf - Jarrod Hardke, et al. Rice Research and Verification Program. Arkansas Rice Production Handbook. 2018. www.uaex.uada.edu/publications/pdf/mp192/mp192.pdf - Summary of Pesticide Use Report Data 2017. California Department of Pesticide Regulation. 2017. - David Pimentel. "Environmental and Economic Costs of the Application of Pesticides Primarily in the United States." Environment, Development, and Sustainability. 2005.

Water Quality - Reduced Polluted Water Export (Post-Harvest Flood)	$481	Nitrate-removal systems in Minnesota caused supply costs to rise from 5 to 10 cents per 1,000 gallons to over $4 per 1,000 gallons. A 2009 study by Scott Manley, et al. finds that flooded fields reduce water export by 1155 m3 per ha, or 123,477 gallons per acre. The study also finds that flooded fields reduced nitrate export by .10 kg per ha (100% reduction rate). Therefore, the amount of polluted water entering local water sources would reduce by 123,477 gallons/acre. This water would not need to be treated for nitrate removal. Multiplied by $3.9 per 1,000 gallons, this reduction in polluted water equals $481 per acre. Sources: - Nutrient Pollution. EPA. Accessed 2021. - Manley et al. “Soil and Nutrient Retention in Winter-Flooded Ricefields with Implications for Watershed Management.” Journal of Soil and Water Conservation. 2009. www.jswconline.org/content/64/3/173
Reduced Soil Erosion (Post-Harvest Flood)	$4	According to a Mississippi State University report, fall-disked fields allowed to drain freely after winter rains lost about 1,000 pounds of soil per acre. Fields with drain pipes closed to impound water during winter and with stubble left undisturbed after harvest lost only 31 pounds of soil per acre. With post-harvest flood, soil savings thus equal 969 pounds per acre, or .5 tons per acre. NRCS values reduction in soil loss at $9 per ton in 2021 dollars, which when multiplied by 0.5 tons per acre equals $4.50 per acre. Source: - Richard Kaminski, et al. “Winter-Flooded Rice Fields Provide Waterfowl Habitat and Agricultural Values.” Mississippi State University. 1999. - “Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP).” NRCS. 2010.
Total	**$527**	

Post-Harvest Flood with Dry Seeding (Rice) - specific to California and regions south of I-10, as required by California Air Resources Board

Ecosystem Service	**$/Acre/Year**	**Citation**

Climate Change Mitigation ($51/tonne CO2e)	$10	A 2010 NRCS report indicates that winter flooding combined with dry seeding reduces GHG emissions by 0.20 metric tons CO2e per acre compared to a baseline of only winter flooding and/or residue incorporation. 0.20 metric tons CO2e/acre multiplied by $51 per metric ton CO2e equals $10/acre. Source: "Creating and Quantifying Carbon Credits from Voluntary Practices on Rice Farms in the Sacramento Valley: Accounting for Multiple Benefits for Producers and the Environment." NRCS. 2010.
Water Quality - Reduced Herbicide (Post-Harvest Flood)	$6	A Mississippi State University report shows that post-harvest flooding reduced herbicide costs by $13.19 per acre in 1999, which equates to $24 in 2022 dollars. According to the Arkansas Rice Production Handbook, the average cost of herbicide for the region in 2001 was $69 per acre in 2022 dollars. This equates to a 32% reduction in herbicide application. Around 0.77kg per acre of pesticides are applied each year in California rice production. 32% of 0.77 equals 0.24 kg per acre. A 2005 study shows that 1 kg herbicide costs society $19 in reductions in water quality, biodiversity, and human health. $19 per kg of herbicide multiplied by 0.24 kg/acre = $6/acre. Sources: - Richard Kaminski, et al. "Winter-Flooded Rice Fields Provide Waterfowl Habitat and Agricultural Values." Mississippi State University. 1999. www.fwrc.msstate.edu/pubs/ricefields.pdf - Jarrod Hardke, et al. Rice Research and Verification Program. Arkansas Rice Production Handbook. 2018. www.uaex.uada.edu/publications/pdf/mp192/mp192.pdf - Summary of Pesticide Use Report Data 2017. California Department of Pesticide Regulation. 2017. - David Pimentel. "Environmental and Economic Costs of the Application of Pesticides Primarily in the United States." Environment, Development, and Sustainability. 2005.
Water Quality - Reduced Polluted Water Export (Post-Harvest Flood)	$481	Nitrate-removal systems in Minnesota caused supply costs to rise from 5 to 10 cents per 1,000 gallons to over $4 per 1,000 gallons. A 2009 study by Scott Manley, et al. finds that flooded fields reduce water export by 1155 m3 per ha, or 123,477 gallons per acre. The study also finds that flooded fields reduced nitrate

