

Table S1: Enterprise budget for a three-year organic IWG-red clover polyculture in central New York.

	Category	Output/Input	Units	2017	2018	2019	Total Value
Revenue	Grain	Yield	kg/ha	1124	256	533	
		Market price	\$/kg	1.23	1.17	1.11	
		Gross revenue	\$/ha	1384.27	299.51	592.42	2276.21
	Straw/Hay	Yield	kg/ha	6441	7304	8837	
		Market price	\$/kg	0.15	0.14	0.13	
		Gross revenue	\$/ha	954.34	1028.10	1181.68	3164.12
	Annual revenue		\$/ha	2338.61	1327.61	1816.70	
Total revenue:						5440.32	\$/ha
Production Costs	Field operations	Moldboard plow	\$/ha	54.36	-	-	54.36
		Disk harrow	\$/ha	42.01	-	-	42.01
		Cultipacker	\$/ha	42.50	-	-	42.50
		Dry fertilizer application	\$/ha	17.30	16.43	15.61	49.34
		Small grain drill	\$/ha	43.49	-	-	43.49
		Grain harvest (combine & local haul)	\$/ha	77.84	73.95	70.25	222.03
		Complete hay harvest (mow, bale, haul)	\$/kg	0.02	0.02	0.02	
		Hay Yield	kg/ha	6441	7304	8837	
		Gross cost	\$/ha	125.69	135.41	155.63	416.73
	Kernza seed	Seeding rate	kg/ha	16.8	-	-	
		Seed price	\$/kg	13.23	-	-	
		Gross cost	\$/ha	222.26	-	-	222.26
	Red clover seed	Seeding cate	kg/ha	22.4	22.4	-	
		Seed price	\$/kg	7.94	7.94	-	
		Gross cost	\$/ha	177.81	168.92	-	346.73
	Poultry litter	Fertilizer rate	kg/ha	1800	1800	1800	
		Fertilizer price	\$/kg	0.40	0.38	0.36	
		Gross cost	\$/ha	714.42	678.70	644.76	2037.88
	Land	Rental cost	\$/ha	150.73	147.89	147.19	445.81
	Organic certification		\$/ha	7.41	7.04	6.69	21.15
	Annual costs		\$/ha	1675.83	1228.34	1040.14	
	Production costs subtotal:						3944.31
Interest	5% of production costs	\$				197.22	
Total production costs:						4141.52	\$/ha
Net present value:						1298.80	\$/ha
Mean annual income:						432.93	\$/ha

Table S2: Enterprise budget for three-year continuous organic IWG monoculture in central New York.

	Category	Output/Input	Units	2017	2018	2019	Total Value
Revenue	Grain	Yield	kg/ha	1380	189	385	
		Price	\$/kg	1.32	1.25	1.19	
		Gross Income	\$/ha	1818.96	236.66	457.99	2513.61
	Straw/Hay	Yield	kg/ha	5634	4498	7465	
		Price	\$/kg	0.15	0.14	0.13	
		Gross Income	\$/ha	834.77	633.13	998.22	2466.12
	Annual revenue		\$/ha	2653.73	869.79	1456.21	
Total revenue:						4979.73	\$/ha
Production Costs							
Costs	Field operations	Moldboard plow	\$/ha	54.36	-	-	54.36
		Disk harrow	\$/ha	42.01	-	-	42.01
		Cultipacker	\$/ha	42.50	-	-	42.50
		Dry fertilizer application	\$/ha	17.30	16.43	15.61	49.34
		Small grain drill	\$/ha	43.49	-	-	43.49
		Grain harvest (combine & local haul)	\$/ha	77.84	73.95	70.25	222.03
		Complete hay harvest (mow, bale, haul)	\$/kg	0.02	0.02	0.02	
		Hay Yield	kg/ha	5634	4498	7465	
		Gross cost	\$/ha	109.94	83.39	131.47	324.80
	Kernza seed	Seeding rate	kg/ha	16.8	-	-	
		Seed price	\$/kg	13.23	-	-	
		Gross cost	\$/ha	222.26	-	-	222.26
	Poultry litter	Fertilizer rate	kg/ha	1800	1800	1800	
		Fertilizer price	\$/kg	0.40	0.38	0.36	
		Gross cost	\$/ha	714.42	678.70	644.76	2037.88
	Land	Rental cost	\$/ha	150.73	147.89	147.19	445.81
	Organic certification		\$/ha	7.41	7.04	6.69	21.15
Annual costs		\$/ha	1482.27	1007.40	1015.97		
Production costs subtotal:						3505.65	\$/ha
Interest	5% of production costs	\$				175.28	
Total production costs:						3680.93	\$/ha
Net present value:						1298.80	\$/ha
Mean annual income:						432.93	\$/ha

Table S5: Enterprise budget for three-year organic corn-soybean-spelt rotation in central New York.

