Life-cycle impact assessment of organic and non-organic grass-fed beef production in Japan

Supplementary material

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Table S1
Environmental impacts for the different transport methods (per t.km)

	Unit	10t truck [a]	20t truck [b]	Railroad	Ship for coast	Container ship
Energy consumption	MJ	2.17	1.38	0.19	0.60	0.33
Emissions [c]						
CH_4	mg	171.72	108.80	8.75	47.04	28.10
CO_2	g	151.82	96.49	11.61	43.11	22.48
N_2O	mg	4.93	2.81	0.58	0.70	1.00
NO_x	mg	492.65	449.87	4.21	21.18	603.26
SO_2	mg	0.92	0.58	0.14	46.04	<0.01
SO_x	mg	7.56	4.81	0.90	3.28	485.07
Impact category						
GWP	g CO_2e	157.59	100.04	12.01	44.50	23.48
AP	mg SO_2e	353.34	320.30	3.99	64.14	907.36
EP	mg PO_4e	64.04	58.48	0.55	2.75	78.42

[a] Assumed to be used in Japan.
[b] Assumed to be used in the USA.
[c] NH_3 and NO_2 emissions were lower than 0.01 mg in all methods.
[1] GWP: global warming potential; AP: acidification potential; EP: eutrophication potential; CO_2e: carbon dioxide equivalent; SO_2e: sulfur dioxide equivalent; PO_4e: phosphate equivalent.

Table S2
Life-cycle inventories for grass production in Yakumo Farm (per ton of dry matter)

	Unit	Organic	Non-organic
Resource			
Chemical fertilizer			
N	kg		12.4
P_2O_5	kg		10.0
K_2O	kg		18.3
Magnesium oxide	kg		8.7
Fused magnesium phosphate	kg		12.7
Magnesium-calcium carbonate	kg		44.3
Manure [a]	kg	3129.0	3184.6
Other organic fertilizer	kg	42.7	89.9
Wrap	kg	4.1	2.3
Diesel	L	22.3	21.0
Energy consumption [b]	MJ	1214.76	5320.60 (3393.28)
Emissions [b]			
CH_4	g	92.57	201.15 (88.88)
CO_2	kg	85.17	247.03 (107.98)
N_2O	g	162.73	456.38 (17.16)
NH_3	mg	218.85	234.76 (<0.01)
NO_x	mg	33.72	102.05 (53.96)
SO_2	mg	7.45	73.40 (49.18)
SO_x	mg	4.20	12.70 (5.53)

[a] Contained 0.72% N.
[b] Values in parentheses indicate emissions or energy consumption via chemical fertilizer production. NO_2 emissions were lower than 0.01 mg in both systems.

Table S3
Life-cycle inventories for management of grazing pasture in Yakumo Farm (per day per head) [a]

	Unit	Organic	Non-organic
Resource			
Chemical fertilizer			
N	g		17.33
P_2O_5	g		13.90
K_2O	g		23.50
Magnesium oxide	g		9.51
Fused magnesium phosphate	g		2.20
Magnesium-calcium carbonate	g		67.70
Manure [b]	kg	5.55	4.01
Other organic fertilizer	g	63.66	76.09
Diesel	mL	1.67	2.44
Energy consumption [c]	MJ	0.14	5.78 (4.61)
Emissions [c]			
CH_4	mg	8.93	174.62 (123.42)
CO_2	g	9.07	243.66 (149.84)
N_2O	mg	286.35	612.95 (23.83)
NH_3	mg	388.52	297.39 (<0.01)
NO_x	mg	3.65	102.59 (74.93)
SO_2	mg	2.88	95.20 (68.30)
SO_x	mg	0.57	12.10 (7.66)

[a] These were calculated by dividing the total energy consumption or emissions by the number of cattle older than 1 year. Direct emissions from excreta by grazing animals are not included here.
[b] Contained 0.72% N.
[c] Values in parentheses indicate emissions or energy consumption via chemical fertilizer production. NO_2 emissions were lower than 0.01 mg in both systems.

