Rice LCAs for Arkansas: A simple overview of a complex process

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Four Phases of a Life Cycle Assessment



Every process has inputs and outputs Energy Water **Raw Materials** Manufacturing **Raw Materials** One pt of Glyphosate Process of Glyphosate **Raw Materials** Gas Waste Solid Waste Liquid Waste

The more processes, the more complexity





This inventory is important (it's like the "recipe") if you leave something out, your absolute LCA will be subject to omitted variable bias.

LCA software

- Most LCAs are conducted using pre-populated production methods that have been academically vetted.
 - For instance, in SimaPro, there is a vetted rice production database for China
 - When we want to run an LCA for Arkansas, we have to go into SimaPro "calibrate" variables for Arkansas production processes.
 - These calibration methods are usually taken from production budgets, such as those put out by the Division of Agriculture.

Absolute vs Relative LCA

- Creating an <u>Absolute LCA</u> is difficult. You must pin down everything in the production process and where the inputs were created.
- I have used <u>Relative</u> LCAs in my research.
 - That is, instead of worrying about what country the potash used in production came from, I focused on differences in production practices and find the relative differences
 - Row rice vs conventional irrigation



Absolute values are important but when comparing two things (trucks or rice production practices) relative comparisons are used in decision making.

Previous Rice Arkansas Rice LCAs

- 1- Blast resistant vs. non-Blast resistant varieties
- 2- Impact of Newpath resistance
- 3- Impact of the adoption of NSTaR nitrogen testing
- 4- MIRRI vs Conventional irrigation
- 5- Furrow Irrigated Rice vs Conventional Irrigation
- 6- Hybrid vs Purebred Rice Variaties

Furrow Irrigated Rice

Enterprise budget for conventional irrigated rice (CIR) and furrow irrigated rice (FIR).

	Unit	Conventiona	al Irrigation (CIR)		Furrow-irriga	ted (FIR)	
Revenue							
Yield	Metric ton/ha			9.58			9.58
Price	\$/metric ton			245.10			245.10
Total Revenue (\$/ha)	\$/ha			2347.42			2347.42
Operating Expense		Amount	Price	Costs	Amount	Price	Costs
Seed, feld	Ha	1.00	337.02	337.02	1.00	337.02	337.02
Seed, levees	На	1.00	62.27	62.27	0.00	0.00	0.00
Nitrogen	Kg/ha	68.86	0.84	142.54	89.72	0.84	185.73
Phosphate	Kg/ha	39.46	0.43	41.49	39.46	0.43	41.49
Potash	Kg/ha	45.36	0.38	42.75	45.36	0.38	42.75
Agrotain	На	1.00	25.38	25.38	1.00	25.38	25.38
Herbicide	На	1.00	276.55	276.55	1.00	338.32	338.32
Insecticide	На	1.00	4.32	4.32	1.00	4.32	4.32
Fungicide	На	1.00	14.83	14.83	1.00	14.83	14.83
Ground Apps	На	0.00	18.53	0.00	2.00	18.53	37.06
Air Apps	На	3.00	19.77	59.30	2.00	19.77	39.54
Air App. Lbs	Kg/ha	369.87	0.18	65.23	481.96	0.18	85.00
Diesel, Pre-Post Harvest	Liter/ha	40.81	0.50	20.48	24.86	0.50	12.48
Repair & Maint.	На	1.00	16.56	16.56	1.00	13.37	13.37
Diesel, Harvest	Liter/ha	28.83	0.50	14.47	28.83	0.50	14.47
Repair & Maint.	На	1.00	28.17	28.17	1.00	28.17	28.17
Irrigation Energy	Cm/ha	76.20	2.18	166.05	63.50	2.18	138.37
Irrigation System	Cm/ha Repair & Maint.	76.20	0.23	17.79	63.50	0.23	14.83
Supplies (pipe)	На	0.00	0.00	0.00	1.00	9.59	9.59
Survey/Mark Levees	На	1.00	11.12	11.12	0.00	0.00	0.00
Levee Gates	На	1.00	1.73	1.73	0.00	0.00	0.00
Labor, Field	Hours/ha	0.91	28.00	25.45	0.67	28.00	18.76
Drain Field	На	1.00	7.41	7.41	0.00	0.00	0.00
Scouting Fee	На	1.00	19.77	19.77	1.00	19.77	19.77
Crop Insurance	На	1.00	24.71	24.71	1.00	24.71	24.71
Interest	96	5.50 %	1425.38	39.20	5.50 %	1445.94	39.76
Drving	Metric ton	9.58	19.61	187.79	9.58	19.61	187.79
Hauling	Metric ton	9.58	9.31	89.20	9.58	9.31	89.20
Check Off	Metric ton	9.58	0.66	6.34	9.58	0.66	6.34
Total Operating Expenses	hieldre ton		0.00	1747.91		0100	1769.04
Returns to On Exp				599.51			578.38
Machine & Equin	На	1.00	190.29	190.29	1.00	161.26	161.26
Irrigation Equip	Ha	1.00	102.59	102.59	1.00	102.59	102.59
Farm Overhead	Ha	1.00	9.51	9.51	1.00	8.06	8.06
Total Capital Rec & Fixed Costs	2.24L	1.00	7.01	302.40	1.00	0.00	271 01
Total Expenses				2050.30			2040.04
Net Returns	\$/Ha			2030.30			306.48
Het focturins	dy itel			277.11			300.40