Category		Output/Input	Units	2017	2018	2019	Total Value
Revenue	Grain			Corn	Soybean	Spelt	
		Yield	kg/ha	8278	2614	2585	
		Market price	\$/kg	0.28	0.70	0.24	
	Straw/Hay	Gross revenue	\$/ha	2297.07	1834.69	614.12	4745.88
		Yield	kg/ha	0	0	0	
		Market price	\$/kg	N/a	N/a	N/a	
		Gross revenue	\$/ha	0.00	0.00	0.00	0.00
Annual revenue		\$/ha	2297.07	1834.69	614.12		
Total revenue:						4745.88	\$/ha
Production Costs							
Costs	Field operations	Moldboard plow	\$/ha	54.36	51.64	49.06	155.07
		Disk harrow	\$/ha	42.01	39.91	37.91	119.83
		Cultipacker	\$/ha	42.50	40.38	38.36	121.24
		Dry fertilizer application	\$/ha	17.30	16.43	15.61	49.34
		Planting	\$/ha	52.39	47.42	39.25	139.06
		Interrow cultivation	\$/ha	139.61	83.77	-	223.38
		Mowing	\$/ha	-	26.76	25.42	52.18
		Grain harvest (combine & local haul)	\$/ha	77.84	73.95	70.25	222.03
	Grain seed	Seeding rate	kg/ha	20.3	76.1	135	
		Seed price	\$/kg	7.06	2.21	1.11	
		Gross cost	\$/ha	143.24	167.80	150.44	461.48
	Clover seed	Seeding rate	kg/ha	-	-	16.8	
		Seed price	\$/kg	-	-	7.16	
		Gross cost	\$/ha	-	-	120.36	120.36
	Poultry litter	Fertilizer rate	kg/ha	2000	0	1000	
		Fertilizer price	\$/kg	0.40	0.38	0.36	
		Gross cost	\$/ha	793.80	0.00	358.20	1152.00
	Land	Rental cost	\$/ha	150.73	147.89	147.19	445.81
	Organic certification		\$/ha	7.41	7.04	6.69	21.15
	Annual costs		\$/ha	1521.19	702.99	938.39	
Production cost subtotal:						3282.93	\$/ha
Interest	5% of production costs	\$				164.15	
Total production costs:						3447.08	\$/ha
Net present value:						1298.80	\$/ha
Mean annual income:						432.93	\$/ha

Table S6: Estimates of energy consumption and greenhouse gas emissions calculated using the Farm Energy Analysis Tool (Camargo et al., 2013) for a three-year organic IWG-red clover polyculture in central New York.

Farm inputs and outputs							
Crop year	Kernza - Yr1	Kernza - Yr2	Kernza - Yr 3	Clover - Yr1	Clover - Yr2	Clover - Yr3	Total ha⁻¹ yr⁻¹
Field area (ha yr ⁻¹)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Yield (Mg ha ⁻¹)	1.12	0.26	0.53	-	-	-	0.64
Residue removal after harvest (%)	0.90	0.90	0.90	0.90	0.90	0.90	1.80
Crop moisture at harvest (%)	0.214	0.131	0.164	-	-	-	0.170
Crop moisture at storage (%)	0.135	0.135	0.135	-	-	-	0.135
Poultry litter (kg DM ha ⁻¹)	1800.0	1800.0	1800.0	0.0	0.0	0.0	1800.0
Poultry litter N (kg ha ⁻¹)	90.0	90.0	90.0	0.0	0.0	0.0	90.0
Poultry litter P (kg ha ⁻¹)	72.0	72.0	72.0	0.0	0.0	0.0	72.0
Poultry litter K (kg ha ⁻¹)	54.0	54.0	54.0	0.0	0.0	0.0	54.0
Seed rate (kg ha ⁻¹)	16.8	0.0	0.0	22.4	22.4	0.0	20.5
Diesel fuel (L ha ⁻¹)	82.7	44.7	43.3	0.0	0.0	0.0	56.9
Drying (MJ yr ⁻¹)	322.9	0.0	55.1	-	-	-	126.0
Labor (hr ha ⁻¹)	2.2	1.1	1.0	0.0	0.0	0.0	1.4
Crop production (Mg WM yr ⁻¹)	1.12	0.26	0.53	-	-	-	0.64
Crop production (Mg DM yr ⁻¹)	0.97	0.22	0.46	-	-	-	0.55
Residue harvested (Mg DM yr ⁻¹)	5.6	4.3	8.4	0.8	3.0	0.4	7.5
Total crop biomass	6.6	4.5	8.9	0.8	3.0	0.4	8.1
Energy analysis							MJ ha⁻¹ yr⁻¹
Poultry litter transport	237.5	237.5	237.5	0.0	0.0	0.0	237.5
Poultry litter production	2697.4	2697.4	2697.4	0.0	0.0	0.0	2697.4
Seed	1478.4	0.0	0.0	929.4	929.4	0.0	1112.4
Transportation of inputs	10.8	0.0	0.0	14.3	14.3	0.0	13.1
Equipment	160.7	84.6	82.9	0.0	0.0	0.0	109.4
Drying	322.9	0.0	55.1	0.0	0.0	0.0	126.0
Labor	64.8	32.3	30.7	0.0	0.0	0.0	42.6
Diesel fuel	3709.2	2004.9	1942.0	0.0	0.0	0.0	2552.0
Total energy (MJ ha⁻¹ yr⁻¹)	8681.7	5056.6	5045.7	943.7	943.7	0.0	6890.5

