Supplementary Materials for

Spatial Planning of Centralized and Decentralized Composting for Nutrient Recycling and Sustainable Agricultural Land Management: A Township-Scale Case Study in Rural China

Contents

Figure S1 Location of case study area 3

Table S1 Technical parameters of compost reactor 4

Table S2 Technical parameters of compost bin 5

Supplementary Note S1 Design of Composting Planning in Beiyang Town 6

Figure SN1.1 Framework for composting planning and design in Beiyang Town 6

Table SN1.1 Factors and criteria for siting composting reactors considering environmental, economic, social and topographical factors 7

Figure SN1.2 The GIS-based compost reactor siting process includes the first step of (a) identifying POI points for schools, residential and commercial areas, (b) identifying water bodies; the second step of (c) areas ≥500m from the relevant POI points, (d) areas ≥500m from the water bodies, (e) areas ≤50m from the roads, and (f) areas with slopes of ≤15°; and the third step of (g) obtaining suitable candidate locations and (h) final selection of locations in the corresponding areas 8

Figure SN1.3 Crop cultivation in Beiyang Town obtained through GIS-based grid segmentation and field research (results from remote sensing image map analysis and field research conducted in December 2021) 10

Table SN1.2 Crop-specific parameters used to estimate agricultural residue generation in Beiyang Township 10

Table SN1.3 Total residues from centralised and decentralised production is divided according to the number of grids and village areas 11

Table SN1.4 Volume of waste from centralised and decentralised production according to type and month 14

Table SN1.5 Determination of the proportion of crop residues and pig manure in compost reaction materials 16

Table SN1.6 Detailed operational plans for five composting reactors under three scenarios 17

Table SN1.7 Population size of villages/communities and number of compost bins under different scenarios 20

Table SN1.8 Number of compost bins under different scenarios for public facilities 21

Table S3 Dataset used for TC-loss machine-learning model development 22

Table S4 Dataset used for TN-loss machine-learning model development 26

Supplementary Note S2. Prediction of TC and TN Losses Using Machine-Learning Models 30

Table SN 2.1 Specific sample test methods and standards 30

Table SN 2.2 Sample test and analysis results 30

Table SN 2.3 Final model prediction results 30

Table S5 Crop-specific nitrogen fertilizer application rates used to estimate annual crop N demand in Beiyang Township 31

Table S6 Sources, calculation bases, and verification status of economic parameters used in Tables 3 and 4 32

Supplementary Note S3. Sensitivity Analysis of Nitrogen Recycling Potential 34

Table SN3.1. Sensitivity of theoretical nitrogen recycling potential to variations in total nitrogen retained in compost under Scenario S3. 34

References 35

Figure S1 Location of case study area



Figure S1 Location of Beiyang town, Huangyan District, Taizhou City, Zhejiang Province, China (Map [left] from Ministry of Natural Resources of the PRC: 2020 standard map. [http://bzdt.ch.mnr.gov.cn/browse.html?picId=%224o28b0625501ad13015501ad2bfc0267%22], modified).

Table S1 Technical parameters of compost reactor

Table S1 Technical parameters of compost reactor

Parameters	Values
Volume	10/20/40 m^3
Reaction cycle	Continuous reaction, 10 days/cycle
Aeration rates	0.21 (L/kg min-1, dry matter)

Table S2 Technical parameters of compost bin

Table S2 Technical parameters of compost bin

Parameters	Values
Volume	70 cm × 70 cm × 103 cm
Reaction cycle	Continuous reaction, 80 days/cycle
Weight ratio of output and to input material	30%

Supplementary Note S1 Design of Composting Planning in Beiyang Town

In this study, the composting reactor was primarily designed to treat agricultural waste, while the compost bin was utilized for food waste treatment. As shown in Figure SN 1.1, the initial step for the compost reactor involved selecting an appropriate geographical site. A multi-criteria site selection method, using GIS Points of Interest (POI), was employed to identify a suitable location in Beiyang Township. Subsequently, grid-based calculations were conducted to estimate the quantity of agricultural residues. Additionally, according to existing literature, the optimal ratio of crop residue to swine manure in the composting material was determined, as well as the required input for the reactor. This approach facilitated the development of a tailored composting program for each reactor. The design of the composting bins was focused on determining the number of drums needed, based on population size and drum capacity specifications.

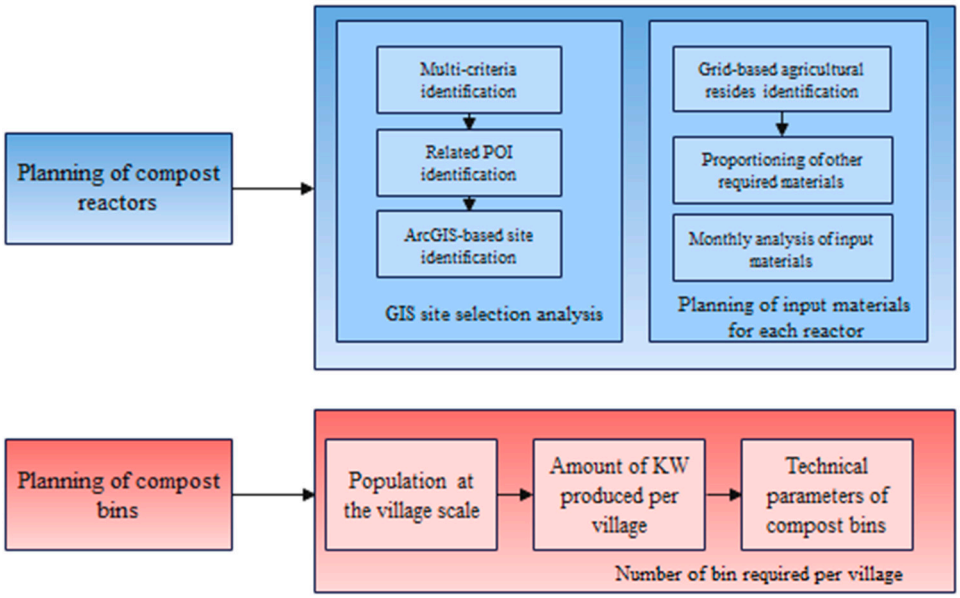


Figure SN1.1 Framework for composting planning and design in Beiyang Town

SN1 .1 Design of compost reactor planning

SN1.1.1 GIS-based siting analysis of composting reactors

When selecting a site for a composting facility, it is often necessary to consider the environmental impact of the facility on the surrounding area, avoiding complaints from residents as much as possible and ensuring environmental safety. According to the requirements for composting facilities in the planning standard for urban environmental sanitation facilities(“Standard for planning of urban environment sanitation facilities,” 2018), the land boundary of composting facilities should be no less than 500 m away from urban and rural residential land. At the same time, according to the requirements of the specification for garbage disposal facilities(“Technical code for agriculture and food waste treatment,” 2012), it is necessary to avoid environmentally sensitive zones in the site selection process. In addition,

transportation accessibility also needs to be considered, and the specific requirements are shown in Table SN1.1. According to the above requirements, in Fig SN1.2a, the points of interest (POI) of schools, residences, and commercial areas collected from Gaode Map are collected. Then, appropriate buffers were screened based on the requirements of Table SN1.1. Schools, residences, and commercial areas are shown in Figure SN1.2c, and water bodies are shown in Figure SN1.2d. And the roads and slopes were considered in Figures SN1.2e and f, respectively. The final selection of suitable areas is shown in Figure SN1.2g. Then it corresponds to the area as shown in Figure SN1.2.

Table SN1.1 Factors and criteria for siting composting reactors considering environmental, economic, social and topographical factors

Factors	**Criteria**	**Index**	**Reference**
Environment	Distance to water bodies (reservoirs, rivers)	≥500m	("Technical code for agriculture and food waste treatment," 2012)
	No farmland occupied		("Technical code for agriculture and food waste treatment," 2012)
Economy	Distance to road	≤50m	(Yalcinkaya et al., 2021)
Society	Distance from residential areas	≥500m	("Standard for planning of urban environment sanitation facilities," 2018)
	Distance from schools	≥500m	("Standard for planning of urban environment sanitation facilities," 2018)
	Distance from commercial areas	≥500m	("Standard for planning of urban environment sanitation facilities," 2018)
Topography	Slope	≤15°	(Yalcinkaya et al., 2021)

