

Supplemental Figures And Tables

Supplemental Table S1. Energy equivalent of inputs and outputs in various agricultural production systems.

Particulars	Unit	Energy equivalent (MJ unit ⁻¹)	References
<i>A. Inputs</i>			
1. Machinery	kW	4.93	[33]
2. Chemical fertilizers			
Nitrogen	kg	66.14	[35]
Phosphorus	kg	12.44	[35]
Potassium	kg	11.15	[33]
Compound fertilizer	kg	12.83	[33]
3. Plastic film	kg	79.00	[33]
4. Diesel	L	56.31	[36]
5. Pesticides	kg	303.80	[33]
<i>B. Outputs</i>			
1. Rice	kg	17.00	[37]
2. Tubers	kg	3.60	[33]
3. Soybeans	kg	14.70	[33]
4. Sugarcane	kg	1.20	[38]
5. Peanuts	kg	25.00	[33]
6. Tobacco	kg	0.80	[33]
7. Vegetables	kg	0.80	[33]
8. Tea	kg	0.80	[33]
9. Mulberry	kg	14.90	[39]
10. Fruits	kg	1.90	[33]

Supplemental Table S2. Emission factors used to estimate greenhouse gas emissions from agricultural inputs.

Particulars	Unit	Emission factor (CO ₂ e kg unit ⁻¹)	References
Machinery	MJ	0.07	[40]
Nitrogen	kg	1.53	[41]
Phosphorus	kg	1.63	[41]
Potassium	kg	0.65	[41]
Plastic agricultural film	kg	22.70	[42]
Diesel	kg	4.10	[43]
Pesticides	kg	14.00	[44]

Supplemental Table S3. Abbreviation for indicators related to energy, carbon input, and economic return.

Item	Abbreviation	Unit	References
Energy input per unit sowing area	EIPA	GJ·ha ⁻¹	[45]
Energy output per unit sowing area	EOPA	GJ·ha ⁻¹	[46]
Carbon input per unit sowing area	CIPA	(CO ₂ e·kg)·ha ⁻¹	[47]
Energy input per carbon input	EICI	MJ·(CO ₂ e·kg) ⁻¹	Defined by authors
Energy output per carbon input	EOCI	MJ·(CO ₂ e·kg) ⁻¹	Defined by authors
Energy input on carbon input per unit sowing area	EICIA	J·(CO ₂ e·kg·ha) ⁻¹	Defined by authors
Energy output on carbon output per unit sowing area	EOCIA	J·(CO ₂ e·kg·ha) ⁻¹	Defined by authors
Nominal economic return in crop production	NEcR	×10 ⁹ Yuan	[48]
Nominal economic return on energy input	NEcRI	Yuan·GJ ⁻¹	[48]
Nominal economic return on energy output	NEcRO	Yuan·GJ ⁻¹	[48]
Nominal economic return per unit sowing area	NEcRA	Yuan·ha ⁻¹	[48]
Nominal economic return on carbon footprint	NEcRC	Yuan·(CO ₂ e·kg) ⁻¹	[48]

Supplemental Table S4. Magnitude of residuals between original values and simulated values to assess model performance.

Year	<i>a</i>				
	NEcR	NEcRI	NEcRO	NEcRA	NEcRC
2011	0.00	0.00	0.00	0.00	0.00
2012	0.02	0.00	0.03	0.02	0.02
2013	0.02	0.01	0.03	0.02	0.02
2014	0.00	0.04	0.01	0.00	0.03
2015	0.02	0.01	0.01	0.01	0.01
2016	0.01	0.00	0.03	0.04	0.00
2017	0.02	0.02	0.01	0.00	0.02
2018	0.03	0.07	0.00	0.01	0.07
2019	0.03	0.02	0.02	0.03	0.02
2020	0.02	0.02	0.00	0.01	0.02
2021	0.01	0.01	0.01	0.03	0.01

Supplemental Table S5. Changes in the specific energy in the production of different crop categories in Guangdong Province, China, from 2011 to 2021 (kg·GJ⁻¹).