Greenhouse gas emissions analysis						kg CO ₂ e ha ⁻¹ yr ⁻¹	
Poultry litter transport	20.3	20.3	20.3	0.0	0.0	0.0	20.3
Poultry litter production	111.3	111.3	111.3	0.0	0.0	0.0	111.3
Seed	29.0	0.0	0.0	46.5	46.5	0.0	40.7
Transportation of inputs	0.8	0.0	0.0	1.1	1.1	0.0	1.0
Equipment	10.4	5.5	5.4	0.0	0.0	0.0	7.1
Drying	25.8	0.0	4.4	0.0	0.0	0.0	10.1
Diesel fuel	266.6	144.1	139.6	0.0	0.0	0.0	183.4
N ₂ O - manure application	600.6	600.6	600.6	0.0	0.0	0.0	600.6
N ₂ O - aboveground crop residues, direct	2.0	0.5	1.0	0.0	0.0	0.0	1.2
N ₂ O - belowground crop residues, direct	30.4	6.9	14.4	0.0	0.0	0.0	17.2
N ₂ O - aboveground crop residues, indirect	0.5	0.1	0.2	0.0	0.0	0.0	0.3
N ₂ O - belowground crop residues, indirect	6.8	1.6	3.2	0.0	0.0	0.0	3.9
N ₂ O - total from crop residue	39.7	9.1	18.9	0.0	0.0	0.0	22.6
Total GHG (kg CO₂e ha⁻¹ yr⁻¹)	1104.6	890.8	900.4	47.6	47.6	0.0	997.0

Table S7: Estimates of energy consumption and greenhouse gas emissions calculated using the Farm Energy Analysis Tool (Camargo et al., 2013) for a three-year continuous organic IWG monoculture in central New York.

Farm inputs and outputs							
Crop year	Kernza - Yr1	Kernza - Yr2	Kernza - Yr 3	-	-	-	Total ha⁻¹ yr⁻¹
Field area (ha yr ⁻¹)	1.0	1.0	1.0	0.0	0.0	0.0	1.0
Yield (Mg ha ⁻¹)	1.38	0.19	0.38	-	-	-	0.65
Residue removal after harvest (%)	0.90	0.90	0.90	0.90	0.90	0.90	1.80
Crop moisture at harvest (%)	0.197	0.135	0.188	-	-	-	0.173
Crop moisture at storage (%)	0.135	0.135	0.135	-	-	-	0.135
Poultry litter (kg DM ha ⁻¹)	1800.0	1800.0	1800.0	0.0	0.0	0.0	1800.0
Poultry litter N (kg ha ⁻¹)	90.0	90.0	90.0	0.0	0.0	0.0	90.0
Poultry litter P (kg ha ⁻¹)	72.0	72.0	72.0	0.0	0.0	0.0	72.0
Poultry litter K (kg ha ⁻¹)	54.0	54.0	54.0	0.0	0.0	0.0	54.0
Seed rate (kg ha ⁻¹)	16.8	0.0	0.0	0.0	0.0	0.0	5.6
Diesel fuel (L ha ⁻¹)	81.3	43.3	43.3	0.0	0.0	0.0	56.0
Drying (MJ yr ⁻¹)	311.4	0.0	74.3	-	-	-	128.6
Labor (hr ha ⁻¹)	2.1	1.0	1.0	0.0	0.0	0.0	1.4
Crop production (Mg WM yr ⁻¹)	1.38	0.19	0.38	-	-	-	0.65
Crop production (Mg DM yr ⁻¹)	1.19	0.16	0.33	-	-	-	0.56
Residue harvested (Mg DM yr ⁻¹)	5.6	3.9	7.4	0.0	0.0	0.0	5.7
Total crop biomass	6.8	4.1	7.8	0.0	0.0	0.0	6.2
Energy analysis							MJ ha⁻¹ yr⁻¹
Poultry litter transport	237.5	237.5	237.5	0.0	0.0	0.0	237.5
Poultry litter production	2697.4	2697.4	2697.4	0.0	0.0	0.0	2697.4
Seed	1478.4	0.0	0.0	0.0	0.0	0.0	492.8
Transportation of inputs	10.8	0.0	0.0	0.0	0.0	0.0	3.6
Equipment	159.1	82.9	82.9				108.3
Drying	311.4	0.0	74.3	0.0	0.0	0.0	128.6
Labor	63.3	30.7	30.7	0.0	0.0	0.0	41.5
Diesel fuel	3646.3	1942.0	1942.0	0.0	0.0	0.0	2510.1
Total energy (MJ ha⁻¹ yr⁻¹)	8604.1	4990.6	5064.9	0.0	0.0	0.0	6219.9