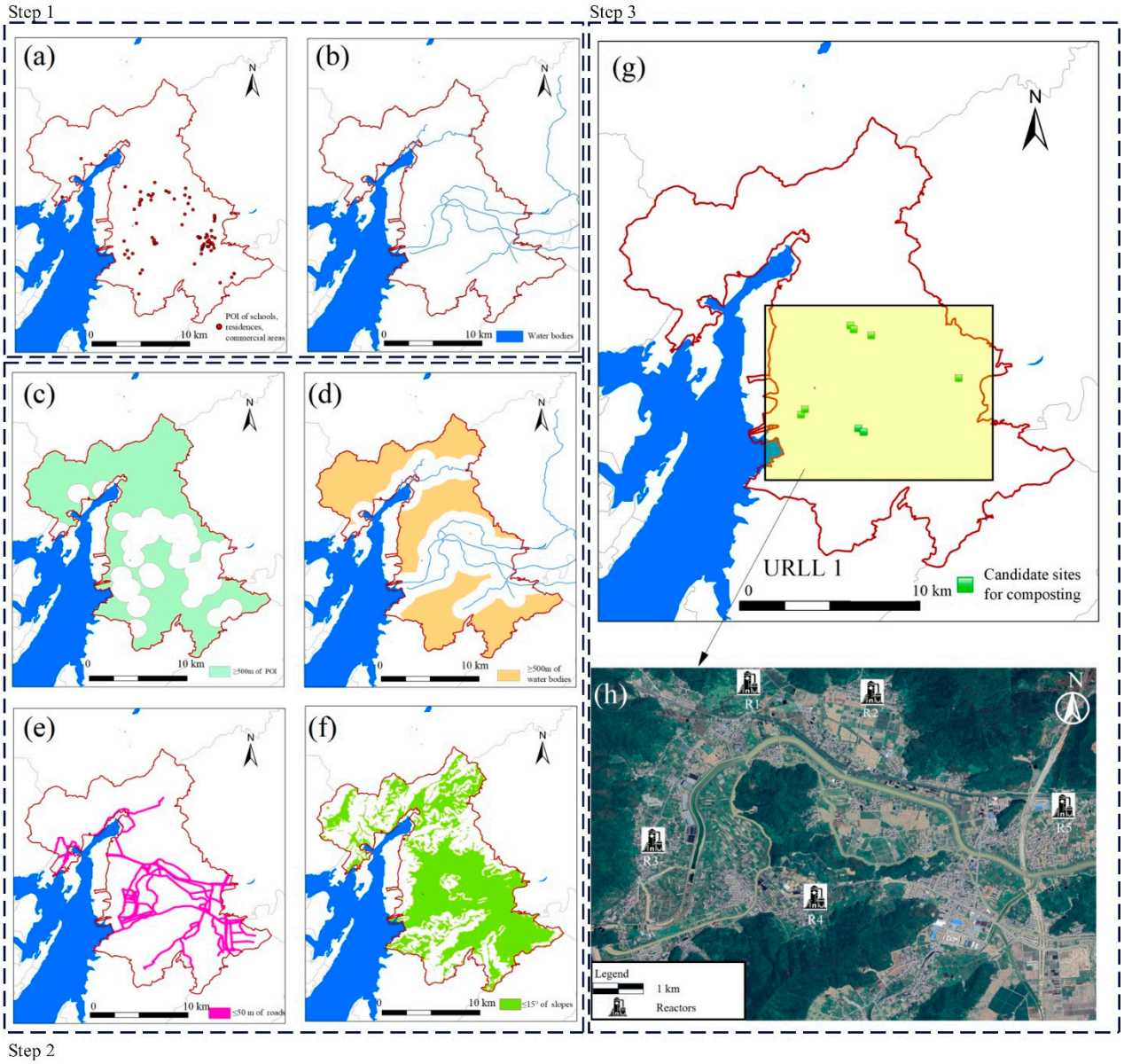
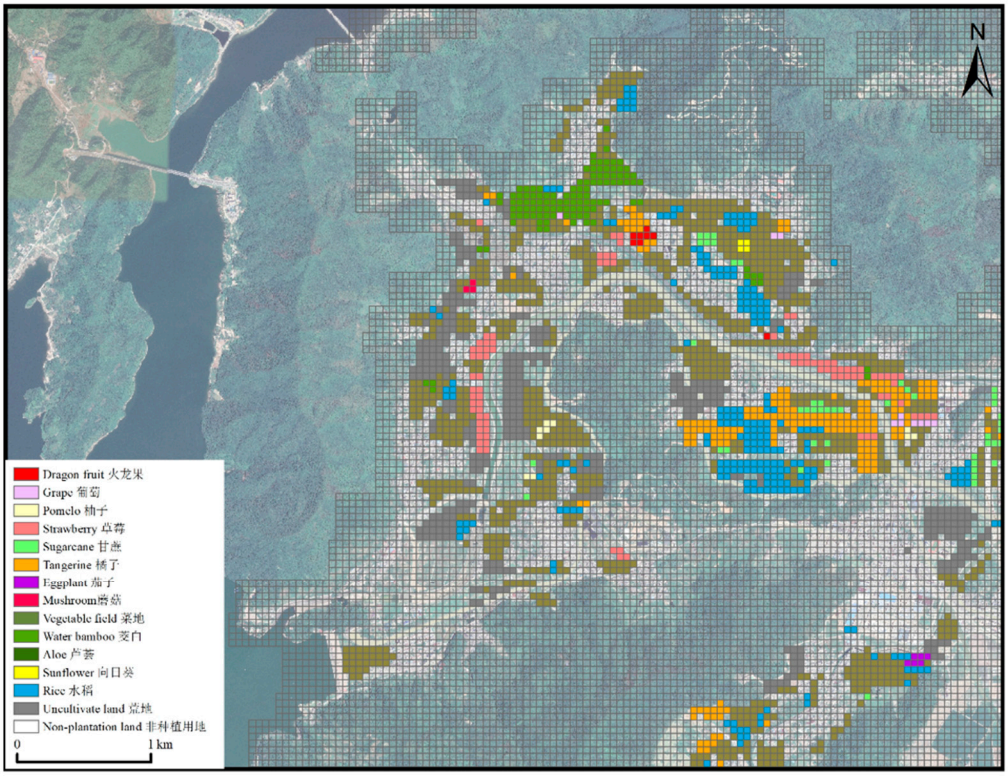


Figure SN1.2 The GIS-based compost reactor siting process includes the first step of (a) identifying POI points for schools, residential and commercial areas, (b) identifying water bodies; the second step of (c) areas ⩾500m from the relevant POI points, (d) areas ⩾500m from the water bodies, (e) areas ⩽50m from the roads, and (f) areas with slopes of ⩽15°; and the third step of (g) obtaining suitable candidate locations and (h) final selection of locations in the corresponding areas

SN1.1.2 GIS Grid-based agricultural residues stock analysis

In order to more accurately characterize the crop cultivation in the area, we first divided the farmland using remote sensing image maps. The farmland was then divided into 50×50 m grids and assigned unique numbers. We conducted field visits to determine the types of crops grown in each grid. We followed the following rule: if there were multiple crops in a grid, the grid was counted based on the crop with the largest planted area. By counting the number of grids, the area planted to different crops was calculated. Figure SN1.3 shows crop cultivation based on the above methodology.

Table SN1.2 shows the calculations for centrally produced agricultural waste. Crop-specific collection factors were first used to estimate the potentially collectable amount of each agricultural residue, as shown in Table SN1.2. Because residues from decentralized production sources are more difficult to aggregate and collect, an additional accessibility factor of 0.30 was applied to the estimated residue quantity from these sources. Residues from centralized production sources were assigned an accessibility factor of 1.0. Thus, the 0.30 factor represents the relative accessibility of decentralized residues rather than a replacement for the crop-specific collection factors listed in Table SN1.2. In this study, we divided the centralized and decentralized agricultural production grids on a village basis, taking into account the geographical boundaries of the village domain, specifics can be found in Table SN1.3. The compost reactor feed consists mainly of agricultural residues that are seasonal and vary from month to month. In order to accurately quantify the monthly production of residues, the study used local research data to determine the percentage of total monthly production, as shown in Table SN1.4.



Main Crops	Vegetables	Rice	Citrus	Water bamboo	Sugarcane	Total of all crops
Number of grids	1067	293	263	118	102	2203

Figure SN1.3 Crop cultivation in Beiyang Town obtained through GIS-based grid segmentation and field research (results from remote sensing image map analysis and field research conducted in December 2021)

Table SN1.2 Crop-specific parameters used to estimate agricultural residue generation in Beiyang Township

Crops	Economic production (kg/mu)	Percentage of waste	Collection factor	Production of residues (kg/mu)
Rice	596(Liu et al., 2014)	0.9(Liu et al., 2014)	0.8(Liu et al., 2014)	429.1
Citrus	1542[a]	0.3 [a]	0.8(Bi, 2010)	370.1

Sugarcane bagasse	6914 [a]	0.3(Liu, 2018)	0.9(Bi, 2010)	1866.8
Water bamboo	3375 [a,b]	0.6 [a]	0.9(Bi, 2010)	1822.5
Vegetables	4706.7(Wu, 2020)	0.4(Wu, 2020)	0.6(Bi, 2010)	1129.6

Note: mu is the common unit of area in China,1mu = 666.7 square meters; a: data from field trip/ interview; b: Water bamboo is harvested in two seasons a year and yields 2250 and 1125 kg/mu respectively; Calculation formula: Production of residues = economic production * waste share * collection factor

Table SN1.3 Total residues from centralised and decentralised production is divided according to the number of grids and village areas

Production method	Locations	Agricultural Residues	Number of grids	Total residues (wet weight, kg)
Centralized production	Guan'ao village	RS	20	32382
	Guan'ao village	WL	98	669732
	Guan'ao village	CP	2	2775.4
	Guan'ao village	VW	69	292270.2
	Guan'ao village	SB	2	14000.2
	Chaoji village	WL	2	13668
	Chaoji village	VW	43	182139.4
	Shanxiajie village	RS	7	11333.7
	Shanxiajie village	VW	90	381222
	Changtan village	VW	28	118602.4
	Qianjiang village	SB	10	70001
	Qianjiang village	RS	20	32382
	Qianjiang village	VW	98	415108.4
	Lianqun village	RS	68	110098.8
	Lianqun village	VW	102	432051.6
	Lianqun village	CP	23	31917.1
	Chengxie village	RS	43	69621.3
	Chengxie village	CP	139	192890.3
	Chengxie village	SB	15	105001.5
	Chengxie village	VW	52	220261.6
	Yijianju	CP	8	11101.6
	Aoli village	RS	16	25905.6
	Aoli village	CP	18	24978.6