Source: Hardke (2020).

FIR Environmental Metrics



Fig. 1. Greenhouse gas emissions per kg of rice produced by conventionally-irrigated rice (CIR) and furrow-irrigated rice (FIR) under three yield loss (% relative to CIR) scenarios.

Typically, LCAs will standardize into a single metric, like CO_2e , like in the figure above.

However, with a Stepwise LCA, we can use USD as our metric.

Results (Environmental)



Environmental impact scores (2018 USD/kg) using a stepwise lifecycle impact assessment method. The single score is the sum of monetary cost of all impact categories.

Gridpoint impact scores Single Score 2018 USD \$ 0.253 \$ 0.264 \$ 0.273 \$ 0.284 Difference from CR 2018 USD - \$ 0.010 \$ 0.019 \$ 0.031 Midpoint impact scores - \$ 0.010 \$ 0.019 \$ 0.024 Human toxicity, carcinogens kg C2H3CLeq 8.96E.03 9.31E.03 9.65E.03 1.01E.02 Human toxicity, non-care. kg C2H3CLeq 8.96E.03 9.017 \$ 0.013 \$ 0.0040 Human toxicity, non-care. kg C2H3CLeq 4.59E.02 4.095.02 4.28E.02 4.52E.02 Ionizing radiation Bq C 14.eq 3.041+00 3.4E-00 3.042+00 3.6E+00 3.6E+00 Ozone layer depletion kg CPC11-eq 4.36E.08 4.300:08 4.00007 \$ 0.00007 \$ 0.00001 Ecotoxicity, aquatic kg TEG-eq.w 3.34E+01 3.11E+01 3.26E+101 3.43E+01 S 0.004 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00001 Ecotoxicity, aquatic kg TEG-eq.w 3.34E+01 3.11E+01	Impact categories	Unit per kg	CIR	FIR	FIR	FIR
				(0 % yield penalty) ^a	(4.67 % yield penalty) ⁶	(10 % yield penalty)
Single Score 2018 USD 5 0.233 5 0.264 5 0.273 8 0.284 Difference from CIR 2018 USD - 5 0.010 \$ 0.019 \$ 0.031 Midpoint Impact Scores - 5 0.010 \$ 0.019 \$ 0.031 Human toxicity, carcinogens kg C2H3CLeq 8.96E.03 9.031E.03 9.65E.03 1.01E.02 Human toxicity, non-care. kg C2H3CLeq 4.59E.02 4.095.02 4.28E.02 4.52E.02 Intrant toxicity, non-care. kg C2H3CLeq 1.01E.03 1.15E.03 1.19E.03 1.24E.03 Respiratory inorganics kg PM2.5-eq 1.10E.03 1.15E.03 1.19E.03 1.24E.03 Ionizing radiation Bq C 14.eq 3.4E+00 3.4E+00 3.45E+00 3.6E+00 Corone layer depletion kg TGF eq.w 3.36E+01 5 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.00007 \$ 0.000007 \$ 0.00001 <t< td=""><td>Endpoint impact scores</td><td></td><td></td><td></td><td></td><td></td></t<>	Endpoint impact scores					
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		· ·	S -	\$ -	S -	\$ -