Greenhouse gas emissions analysis						kg CO ₂ e ha ⁻¹ yr ⁻¹	
Poultry litter transport	20.3	20.3	20.3	0.0	0.0	0.0	20.3
Poultry litter production	111.3	111.3	111.3	0.0	0.0	0.0	111.3
Seed	29.0	0.0	0.0	0.0	0.0	0.0	9.7
Transportation of inputs	0.8	0.0	0.0	0.0	0.0	0.0	0.3
Equipment	10.3	5.4	5.4	0.0	0.0	0.0	7.0
Drying	24.9	0.0	5.9	0.0	0.0	0.0	10.3
Diesel fuel	262.1	139.6	139.6	0.0	0.0	0.0	180.4
N ₂ O - manure application	600.6	600.6	600.6	0.0	0.0	0.0	600.6
N ₂ O - aboveground crop residues, direct	2.5	0.3	0.7	0.0	0.0	0.0	1.2
N ₂ O - belowground crop residues, direct	37.3	5.1	10.4	0.0	0.0	0.0	17.6
N ₂ O - aboveground crop residues, indirect	0.6	0.1	0.2	0.0	0.0	0.0	0.3
N ₂ O - belowground crop residues, indirect	8.4	1.2	2.3	0.0	0.0	0.0	4.0
N ₂ O - total from crop residue	48.8	6.7	13.6	0.0	0.0	0.0	23.0
Total GHG (kg CO₂e ha⁻¹ yr⁻¹)	1108.1	883.8	896.7	0.0	0.0	0.0	962.9

Table S8: Estimates of energy consumption and greenhouse gas emissions calculated using the Farm Energy Analysis Tool (Camargo et al., 2013) for a three-year continuous organic hard red winter wheat-red clover polyculture in central New York.

Farm inputs and outputs							
Crop year	Wheat - Yr1	Wheat - Yr2	Wheat - Yr 3	Clover - Yr1	Clover - Yr2	Clover - Yr3	Total ha⁻¹ yr⁻¹
Field area (ha yr ⁻¹)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Yield (Mg ha ⁻¹)	3.3	3.3	2.8	-	-	-	3.1
Residue removal after harvest (%)	0.90	0.90	0.90	0.90	0.90	0.90	1.80
Crop moisture at harvest (%)	0.037	0.081	0.161	-	-	-	0.093
Crop moisture at storage (%)	0.135	0.135	0.135	-	-	-	0.135
Poultry litter (kg DM ha ⁻¹)	1800.0	1800.0	1800.0	0.0	0.0	0.0	1800.0
Poultry litter N (kg ha ⁻¹)	90.0	90.0	90.0	0.0	0.0	0.0	90.0
Poultry litter P (kg ha ⁻¹)	72.0	72.0	72.0	0.0	0.0	0.0	72.0
Poultry litter K (kg ha ⁻¹)	54.0	54.0	54.0	0.0	0.0	0.0	54.0
Seed rate (kg ha ⁻¹)	107.6	107.6	107.6	22.4	22.4	22.4	130.0
Diesel fuel (L ha ⁻¹)	63.7	63.7	63.7	0.0	0.0	0.0	63.7
Drying (MJ yr ⁻¹)	0.0	0.0	261.9	-	-	-	87.3
Labor (hr ha ⁻¹)	2.1	2.1	2.1	0.0	0.0	0.0	2.1
Crop production (Mg WM yr ⁻¹)	3.3	3.3	2.8	-	-	-	3.1
Crop production (Mg DM yr ⁻¹)	2.9	2.9	2.4	-	-	-	2.7
Residue harvested (Mg DM yr ⁻¹)	4.9	3.5	3.7	0.5	0.2	0.6	4.4
Total crop biomass	7.7	6.3	6.1	0.5	0.2	0.6	7.1
Energy analysis							MJ ha⁻¹ yr⁻¹
Poultry litter transport	237.5	237.5	237.5	0.0	0.0	0.0	237.5
Poultry litter production	2697.4	2697.4	2697.4	0.0	0.0	0.0	2697.4
Seed	930.2	930.2	930.2	929.4	929.4	929.4	1859.6
Transportation of inputs	68.9	68.9	68.9	14.3	14.3	14.3	83.2
Equipment	156.8	156.8	150.5	-	-	-	154.7
Drying	0.0	0.0	261.9	0.0	0.0	0.0	87.3
Labor	63.6	63.6	63.6	0.0	0.0	0.0	63.6
Diesel fuel	2857.3	2857.3	2857.3	0.0	0.0	0.0	2857.3
Total energy (MJ ha⁻¹ yr⁻¹)	7011.7	7011.7	7267.3	943.7	943.7	943.7	8040.6