	Aoli village	VW	60	254148
	Xiaoliqiao village	VW	10	42358
	Kangshan village	RS	11	17810.1
	Kangshan village	CP	45	62446.5
	Kangshan village	SB	23	161002.3
	Kangshan village	VW	42	177903.6
	Seeher farm	RS	17	27524.7
	Seeher farm	CP	7	9713.9
	Seeher farm	VW	79	334628.2
	Seeher farm	SB	10	70001
	Seeher farm	WL	6	41004
	Sinogerman farm	VW	12	50829.6
	Sinogerman farm	SB	1	7000.1
	Sinogerman farm	RS	55	89050.5
Decentralised production	Guan'ao village	RS	3	4857.3
	Guan'ao village	WL	7	47838
	Guan'ao village	CP	1	1387.7
	Guan'ao village	VW	36	152488.8
	Guan'ao village	SB	5	35000.5
	Chaoji village	CP	1	1387.7
	Chaoji village	VW	40	169432
	Shanxiajie village	WL	3	20502
	Shanxiajie village	RS	2	3238.2
	Shanxiajie village	VW	33	139781.4
	Qianjiang village	SB	17	119001.7
	Qianjiang village	RS	7	11333.7
	Qianjiang village	CP	2	2775.4
	Qianjiang village	VW	75	317685
	Lianqun village	RS	4	6476.4
	Lianqun village	SB	7	49000.7
	Lianqun village	VW	78	330392.4
	Lianqun village	CP	2	2775.4
	Chengxie village	RS	8	12952.8
	Chengxie village	CP	2	2775.4
	Chengxie village	SB	5	35000.5
	Chengxie village	VW	72	304977.6
	Beiyangju	VW	8	33886.4
	Aoli village	RS	10	16191
	Aoli village	CP	2	2775.4
	Aoli village	VW	75	317685
	Xiaoliqiao village	VW	15	63537
	Kangshan village	RS	2	3238.2
	Kangshan village	CP	2	2775.4
	Kangshan village	SB	7	49000.7

	Kangshan village	VW	38	160960.4
	Kangshan village	WL	2	13668

Note: Total residues = Production of residues per grid * Number of grids

Table SN1.4 Volume of waste from centralised and decentralised production according to type and month

Agricultural residues	Harvest month	Percentage of total production in that month	Monthly production/grid (kg)	Centralized production		Decentralized production	
				Number of grids	Weight of residue (wet weight, kg)	Number of grids	Weight of residue (wet weight, kg)
RS	9	20%	321.8	257	82708.7	36	3475.7
	10	40%	643.6		165417.5		6951.4
	11	40%	643.6		165417.5		6951.4
CP	10	15%	208.2	242	50374.6	12	749.4
	11	30%	416.3		100749.2		1498.7
	12	30%	416.3		100749.2		1498.7
	1	15%	208.2		50374.6		749.4
	2	10%	138.8		33583.1		499.6
SB	10	25%	1750.0	61	106751.1	41	21525.2
	11	30%	2100.0		128101.4		25830.3
	12	30%	2100.0		128101.4		25830.3
	1	15%	1050.0		64050.7		12915.1
WL	3	20%	911.2	106	96587.7	12	3280.3
	4	30%	1366.8		144881.5		4920.5
	5	30%	1366.8		144881.5		4920.5
	6	20%	911.2		96587.7		3280.3
	10	20%	455.6		48293.8		1640.2
	11	40%	911.2		96587.7		3280.3
	12	10%	227.8		24146.9		820.1

	1	10%	227.8		24146.9	820.1
VW	1	5%	211.8	609	128980.7	29100.1
	2	5%	211.8		128980.7	29100.1
	3	8%	338.9		206369.1	46560.1
	4	10%	423.6		257961.3	58200.1
	5	12%	508.3		309553.6	69840.2
	6	12%	508.3		309553.6	69840.2
	7	15%	635.4		386942.0	87300.2
	8	15%	635.4		386942.0	87300.2
	9	10%	423.6		257961.3	58200.1
	10	8%	338.9		206369.1	46560.1
	11	5%	211.8		128980.7	29100.1
	12	5%	211.8		128980.7	29100.1

SN1.1.3 Scenario-Based Feedstock Arrangement for Centralized Composting Reactors

Following the GIS-based identification of five suitable composting-reactor locations, the availability of agricultural residues was evaluated using the village-level waste inventory (Table SN1.3) and the monthly generation patterns of different crop residues (Table SN1.4). The quantities available for composting under Scenarios S1–S3 were determined according to the corresponding composting-adoption assumptions.

Based on these estimated quantities and seasonal feedstock characteristics, operational arrangements were developed for the five centralized reactors. The proportions of crop residues, pig manure, and auxiliary materials were determined using the assumed co-composting formulations (Table SN1.5). The resulting monthly feedstock compositions and treatment schedules for individual reactors are presented in Table SN1.6.

These arrangements were established for scenario-based treatment planning and reactor operation. The study did not employ an explicit source-to-facility allocation optimization model, and individual waste-generation locations were not assigned to reactors through a minimum-distance or minimum-transport-cost algorithm. Consequently, transport distances and tonne-kilometre indicators were not calculated. The proposed arrangements should therefore be interpreted as planning configurations rather than optimized waste-transport routes.

SN1.1.4 Specific operational planning for each reactor

The rational planning of the reaction material input for each compost reactor. The ratios of agricultural waste to pig manure and their reference basis are shown in Table SN1.5. Here, in order to facilitate the operation of the reaction equipment and the homogeneity of the compost quality, it is assumed that each reactor processes only one type of agricultural waste per month and that only one type of agricultural waste is considered to be composted with pig manure and calcium superphosphate in this scenario. The specific scenario is shown in Table SN1.6.

Table SN1.5 Determination of the proportion of crop residues and pig manure in compost reaction materials

No.	Crop	Crop residues: Pig manure	C:N	References
1	Rice straw	1:2	17.8	(Tong et al., 2020)
2	Citrus peels	1:1	19.6	(OJO et al., 2021)
3	Sugarcane bagasse	1:1	22.8	(OJO et al., 2021)

4	Water bamboo leaves	1:2	14.7	(WU et al., 2023)
5	Vegetable waste	10:1	16.7	(Lu et al., 2022)

Table SN1.6 Detailed operational plans for five composting reactors under three scenarios

S1															
Months	R1			R2			R3			R4			R5		
	CW	CWW	PMW	CW	CWW	PMW	CW	CWW	PMW	CW	CWW	PMW	CW	CWW	PMW
1	WL	107.0	214.0	SB	297.9	297.9	CP	197.8	197.8	VW	611.9	61.2	RS	344.8	689.6
2	-	0.0	0.0	-	0.0	0.0	CP	146.1	146.1	VW	677.5	67.8	-	0.0	0.0
3	WL	386.6	773.2	VW	284.3	28.4	VW	284.3	28.4	VW	284.3	28.4	VW	284.3	28.4
4	WL	599.2	1198.4	VW	316.2	31.6	VW	316.2	31.6	VW	316.2	31.6	VW	316.2	31.6
5	WL	579.9	1159.8	VW	367.2	36.7	VW	367.2	36.7	VW	367.2	36.7	VW	367.2	36.7
6	WL	399.5	799.0	VW	379.4	37.9	VW	379.4	37.9	VW	379.4	37.9	VW	379.4	37.9
7	VW	367.2	36.7	VW	367.2	36.7	VW	367.2	36.7	VW	367.2	36.7	VW	367.2	36.7
8	VW	367.2	36.7	VW	367.2	36.7	VW	367.2	36.7	VW	367.2	36.7	VW	367.2	36.7
9	VW	316.2	31.6	VW	316.2	31.6	VW	316.2	31.6	VW	316.2	31.6	RS	344.7	689.4
10	WL	193.3	386.6	SB	496.6	496.6	CP	197.9	197.9	VW	979.1	97.9	RS	333.6	667.2
11	WL	399.5	799.0	SB	615.7	615.7	CP	409.0	409.0	VW	632.3	63.2	RS	333.6	667.2
12	WL	96.6	193.2	SB	595.9	595.9	CP	395.8	395.8	VW	611.9	61.2	RS	344.8	689.6
S2															
Months	R1			R2			R3			R4			R5		

	CW	CWW	PMW	CW	CWW	PMW	CW	CWW	PMW	CW	CWW	PMW	CW	CWW	PMW
1	WL	356.7	713.4	SB	993.1	993.1	CP	659.7	659.7	VW	2039.8	204.0	RS	1149.1	2298.2
2	-	0.0	0.0	-	0.0	0.0	CP	486.9	486.9	VW	2258.3	225.8	-	0.0	0.0
3	WL	1288.6	2577.2	VW	815.9	81.6	VW	815.9	81.6	VW	815.9	81.6	VW	815.9	81.6
4	WL	1997.4	3994.8	VW	1053.9	105.4	VW	1053.9	105.4	VW	1053.9	105.4	VW	1053.9	105.4
5	WL	1932.9	3865.8	VW	1223.9	122.4	VW	1223.9	122.4	VW	1223.9	122.4	VW	1223.9	122.4
6	WL	1331.6	2663.2	VW	1264.6	126.5	VW	1264.6	126.5	VW	1264.6	126.5	VW	1264.6	126.5
7	VW	1223.8	122.4	VW	1223.8	122.4	VW	1223.8	122.4	VW	1223.8	122.4	VW	1223.8	122.4
8	VW	1223.8	122.4	VW	1223.8	122.4	VW	1223.8	122.4	VW	1223.8	122.4	VW	1223.8	122.4
9	VW	1053.9	105.4	VW	1053.9	105.4	VW	1053.9	105.4	VW	1053.9	105.4	RS	1149.1	2298.2
10	WL	644.3	1288.6	SB	1655.2	1655.2	CP	659.7	659.7	VW	3263.6	326.4	RS	1112.1	2224.2
11	WL	1331.6	2663.2	SB	2052.4	2052.4	CP	1363.3	1363.3	VW	2107.8	210.8	RS	1112.1	2224.2
12	WL	322.2	644.4	SB	1986.2	1986.2	CP	1319.3	1319.3	VW	2039.8	204.0	RS	1149.1	2298.2