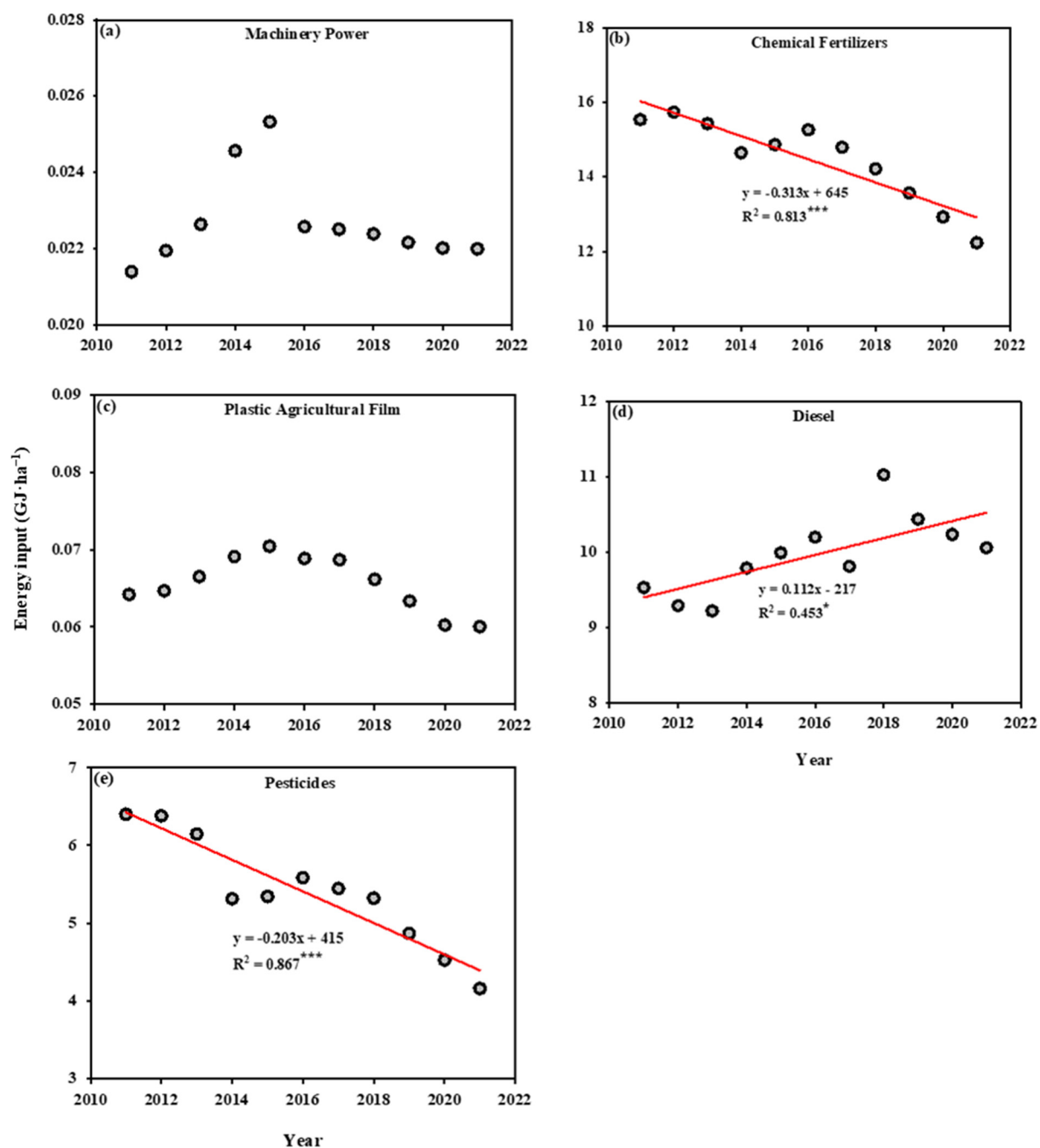
Year	Rice	Tubers	Soybean	Sugarcane	Peanuts	Tobacco	Vegetables	Tea	Mulberry	Fruits
2011	5.58	6.37	13.97	0.40	12.61	15.31	1.45	21.50	1.06	3.15
2012	5.45	6.23	12.80	0.39	12.47	14.91	1.42	20.62	1.03	3.02
2013	5.64	6.22	12.14	0.39	12.16	15.05	1.44	19.27	1.01	2.87
2014	5.18	6.26	11.48	0.38	11.62	14.71	1.39	20.24	0.92	2.32
2015	5.25	6.31	11.56	0.39	11.73	15.09	1.40	19.55	0.91	2.26
2016	5.41	6.54	11.66	0.41	10.26	12.61	1.22	19.69	0.92	2.22
2017	5.20	6.32	11.08	0.39	9.77	12.31	1.16	18.96	0.86	2.04
2018	5.31	6.47	11.19	0.38	9.76	12.36	1.17	19.45	0.79	1.95
2019	4.83	6.02	10.43	0.34	9.07	11.63	1.08	18.88	0.73	1.77
2020	4.63	5.79	9.95	0.32	8.61	11.11	1.02	16.93	0.69	1.63
2021	4.39	5.46	10.02	0.30	8.01	10.84	0.96	16.98	0.62	1.53

Supplemental Table S6. Changes in the energy productivity in the production of different crop categories in Guangdong Province, China, from 2011 to 2021 (GJ·kg⁻¹).