		export by .10 kg per ha (100% reduction rate). Therefore, the amount of polluted water entering local water sources would reduce by 123,477 gallons/acre. This water would not need to be treated for nitrate removal. Multiplied by $3.9 per 1,000 gallons, this reduction in polluted water equals $481 per acre. Sources: - Nutrient Pollution. EPA. Accessed 2021. - Manley et al. "Soil and Nutrient Retention in Winter-Flooded Ricefields with Implications for Watershed Management." Journal of Soil and Water Conservation. 2009. www.jswconline.org/content/64/3/173
Water Quality - Reduced Soil Erosion (Post-Harvest Flood)	$4	According to a Mississippi State University report, fall-disked fields allowed to drain freely after winter rains lost about 1,000 pounds of soil per acre. Fields with drain pipes closed to impound water during winter and with stubble left undisturbed after harvest lost only 31 pounds of soil per acre. With post-harvest flood, soil savings thus equal 969 pounds per acre, or .5 tons per acre. NRCS values reduction in soil loss at $7 per ton in 2021 dollars, which when multiplied by 0.5 tons per acre equals $4 per acre. Source: - Richard Kaminski, et al. "Winter-Flooded Rice Fields Provide Waterfowl Habitat and Agricultural Values." Mississippi State University. 1999. - "Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP)." NRCS. 2010.
Water Savings (Dry Seeding)	$9	A 2015 study shows a mean water use reduction of 271.5 fewer cubed meters per acre, or .22 acre-feet, for dry-seeded rice compared to wet-seeded rice in California. NRCS values water savings at $41 per acre-foot in 2022 dollar values. Multiplying the two values equals $9 per acre. Sources: - Bruce Linquist, et al. "Water Balances and Evapotranspiration in Water- and Dry-Seeded Systems." 2016. - "Final Benefit-Cost Analysis for the Environmental Quality Incentives Program (EQIP)." NRCS. 2010.
Air Quality - Human	$79	According to the Arkansas Rice Production Handbook,

Health (Dry Seeding)		wet-seeded rice requires 25% more nitrogen fertilizer than dry-seeded rice. The handbook provides guidance for N application for dry-seeded rice at an average rate of 135 pounds N per acre, or 61.23 kg N per acre. A 25% increase would thus equal 15kg N per acre. Keeler et al. (2016) found the human health cost of N fertilizer in each county of Minnesota due to NH3 emissions. The average cost in a single county was $4.75 per kg of N fertilizer, or $5.24 per kg N in 2021 dollars. Multiplying 15kg N per acre by $5.24 per kg = $78.60 per acre. Sources: - Jarrod Hardke and Bob Scott. Water-Seeded Rice, Arkansas Rice Production Handbook. 2018. - Trenton Roberts, et al. Soil Fertility, Arkansas Rice Production Handbook. 2018. - Keeler, et al. "The Social Costs of Nitrogen." *Science Advances*. 2016. Note: Additional international sources indicate increased nitrogen use efficiency for dry seeded rice compared to transplant-flooded rice (e.g., 6-26% increased NUE according to Liu et al., 2014).
Total	**$589**	