Greenhouse gas emissions analysis						kg CO ₂ e ha ⁻¹ yr ⁻¹	
Poultry litter transport	20.3	20.3	20.3	0.0	0.0	0.0	20.3
Poultry litter production	111.3	111.3	111.3	0.0	0.0	0.0	111.3
Seed	42.8	42.8	42.8	46.5	46.5	46.5	89.3
Transportation of inputs	5.4	5.4	5.4	1.1	1.1	1.1	6.5
Equipment	10.2	10.2	9.8	0.0	0.0	0.0	10.1
Drying	0.0	0.0	21.0	0.0	0.0	0.0	7.0
Diesel fuel	205.4	205.4	205.4	0.0	0.0	0.0	205.4
N ₂ O - manure application	600.6	600.6	600.6	0.0	0.0	0.0	600.6
N ₂ O - aboveground crop residues, direct	13.6	13.6	11.7	0.0	0.0	0.0	13.0
N ₂ O - belowground crop residues, direct	33.9	33.9	28.6	0.0	0.0	0.0	32.1
N ₂ O - aboveground crop residues, indirect	3.1	3.1	2.6	0.0	0.0	0.0	2.9
N ₂ O - belowground crop residues, indirect	7.6	7.6	6.3	0.0	0.0	0.0	7.2
N ₂ O - total from crop residue	58.2	58.1	49.2	0.0	0.0	0.0	55.2
Total GHG (kg CO₂e ha⁻¹ yr⁻¹)	1054.1	1054.1	1065.7	47.6	47.6	47.6	1105.6

Table S9: Estimates of energy consumption and greenhouse gas emissions calculated using the Farm Energy Analysis Tool (Camargo et al., 2013) for a three-year continuous organic hard red winter wheat monoculture in central New York.

Farm inputs and outputs							
Crop year	Wheat - Yr1	Wheat - Yr2	Wheat - Yr 3	-	-	-	Total ha⁻¹ yr⁻¹
Field area (ha yr ⁻¹)	1.0	1.0	1.0	0.0	0.0	0.0	1.0
Yield (Mg ha ⁻¹)	3.7	2.2	2.2				2.7
Residue removal after harvest (%)	0.90	0.90	0.90	0.90	0.90	0.90	1.80
Crop moisture at harvest (%)	0.033	0.082	0.134	0.000	0.000	0.000	0.083
Crop moisture at storage (%)	0.135	0.135	0.135	0.000	0.000	0.000	0.135
Poultry litter (kg DM ha ⁻¹)	1800.0	1800.0	1800.0	0.0	0.0	0.0	1800.0
Poultry litter N (kg ha ⁻¹)	90.0	90.0	90.0	0.0	0.0	0.0	90.0
Poultry litter P (kg ha ⁻¹)	72.0	72.0	72.0	0.0	0.0	0.0	72.0
Poultry litter K (kg ha ⁻¹)	54.0	54.0	54.0	0.0	0.0	0.0	54.0
Seed rate (kg ha ⁻¹)	107.6	107.6	107.6	0.0	0.0	0.0	107.6
Diesel fuel (L ha ⁻¹)	62.3	62.3	62.3	0.0	0.0	0.0	62.3
Drying (MJ yr ⁻¹)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Labor (hr ha ⁻¹)	2.1	2.1	2.1	0.0	0.0	0.0	2.1
Crop production (Mg WM yr ⁻¹)	3.7	2.2	2.2	0.0	0.0	0.0	2.7
Crop production (Mg DM yr ⁻¹)	3.2	1.9	1.9	0.0	0.0	0.0	2.4
Residue harvested (Mg DM yr ⁻¹)	5.7	2.8	3.5	0.0	0.0	0.0	4.0
Total crop biomass	8.9	4.7	5.4	0.0	0.0	0.0	6.3
Energy analysis							MJ ha⁻¹ yr⁻¹
Poultry litter transport	237.5	237.5	237.5	0.0	0.0	0.0	237.5
Poultry litter production	2697.4	2697.4	2697.4	0.0	0.0	0.0	2697.4
Seed	930.2	930.2	930.2	0.0	0.0	0.0	930.2
Transportation of inputs	68.9	68.9	68.9	0.0	0.0	0.0	68.9
Equipment	160.7	155.2	155.2				157.0
Drying	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Labor	62.0	62.0	62.0	0.0	0.0	0.0	62.0
Diesel fuel	2794.4	2794.4	2794.4	0.0	0.0	0.0	2794.4
Total energy (MJ ha⁻¹ yr⁻¹)	6951.1	6945.6	6945.6	0.0	0.0	0.0	6947.5