S3

Months	R1			R2			R3			R4			R5		
	CW	CWW	PMW	CW	CWW	PMW	CW	CWW	PMW	CW	CWW	PMW	CW	CWW	PMW
1	WL	624.2	1248.4	SB	1737.9	1737.9	CP	1154.4	1154.4	VW	3569.6	357.0	RS	2010.9	4021.8
2	-	0.0	0.0	-	0.0	0.0	CP	852.1	852.1	VW	3952.0	395.2	-	0.0	0.0
3	WL	2255.1	4510.2	VW	1427.8	142.8	VW	1427.8	142.8	VW	1427.8	142.8	VW	1427.8	142.8
4	WL	3495.4	6990.8	VW	1844.3	184.4	VW	1844.3	184.4	VW	1844.3	184.4	VW	1844.3	184.4
5	WL	3382.6	6765.2	VW	2141.8	214.2	VW	2141.8	214.2	VW	2141.8	214.2	VW	2141.8	214.2
6	WL	2330.3	4660.6	VW	2213.1	221.3	VW	2213.1	221.3	VW	2213.1	221.3	VW	2213.1	221.3

7	VW	2141.7	214.2	VW	2141.7	214.2	VW	2141.7	214.2	VW	2141.7	214.2	VW	2141.7	214.2
8	VW	2141.7	214.2	VW	2141.7	214.2	VW	2141.7	214.2	VW	2141.7	214.2	VW	2141.7	214.2
9	VW	1844.3	184.4	VW	1844.3	184.4	VW	1844.3	184.4	VW	1844.3	184.4	RS	2011.0	4022.0
10	WL	1127.5	2255.0	SB	2896.6	2896.6	CP	1154.4	1154.4	VW	5711.3	571.1	RS	1946.1	3892.2
11	WL	2330.3	4660.6	SB	3591.7	3591.7	CP	2385.8	2385.8	VW	3688.6	368.9	RS	1946.1	3892.2
12	WL	563.8	1127.6	SB	3475.9	3475.9	CP	2308.8	2308.8	VW	3569.6	357.0	RS	2010.9	4021.8

Note: abbreviation: S1: Scenario 1, S2: Scenario 2, S3: Scenario 3, R1: Reactor 1, R2: Reactor 2, R3: Reactor 3, R4: Reactor 4, R5: Reactor 5; WL: Water bamboo leaves; VW: Vegetables waste; SB: Sugarcane bagasse; RS: Rice straw; CP: Citrus peels; CW：Crop waste; CWW: Crop waste weight; PMW: Pig manure weight；Weight unit (wet weight): kg

SN 1.2 Design of compost bin planning

In this study, the amount of KW per village per day was calculated by using the population size of each village and the per capita production of KW per day. According to the specification of CB, the amount of KW that can be put into one bin per day is 5.5kg, so based on the amount of KW per village or per public facility, the amount of CB was calculated to get the amount of CB for the three scenarios, as shown in Table SN1.7 for Villages/Community and Table SN1.8 for public facilities. Data on the population size of each village was obtained from the Statistical Yearbook, while the amount of food waste in public places was obtained from research visits.

Table SN1.7 Population size of villages/communities and number of compost bins under different scenarios

Villages/Community	Population	Scenarios	Volume of KW to be composted	Number of bins
Guan'ao village	1178	S1	10233.3	6
		S2	27088.1	14
		S3	45146.9	23
Changtan village	1422	S1	12352.9	7
		S2	32698.9	17
		S3	54498.2	28
Chaoji village	2138	S1	18572.8	10
		S2	49163.3	25
		S3	81938.9	41
Shanxiajie1 village	2525	S1	21934.7	11
		S2	58062.4	29
		S3	96770.6	49
Qianjiang village	2837	S1	24645.0	13
		S2	65236.8	33
		S3	108728.0	55
Lianqun village	2900	S1	25192.3	13
		S2	66562.5	34
		S3	110937.4	56
Chenxie village	1919	S1	16670.4	9
		S2	44127.4	22
		S3	73545.7	37
Beiyangju	2637	S1	22907.6	12
		S2	60637.8	31
		S3	101063.0	51
Yijianju	759	S1	6593.4	4
		S2	17453.2	9
		S3	29088.7	15
Aoli village	1155	S1	10033.5	5

		S2	26559.2	14
		S3	44265.4	23
Kangshan village	1501	S1	13039.2	7
		S2	34515.5	18
		S3	57525.8	29
Xiaoliqiao village	1151	S1	9998.7	5
		S2	26467.2	14
		S3	44112.1	22

Table SN1.8 Number of compost bins under different scenarios for public facilities

Public facilities	**Total volumes of KW per year**	**Scenarios**	**Volume of KW to be composted**	**Number of CB**
Beiyang Primary School	8800	S1	1496.0	1
		S2	3960.0	2
		S3	6600.0	4
Food market	365000	S1	62050.0	31
		S2	164250.0	82
		S3	273750.0	137
Beiyang Township Hospital	1460	S1	248.2	1
		S2	657.0	1
		S3	1095.0	1

Table S3 Dataset used for TC-loss machine-learning model development

Table S3 Dataset used for TC-loss machine-learning model development

No.	Moisture conten	C/N	Aeration rate	superphosphate content (%, dry matter).	TC loss	References
1.	67.60	15.40	0.00	0.00	66.0	(Luo et al., 2012)
2.	67.60	15.40	0.00	3.30	59.5	(Luo et al., 2012)
3.	67.60	15.40	0.00	6.60	60.5	(Luo et al., 2012)
4.	67.60	15.40	0.00	9.90	55.5	(Luo et al., 2012)
5.	67.60	15.40	0.00	13.20	44.3	(Luo et al., 2012)
6.	67.60	15.40	0.00	15.90	45.7	(Luo et al., 2012)
7.	67.60	15.40	0.00	16.20	47.6	(Luo et al., 2012)
8.	55.00	15.00	0.12	10.00	65.9	(Wu et al., 2017)
9.	60.00	18.00	0.12	10.00	54.9	(Wu et al., 2017)
10.	65.00	21.00	0.12	10.00	46.2	(Wu et al., 2017)
11.	55.00	18.00	0.24	10.00	53.0	(Wu et al., 2017)
12.	60.00	21.00	0.24	10.00	60.0	(Wu et al., 2017)
13.	65.00	15.00	0.24	10.00	65.9	(Wu et al., 2017)
14.	55.00	21.00	0.36	10.00	63.2	(Wu et al., 2017)
15.	60.00	15.00	0.36	10.00	65.0	(Wu et al., 2017)
16.	65.00	18.00	0.36	10.00	60.7	(Wu et al., 2017)
17.	65.00	21.00	0.12	10.00	51.3	(Wu et al., 2017)
18.	55.00	18.00	0.24	10.00	53.5	(Wu et al., 2017)
19.	60.00	15.00	0.36	10.00	56.7	(Wu et al., 2017)
20.	65.00	15.00	0.24	0.00	42.7	(Jiang et al., 2011)
21.	65.00	18.00	0.48	0.00	51.0	(Jiang et al., 2011)
22.	65.00	21.00	0.72	0.00	50.7	(Jiang et al., 2011)
23.	70.00	18.00	0.24	0.00	41.6	(Jiang et al., 2011)
24.	70.00	21.00	0.48	0.00	54.0	(Jiang et al., 2011)
25.	70.00	15.00	0.72	0.00	50.3	(Jiang et al., 2011)
26.	75.00	21.00	0.24	0.00	45.6	(Jiang et al., 2011)
27.	75.00	15.00	0.48	0.00	33.8	(Jiang et al., 2011)
28.	75.00	18.00	0.72	0.00	48.9	(Jiang et al., 2011)
29.	65.00	21.00	0.24	0.00	48.9	(Jiang et al., 2011)
30.	70.00	18.00	0.47	0.00	47.1	(Jiang et al., 2011)
31.	75.00	15.00	0.72	0.00	42.7	(Jiang et al., 2011)
32.	80.00	21.00	0.24	0.00	50.4	(Jiang et al., 2011)
33.	80.00	15.00	0.48	0.00	43.4	(Jiang et al., 2011)
34.	80.00	18.00	0.72	0.00	52.4	(Jiang et al., 2011)