x_{c}	Global warming, fossil	kg CO2-eq	6.77E-01	7.37E-01	7.62E-01	7.93E-01
Acidification m2 UES 9.82E-02 1.11E-01 1.15E-01 1.20E-01 Eutrophication, aquatic kg N03-eq 6.94E-03 7.03E-03 7.10E-03 7.18E-03 Eutrophication, aquatic kg N03-eq 6.94E-03 7.03E-03 7.10E-03 7.18E-03 Eutrophication, terrestrial m2 UES 2.87E-01 3.46E-01 3.62E-01 3.82E-01 Eutrophication, terrestrial m2 UES 2.87E-01 3.46E-01 3.62E-01 3.82E-01 Respiratory organics pers ppm-h 7.09E-04 5.58E-04 5.80E-04 7.02E+00 Photochemical ozone, vegetat. m2 ppm-hours 7.66E+00 6.46E+00 6.71E+00 7.02E+00 Non-renewable energy MJ-primary 6.52E+00 6.54E+00 6.75E+00 7.00E+00 \$- \$- \$- \$- \$- \$- Mineral extraction MJ-extra 1.82E-02 1.79E-02 1.87E-02 1.87E-02		· ·	\$ 0.0848	\$ 0.0922	\$ 0.0954	\$ 0.09924
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Acidification	m2 UES	9.82E-02	1.11E-01	1.15E-01	1.20E-01
Eutrophication, aquatic kg NO3-eq 6.94E-03 7.03E-03 7.10E-03 7.18E-03 Eutrophication, terrestrial m2 UES 2.87E-01 3.46E-01 3.62E-01 3.82E-01 Eutrophication, terrestrial m2 UES 2.87E-01 3.46E-01 3.62E-01 3.82E-01 Respiratory organics pers ppm-h 7.09E-04 \$0.0065 \$0.0002 \$0.00024 Photochemical ozone, vegetat. m2 ppm-hours 7.66E+00 6.46E+00 6.71E+00 \$0.0033 \$0.0036 \$0.0038 \$0.00393 Non-renewable energy MJ-primary 6.52E+00 6.54E+00 6.75E+00 7.09E+00 % - \$- \$- \$- \$- \$- \$- Mineral extraction MJ-extra 1.82E-02 1.79E-02 \$.87E-02 1.96E-02			\$ 0.0011	\$ 0.0013	\$ 0.0013	\$ 0.00140
Image: And the strength Solution Soluti	Eutrophication, aquatic	kg NO3-eq	6.94E-03	7.03E-03	7.10E-03	7.18E-03
Eutrophication, terrestrial m2 UES $2.87E-01$ $3.46E-01$ $3.62E-01$ $3.82E-01$ Respiratory organics pers ppm-h 5.00054 $$0.00655$ $$0.0068$ $$0.00712$ Respiratory organics pers ppm-h $7.09E-04$ $5.58E-04$ $5.80E-04$ $7.02E+00$ Photochemical ozone, vegetat. m2 ppm-hours $7.66E+00$ $6.46E+00$ $6.71E+00$ $7.02E+00$ Non-renewable energy MJ-primary $6.52E+00$ $6.54E+00$ $6.75E+00$ $7.00E+00$ Nineral extraction MJ-extra $1.82E-02$ $1.79E-02$ $1.87E-02$ $1.96E-02$ Non-renewable MJ-extra $1.82E-02$ $1.79E-02$ $1.87E-02$ $1.96E-02$		0 1	\$ 0.0011	\$ 0.0011	\$ 0.0011	\$ 0.00110