Greenhouse gas emissions analysis						kg CO ₂ e ha ⁻¹ yr ⁻¹	
Poultry litter transport	20.3	20.3	20.3	0.0	0.0	0.0	20.3
Poultry litter production	111.3	111.3	111.3	0.0	0.0	0.0	111.3
Seed	42.8	42.8	42.8	0.0	0.0	0.0	42.8
Transportation of inputs	5.4	5.4	5.4	0.0	0.0	0.0	5.4
Equipment	10.4	10.1	10.1	0.0	0.0	0.0	10.2
Drying	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diesel fuel	200.8	200.8	200.8	0.0	0.0	0.0	200.8
N ₂ O - manure application	600.6	600.6	600.6	0.0	0.0	0.0	600.6
N ₂ O - aboveground crop residues, direct	15.2	9.6	4.0	0.0	0.0	0.0	9.6
N ₂ O - belowground crop residues, direct	38.1	22.9	22.9	0.0	0.0	0.0	28.0
N ₂ O - aboveground crop residues, indirect	3.4	2.2	2.2	0.0	0.0	0.0	2.6
N ₂ O - belowground crop residues, indirect	8.6	5.2	5.1	0.0	0.0	0.0	6.3
N ₂ O - total from crop residue	65.3	39.9	34.2	0.0	0.0	0.0	46.4
Total GHG (kg CO₂e ha⁻¹ yr⁻¹)	1057.0	1031.2	1025.5	0.0	0.0	0.0	1037.9

Table S10: Estimates of energy consumption and greenhouse gas emissions calculated using the Farm Energy Analysis Tool (Camargo et al., 2013) for a three-year organic corn-soybean-spelt rotation in central New York.

Farm inputs and outputs								
	Crop year	Corn	Soybean	Spelt	-	-	Clover (w/spelt)	Total ha ⁻¹ yr ⁻¹
Field area (ha yr ⁻¹)		1.0	1.0	1.0	1.0	1.0	1.0	1.0
Yield (Mg ha ⁻¹)		10.8	2.6	2.5			4.9	5.3
Residue removal after harvest (%)		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crop moisture at harvest (%)		0.000	0.000	0.000	-	-	-	0.000
Crop moisture at storage (%)		0.150	0.130	0.130	-	-	-	0.137
Poultry litter (kg DM ha ⁻¹)		2000.0	0.0	1000.0	0.0	0.0	0.0	1000.0
Poultry litter N (kg ha ⁻¹)		100.0	0.0	50.0	0.0	0.0	0.0	50.0
Poultry litter P (kg ha ⁻¹)		100.0	0.0	50.0	0.0	0.0	0.0	50.0
Poultry litter K (kg ha ⁻¹)		60.0	0.0	30.0	0.0	0.0	0.0	30.0
Seed rate (kg ha ⁻¹)		20.3	76.1	135.0	0.0	0.0	16.8	82.7
Diesel fuel (L ha ⁻¹)		79.0	71.6	62.1	0.0	0.0	0.0	70.9
Drying (MJ yr ⁻¹)		0.0	0.0	0.0	-	-	-	0.0
Labor (hr ha ⁻¹)		2.8	2.6	1.8	0.0	0.0	0.0	2.4
Crop production (Mg WM yr ⁻¹)		10.8	2.6	2.5	-	-	-	5.3
Crop production (Mg DM yr ⁻¹)		9.1	2.3	2.2	-	-	-	4.5
Residue harvested (Mg DM yr ⁻¹)		0.0	0.0	0.0	-	-	-	0.0
Total crop biomass		9.1	2.3	2.2	0.0	0.0	0.0	4.5
Energy analysis								MJ ha ⁻¹ yr ⁻¹
Poultry litter transport		263.9	0.0	132.0	0.0	0.0	0.0	132.0
Poultry litter production		3203.6	0.0	1601.8	0.0	0.0	0.0	1601.8
Seed		918.7	1295.2	1167.1	0.0	0.0	697.0	1359.4
Transportation of inputs		13.0	48.7	86.4	0.0	0.0	10.8	52.9
Equipment		179.7	175.3	148.3	0.0	0.0	0.0	167.8
Drying		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Labor		84.1	76.5	54.4	0.0	0.0	0.0	71.7
Diesel fuel		3541.8	3210.9	2781.6	0.0	0.0	0.0	3178.1
Total energy (MJ ha ⁻¹ yr ⁻¹)		8204.9	4806.7	5971.6	0.0	0.0	707.8	6563.7