35.	65.00	21.00	0.24	0.00	48.9	(Li et al., 2016)
36.	70.00	18.00	0.47	0.00	47.1	(Fu et al., 2017)
37.	75.00	15.00	0.72	0.00	42.7	(Jiang et al., 2016a)
38.	60.00	17.00	0.20	0.00	60.3	(Wu, 2017)
39.	60.00	17.00	0.20	10.00	41.0	(Wu, 2017)
40.	60.00	17.00	0.20	14.00	40.6	(Wu, 2017)
41.	60.00	17.00	0.20	18.00	37.3	(Wu, 2017)
42.	60.00	17.00	0.20	22.00	39.3	(Wu, 2017)
43.	60.00	17.00	0.20	26.00	37.5	(Wu, 2017)
44.	60.00	17.00	0.20	30.00	37.1	(Wu, 2017)
45.	60.00	17.00	0.20	34.00	38.1	(Wu, 2017)
46.	60.00	17.00	0.20	38.00	38.8	(Wu, 2017)
47.	60.00	15.00	0.24	0.00	45.1	(Shen, 2009)
48.	60.00	20.00	0.24	0.00	53.9	(Shen, 2009)
49.	60.00	25.00	0.24	0.00	67.7	(Shen, 2009)
50.	60.00	30.00	0.24	0.00	73.3	(Shen, 2009)
51.	60.00	35.00	0.24	0.00	71.3	(Shen, 2009)
52.	70.00	15.00	0.50	0.00	41.8	(Ren, 2009)
53.	70.00	20.00	0.50	0.00	48.9	(Ren, 2009)
54.	70.00	25.00	0.50	0.00	62.0	(Ren, 2009)
55.	70.00	30.00	0.50	0.00	66.8	(Ren, 2009)
56.	70.00	35.00	0.50	0.00	65.8	(Ren, 2009)
57.	60.00	20.00	0.12	0.00	67.7	(He, 2016)
58.	60.00	20.00	0.12	4.00	58.0	(He, 2016)
59.	60.00	20.00	0.12	8.00	58.3	(He, 2016)
60.	60.00	20.00	0.12	12.00	53.4	(He, 2016)
61.	60.00	20.00	0.12	16.00	53.6	(He, 2016)
62.	60.00	20.00	0.12	20.00	52.6	(He, 2016)
63.	60.00	20.00	0.12	24.00	51.8	(He, 2016)
64.	55.00	15.00	0.12	12.00	54.9	(He, 2016)
65.	55.00	18.00	0.24	12.00	44.8	(He, 2016)
66.	55.00	21.00	0.36	12.00	48.3	(He, 2016)
67.	60.00	18.00	0.12	12.00	45.7	(He, 2016)
68.	60.00	21.00	0.24	12.00	49.4	(He, 2016)
69.	60.00	15.00	0.36	12.00	48.3	(He, 2016)
70.	65.00	21.00	0.12	12.00	40.9	(He, 2016)
71.	65.00	15.00	0.24	12.00	42.1	(He, 2016)
72.	65.00	18.00	0.36	12.00	47.9	(He, 2016)
73.	55.00	15.00	0.12	20.00	51.8	(He, 2016)
74.	55.00	18.00	0.24	20.00	44.1	(He, 2016)
75.	55.00	21.00	0.36	20.00	55.8	(He, 2016)
76.	65.00	15.00	0.24	0.00	42.7	(Jiang, 2011)

77.	65.00	18.00	0.48	0.00	51.0	(Jiang, 2011)
78.	65.00	21.00	0.72	0.00	50.7	(Jiang, 2011)
79.	70.00	18.00	0.24	0.00	41.6	(Jiang, 2011)
80.	70.00	21.00	0.48	0.00	54.0	(Jiang, 2011)
81.	70.00	15.00	0.72	0.00	50.3	(Jiang, 2011)
82.	75.00	21.00	0.24	0.00	45.6	(Jiang, 2011)
83.	75.00	15.00	0.48	0.00	33.8	(Jiang, 2011)
84.	75.00	18.00	0.72	0.00	48.9	(Jiang, 2011)
85.	63.60	17.30	0.00	0.00	45.4	(Jiang, 2011)
86.	63.60	17.30	0.18	0.00	54.2	(Jiang, 2011)
87.	63.60	17.30	0.36	0.00	54.7	(Jiang, 2011)
88.	63.60	17.30	0.54	0.00	52.2	(Jiang, 2011)
89.	65.00	17.30	0.00	0.00	55.4	(Jiang, 2011)
90.	70.00	17.30	0.00	0.00	51.2	(Jiang, 2011)
91.	75.00	17.30	0.00	0.00	51.6	(Jiang, 2011)
92.	63.60	17.30	0.00	0.00	52.5	(Jiang, 2011)
93.	64.00	16.50	0.00	0.00	63.2	(Hua et al., 2011)
94.	65.00	13.00	0.60	0.00	48.1	(Jiang et al., 2014)
95.	65.00	12.60	0.00	0.00	63.2	(Jiang et al., 2015)
96.	52.20	24.80	0.00	0.00	67.4	(Jiang et al., 2016b)
97.	69.20	18.40	0.00	0.00	58.0	(Jiang et al., 2016b)
98.	65.00	18.00	0.60	0.00	51.0	(Jiang and Yao, 2017)
99.	65.00	16.20	0.20	0.00	44.8	(Zang et al., 2016)
100.	65.00	16.20	0.00	0.00	63.4	(Zhang et al., 2016)
101.	80.30	15.00	0.00	0.00	60.3	(Zhang et al., 2017)
102.	70.40	28.30	0.00	0.00	33.7	(Jiang, 2005)
103.	71.60	30.20	0.00	0.00	33.7	(Jiang, 2005)
104.	70.10	24.70	0.00	0.00	61.9	(Jiang, 2005)
105.	70.90	22.70	0.00	0.00	57.2	(Jiang, 2005)
106.	65.00	19.80	0.00	0.00	59.4	(Tao, 2014)
107.	65.00	23.40	0.00	0.00	64.1	(Tao, 2014)
108.	65.00	12.20	0.00	0.00	63.2	(Tao, 2014)
109.	65.00	11.50	0.00	0.00	62.4	(Tao, 2014)
110.	81.00	15.30	0.00	0.00	59.6	(Vu et al., 2015)
111.	74.80	22.30	0.00	0.00	58.8	(Vu et al., 2015)
112.	77.30	20.10	0.00	0.00	58.8	(Vu et al., 2015)
113.	77.00	29.90	0.00	0.00	33.7	(Vu et al., 2015)
114.	80.00	20.50	0.00	0.00	58.8	(Vu et al., 2015)
115.	76.00	21.50	0.00	0.00	53.9	(Vu et al., 2015)

116.	60.50	22.75	0.00	0.00	62.9	(Zheng et al., 2022)
117.	65.00	22.75	0.00	0.00	59.4	(Zheng et al., 2022)
118.	62.00	22.75	0.00	0.00	62.7	(Zheng et al., 2022)
119.	59.00	20.75	0.00	0.00	55.8	(Zheng et al., 2022)
120.	60.00	17.60	0.00	0.00	63.8	(Zheng, 2005)
121.	60.00	24.00	0.00	0.00	67.4	(Zheng, 2005)
122.	60.00	32.40	0.00	0.00	27.1	(Zheng, 2005)
123.	60.00	43.70	0.00	0.00	28.0	(Zheng, 2005)
124.	58.50	16.30	0.00	0.00	64.7	(Zhou, 2017)
125.	58.50	19.10	0.00	0.00	63.8	(Zhou, 2017)
126.	58.50	24.10	0.00	0.00	67.4	(Zhou, 2017)
127.	58.50	29.60	0.00	0.00	27.1	(Zhou, 2017)
128.	58.50	32.20	0.00	0.00	28.5	(Zhou, 2017)

Table S4 Dataset used for TN-loss machine-learning model development

Table S4 Dataset used for TN-loss machine-learning model development

No.	Moisture content	C/N	Aeration rate	superphosphate content	TN loss	References
1.	67.60	15.40	0.00	0.00	39.2	(Luo et al., 2012)
2.	67.60	15.40	0.00	3.30	34.1	(Luo et al., 2012)
3.	67.60	15.40	0.00	6.60	28.0	(Luo et al., 2012)
4.	67.60	15.40	0.00	9.90	21.8	(Luo et al., 2012)
5.	67.60	15.40	0.00	13.20	14.3	(Luo et al., 2012)
6.	67.60	15.40	0.00	15.90	14.4	(Luo et al., 2012)
7.	67.60	15.40	0.00	16.20	18.6	(Luo et al., 2012)
8.	55.00	15.00	0.12	10.00	24.0	(Wu et al., 2017)
9.	60.00	18.00	0.12	10.00	36.3	(Wu et al., 2017)
10.	65.00	21.00	0.12	10.00	35.7	(Wu et al., 2017)
11.	55.00	18.00	0.24	10.00	39.2	(Wu et al., 2017)
12.	60.00	21.00	0.24	10.00	26.4	(Wu et al., 2017)
13.	65.00	15.00	0.24	10.00	28.7	(Wu et al., 2017)
14.	55.00	21.00	0.36	10.00	41.5	(Wu et al., 2017)
15.	60.00	15.00	0.36	10.00	40.7	(Wu et al., 2017)
16.	65.00	18.00	0.36	10.00	31.8	(Wu et al., 2017)
17.	65.00	21.00	0.12	10.00	30.7	(Wu et al., 2017)
18.	55.00	18.00	0.24	10.00	39.2	(Wu et al., 2017)
19.	60.00	15.00	0.36	10.00	37.7	(Wu et al., 2017)
20.	65.00	15.00	0.24	0.00	21.3	(Jiang et al., 2011)
21.	65.00	18.00	0.48	0.00	27.3	(Jiang et al., 2011)
22.	65.00	21.00	0.72	0.00	36.8	(Jiang et al., 2011)
23.	70.00	18.00	0.24	0.00	22.0	(Jiang et al., 2011)
24.	70.00	21.00	0.48	0.00	25.4	(Jiang et al., 2011)
25.	70.00	15.00	0.72	0.00	38.4	(Jiang et al., 2011)
26.	75.00	21.00	0.24	0.00	18.4	(Jiang et al., 2011)
27.	75.00	15.00	0.48	0.00	30.3	(Jiang et al., 2011)
28.	75.00	18.00	0.72	0.00	28.2	(Jiang et al., 2011)
29.	70.00	20.00	0.38	0.00	32.0	(Liu et al., 2020)
30.	65.00	22.50	0.00	0.00	17.4	(Li et al., 2016)
31.	65.00	25.00	0.25	0.00	23.9	(Jiang et al., 2016a)
32.	60.00	17.00	0.20	0.00	33.8	(Wu, 2017)
33.	60.00	17.00	0.20	10.00	23.4	(Wu, 2017)
34.	60.00	17.00	0.20	14.00	30.8	(Wu, 2017)
35.	60.00	17.00	0.20	18.00	31.0	(Wu, 2017)
36.	60.00	17.00	0.20	22.00	25.9	(Wu, 2017)
37.	60.00	17.00	0.20	26.00	22.8	(Wu, 2017)