************************************	Eutrophication, terrestrial	m2 UES	2.87E-01	3.46E-01	3.62E-01	3.82E-01
Respiratory organics pers ppm-h 7.09E-04 5.58E-04 5.80E-04 7.02E+00 Photochemical ozone, vegetat. m2 ppm-hours 7.66E+00 6.46E+00 6.71E+00 7.02E+00 Non-renewable energy MJ-primary 6.52E+00 6.54E+00 6.75E+00 7.00E+00 \$ - \$ - \$ - \$ - \$ - \$ - Mineral extraction MJ-extra 1.82E-02 1.79E-02 1.87E-02 1.96E-02 \$ 0.0001 \$ 0.0001 \$ 0.0001 \$ 0.0001 \$ 0.0001 \$ 0.00012	1		\$ 0.0054	\$ 0.0065	\$ 0.0068	\$ 0.00712
\$ 0.0003 \$ 0.0002 \$ 0.0002 \$ 0.00024 Photochemical ozone, vegetat. m2 ppm-hours 7.66E+00 6.46E+00 6.71E+00 7.02E+00 \$ 0.0043 \$ 0.0036 \$ 0.0038 \$ 0.00393 Non-renewable energy MJ-primary 6.52E+00 6.54E+00 6.75E+00 7.00E+00 \$ - \$ - \$ - \$ - \$ - \$ - Mineral extraction MJ-extra 1.82E-02 1.79E-02 1.87E-02 1.96E-02 \$ 0.0001 \$ 0.0001 \$ 0.0001 \$ 0.00012 1.96E-02	Respiratory organics	pers ppm-h	7.09E-04	5.58E-04	5.80E-04	7.02E+00
Photochemical ozone, vegetat. m2 ppm-hours 7.66E+00 6.46E+00 6.71E+00 7.02E+00 \$ 0.0043 \$ 0.0036 \$ 0.0038 \$ 0.00393 \$ 0.00393 Non-renewable energy MJ-primary 6.52E+00 6.54E+00 6.75E+00 7.00E+00 \$ - \$ - \$ - \$ - \$ - \$ - Mineral extraction MJ-extra 1.82E-02 1.79E-02 1.87E-02 1.96E-02 \$ 0.0001 \$ 0.0001 \$ 0.0001 \$ 0.00012 \$ 0.00012	1	I I I	\$ 0.0003	\$ 0.0002	\$ 0.0002	\$ 0.00024
\$ 0.0043 \$ 0.0036 \$ 0.0038 \$ 0.00393 Non-renewable energy MJ-primary 6.52E+00 6.54E+00 6.75E+00 7.00E+00 \$ - \$ - \$ - \$ - \$ - \$ - Mineral extraction MJ-extra 1.82E-02 1.79E-02 1.87E-02 1.96E-02 \$ 0.0001 \$ 0.0001 \$ 0.00012 \$ 0.00012	Photochemical ozone, vegetat.	m2 ppm-hours	7.66E+00	6.46E+00	6.71E+00	7.02E+00
Non-renewable energy MJ-primary 6.52E+00 6.54E+00 6.75E+00 7.00E+00 \$- \$- \$- \$- \$- \$- \$- Mineral extraction MJ-extra 1.82E-02 1.79E-02 1.87E-02 1.96E-02 \$0.0001 \$0.0001 \$0.0001 \$0.00012	, 0		\$ 0.0043	\$ 0.0036	\$ 0.0038	\$ 0.00393
S - S - <td>Non-renewable energy</td> <td>MJ-primary</td> <td>6.52E + 00</td> <td>6.54E+00</td> <td>6.75E+00</td> <td>7.00E+00</td>	Non-renewable energy	MJ-primary	6.52E + 00	6.54E+00	6.75E+00	7.00E+00
Mineral extraction MJ-extra 1.82E-02 1.79E-02 1.87E-02 1.96E-02 \$ 0.0001 \$ 0.0001 \$ 0.0001 \$ 0.00012		···· .	S -	\$ -	\$ -	\$ -
\$ 0.0001 \$ 0.0001 \$ 0.0001 \$ 0.00012	Mineral extraction	MJ-extra	1.82E-02	1.79E-02	1.87E-02	1.96E-02
			\$ 0.0001	\$ 0.0001	\$ 0.0001	\$ 0,00012