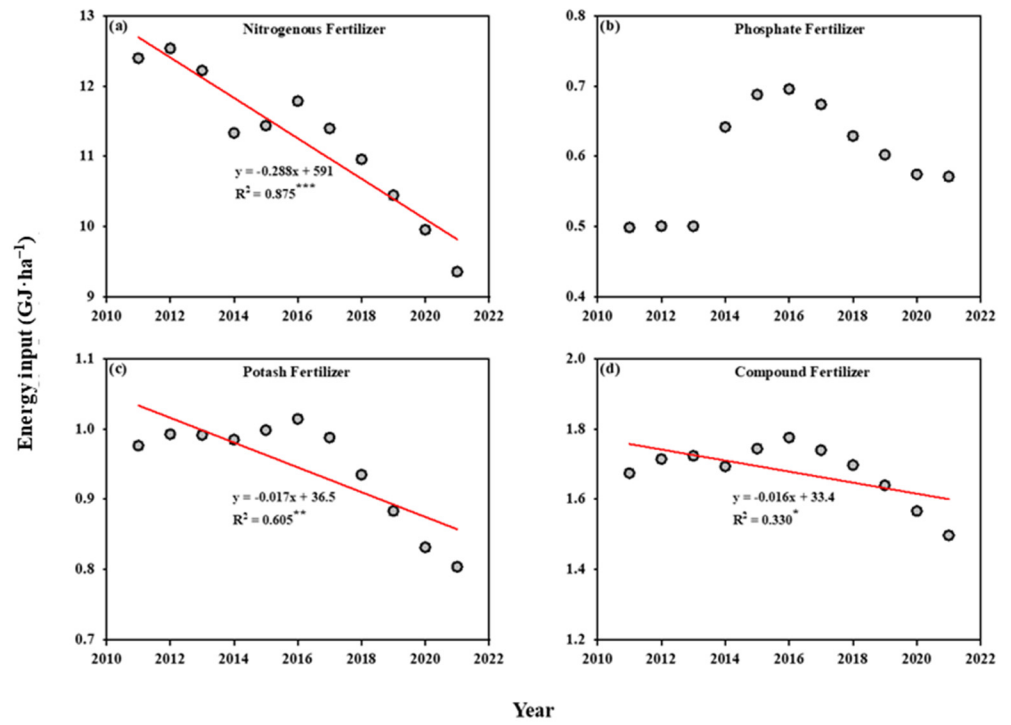
Year	Rice	Tubers	Soybean	Sugarcane	Peanuts	Tobacco	Vegetables	Tea	Mulberry	Fruits
2011	0.179	0.157	0.072	2.505	0.079	0.065	0.690	0.047	0.942	0.318
2012	0.183	0.161	0.078	2.540	0.080	0.067	0.703	0.048	0.969	0.331
2013	0.177	0.161	0.082	2.580	0.082	0.066	0.695	0.052	0.990	0.349
2014	0.193	0.160	0.087	2.617	0.086	0.068	0.719	0.049	1.083	0.430
2015	0.190	0.158	0.086	2.551	0.085	0.066	0.715	0.051	1.097	0.443
2016	0.185	0.153	0.086	2.464	0.097	0.079	0.819	0.051	1.090	0.451
2017	0.192	0.158	0.090	2.595	0.102	0.081	0.859	0.053	1.157	0.491
2018	0.188	0.155	0.089	2.649	0.102	0.081	0.854	0.051	1.258	0.514
2019	0.207	0.166	0.096	2.915	0.110	0.086	0.923	0.053	1.361	0.564
2020	0.216	0.173	0.100	3.097	0.116	0.090	0.979	0.059	1.440	0.613
2021	0.228	0.183	0.100	3.283	0.125	0.092	1.044	0.059	1.601	0.655

Supplemental Table S7. Changes in greenhouse gas emissions from agricultural inputs in Guangdong Province, China, from 2011 to 2021 ((CO₂e·kg)·ha⁻¹).

Year	Machinery power	Nitrogenous fertilizer	Phosphate fertilizer	Potash fertilizer	Plastic agricultural film	Diesel	Pesticides
2011	1.50	286.80	65.34	56.91	184.44	586.24	294.94
2012	1.54	290.00	65.61	57.86	185.84	571.51	294.02
2013	1.58	282.73	65.60	57.80	191.09	567.22	283.28
2014	1.72	262.16	84.09	57.40	198.54	602.23	244.89
2015	1.77	264.60	90.14	58.20	202.38	614.70	246.17
2016	1.58	272.64	91.17	59.13	197.84	627.42	257.32
2017	1.58	263.66	88.30	57.58	197.35	603.48	250.91
2018	1.57	253.48	82.41	54.50	190.08	678.34	245.18
2019	1.55	241.63	78.92	51.49	182.02	642.12	224.23
2020	1.54	230.29	75.26	48.48	173.06	629.63	208.50
2021	1.54	216.45	74.83	46.86	172.48	618.87	191.58



Supplemental Figure S1. Changes in the energy input categories, i.e., machinery (a), chemical fertilizers (b), plastic agricultural films (c), diesel (d), and pesticides (e), in crop production in Guangdong Province, China, from 2011 to 2021 ($\text{GJ} \cdot \text{ha}^{-1}$).



Supplemental Figure S2. Changes in the energy input of fertilizers, i.e., nitrogen fertilizers (a), phosphorus fertilizers (b), potassium fertilizers (c), and compound fertilizers (d), in crop production in Guangdong Province, China, from 2011 to 2021 ($\text{GJ} \cdot \text{ha}^{-1}$).