38.	60.00	17.00	0.20	30.00	24.2	(Wu, 2017)
39.	60.00	17.00	0.20	34.00	23.0	(Wu, 2017)
40.	60.00	17.00	0.20	38.00	26.1	(Wu, 2017)
41.	60.00	15.00	0.24	0.00	42.3	(Shen, 2009)
42.	60.00	20.00	0.24	0.00	29.0	(Shen, 2009)
43.	60.00	25.00	0.24	0.00	26.0	(Shen, 2009)
44.	60.00	30.00	0.24	0.00	26.1	(Shen, 2009)
45.	60.00	35.00	0.24	0.00	25.2	(Shen, 2009)
46.	70.00	15.00	0.50	0.00	42.3	(Ren, 2009)
47.	70.00	20.00	0.50	0.00	32.4	(Ren, 2009)
48.	70.00	25.00	0.50	0.00	30.5	(Ren, 2009)
49.	70.00	30.00	0.50	0.00	31.8	(Ren, 2009)
50.	70.00	35.00	0.50	0.00	31.7	(Ren, 2009)
51.	60.00	20.00	0.12	0.00	39.2	(He, 2016)
52.	60.00	20.00	0.12	4.00	31.2	(He, 2016)
53.	60.00	20.00	0.12	8.00	31.4	(He, 2016)
54.	60.00	20.00	0.12	12.00	29.6	(He, 2016)
55.	60.00	20.00	0.12	16.00	29.5	(He, 2016)
56.	60.00	20.00	0.12	20.00	26.5	(He, 2016)
57.	60.00	20.00	0.12	24.00	31.7	(He, 2016)
58.	55.00	15.00	0.12	12.00	28.7	(He, 2016)
59.	55.00	18.00	0.24	12.00	30.2	(He, 2016)
60.	55.00	21.00	0.36	12.00	38.3	(He, 2016)
61.	60.00	18.00	0.12	12.00	32.0	(He, 2016)
62.	60.00	21.00	0.24	12.00	34.4	(He, 2016)
63.	60.00	15.00	0.36	12.00	42.2	(He, 2016)
64.	65.00	21.00	0.12	12.00	30.3	(He, 2016)
65.	65.00	15.00	0.24	12.00	35.2	(He, 2016)
66.	65.00	18.00	0.36	12.00	27.3	(He, 2016)
67.	55.00	15.00	0.12	20.00	32.8	(He, 2016)
68.	55.00	18.00	0.24	20.00	37.4	(He, 2016)
69.	55.00	21.00	0.36	20.00	37.8	(He, 2016)
70.	65.00	15.00	0.24	0.00	20.5	(Jiang, 2011)
71.	65.00	18.00	0.48	0.00	26.6	(Jiang, 2011)
72.	65.00	21.00	0.72	0.00	36.7	(Jiang, 2011)
73.	70.00	18.00	0.24	0.00	22.0	(Jiang, 2011)
74.	70.00	21.00	0.48	0.00	28.4	(Jiang, 2011)
75.	70.00	15.00	0.72	0.00	48.9	(Jiang, 2011)
76.	75.00	21.00	0.24	0.00	18.4	(Jiang, 2011)
77.	75.00	15.00	0.48	0.00	40.3	(Jiang, 2011)
78.	75.00	18.00	0.72	0.00	38.3	(Jiang, 2011)
79.	63.60	17.30	0.00	0.00	19.9	(Jiang, 2011)
80.	63.60	17.30	0.18	0.00	23.0	(Jiang, 2011)
81.	63.60	17.30	0.36	0.00	32.5	(Jiang, 2011)

82.	63.60	17.30	0.54	0.00	44.1	(Jiang, 2011)
83.	65.00	17.30	0.00	0.00	23.5	(Jiang, 2011)
84.	70.00	17.30	0.00	0.00	27.6	(Jiang, 2011)
85.	75.00	17.30	0.00	0.00	24.2	(Jiang, 2011)
86.	63.60	17.30	0.00	0.00	19.9	(Jiang, 2011)
87.	65.00	15.00	0.24	0.00	21.3	(Zhao, 2010)
88.	65.00	18.00	0.48	0.00	26.6	(Zhao, 2010)
89.	65.00	21.00	0.72	0.00	36.7	(Zhao, 2010)
90.	70.00	19.00	0.24	0.00	33.1	(Zhao, 2010)
91.	70.00	21.00	0.48	0.00	28.4	(Zhao, 2010)
92.	70.00	15.00	0.72	0.00	48.8	(Zhao, 2010)
93.	75.00	21.00	0.24	0.00	18.5	(Zhao, 2010)
94.	75.00	15.00	0.48	0.00	38.3	(Zhao, 2010)
95.	75.00	18.00	0.72	0.00	36.1	(Zhao, 2010)
96.	64.00	16.50	0.00	0.00	27.0	(Hua et al., 2011)
97.	65.00	13.00	0.60	0.00	45.5	(Jiang et al., 2014)
98.	65.00	12.60	0.00	0.00	23.9	(Jiang et al. 2015)
99.	52.20	24.80	0.00	0.00	25.1	(Jiang et al., 2016b)
100.	69.20	18.40	0.00	0.00	37.2	(Jiang et al., 2016b)
101.	65.00	18.00	0.60	0.00	38.1	(Jiang and Yao, 2017)
102.	65.00	16.20	0.20	0.00	31.3	(Zang et al., 2016)
103.	65.00	16.20	0.00	0.00	28.6	(Zhang et al., 2016)
104.	80.30	15.00	0.00	0.00	25.3	(Zhang et al., 2017)
105.	70.40	28.30	0.00	0.00	33.6	(Jiang, 2005)
106.	71.60	30.20	0.00	0.00	30.1	(Jiang, 2005)
107.	70.10	24.70	0.00	0.00	31.3	(Jiang, 2005)
108.	70.90	22.70	0.00	0.00	21.3	(Jiang, 2005)
109.	65.00	19.80	0.00	0.00	24.6	(Tao, 2014)
110.	65.00	23.40	0.00	0.00	23.2	(Tao, 2014)
111.	65.00	12.20	0.00	0.00	25.5	(Tao, 2014)
112.	81.00	15.30	0.00	0.00	17.6	(Vu et al., 2015)
113.	74.80	22.30	0.00	0.00	18.7	(Vu et al., 2015)
114.	77.30	20.10	0.00	0.00	21.7	(Vu et al., 2015)
115.	77.00	29.90	0.00	0.00	29.2	(Vu et al., 2015)
116.	80.00	20.50	0.00	0.00	25.9	(Vu et al., 2015)
117.	80.00	20.50	0.00	0.00	21.6	(Vu et al., 2015)
118.	76.00	21.50	0.00	0.00	20.1	(Vu et al., 2015)
119.	60.50	22.75	0.00	0.00	22.7	(Zheng et al., 2010)
120.	65.00	22.75	0.00	0.00	16.5	(Zheng et al., 2010)
121.	62.00	22.75	0.00	0.00	24.5	(Zheng et al., 2010)
122.	59.00	20.75	0.00	0.00	20.1	(Zheng et al., 2010)
123.	60.00	17.60	0.00	0.00	18.8	(Zheng, 2005)
124.	60.00	24.00	0.00	0.00	24.5	(Zheng, 2005)
125.	60.00	32.40	0.00	0.00	23.5	(Zheng, 2005)

126.	60.00	40.30	0.00	0.00	24.4	(Zheng, 2005)
127.	58.50	16.30	0.00	0.00	27.5	(Zheng, 2005)
128.	58.50	19.10	0.00	0.00	28.5	(Zhou, 2017)
129.	58.50	24.10	0.00	0.00	24.9	(Zhou, 2017)
130.	58.50	29.60	0.00	0.00	22.9	(Zhou, 2017)
131.	58.50	32.20	0.00	0.00	26.5	(Zhou, 2017)

Supplementary Note S2. Prediction of TC and TN Losses Using Machine-Learning Models

The samples were collected at fieldtrip between 2022-2023 from local rice straw, citrus peels, bagasse, water bamboo leaves, various types of planted vegetable wastes (including bok choy leaves, chili stalks, tomato vines, etc.) and pig manure. The analytical methods and measured physicochemical properties are presented in Tables SN2.1 and SN2.2, respectively. While the aeration rate and superphosphate addition were 0.21 (L/kg min^{-1}, dry matter) and 5 (%, dry matter). The final results obtained from GB for TC loss and ETR for TN loss are shown in Table SN 2.3.