The single score is the sum of the monetary costs of all impact categories.

Results Furrow Irrigated

ivironmental damage comparisons of conventional irrigated rice (CIR) to furrow irrigated rice (FIR) assuming full adoption to provide the 2021 Arkansas rice crop

	CIR	FIR (no yield penalty)	FIR (4.67 % yield penalty)	FIR (10 % yield penalty)
CA Single Scores ^a	\$ 0.253	\$ 0.264	\$ 0.273	\$ 0.284
Yield	9583	9583	9136	8625
Hectares needed for 2021 Arkansas Crop ^b	431,209	431,209	452,307	479,104
Environmental Cost for 2021 Rice Crop ^e	\$ 1,047,523,812	\$ 1,089,270,895	\$ 1,127,049,374	\$ 1,173,630,433
Difference compared to CIR	-	\$ 41,747,083	\$ 79,525,561	\$ 126,106,620

- These results are from an initial LCA on Furrow irrigated rice and more input on what producers are doing is needed. However; the results highlight the issue that LCAs can present:
 - A production practice that uses less water
 - Or a production practice that may have higher overall environmental impacts
 - Not all environmental metrics move in the same direction!

NSTaR LCA

A total of 1,117 rice producers' N samples were analyzed and subsequently given a N recommendation by the N-STaR program and compared to the blanket recommendation of 180 lbs/ac for clay soils and 150 lbs/ac for silt loam soils

Ecosystem Impact Scores Using Stepwise Life Cycle Analysis per Kg of Rice Produced Conventional Nitrogen (N) Recommendations (Baseline) and N-STaR Production

Impact categories	Unit	Scenarios		
		Baseline	N-STaR	
End point impact scores				
Single Scores	US\$ 2018	0.3734	0.3603ª	
Global warming, fossil	US\$ 2018	0.1977	0.1912	
Mid point impact scores				
Human toxicity, carcinogons	kg C2H3Cl-eq	9.65E-03	8.94E-03	
numan toxicity, carcinogens	US\$ 2018	3.84E-03	3.56E-03	
Human toxicity, non-care	kg C2H3Cl-eq	5.65E-02	5.61E-02	
Human toxicity, non-care.	US\$ 2018	2.31E-02	2.29E-02	
Pospiratory inorganics	kg PM2.5-eq	1.08E-03	1.03E-03	
Respiratory morganics	US\$ 2018	1.11E-01	1.05E-01	
Ionizing radiation	Bq C 14.eq	3.55E+00	3.46E+00	
	US\$ 2018	1.07E-04	1.04E-04	
Ozona lawar deplotion	kg CFC11-eq	7.65E-08	7.41E-08	
	US\$ 2018	1.19E-05	1.15E-05	
Ecotovicity aquatic	kg TEG-eq.w	3.10E+01	3.06E+01	
	US\$ 2018	3.44E-04	3.40E-04	
Ecotovicity torrostrial	kg TEG-eq.s	2.55E+00	2.43E+00	
	US\$ 2018	4.25E-03	4.06E-03	
Nature occupation	m2 years-agr	8.78E-02	8.77E-02	
	US\$ 2018	1.64E-02	1.64E-02	
Global warming non-fossil	kg CO2-eq	1.38E+00	1.38E+00	
	US\$ 2018	0.00E+00	0.00E+00	
Global warming fossil	kg CO2-eq	1.58E+00	1.53E+00	
Giobar warming, iossii	US\$ 2018	1.98E-01	1.91E-01	
Acidification	m2 UES	7.59E-02	6.98E-02	
Actometion	US\$ 2018	8.86E-04	8.14E-04	

- The LCA single score for a kg of traditional rice is estimated at \$0.3734, and for N-STaR, it was estimated at \$0.3603, a reduction of \$0.0131 for every kg of rice produced with N-STaR.
- That's \$0.27 per bushel or \$48.13 per acre (assuming a 180 bu/yield)



Results Furrow Irrigated

vironmental damage comparisons of conventional irrigated rice (CIR) to furrow irrigated rice (FIR) assuming full adoption to provide the 2021 Arkansas rice crop.