Greenhouse gas emissions analysis						kg CO ₂ e ha ⁻¹ yr ⁻¹	
Poultry litter transport	22.5	0.0	11.3	0.0	0.0	0.0	11.3
Poultry litter production	123.7	0.0	61.8	0.0	0.0	0.0	61.8
Seed	77.2	68.9	53.8	0.0	0.0	34.9	78.2
Transportation of inputs	1.0	3.8	6.8	0.0	0.0	0.8	4.1
Equipment	11.7	11.4	9.6	0.0	0.0	0.0	10.9
Drying	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diesel fuel	254.6	230.8	199.9	0.0	0.0	0.0	228.4
N ₂ O - manure application	667.3	0.0	333.7	0.0	0.0	0.0	333.7
N ₂ O - aboveground crop residues, direct	281.7	130.1	108.2	0.0	0.0	0.0	173.3
N ₂ O - belowground crop residues, direct	138.2	41.0	61.3	0.0	0.0	0.0	80.2
N ₂ O - aboveground crop residues, indirect	63.4	29.3	24.3	0.0	0.0	0.0	39.0
N ₂ O - belowground crop residues, indirect	31.1	9.2	13.8	0.0	0.0	0.0	18.0
N ₂ O - total from crop residue	514.4	209.6	207.6	0.0	0.0	0.0	310.5
Total GHG (kg CO₂e ha⁻¹ yr⁻¹)	1672.4	524.5	884.4	0.0	0.0	35.7	1039.0

Table S11: Emergy table for a three-year organic IWG-red clover polyculture in central New York.

Inputs	Unit	Quantity	UEV (sej/g or sej/J)	Emergy Flow (sej ha⁻¹ yr⁻¹)
IWG Seed	g	1.68E+04	1.45E+09	8.13E+12
Clover Seed	g	2.24E+04	1.45E+09	3.25E+13
Fertilizer	g	5.38E+06	2.13E+08	3.82E+14
Labor	J	3.39E+07	1.24E+07	1.40E+14
Machinery - grain	g	1.20E+04	1.13E+10	4.51E+13
Machinery - forage	g	1.25E+04	1.13E+10	4.71E+13
Fuel	J	1.09E+09	1.10E+05	3.99E+13
Rain	J	1.43E+11	3.10E+04	1.48E+15
Sun	J	1.23E+14	1.00E+00	4.11E+13
Wind	J	6.04E+10	2.45E+03	4.93E+13
Soil Erosion	J	6.15E+09	1.24E+05	2.81E+14
Fraction	Year 1	Year 2	Year 3	Total
Renewable Local	1.57E+15	1.57E+15	1.57E+15	4.70E+15
Nonrenewable Local	6.01E+14	8.07E+13	8.07E+13	7.62E+14
Purchased - grain	6.89E+14	4.53E+14	4.21E+14	1.56E+15
Purchased - forage	7.42E+14	4.63E+14	4.31E+14	1.64E+15
Emergy Yield - grain	2.86E+15	2.10E+15	2.07E+15	7.03E+15
Emergy Yield - forage	2.91E+15	2.11E+15	2.08E+15	7.10E+15
Outputs	Unit	Quantity	Specific Emergy (sej g⁻¹)	
Grain Yield	g	1.91E+06	3.67E+09	
Forage Yield	g	2.26E+07	3.15E+08	

Table S12: Emery table for a three-year continuous organic IWG monoculture in central New York.

Inputs	Unit	Quantity	UEV (sej/g or sej/J)	Emery Flow (sej ha⁻¹ yr⁻¹)
Kernza Seed	g	1.68E+04	1.45E+09	2.44E+13
Fertilizer	g	5.38E+06	2.13E+08	3.82E+14
Labor	J	3.39E+07	1.24E+07	1.40E+14
Machinery - grain	g	1.20E+04	1.13E+10	4.51E+13
Machinery - forage	g	1.25E+04	1.13E+10	4.71E+13
Fuel	J	1.09E+09	1.10E+05	3.99E+13
Rain	J	1.43E+11	3.10E+04	1.48E+15
Sun	J	1.23E+14	1.00E+00	4.11E+13
Wind	J	6.04E+10	2.45E+03	4.93E+13
Soil Erosion	J	6.15E+09	1.24E+05	2.54E+14
Fraction	Year 1	Year 2	Year 3	Total
Renewable	1.57E+15	1.57E+15	1.57E+15	4.70E+15
Nonrenewable Local	6.01E+14	8.07E+13	8.07E+13	7.62E+14
Purchased - grain	5.30E+14	4.21E+14	4.21E+14	1.37E+15
Purchased - forage	5.40E+14	4.31E+14	4.31E+14	1.40E+15
Total Emery Yield - grain	2.70E+15	2.07E+15	2.07E+15	6.84E+15
Total Emery Yield - forage	2.71E+15	2.08E+15	2.08E+15	6.87E+15
Outputs	Unit	Quantity	Specific Emery (sej g⁻¹)	
Grain Yield	g	1.95E+06	3.50E+09	
Forage Yield	g	1.76E+07	3.90E+08	

Table S13: Emergy table for a three-year continuous organic hard red winter wheat-red clover polyculture in central New York.