Table SN 2.1 Specific sample test methods and standards

Parameters	**Standards/References**	**Equipment**
C(%) N(%)	(Poggio et al., 2016)	Elementa: Vario EL cube
Moisture content(%)	Dry weight loss	Oven

Table SN 2.2 Sample test and analysis results

Samples	**C (%TS)**	**N (%TS)**	**Moisture content (%FM)**
RS	40.1 ± 1.1	0.5 ± 0.1	25.2 ± 1.5
WL	38.4 ± 1.0	2.2 ± 0.1	60.6 ± 3.7
CP	43.2 ± 1.1	1.2 ± 0.1	37.1 ± 5.1
SB	46.1 ± 0.4	0.9 ± 0.1	31.3 ± 3.7
VW	36.2 ± 5.0	2.1 ± 0.5	43.6 ± 6.5
PM	35.2 ± 1.8	2.8 ± 0.3	71.0 ± 1.2

Table SN 2.3 Final model prediction results

Raw materials	**TC Loss (%Raw materials)**	**TN Loss (%Raw materials)**
RS+PM	65.4%	33.9%
CP+PM	65.5%	35.0%
SB+PM	55.6%	34.8%
WL+PM	47.2%	29.2%
VW+PM	65.5%	35.0%

Table S5 Crop-specific nitrogen fertilizer application rates used to estimate annual crop N demand in Beiyang Township

Table S5 Crop-specific nitrogen fertilizer application rates used to estimate annual crop N demand in Beiyang Township

Crop	N fertilizer application rate (kg N mu^{-1} yr^{-1})	Converted rate (kg N ha^{-1} yr^{-1})	Source
Rice	14	210	(Ding et al., 2020)
Water bamboo	60	900	(Tao et al., 2014)
Citrus	32	480	(Li et al., 2019)
Sugarcane	37	555	(Gu et al., 2021)
Vegetables	30	450	(Wang et al., 2024)

Note: 1 mu = 666.7 m^2; therefore, 1 kg N mu^{-1} = 15 kg N ha^{-1}.

Table S6 Sources, calculation bases, and verification status of economic parameters used in Tables 3 and 4.

Table S6. Sources, calculation bases, and verification status of economic parameters used in Tables 3 and 4.

Parameter	Value adopted in this study	Basis / classification	Data source
Centralized reactor equipment and installation	USD 49,900 / 107,600 / 175,200 per reactor (S1/S2/S3)	Study-specific capital-cost estimate; scenario-dependent equipment capacities	Study-specific estimate; original quotations or costing records not provided
Electricity price	USD 0.086 kWh−1	Assumed local electricity tariff	Local cost estimate; tariff year and supporting record to be verified
Electricity consumption	Site- and scenario-specific; Table 3	Calculated from throughput and assumed reactor energy demand	Model-derived from throughput and assumed energy requirements; see Table 3
Labor expenditure	USD 5,400 reactor−1 year−1	Assumed annual paid-labor expenditure	Local labor-cost estimate; wage basis and survey year to be verified
Other raw-material costs	Site- and scenario-specific; Table 3	Model-derived operating input costs	Study-specific estimates; input quantities and local unit-price records to be verified
Compost selling price	USD 77.4 t−1	Literature-based price benchmark (rounded)	Wang et al. (2023); comparable literature benchmark, not a verified local selling price
Agricultural-residue treatment subsidy	USD 54.2 t−1 (unrounded USD 54.15 t−1)	Assumed policy-incentive rate; not a verified local subsidy	Study-specific scenario assumption; no corresponding local policy document verified
Equipment service life and discount rate	10 years; 10%	Comparative economic model	Wang et al. (2023) used comparable assumptions; not evidence of actual equipment lifetime

		assumptions	
Corporate income tax rate	25%	Statutory standard tax rate	Enterprise Income Tax Law of the PRC, Article 4 (general rate; tax eligibility to be checked)
Centralized depreciation and residual values	Scenario-specific; Table 3	Model-specific depreciation and residual assumptions	Model-derived; calculation method and terminal residual assumptions in Table 3
Composting-bin purchase price	USD 137.8 bin−1	Assumed bin purchase price	Study-specific estimate; purchase quotation not independently verified
Decentralized treatment cost	USD 4.2 t−1	Assumed unit operating cost	Study-specific estimate; cost components and original calculation require documentation
Bin number, capital cost and fertilizer output	Scenario-specific; Table 4	Derived from throughput, unit price, conversion yield and bin treatment capacity	Model-derived; scenario values and assumptions in Table 4 and Supplementary Note S1
Bin depreciation and terminal residual value	USD 13.8 bin−1 year−1; zero residual	Straight-line depreciation and assumed zero residual	Model-derived from rounded bin purchase price over 10 years; zero-residual assumption

Supplementary Note S3. Sensitivity Analysis of Nitrogen Recycling Potential

To evaluate the sensitivity of the estimated nitrogen recycling potential to variations in nitrogen retention during composting, a deterministic one-at-a-time sensitivity analysis was conducted for Scenario S3, which represented the highest composting-adoption level. The analysis focused on the total nitrogen retained in compost, as this parameter directly determines the potential contribution of compost-derived nitrogen to local agricultural nitrogen demand.

The baseline nitrogen recycling potential was estimated at 27.9%, calculated as the ratio of total nitrogen retained in compost to annual local crop nitrogen fertilizer demand, as defined in Equation (3) of the main manuscript. To examine the sensitivity of this indicator, the baseline amount of retained nitrogen was independently varied by −20%, −10%, +10%, and +20%, while annual crop nitrogen demand and all other parameters were held constant.

The adjusted nitrogen recycling potential was calculated as follows:

$$R_{N,\text{scenario}} = R_{N,\text{baseline}} \times (1 + \delta)$$

where $R_{N,\text{scenario}}$ is the nitrogen recycling potential under the sensitivity scenario (%), $R_{N,\text{baseline}}$ is the baseline nitrogen recycling potential (27.9%), and δ is the assumed relative variation in total nitrogen retained in compost (−0.20 to +0.20).

Table SN3.1. Sensitivity of theoretical nitrogen recycling potential to variations in total nitrogen retained in compost under Scenario S3.

Variation in retained TN	Nitrogen recycling potential (%)
−20%	22.32
−10%	25.11
Baseline	27.90
+10%	30.69
+20%	33.48

The results indicated that the estimated nitrogen recycling potential varied from 22.32% to 33.48% under the assumed ±20% changes in retained TN, compared with the baseline estimate of 27.9%. Because annual crop nitrogen demand was held constant, the recycling indicator changed proportionally with the amount of nitrogen retained in compost.

These results illustrate the sensitivity of theoretical nitrogen recycling potential to uncertainty in nitrogen retention assumptions. However, the tested variation represents a hypothetical sensitivity range rather than a statistically derived confidence interval. Furthermore, the indicator remains based on total nitrogen and does not account for nitrogen mineralization, plant availability, or field-level nitrogen losses. Therefore, the calculated values should not be interpreted as actual mineral nitrogen fertilizer substitution rates.

References

Bi, Y., 2010. Study on Straw Resources Evatulation and Utilization in China (Doctoral dissertation). Chinese Academy of Agricultural Sciences, Beijing, China.

Colón, J., Martínez-Blanco, J., Gabarrell, X., Artola, A., Sánchez, A., Rieradevall, J., Font, X., 2010. Environmental assessment of home composting. Resources, Conservation and Recycling 54, 893–904. https://doi.org/10.1016/j.resconrec.2010.01.008

Ding, W., Xu, X., He, P., Zhang, J., Cui, Z., Zhou, W., 2020. Estimating regional N application rates for rice in China based on target yield, indigenous N supply, and N loss. Environmental Pollution 263, 114408. https://doi.org/10.1016/j.envpol.2020.114408

Fang, H., Zhang, X., Guo, L., 2023. Productivity effects of corporate income tax: Evidence from China. World Economy 46, 1815–1842. https://doi.org/10.1111/twec.13328

Fu, X., LIU, Q., Li, L., Pan, G., Zheng, J., Zhang, X., Cheng, K., 2017. Effects of biochar on nitrogen transformation and greenhouse gas emissions during swine manure composting. Journal of Agro-Environment Science 36, 1893–1900.

Gu, Y., Wang, J., Cai, W., Li, G., Mei, Y., Yang, S., 2021. Different Amounts of Nitrogen Fertilizer Applications Alter the Bacterial Diversity and Community Structure in the Rhizosphere Soil of Sugarcane. Front. Microbiol. 12, 721441. https://doi.org/10.3389/fmicb.2021.721441

He, S., 2016. The investigation of adding proportion of Superphosphate andcontrol condition during composting based on the reduction of CO2 (doctoral dissertation). Beijing Agricultural University, Beijing, China.

Hua, D., Liu, F., Li, G., Jiang, T., 2011. Effect of turning and covering techniques on pig manure-straw composting property. Transactions of the Chinese Society of Agricultural Engineering 12, 210–216.

Jiang, J., Huang, Y., Liu, X., Huang, H., 2014. The effects of apple pomace, bentonite and calcium superphosphate on swine manure aerobic composting. Waste management (New York, N.Y.) 34, 1595–1602. https://doi.org/10.1016/j.wasman.2014.05.002

Jiang, J., Liu, X., Huang, Y., Huang, H., 2015. Inoculation with nitrogen turnover bacterial agent appropriately increasing nitrogen and promoting maturity in pig manure composting. Waste management (New York, N.Y.) 39, 78–85. https://doi.org/10.1016/j.wasman.2015.02.025

Jiang, J., Yao, Q., 2017. Effects of Acidic Materials on the N Transformations During the Composting Pig Manure and Wheat Straw. Huan Jing Ke Xue 38, 1272–1278. https://doi.org/10.13227/j.hjkx.201609161

Jiang, L., 2005. Research on nitrogen preservation technology in pig manure composting process (master dissertation). Sichuan Agricultural University, Chengdu, Sichuan.