	CIR	FIR (no yield penalty)	FIR (4.67 % yield penalty)	FIR (10 % yield penalty)
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Difference compared to CIR	-	\$ 41,747,083	\$ 79,525,561	\$ 126,106,620

- These results are from an initial LCA on Furrow irrigated rice and more input on what producers are doing is needed. However; the results highlight the issue that LCAs can present:
 - A production practice that uses less water
 - Or a production practice that may have higher overall environmental impacts
 - Not all environmental metrics move in the same direction!

Clearfield LCA

Environmental impact scores using Stepwise lifecycle impact assessment method. The single score is the sum of monetary cost of all impact categories. Only the two most costly are shown individually.

			Initial Infestation L	evel*	
Impact category	Unit	Clearfield [*]	Light	Moderate	Severe
Endpoint Impact Scores					
Single Score	US\$ 2016	\$31.87 ^a	\$36.47 ^b	\$40.12 ^c	\$42.93 ^d
Global warming, fossil	US\$ 2016	\$16.44 ^a	\$17.99 ^b	\$19.21 ^b	\$20.15 ^d
Respiratory inorganics	US\$ 2016	\$11.32 ^a	\$13.51 ^b	\$15.28 ^b	\$16.65 ^d
Midpoint Impact Scores [§]					
Global warming, fossil	kg CO2-eq	121 ^a	132^{b}	141 ^c	148^{d}
Respiratory inorganics	kg PM2.5-eq	$0.10^{\rm a}$	0.12^{b}	$0.14^{\rm c}$	0.15^{d}
Photochemical ozone, vegetation	m2 *ppm*hr	2210 ^a	2520 ^b	2780 ^c	2970 ^d
Eutrophication, terrestrial	m2 UES	32.2 ^a	36.5 ^b	40.0 ^c	42.8^{d}
Human toxicity, non-carc.	kg C2H3Cl-eq	0.83 ^a	1.64 ^b	2.26 ^c	2.73 ^d
Ecotoxicity, aquatic	kg TEG-eq w	43,100 ^a	44,300 ^a	45,400 ^a	46,100 ^a
Ecotoxicity, terrestrial	kg TEG-eq s	205 ^a	239 ^a	260^{b}	277 ^c
Human toxicity, carcinogens	kg C2H3Cl-eq	0.66 ^a	$0.80^{\rm b}$	0.91 ^c	0.99^{d}
Nature occupation	m2-years ag	1.23 ^a	1.44 ^b	1.61 ^c	1.74 ^d
Eutrophication, aquatic	kg NO3-eq	0.67 ^a	0.74 ^b	0.78 ^c	0.82^{d}
Acidification	m2 UES	8.1 ^a	9.2 ^b	10.1 ^c	10.8^{d}
Global warming, non-fossil	kg CO2-eq	6.3 ^a	6.2 ^a	6.2^{a}	6.2^{a}
Respiratory organics	pers*ppm*hr	0.22 ^a	0.25^{b}	0.27 ^c	0.29 <u>d</u>
Mineral extraction	MJ extra	3.08 ^a	3.89 ^b	4.46 ^c	4.89 ^d
Ozone layer depletion	kg CFC – 11-eq	$2.0E - 06^{a}$	$2.4E - 06^{b}$	$2.7E - 06^{c}$	$2.8E - 06^{d}$
Non-renewable energy	MJ primary	921 ^a	1090 ^b	1230 ^c	1340 ^d

* Each scenario, in each row, with a different identification letter, is significantly different from other scenarios, by row, for each impact category (p < 0.005). § Economic cost of each category for Clearfield varieties is less than 2016 US\$ 1.4 for each category after respiratory inorganics.

In this study we estimated the impact of red rice infestations because of NewPath resistance, so we used an LCA to "value" a technology.

Here, our metric was how much does it cost in environmental damage to meet the global average per capita rice consumption (126.1 lbs/year)

Ecosystem vs Tangible Benefits



Benefit-cost ratio (2018 USD) for Arkansas rice checkoff funds used for MIRI research and adoption: 2002-2018.

