Partial Order Ranking of the Key Drivers of Grassland Conversion in the Urban-Grassland Interface: A Case Study of the Hohhot-Baotou-Ordos Region

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Supplementary Materials

Table S1. Land-use transition matrix for 2000–2010 (km^2).

	2000–2010					
	Cropland	Forest	Grassland	Bare areas	Water body	Impervious surface
Cropland	10477	10	1504	150	162	219
Forest	13	883	142	12	1	4
Grassland	1343	63	74137	909	28	434
Bare areas	554	100	2938	35067	79	161
Water body	153	0	22	86	914	7
Impervious surface	0	0	0	0	0	1229

Table S2. Land-use transition matrix for 2010–2020 (km^2).

	2010–2020					
	Cropland	Forest	Grassland	Bare areas	Water body	Impervious surface
Cropland	10569	20	1446	206	177	122
Forest	12	914	92	35	0	3
Grassland	4191	109	72381	1670	77	315
Bare areas	774	116	4602	30488	154	90
Water body	157	1	12	57	953	4
Impervious surface	0	0	0	0	0	2054

Table S3. Hasse diagrams input data for all indicator groups (2000 to 2010).

(a) Climate driver group						(b) Human activities driver group				
County/league	County	Temperature 2000	Precipitation 2000	Temperature 2010	Precipitation 2010	County	Population density 2000	Sheep density 2000	Population density 2010	Sheep density 2010
Hohhot	HH	0.53	0.12	0.44	0.25	HH	1.00	0.67	1.00	0.78
	WC	0.00	0.00	0.00	0.30	WC	0.06	0.19	0.02	0.08
	TKT	0.70	0.26	0.92	0.11	TKT	0.16	1.00	0.12	0.79
	TMZ	0.63	0.28	0.61	0.23	TMZ	0.16	0.67	0.11	0.84
	QSH	0.68	0.04	0.85	0.00	QSH	0.06	0.31	0.03	0.19
	HL	0.52	0.09	0.71	0.05	HL	0.06	0.33	0.05	0.52
Baotou	BT	0.68	0.70	0.61	0.77	BT	0.80	0.54	0.83	0.76
	TMY	0.72	0.53	0.72	0.30	TMY	0.16	0.72	0.10	1.00
	GY	0.34	0.60	0.24	0.75	GY	0.06	0.18	0.03	0.11
	DMJ	0.13	0.76	0.31	1.00	DMJ	0.03	0.06	0.01	0.00
Ordos	DS	0.62	0.75	0.73	0.40	DS	0.16	0.02	0.30	0.02
	HJ	0.75	1.00	0.90	0.93	HJ	0.00	0.02	0.00	0.06
	DLT	0.68	0.61	0.94	0.57	DLT	0.04	0.17	0.04	0.41
	ZGE	0.78	0.38	0.93	0.15	ZGE	0.04	0.03	0.05	0.06
	YJHL	0.69	0.68	0.79	0.60	YJHL	0.03	0.17	0.05	0.08
	WS	0.82	0.77	0.95	0.49	WS	0.00	0.07	0.01	0.13
	ETKQ	1.00	0.86	1.00	0.46	ETKQ	0.00	0.08	0.00	0.05
	ETK	0.96	0.95	0.90	0.74	ETK	0.02	0.00	0.01	0.04

(c) Economic driver group									
County/league	County	GDP	Primary	Secondary	Tertiary	GDP	Primary	Secondary	Tertiary

		density 2000	Industry GDP Density 2000	Industry GDP Density 2000	Industry GDP Density 2000	density 2010	Industry GDP Density 2010	Industry GDP Density 2010	Industry GDP Density 2010
Hohhot	HH	0.72	0.66	0.48	1.00	0.66	0.85	0.27	1.00
	WC	0.01	0.15	0.01	0.01	0.01	0.06	0.01	0.01
	TKT	0.11	0.73	0.06	0.10	0.14	0.96	0.21	0.04
	TMZ	0.09	0.82	0.06	0.03	0.06	0.94	0.05	0.05
	QSH	0.02	0.23	0.02	0.02	0.01	0.12	0.01	0.01
	HL	0.02	0.25	0.01	0.00	0.04	0.43	0.05	0.02
Baotou	BT	1.00	0.77	1.00	0.79	1.00	0.69	1.00	0.94
	TMY	0.11	1.00	0.03	0.11	0.08	1.00	0.08	0.06
	GY	0.02	0.13	0.02	0.02	0.01	0.15	0.02	0.00
	DMJ	0.01	0.02	0.01	0.00	0.01	0.03	0.02	0.00
Ordos	DS	0.22	0.08	0.23	0.16	0.37	0.05	0.29	0.44
	HJ	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00
	DLT	0.04	0.24	0.04	0.03	0.04	0.23	0.06	0.03
	ZGE	0.04	0.07	0.04	0.03	0.10	0.06	0.13	0.07
	YJHL	0.03	0.09	0.03	0.02	0.09	0.07	0.12	0.06
	WS	0.00	0.05	0.00	0.00	0.02	0.05	0.03	0.01
	ETKQ	0.00	0.03	0.00	0.00	0.00	0.04	0.00	0.00
	ETK	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.00