Jiang, T., 2011. The Greenhouse Gas Formation Mechanism DuringComposting and Mitigation Technologies Research (doctoral dissertation). Beijing Agricultural University, Beijing, China.

Jiang, T., Ma, X., Tang, Q., Yang, J., Li, G., Schuchardt, F., 2016a. Combined use of nitrification inhibitor and struvite crystallization to reduce the NH3 and N2O emissions during composting. Bioresource technology 217, 210–218. https://doi.org/10.1016/j.biortech.2016.01.089

Jiang, T., Ma, X., Yang, J., Tang, Q., Yi, Z., Chen, M., Li, G., 2016b. Effect of different struvite crystallization methods on gaseous emission and the comprehensive comparison during the composting. Bioresource technology 217, 219–226. https://doi.org/10.1016/j.biortech.2016.02.046

Jiang, T., Schuchardt, F., Li, G., Guo, R., Zhao, Y., 2011. Effect of C/N ratio, aeration rate and

moisture content on ammonia and greenhouse gas emission during the composting. Journal of environmental sciences (China) 23, 1754–1760. https://doi.org/10.1016/S1001-0742(10)60591-8
Li, D., Li. Shuyan, Li, G., Wang, K., 2016. Effects of additive on nitrogen loss during composting of pig manure and corn straw. Transactions of the Chinese Society of Agricultural Engineering 32, 260–267. https://doi.org/10.11975/j.issn.1002-6819.2016.z2.036
Li, Y.J., Yang, M., Zhang, Z.Z., Li, W.L., 2019. An ecological research on potential for zero-growth of chemical fertilizer use in citrus production in China. Ekoloji 28, 1049–1059.
Liu, X., 2018. Study on Nutrients Balance and Requirement in Agricultueal Production in China (doctoral dissertation).
Liu, Z., Ren, A., Gao, C., Fu, W., Chen, C., 2014. Power Generation Potential Assessment of Agricultural Biomass Resources In China. Chinese Journal of Agricultural R esources and Regional Planning 35, 133–140.
Liu, Z., Wang, X., Wang, F., Bai, Z., Chadwick, D., Misselbrook, T., Ma, L., 2020. The progress of composting technologies from static heap to intelligent reactor: Benefits and limitations. Journal of Cleaner Production 270, 122328. https://doi.org/10.1016/j.jclepro.2020.122328
Lu, X., Yang, Y., Hong, C., Zhu, W., Zhu, F., Yao, Y., Hong, L., Wang, W., 2022. Pig manure amendment improves the quality of products during composting of solanaceous vegetable waste: Insights into the microbial mechanism. Journal of Agro-Environment Science 41, 1097–1107. https://doi.org/10.11654/jaes.2021-0834
Luo, Y., Li, G., Frank, S., Wang, K., Jiang, T., Luo, W., 2012. Effects of additive superphosphate on NH3, N2O and CH4 emissions during pig manure composting. Transactions of the Chinese Society of Agricultural Engineering, 28, 235–242.
OJO, A.O., UTHMAN, A.C.O., OGUNMOLA, J.R., 2021. Changes in chemical and biological properties during co-composting of swine dung and different plant materials. EURASIAN JOURNAL OF SOIL SCIENCE (EJSS) 10, 17–25. https://doi.org/10.18393/ejss.799988
Poggio, D., Walker, M., Nimmo, W., Ma, L., Pourkashanian, M., 2016. Modelling the anaerobic digestion of solid organic waste - Substrate characterisation method for ADM1 using a combined biochemical and kinetic parameter estimation approach. Waste management (New York, N.Y.) 53, 40–54. https://doi.org/10.1016/j.wasman.2016.04.024
Ren, L., 2009. Study on Mechanism of Carbon and Nitrogen Loss and Control during Composting (doctoral dissertation). Beijing Agricultural University, Beijing, China.
Santolin, J., Larsen, O.C., Fritze, A., Xue, B., Yang, Z., Rotter, V.S., 2024. Reaching China's fertilizer reduction goals through nitrogen and phosphorus recovery: a substance flow analysis case study. J Mater Cycles Waste Manag. https://doi.org/10.1007/s10163-024-02067-6
Shen, Y., 2009. The Effect of Different Parameters on Gas Emission during Aerobic Composting (master dissertation). Beijing Agricultural University, Beijing, China.
Standard for planning of urban environment sanitation facilities, 2018.
Tao, H., Wang, J., Tang, Q., Shao, D., Chen, W., 2014. Preliminary Report of Nitrogen Fertilizer Gradient Experiment of "Qinglian water bamboo no. 2" in Qingpu district. Shanghai Agricultural Science and Technology 2014, 100.
Tao, J., 2014. EFFECT OF ADDING BIOCHAR ONCYANOBACTERIAAND SWINE MANURE COMPOSTING (master dissertation). Nanjing Agricultural University, Nanjing, Jiangsu.
Technical code for agriculture and food waste treatment, 2012.
Tong, W., Liu, Y., Zhang, Z., Song, J., Wang, W., Yao, Y., 2020. Production of commercial organic

fertilizer from straw and its application effect on rice. Journal of Zhejiang Agricultural Sciences 61, 8–11. https://doi.org/10.16178/j.issn.0528-9017.20200103
Vu, Q.D., Neergaard, A., Tran, T.D., Hoang, H.T.T., van Vu, T.K., Jensen, L.S., 2015. Greenhouse gas emissions from passive composting of manure and digestate with crop residues and biochar on small-scale livestock farms in Vietnam. Environmental technology 36, 2924–2935. https://doi.org/10.1080/09593330.2014.960475
Wang, H., Qin, Y., Xin, L., Zhao, C., Ma, Z., Hu, J., Wu, W., 2023. Preliminary techno-economic analysis of three typical decentralized composting technologies treating rural kitchen waste: a case study in China. Front. Environ. Sci. Eng. 17. https://doi.org/10.1007/s11783-023-1647-7
Wang, Z., Li, D., Gruda, N.S., Duan, Z., Li, X., 2024. Fertilizer application rate and nutrient use efficiency in Chinese greenhouse vegetable production. Resources, Conservation and Recycling 203, 107431. https://doi.org/10.1016/j.resconrec.2024.107431
WU, G., YU, F., MA Chao, CHEN, J., YUAN, M., WANG, J., SUN, Z., GE, Z., DONG, Y., SUN, Y., 2023. Efficacy of decomposing agents on water oat straw composting. Soils and Crops 23, 306–313. https://doi.org/10.11689/sc.2022052201
Wu, J., 2017. Technology Mechanism of Organic Matter Degradation Mitigation adn Carbon, Nitrogen Transformation with Superphosphate Addition During Pig Manure Composting (Doctoral dissertation). Beijing Agricultural University, Beijing, China.
Wu, J., He, S., Li, G., Li, Z., Bao, Y., Liang, Y., 2017. Process Optimization of Pollutant Gases Emission Reduction with Superphosphate Addition during Pig Manure Composting. Transactions of the Chinese Society for Agricultural Machinery 48, 304–312.
Wu, W., 2020. Analysis of the potential for resource utilization of vegetable waste back to the field. Journal of Zhejiang Agricultural Sciences 61. https://doi.org/10.16178/j.issn.0528-9017.20201021
Yalcinkaya, S., Uzer, S., Kaleli, H.İ., Doğan, F., Kayalık, M., 2021. Compost Plant Site Selection for Food Waste Using GIS Based Multicriteria Analysis. Turkish JAF Sci.Tech. 9, 1908–1914. https://doi.org/10.24925/turjaf.v9i10.1908-1914.4614
Zang, B., Li, S., Li, G., 2016. Effects of air-dry pretreatment on maturity and odors during composting of pig manure and corn stalks. Transactions of the Chinese Society of Agricultural Engineering 32, 247–253. https://doi.org/10.11975/j.issn.1002-6819.2016.z2.034
Zhang, D., Luo, W., Yuan, J., Li, G., Luo, Y., 2017. Effects of woody peat and superphosphate on compost maturity and gaseous emissions during pig manure composting. Waste management (New York, N.Y.) 68, 56–63. https://doi.org/10.1016/j.wasman.2017.05.042
Zhang, D., Yuan, J., Wang, G., Li, G., Luo, Y., Zhang, B., 2016. Effects of woody peat addition on maturity and gaseous emissions during pig manure composting. Transactions of the Chinese Society of Agricultural Engineering 32, 233–240. https://doi.org/10.11975/j.issn.1002-6819.2016.z2.032
Zhao, Y., 2010. The study on gases nitrogen emission rules during aerobic composting (master dissertation). Beijing Agricultural University, Beijing, China.
Zheng, D., Shen, J., Li, R., Jian, B., Zeng, J., Mao, Y., Zhang, X., Halder, P., Qu, M., 2022. Understanding the key factors determining rural domestic waste treatment behavior in China: a meta-analysis. Environmental science and pollution research international 29, 11076–11090. https://doi.org/10.1007/s11356-021-17999-x
Zheng, R., 2005. Research on ammonia release pattern and regulation measures of pig manure composting treatment (master dissertation). Fujian Agriculture and Forestry University, Fujian.
Zheng, R., Feng, H., Li, Y., 2010. Nitrogen conservation in swine manure compost with zeolite

usage. Acta Scientiae Circumstantiae 30, 1017–1022. https://doi.org/10.13671/j.hjkxxb.2010.05.031
Zhou, J.-M., 2017. The Effect of Different C/N Ratios on the Composting of Pig Manure and Edible Fungus Residue with Rice Bran. Compost Science & Utilization 25, 120–129. https://doi.org/10.1080/1065657X.2016.1233081