Feed Management - Beef

Ecosystem Service	**$/Animal Unit/Year**	**Citation**
GHG Mitigation (at $51/tonne CO2e)	$26	The meta-analysis "Mitigating Greenhouse Gas and Ammonia Emissions from Beef Cattle Feedlot Production: A System Meta-Analysis," (Wang et al., *Environ. Sci. Technol.,* 2018) provides data on the mitigation of greenhouse gas emissions in beef cattle from to feed additives and feed management. The value of CO2e mitigation is estimated at $51 per tonne.
Air Quality Benefits (Human Health)	$679	The meta-analysis "Mitigating Greenhouse Gas and Ammonia Emissions from Beef Cattle Feedlot Production: A System Meta-Analysis" (Wang et al., *Environ. Sci. Technol.*, 2018) provides data on the mitigation of ammonia emissions in beef cattle from to feed additives and feed management. The average public health cost of ammonia is $54,000 per ton NH3 in 2022 dollars (Heo et al., "Public Health Costs of Primary

		PM2.5 and Inorganic PM2.5 Precursor Emissions in the United States," *Environ. Sci. Technol.*, 2016).
Total	**$705**	

Feed Management - Swine

Ecosystem Service	**$/Animal Unit/Year**	**Citation**
Air Quality Benefits (Human Health)	$274	In "Mitigation of ammonia emissions from pig production using reduced dietary crude protein with amino acid supplementation," Liu et al. (2017) found that swine fed a lower CP diet emitted on average 0.005 fewer tons of ammonia per AU per year. The public health cost of ammonia is $54,900 per ton NH3 in 2022 dollars (Heo et al., "Public Health Costs of Primary PM2.5 and Inorganic PM2.5 Precursor Emissions in the United States," *Environ. Sci. Technol.*, 2016).
Total	**$274**	

Feed Management - Dairy

Ecosystem Service	**$/Animal Unit/Year**	**Citation**
GHG Mitigation (at $51/tonne CO2e)	$31	In "Gas Emissions from Dairy Cows Fed Typical Diets of Midwest, South, and West Regions of the United States," Liu et al. (2012) found that dairy cows fed a reduced crude protein (CP) diet emitted 0.6 fewer tonnes CO2e. This equates to $31 per AU at $51 per tonne.
Air Quality Benefits (Human Health)	$165	Dairy cows in the United States fed a reduced CP diet emitted up to 39% less ammonia, or an average of .003 fewer tons per AU per year (Liu et al., "Gas Emissions from Dairy Cows Fed Typical Diets of Midwest, South, and West Regions of the United States," *Journal of Environmental Quality,* 2012). The public cost of ammonia emissions in the United States is $54,900 per ton NH3 in 2022 dollars (Heo, et al., "Public Health Costs of Primary PM2.5 and Inorganic PM2.5 Precursor Emissions in the United States," *Environ. Sci. Technol.*, 2016).
Total	**$196**	

Feed Management - Poultry

Ecosystem Service	**$/Animal Unit/Year**	**Citation**
GHG Mitigation (at $51/tonne CO2e)	$5	Cappelaere, et al. "Amino Acid Supplementation to Reduce Environmental Impacts of Broiler and Pig Production: A Review." 2021. The value of CO2e is estimated at $51 per tonne.
Air Quality Benefits (Human Health)	$167	Cappelaere, et al."Amino Acid Supplementation to Reduce Environmental Impacts of Broiler and Pig Production: A Review." *Front. Vet. Sci.* 2021. Van Emous, et al. "Effects of dietary crude protein levels on ammonia emission, litter and manure composition, N losses, and water intake in broiler breeders." Poultry Science. 2019. The public health cost of ammonia is $54,900 per ton NH3 in 2022 dollars (Heo et al., "Public Health Costs of Primary PM2.5 and Inorganic PM2.5 Precursor Emissions in the United States," *Environ. Sci. Technol.*, 2016). Russ & Schaeffer. "Ammonia Emissions from Broiler Operations Higher than Previously Thought." Environmental Integrity Project. 2017.
Total	**$172**	