Supplementary Material

File S1: Greenhouse gas emission calculation

$$GHG_{raw\ material} = \sum_{i=1}^{n}(R_i \times EF_{Ri}) \tag{S1}$$

where $GHG_{raw\ material}$ is GHG emissions during raw material production phase (kg CO_2eq ha^{-1} $year^{-1}$), R_i is the amount of agriculture input type i (kg ha^{-1} $crop^{-1}$), EF_{Ri} is the emission factor (EF) of agricultural input type i.

$$GHG_{transportation} = \sum_{i=1}^{n}(W(i) \times D(i) \times EF(ti)) \tag{S2}$$

where $GHG_{transportation}$ is GHG emissions during transportation (kg CO_2eq $year^{-1}$), $W(i)$ is the weight of type i (ton $year^{-1}$), $D(i)$ is the distance for transportation (km $year^{-1}$), $EF(ti)$ is the emissions factor of vehicle type t to transport material type i (kg CO_2eq·t km^{-1}).

$$GHG_{utilization} = \sum_{i=1}^{n}(M(i) \times EF(ui)) \tag{S3}$$

where $GHG_{utilization}$ is GHG emissions during utilization phase of agriculture input (kg CO_2eq ha^{-1} $year^{-1}$), $M(i)$ is the amount of agricultural input type i used (kg ha^{-1} $crop^{-1}$), $EF(ui)$ is the emissions factor for using agriculture input type i.

$$GHG_{CH_4} = EF_{adj} \times t \tag{S4}$$

where GHG_{CH_4} is the methane emissions during rice cultivation (kg CH_4 ha^{-1}); EF_{adj} is the adjusted daily emissions factor (kg CH_4 ha^{-1} day^{-1}); and t is the duration of rice growth (days).

The EF_{adj} can be calculated using Equation (10) [41].

$$EF_{adj} = (EF_c \times SF_w \times SF_p \times SF_o) \tag{S5}$$

where EF_c is the baseline emissions factor for continuously flooded fields without organic amendments. SF_w and SF_p are scaling factors to account for the differences in water regime during and before the cultivation period, respectively. SF_0 is the scaling factor to account for both type and amount of organic amendment applied.

$$SF_o = (1 + \sum_i ROA_i \times CFOA_i)^{0.59} \tag{S6}$$

where SF_0 is the scaling factor for both type and amount of organic amendment applied, ROA_i is the application rate of organic amendment i (ton ha^{-1}), and $CFOA_i$ is the conversion factor for organic amendment i.

The direct N_2O emissions from paddy fields were calculated as the following equation [105]:

$$GHG_{N_2O} = N \times \emptyset \times \frac{44}{28} \tag{S7}$$

where N is the quantity of nitrogen applications from compound fertilizers and organic fertilizers (kg N $year^{-1}$), $\emptyset$ is the emission factor of N_2O emission due to N application (0.003 kg N_2O-N kg^{-1} of N for continuous flooding), and 44/28 is the molecular weight ratio of N_2O to N_2O-N.

Life cycle inventory (LCI) data and sources for materials

Table S1. Emissions factors used for calculation of GHG emissions from raw materials production phase

Activity	Emissions factor	Unit	Source
Thailand's country specific emission factors			
Gasoline	0.3409	kg CO_2eq L^{-1}	The National Technical Committee on Product Carbon Footprinting (Thailand) [43]
Alachlor	8.0900	kg CO_2eq kg^{-1}	
Paraquat	3.2300	kg CO_2eq kg^{-1}	
Fertilizer 15-15-15	2.0500	kg CO_2eq kg^{-1}	
Fertilizer 0-0-60 (Potassium chloride)	0.5330	kg CO_2eq kg^{-1}	
Fertilizer 16-20-0 (Ammonium phosphate)	3.7700	kg CO_2eq kg^{-1}	
Rice seed	0.2500	kg CO_2eq kg^{-1}	TGO [44]
LCI dataset name			
Diesel	0.38664	kg CO_2eq L^{-1}	Ecoinvent Centre [47] (IPCC 2013 GWP 100a)
Nitrogen (N)	2.1178	kg CO_2eq kg^{-1}	
Phosphorus (P_2O_5)	0.34464	kg CO_2eq kg^{-1}	
Potassium (K_2O)	0.26885	kg CO_2eq kg^{-1}	
Urea	3.3036	kg CO_2eq kg^{-1}	
Acephate (Organophosphorus compound)	7.8097	kg CO_2eq kg^{-1}	
Chlorpyrifos (Organophosphorus compound)	7.8097	kg CO_2eq kg^{-1}	
Insecticide (unspecific)	10.2089	kg CO_2eq kg^{-1}	The National Technical Committee on Product Carbon Footprinting (Thailand) [46]
Herbicide (unspecific)	16.5873	kg CO_2eq kg^{-1}	

Table S2. Emissions factors used for calculation of GHG emissions from utilization phase

Activity	Emissions factor	Unit	Source
Glyphosate	16.0000	kg CO_2eq kg^{-1}	The National Technical Committee on Product Carbon Footprinting (Thailand) [46]
Paraquat	3.2300	kg CO_2eq kg^{-1}	
Alachlor	8.0900	kg CO_2eq kg^{-1}	
Acephate (Organophosphorus compound)	7.8097	kg CO_2eq kg^{-1}	Ecoinvent Centre [47] (IPCC 2013 GWP 100a)
Chlorpyrifos (Organophosphorus compound)	7.8097	kg CO_2eq kg^{-1}	
Transportation agriculture inputs to farm			
4 wheels truck: 7 tonnes (Diesel used)	0% Loading = 0.3111 50% Loading = 0.2681 75% Loading = 0.1829 100% Loading = 0.1402	kg CO_2eq tonnes km^{-1}	The National Technical Committee on Product Carbon Footprinting (Thailand) [43]
Agriculture input			
Diesel used (stationary combustion) for farm operation	2.7446	kg CO_2eq L^{-1}	IPCC [41]
Gasoline used (stationary combustion) for farm operation	2.1896	kg CO_2eq L^{-1}	
Diesel used (mobile combustion) for farm operation	Tractor = 3.908 Harvester = 2.645	kg CO_2eq L^{-1}	Maciel et al. [48] (calculated with diesel density of 0.832 kg L^{-1})
Gasoline used (mobile combustion) for farm operation	2.319	kg CO_2eq L^{-1}	EPA [45]
CH_4 emission from rice cultivation			
EF_c	Southeast Asia = 1.22	kg CH_4 ha^{-1} day^{-1}	IPCC [41]
SF_w	Irrigated areas (continuously flooded, single drainage period, and multiple drainage periods) = 0.60		
SF_p	Non flooded pre -season >180 days = 0.89		
$CFOA_i$	Straw incorporated shortly (< 30 days) before cultivation = 1.00		
	Straw incorporated long		

	(> 30 days) before cultivation = 0.19		
	Compost = 0.17		
	Farm yard manure = 0.21		
	Green manure = 0.45		

EF_c = the baseline emissions factor for continuously flooded fields without organic amendments; SF_w = a scaling factor to account for the differences in water regime during the cultivation period; SF_p = a scaling factor to account for the differences in water regime in the pre-season before the cultivation period; SF_0 = a scaling factor that accounts for differences in both type and amount of organic amendment applied source, $SF_{s,r}$ = a scaling factor for soil type, rice cultivar, etc; $CFOA$ = the conversion factor for organic amendment i.