2002138,230364,1121,898,28499,85370,6130.545.7032.582003241,732502,3942,690,091137,77470,6131.478.5946.682004291,217593,0913,351,625162,64752,062.4613.8278.022005497,132698,8103,765,321191,63957,5395.311.7.4582.892006412,601525,9462,938,85144,23374,453.611.06750.162007467,582566,5213,315,265155,36088,7493.529.9047.262008825,355708,7933,822,190194,37654,05711.6824.7995.492009679,677837,5174,617,159229,67771,2546.3218.0782.872010780,5021,113,8525,841,361305,45870,6136.7322.50105.232011515,246678,1273,732,404185,96755,3145.95518.2185.692012687,746655,6033,962,672179,79053,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914912,0684,973,492222,69832,05317.4842.81197.982015703,473649,734,92222,69832,05317.4842.81197.982014782,914<	Year	Fuel cost savings ^a	Value of water conserved ^b	Value of ecosystem services ^c	Additional MIRI costs ^d	Checkoff funds ^e	Fuel savings BCR	Fuel savings + value of water conserved BCR	Fuel savings + value of water conserved + ecosystem services BCR
2003241,732502,3942,690,091137,77470,6131.478.5946.682004291,217593,0913,351,625162,64752,2062.4613.8278.022005497,132698,8103,765,321191,63957,5395.3117.4582.892006412,601525,9462,938,885144,23374,4253.6110.6750.162007467,582566,5213,315,265155,36088,7493.529.9047.262008825,535708,7933,822,190194,37654,05711.6824.7995.492009679,677837,5174,617,159229,67771,2546.3218.0782.872010780,5021,113,8525,841,361305,45870,6136.7322.50105.232011515,246678,1273,732,404185,9675,3145.95518.2185.692012687,746655,6033,962,672179,7905,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017	2002	138,230	364,112	1,898,284	99,853	70,613	0.54	5.70	32.58
2004291,217593,0913,351,625162,64752,2062.4613.8278.022005497,132698,8103,765,321191,63957,5395.3117.4582.892006412,601525,9462,938,885144,23374,4253.6110.6750.162007467,582566,5213,315,265155,36088,7493.529.9047.262008825,535708,7933,822,190194,37654,05711.6824.7995.492009679,677837,5174,617,159229,67771,2546.3218.0782.872010780,5021,113,8525,841,361305,45870,6136.7322.50105.232011515,246655,6033,962,672179,79053,0429.581.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2003	241,732	502,394	2,690,091	137,774	70,613	1.47	8.59	46.68
2005497,132698,8103,765,321191,63957,5395.3117.4582.892006412,601525,9462,938,885144,23374,4253.6110.6750.162007467,582566,5213,315,265155,36088,7493.529.9047.262008825,535708,7933,822,190194,37654,05711.6824.7995.492009679,677837,5174,617,159229,67771,2546.3218.0782.872010780,5021,113,8525,841,361305,45870,6136.7322.50105.232011515,246678,1273,732,404185,96755,3145.9518.2185.692012687,746655,6033,962,672179,79053,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914 8 12,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2004	291,217	593,091	3,351,625	162,647	52,206	2.46	13.82	78.02
2006412,601525,9462,938,885144,23374,4253.6110.6750.162007467,582566,5213,315,265155,36088,7493.529.9047.262008825,535708,7933,822,190194,37654,05711.6824.7995.492009679,677837,5174,617,159229,67771,2546.3218.0782.872010780,5021,113,8525,841,361305,45870,6136.7322.50105.232011515,246678,1273,732,404185,96755,3145.9518.2185.692012687,746655,6033,962,672179,79053,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914§12,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2005	497,132	698,810	3,765,321	191,639	57,539	5.31	17.45	82.89
2007467,582566,5213,315,265155,36088,7493,529,9047.262008825,535708,7933,822,190194,37654,05711.6824.7995.492009679,677837,5174,617,159229,67771,2546.3218.0782.872010780,5021,113,8525,841,361305,45870,6136.7322.50105.232011515,246678,1273,732,404185,96755,3145.95518.2185.692012687,746655,6033,962,672179,79053,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2006	412,601	525,946	2,938,885	144,233	74,425	3.61	10.67	50.16