Inputs	Unit	Quantity	UEV (sej/g or sej/J)	Emergy Flow (sej ha ⁻¹ yr ⁻¹)
Wheat Seed	g	1.08E+05	1.45E+09	1.56E+14
Clover Seed	g	2.24E+04	1.45E+09	3.25E+13
Fertilizer	g	1.79E+06	2.13E+08	3.82E+14
Labor	J	1.61E+07	1.24E+07	2.00E+14
Machinery - grain	g	7.21E+03	1.13E+10	8.15E+13
Machinery - forage	g	7.39E+03	1.13E+10	8.35E+13
Fuel	J	5.64E+08	1.10E+05	6.20E+13
Rain	J	4.77E+10	3.10E+04	1.48E+15
Sun	J	4.11E+13	1.00E+00	4.11E+13
Wind	J	2.01E+10	2.45E+03	4.93E+13
Soil Erosion	J	7.57E+09	1.24E+05	9.39E+14
Fraction	Year 1	Year 2	Year 3	Total
Renewable Local	1.57E+15	1.57E+15	1.57E+15	4.70E+15
Nonrenewable Local	9.39E+14	9.39E+14	9.39E+14	2.82E+15
Purchased - grain	9.14E+14	9.14E+14	9.14E+14	2.74E+15
Purchased - straw	9.16E+14	9.16E+14	9.16E+14	2.75E+15
Emergy Yield - grain	3.42E+15	3.42E+15	3.42E+15	1.03E+16
Emergy Yield - straw	3.42E+15	3.42E+15	3.42E+15	1.03E+16
Outputs	Unit	Quantity	Specific Emergy (sej g ⁻¹)	
Grain Yield	g	9.41E+06	1.09E+09	
Straw Yield	g	1.32E+07	7.78E+08	

Table S14: Emergy table for a three-year continuous organic hard red winter wheat monoculture in central New York.

Inputs	Unit	Quantity	UEV (sej/g or sej/J)	Emergy Flow (sej ha⁻¹ yr⁻¹)
Wheat Seed	g	1.08E+05	1.45E+09	1.56E+14
Fertilizer	g	1.79E+06	2.13E+08	3.82E+14
Labor	J	1.61E+07	1.24E+07	2.00E+14
Machinery - grain	g	7.21E+03	1.13E+10	8.15E+13
Machinery - forage	g	7.39E+03	1.13E+10	8.35E+13
Fuel	J	5.64E+08	1.10E+05	6.20E+13
Rain	J	4.77E+10	3.10E+04	1.48E+15
Sun	J	4.11E+13	1.00E+00	4.11E+13
Wind	J	2.01E+10	2.45E+03	4.93E+13
Soil Erosion	J	7.57E+09	1.24E+05	9.39E+14
Fraction	Year 1	Year 2	Year 3	Total
Renewable Local	1.57E+15	1.57E+15	1.57E+15	4.70E+15
Nonrenewable Local	9.39E+14	9.39E+14	9.39E+14	2.82E+15
Purchased - grain	8.82E+14	8.82E+14	8.82E+14	2.64E+15
Purchased - straw	8.84E+14	8.84E+14	8.84E+14	2.65E+15
Emergy Yield - grain	3.39E+15	3.39E+15	3.39E+15	1.02E+16
Emergy Yield - straw	3.39E+15	3.39E+15	3.39E+15	1.02E+16
Outputs	Unit	Quantity	Specific Emergy (sej g⁻¹)	
Grain Yield	g	8.19E+06	1.24E+09	
Straw Yield	g	1.21E+07	8.44E+08	

Table S15: Emergy table for a three-year organic corn-soybean-spelt rotation in central New York.

Inputs	Unit	Quantity	UEV (sej/g or sej/J)	Emergy Flow (sej ha⁻¹ yr⁻¹)
Corn seed	g	2.03E+04	8.67E+08	1.76E+13
Soybean seed	g	7.61E+04	1.82E+09	1.39E+14
Spelt seed	g	1.35E+05	1.45E+09	1.96E+14
Clover Seed	g	1.68E+04	1.45E+09	2.44E+13
Fertilizer	g	3.00E+06	2.13E+08	6.39E+14
Labor	J	3.19E+07	1.24E+07	3.96E+14
Machinery - grain	g	2.11E+04	1.13E+10	2.39E+14
Fuel	J	1.16E+09	1.10E+05	1.28E+14
Rain	J	4.77E+10	3.10E+04	1.48E+15
Sun	J	4.11E+13	1.00E+00	4.11E+13
Wind	J	2.01E+10	2.45E+03	4.93E+13
Soil Erosion	J	7.57E+09	1.24E+05	9.39E+14
Fraction	Year 1	Year 2	Year 3	Total
Renewable Local	1.57E+15	1.57E+15	1.57E+15	4.70E+15
Nonrenewable Local	9.39E+14	9.39E+14	9.39E+14	2.82E+15
Purchased - grain	4.85E+14	6.06E+14	6.87E+14	1.78E+15
Emergy Yield - grain	2.99E+15	3.11E+15	3.19E+15	9.30E+15
Outputs	Unit	Quantity	Specific Emergy (sej g⁻¹)	
Grain Yield	g	1.60E+07	5.82E+08	