Table S1 Carbon emission coefficients of each item of carbon sources

Item	Type code	Coefficient	Source
Crop seeding (kg/hm^2)	f_1	16.47	[1]
Agricultural machinery activity (kg/kW)	f_2	0.18	[1]
Irrigation process (kg/hm^2)	f_3	266.48	[1]
Fertilizer application (kg/t)	f_4	857.54	[1]
Pig respiration (kg/head/a)	f_5	83.5	[2]
Cattle respiration (kg/head/a)	f_6	797.0	[2]
Sheep respiration (kg/head/a)	f_7	237.25	[3]
Rice respiration (g/m^2)	f_8	16.07	[4]
Bus operation (kg/100 km)	f_9	88.1	[5]
Taxi operation (kg/100 km)	f_{10}	28.3	[5]
Private car operation (kg/100 km)	f_{11}	22.3	[5]
Motorcycle operation (kg/100 km)	f_{12}	6.7	[5]
Road passenger and freight (kg/tkm)	f_{13}	0.0556	[5]
Rail passenger and freight (kg/tkm)	f_{14}	0.0217	[5]
Urban/rural living electricity consumption (kg/kW·h)	f_{15} / f_{17}	0.1229	[3]
Urban/rural permanent population breathing (kg/person/a)	f_{16} / f_{18}	79	[2]
Raw coal (kg/t)	d_1	0.7559	[2,6]
Coal washed (kg/t)	d_2	0.7559	[2,6]
Coke (kg/t)	d_3	0.8550	[2,6]
Coke oven gas (kg/m^3)	d_4	0.3548	[2,6]
Natural gas (kg/m^3)	d_5	0.4483	[2,6]
Gasoline (kg/t)	d_6	0.5538	[2,6]
Kerosene (kg/t)	d_7	0.5714	[2,6]
Diesel oil (kg/t)	d_8	0.5921	[2,6]
Combustion oil (kg/t)	d_9	0.6185	[2,6]
Liquefied petroleum gas (kg/t)	d_{10}	0.5042	[2,6]
Other petroleum products (kg/t)	d_{11}	0.5857	[2,6]
Conversion coefficient of CO_2 and carbon		0.27	[5]
Conversion coefficient of CH_4 and carbon		0.75	[5]

Table S2 Carbon sequestration coefficients of each secondary land type

PLE space types	Secondary classification of land use system	Carbon sequestration coefficient	Source
Agricultural production space	-	0.0007	[2]
Grassland ecological space	High cover grassland	0.0138	[7]
	Medium cover grassland	0.0046	[7]
	Low cover grassland	0.0021	[8]
Forest ecological space	Wooded land	0.0657	[5]
	Shrubland	0.0161	[7]
	Open woodland	0.0581	[8]
	Other woodland	0.0103	[7]
Water ecological space	River	0.025	[9]
	Lakes	0.039	[10]

Table S3 Direct carbon flow matrix F from 2000 to 2005 /(t C/a)

2000	2005							
	CU	IN	UR	RU	G	F	W	B
CU	0.00	952083.02	122550.88	75505.25	39.67	793.83	11559.45	2.05
IN	12348.25	0.00	17906.86	9671.75	2020.20	6969.39	3938.03	542.06
UR	5965.95	4425.36	0.00	528.75	8.97	388.40	844.13	4.91
RU	21257.65	18451.26	620.59	0.00	34.22	992.21	2921.42	15.15
G	60.74	2084.67	16.77	81.03	0.00	1.98	11.84	0.12
F	301.40	6130.62	443.44	964.17	1.72	0.00	13.97	4.23
W	4763.39	20271.13	3601.07	4308.14	19.99	15.17	0.00	3.61
B	2.84	407.32	4.16	13.73	0.19	3.58	3.98	0.00

Note: [a] Red represents negative carbon flow and green represents positive carbon flow. [b] IN, industrial production space; UR, urban living space; RU, rural living space; G, grassland ecological space; F, forest ecological space; W, water ecological space; CU, agricultural production space; B, other ecological space.

Table S4 Direct carbon flow matrix F from 2005 to 2010 /(t C/a)

2005	2010							
	CU	IN	UR	RU	G	F	W	B
CU	0.00	1933428.59	307311.39	234516.55	109.16	957.06	25119.43	302.67
IN	43895.78	0.00	1579931.93	118875.50	2272.44	35321.88	43248.92	193.68
UR	7630.17	11265.92	0.00	7140.20	15.27	359.18	1124.91	15.21
RU	33163.30	77089.04	32533.74	0.00	75.62	1373.51	8273.32	103.09
G	99.86	128810.38	291.06	317.33	0.00	5.20	25.20	7.76
F	853.56	22014.05	4589.12	4129.36	2.93	0.00	68.02	4.02
W	5342.68	449049.49	32156.39	8761.41	24.70	23.39	0.00	5.83
B	2.28	2702.49	47.03	670.79	0.17	19.77	12.35	0.00

Note: [a] Red represents negative carbon flow and green represents positive carbon flow. [b] IN, industrial production space; UR, urban living space; RU, rural living space; G, grassland ecological space; F, forest ecological space; W, water ecological space; CU, agricultural production space; B, other ecological space.