2008825,535708,7933,822,190194,37654,05711.6824.7995.492009679,677837,5174,617,159229,67771,2546.3218.0782.872010780,5021,113,8525,841,361305,45870,6136.7322.50105.232011515,246678,1273,732,404185,96755,3145.9518.2185.692012687,746655,6033,962,672179,79053,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2007	467,582	566,521	3,315,265	155,360	88,749	3.52	9.90	47.26
2009679,677837,5174,617,159229,67771,2546.3218.0782.872010780,5021,113,8525,841,361305,45870,6136.7322.50105.232011515,246678,1273,732,404185,96755,3145.9518.2185.692012687,746655,6033,962,672179,79053,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2008	825,535	708,793	3,822,190	194,376	54,057	11.68	24.79	95.49
2010780,5021,113,8525,841,361305,45870,6136.7322.50105.232011515,246678,1273,732,404185,96755,3145.9518.2185.692012687,746655,6033,962,672179,79053,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2009	679,677	837,517	4,617,159	229,677	71,254	6.32	18.07	82.87
2011515,246678,1273,732,404185,96755,3145.9518.2185.692012687,746655,6033,962,672179,79053,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2010	780,502	1,113,852	5,841,361	305,458	70,613	6.73	22.50	105.23
2012687,746655,6033,962,672179,79053,0429.5821.9496.642013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2011	515,246	678,127	3,732,404	185,967	55,314	5.95	18.21	85.69
2013547,307510,3843,126,211139,966109,1273.738.4137.062014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2012	687,746	655,603	3,962,672	179,790	53,042	9.58	21.94	96.64
2014782,914812,0684,973,492222,69832,05317.4842.81197.982015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2013	547,307	510,384	3,126,211	139,966	109,127	3.73	8.41	37.06
2015703,473737,1364,374,757202,14932,92515.2337.61170.482016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2014	782,914	8 12,068	4,973,492	222,698	32,053	17.48	42.81	197.98
2016390,656669,7293,759,324183,664146,5751.415.9831.632017257,270535,2583,238,774146,78781,9531.357.8847.40	2015	703,473	737,136	4,374,757	202,149	32,925	15.23	37.61	170.48
2017 257,270 535,258 3,238,774 146,787 81,953 1.35 7.88 47.40	2016	390,656	669,729	3,759,324	183,664	146,575	1.41	5.98	31.63
	2017	257,270	535,258	3,238,774	146,787	81,953	1.35	7.88	47.40
2018 436,866 623,729 3,787,317 171,049 80,000 3.32 11.12 58.46	2018	436,866	623,729	3,787,317	171,049	80,000	3.32	11.12	58.46
Total 8,655,687 11,133,069 6,3,195,132 3,053,087 1,201,058	Total	8,655,687	11,133,069	6,3,195,132	3,053,087	1,201,058	-	_	_
Average 509,158 654,886 3,717,361 179,593 70,650 5.86 16.79 79.21	Average	509,158	654,886	3,717,361	179,593	70,650	5.86	16.79	79.21

- In this study, we conducted an LCA looking at the benefits (environmental, water savings, and fuel) from actual **MIRI adoption** in Arkansas and compared that to funding the Rice Board provided for MIRI research.
- Accounting for Ecosystem services can make a big difference in how you look at the bottom line

Conclusion

- While many stakeholders want a "one size fits all" LCA to represent their industry, in reality, establishing a baseline LCA first and then highlighting production or technology changes is ideal.
- These "ecosystem benefits," although monetized in several of these studies, are likely not going to be payments for producers.
 - But when you want to market your product against another, they are valuable information for buyers who want to pass this information on to consumers

Conclusion

- My thoughts on LCAs boil down to what your objective is.
 - If it's comparing US rice to Thai rice, a simple baseline LCA for both countries would work
 - If it's quantifying a "more sustainable rice" produced in the USA, then a baseline is needed, and several LCAs where single changes from that baseline can be summed.
 - If you change too many things at once, you can't tell what is driving the change.
- Knowing what you want and who your target audience is, is vital prior to starting.