Table S4
Life-cycle inventories for domestic feed production used in the conventional system (per ton)

	Unit	Italian ryegrass hay	Rice straw [a]	Wild grass hay
Resource				
Chemical fertilizer				
N	kg	11.12	0.64	
P_2O_5	kg		0.39	
K_2O	kg	10.84	0.64	
Fused magnesium phosphate	kg	17.11	2.42	
Magnesium-calcium carbonate	kg	74.40		
Calcium carbonate	kg		14.55	
Manure [b]	kg	1488.10		
Herbicide	g	390.30		
Insecticide (emulsion)	mL	36.36		
Wrap	g	223.21		
Diesel	L	8.39	0.96	2.46
Gasoline	mL	80.54	732.12	
Liquefied natural gas	g	208.40		
Liquefied petroleum gas	mg	29.11		
Electricity	Wh	1398.90	1.21	
Energy consumption	MJ	3481.06	443.32	99.28
Emissions				
CH_4	g	126.59	5340.54	7.76
CO_2	kg	184.60	28.91	6.94
N_2O	g	306.70	4.70	0.12
NH_3	g	75.86	53.42	<0.01
NO_2	mg	15.99	146.50	<0.01
NO_x	g	67.34	9.12	2.47
SO_2	g	54.26	7.48	0.14
SO_x	g	9.16	1.62	0.35

[a] Allocation was carried out as described in the text.
[b] Assumed to contain 0.45% N.

Table S5
Life-cycle inventories for imported feed production used in the conventional system (per ton)

	Unit	Maize	Wheat bran [a]	Alfalfa hay	Soybean meal [a,b]	Grass hay
Resource						
Chemical fertilizer						
N	kg	16.90	7.15		0.87	20.74
P_2O_5	kg	6.32	5.40	7.64	3.20	5.56
K_2O	kg	7.39	6.91	25.17	5.92	32.47
Lime	kg				122.64	
Calcium carbonate	kg	38.43				
Sulfur	g	181.09				
Herbicide	g	362.17	31.17[c]		423.17	
Insecticide	g	50.30			10.58	
Diesel	L	12.37	4.27	4.33	8.81	4.53
Gasoline	L	4.60	0.98		3.39	
Liquefied natural gas	kg	2.83				
Liquefied petroleum gas	kg	4.09	0.64		0.28	
Natural gas	m^3				15.81	
Electricity	kWh	130.59	43.42		33.80	

Table S5
Continued

	Unit	Maize		Wheat bran [a]		Alfalfa hay		Soybean meal [a,b]		Grass hay	
Energy consumption [d]	MJ	6536.07 (3040.61)		2594.89 (1710.12)		2308.19 (2078.56)		3590.82 (698.71)		5190.24 (5007.33)	
Emissions [d]											
CH_4	g	221.84	(30.03)	79.15	(49.18)	41.66	(25.71)	121.34	(13.36)	139.64	(125.34)
CO_2	kg	320.98	(39.91)	106.33	(59.53)	48.90	(34.03)	238.09	(17.01)	162.31	(149.53)
N_2O	g	303.75	(6.33)	124.18	(9.49)	5.51	(5.22)	62.31	(2.67)	349.84	(23.70)
NH_3	g	1436.61	(<0.01)	607.65	(<0.01)	<0.01		74.19	(<0.01)	1762.96	(<0.01)
NO_2	mg	887.17	(0.13)	195.43	(0.08)	0.11	(0.11)	677.68	(0.04)	0.21	(0.21)
NO_x	g	224.51	(58.42)	82.86	(29.77)	68.47	(17.48)	110.39	(8.70)	78.20	(73.65)
SO_2	g	92.03	(53.83)	35.42	(27.20)	16.81	(15.17)	46.29	(7.74)	67.81	(67.55)
SO_x	g	47.79	(5.82)	22.34	(3.02)	36.92	(2.03)	11.04	(0.94)	8.19	(7.55)

[a] Allocation was carried out as described in the text.
[b] Although 1.53 kg of hexane was used in processing, this was not considered for calculation of energy consumption and emissions according to the Inventory Database for Environmental Analysis.
[c] Including insecticide (see Pelletier et al., 2010).
[d] Values in parentheses indicate energy consumption or emissions via chemical fertilizer production.