Table S5 Direct carbon flow matrix F from 2010 to 2018 /(t C/a)

2010	2018							
	CU	IN	UR	RU	G	F	W	B
CU	0	3294222.80	116480.85	137045.46	405.79	398.94	5519.42	41.04
IN	161333.49	0	108592.10	27468.84	258613.64	17538.30	34525.73	3143.10
UR	19130.01	69683.66	0	1616.22	172.94	699.01	4464.95	35.48
RU	57648.66	55217.28	2291.59	0	123.18	1943.50	5000.49	32.96
G	122.65	501155.69	199.45	293.49	0	2.06	9.16	0.76
F	274.84	86642.69	846.73	3154.39	112.70	0	36.86	7.49
W	9936.43	2930527.40	29191.18	23033.39	809.98	35.56	0	10.27
B	54.70	897.68	2168.28	200.73	0.81	2.72	14.01	0

Note: [a] Red represents negative carbon flow and green represents positive carbon flow. [b] IN, industrial production space; UR, urban living space; RU, rural living space; G, grassland ecological space; F, forest ecological space; W, water ecological space; CU, agricultural production space; B, other ecological space.

Table S6 Ecological relationships between PLE space types in the network from 2000 to 2005

	CU	IN	UR	RU	G	F	W	B
CU		+	+	+	-	+	-	+
IN	-		-	-	-	+	-	+
UR	-	-		-	-	-	-	-
RU	-	-	-		-	+	-	-
G	-	+	+	+		+	-	-
F	-	-	+	-	-		+	+
W	-	+	+	+	+	-		+
B	+	-	+	+	+	-	+	

mutualism control competition exploitation

Note: [a] "+/-" indicates the positivity or negativity of the elements in the overall utility matrix U. [b] IN, industrial production space; UR, urban living space; RU, rural living space; G, grassland ecological space; F, forest ecological space; W, water ecological space; CU, agricultural production space; B, other ecological space.

Table S7 Ecological relationships between PLE space types in the network from 2005 to 2010

	CU	IN	UR	RU	G	F	W	B
CU		+	+	+	-	-	-	-
IN	-		+	-	-	+	-	-
UR	-	-		-	+	-	+	+
RU	-	-	-		+	-	+	-
G	-	+	+	-		+	-	-
F	+	-	+	+	+		+	+
W	-	+	+	-	-	+		-
B	-	+	+	+	-	+	-	

mutualism control competition exploitation

Note: [a] "+/-" indicates the positivity or negativity of the elements in the overall utility matrix U. [b] IN, industrial production space; UR, urban living space; RU, rural living space; G, grassland ecological space; F, forest ecological space; W, water ecological space; CU, agricultural production space; B, other ecological space.

Table S8 Ecological relationships between PLE space types in the network from 2010 to 2018

	CU	IN	UR	RU	G	F	W	B
CU		+	+	+	-	-	-	+
IN	-		-	-	-	-	-	+
UR	-	-		-	+	+	+	-
RU	-	-	-		+	-	+	-
G	-	+	-	-		-	-	+
F	-	+	-	+	-		-	+
W	-	+	-	-	-	-		+
B	+	-	+	+	+	+	+	

(green)	mutualism	(blue)	control	(yellow)	competition	(red)	exploitation

Note: [a] "+/-" indicates the positivity or negativity of the elements in the overall utility matrix U. [b] IN, industrial production space; UR, urban living space; RU, rural living space; G, grassland ecological space; F, forest ecological space; W, water ecological space; CU, agricultural production space; B, other ecological space.

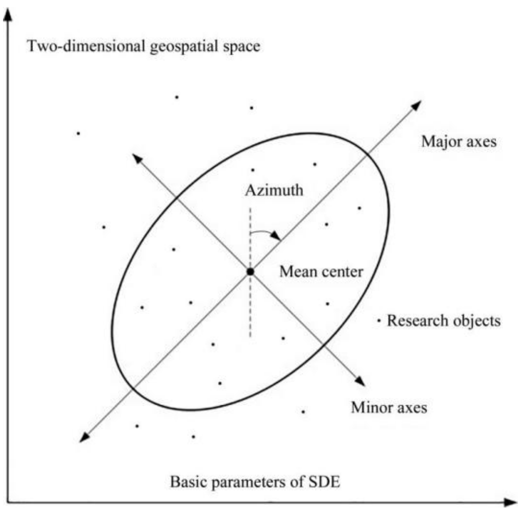

Figure S1. Diagrammatic sketch of SDE

Explanation: The SDE method was first proposed by Lefever in 1926 to reveal the spatial distribution characteristics of geographical elements [11]. It quantitatively describes the multivariate characteristics of the spatial distribution of study objects by statistically calculating the spatial distribution ellipse with basic parameters such as center, long and short axes, and azimuth. The area of the ellipse can indicate the main distribution range of the spatial elements, the change of mean center reflects the relative position of the carbon flow in different study periods, the direction of the ellipse's long axis and its azimuthal angle (the angle produced by the long axis and the due north direction) can indicate the main spreading direction of the carbon flow, and the short axis of the ellipse indicates the degree of dispersion of the data, the shorter the short axis, the more obvious the centripetal force presented by geographical elements, and vice versa. then indicates the greater dispersion of the data distribution. The specific calculation formula is shown in the study of Du et at. [12]. The SDE spatial statis-tics calculation in this study is mainly based on ArcGIS platform, using an ellipse with one standard deviation for spatial statistics, which can cover about 68% of the spatial elements. On this basis, the value of carbon flows is used as the weight field, so as to show the core area of the spatial distribution of carbon flow.

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