(d) Urbanization driver group

County/league	County	Distance to urban 2000	Distance to rural 2000	Distance to road 2000	Distance to mine 2000	Distance to urban 2010	Distance to rural 2010	Distance to road 2010	Distance to mine 2010
Hohhot	HH	1.00	0.98	1.00	1.00	1.00	0.96	0.88	0.90

	WC	0.85	0.99	0.98	0.87	0.80	0.93	0.89	0.43
	TKT	0.82	1.00	0.94	0.75	0.80	1.00	0.84	0.60
	TMZ	0.92	0.96	0.97	0.82	0.90	0.94	0.86	0.30
	QSH	0.76	0.96	0.95	0.80	0.72	0.93	0.88	0.82
	HL	0.71	0.99	0.97	0.79	0.65	0.96	0.81	0.41
Baotou	BT	0.80	0.97	0.99	0.98	0.91	0.89	0.98	0.99
	TMY	0.89	0.97	0.91	0.89	0.83	0.93	0.89	0.77
	GY	0.66	0.96	0.93	0.73	0.60	0.94	0.91	0.49
	DMJ	0.30	0.78	0.74	0.83	0.15	0.70	0.00	0.63
Ordos	DS	0.96	0.95	1.00	0.74	0.96	0.97	1.00	1.00
	HJ	0.08	0.48	0.71	0.81	0.00	0.41	0.47	0.51
	DLT	0.50	0.93	0.87	0.90	0.48	0.85	0.52	0.86
	ZGE	0.63	0.92	0.89	0.89	0.77	0.84	0.70	0.91
	YJHL	0.41	0.64	0.91	0.78	0.51	0.52	0.75	0.90
	WS	0.14	0.38	0.27	0.10	0.33	0.31	0.21	0.73
	ETKQ	0.14	0.00	0.00	0.00	0.30	0.16	0.69	0.38
	ETK	0.00	0.19	0.69	0.49	0.06	0.00	0.56	0.00

Table S4. Livestock-dominant chain (2000–2010).

No	chain	No	chain
1	WC→QSH→HL	38	GY→QSH→HL→TMZ
2	GY→QSH→HL	39	DLT→HL→TMZ
3	DLT→HL	40	YJHL→HL→TMZ
4	YJHL→HL	41	HJ→WC→QSH→HL→TMZ
5	HJ→WC→QSH→HL	42	HJ→GY→QSH→HL→TMZ
6	HJ→GY→QSH→HL	43	HJ→WS→QSH→HL→TMZ
7	HJ→WS→QSH→HL	44	HJ→WS→DLT→HL→TMZ
8	HJ→WS→DLT→HL	45	HL→TMZ
9	HJ→YJHL→HL	46	HJ→YJHL→HL→TMZ
10	ETKQ→WC→QSH→HL	47	ETKQ→WC→QSH→HL→TMZ
11	ETKQ→GY→QSH→HL	48	ETKQ→GY→QSH→HL→TMZ
12	ETKQ→DLT→HL	49	ETKQ→DLT→HL→TMZ
13	ETKQ→YJHL→HL	50	ETKQ→YJHL→HL→TMZ
14	WC→QSH→HL	51	WC→QSH→HL→TMZ
15	GY→QSH→HL	52	GY→QSH→HL→TMZ
16	DLT→HL	53	DLT→HL→TMZ
17	YJHL→HL	54	HL→TMZ
18	WC→QSH→HL→TKT	55	YJHL→HL→TMZ
19	GY→QSH→HL→TKT	56	WC→QSH→HL→TMY
20	DLT→HL→TKT	57	GY→QSH→HL→TMY
21	YJHL→HL→TKT	58	DLT→HL→TMY
22	HJ→WC→QSH→HL→TKT	59	YJHL→HL→TMY
23	HJ→GY→QSH→HL→TKT	60	HJ→WC→QSH→HL→TMY
24	HJ→WS→QSH→HL→TKT	61	HJ→GY→QSH→HL→TMY
25	HJ→WS→DLT→HL→TKT	62	HJ→WS→QSH→HL→TMY
26	HL→TKT	63	HJ→WS→DLT→HL→TMY
27	HJ→YJHL→HL→TKT	64	HL→TMY
28	ETKQ→WC→QSH→HL→TKT	65	HJ→YJHL→HL→TMY
29	ETKQ→GY→QSH→HL→TKT	66	ETKQ→WC→QSH→HL→TMY
30	ETKQ→DLT→HL→TKT	67	ETKQ→GY→QSH→HL→TMY
31	ETKQ→YJHL→HL→TKT	68	ETKQ→DLT→HL→TMY
32	WC→QSH→HL→TKT	69	ETKQ→YJHL→HL→TMY
33	GY→QSH→HL→TKT	70	WC→QSH→HL→TMY
34	DLT→HL→TKT	71	GY→QSH→HL→TMY
35	HL→TKT	72	DLT→HL→TMY
36	YJHL→HL→TKT	73	HL→TMY
37	WC→QSH→HL→TMZ	74	YJHL→HL→TMY

Table S5. Hasse diagrams input data for all indicator groups (2010 to 2020).

(a) Climate driver group						(b) Human activities driver group				
County/league	County	Temperature 2010	Precipitation 2010	Temperature 2020	Precipitation 2020	County	Population Density 2010	Sheep Density 2010	Population Density 2020	Sheep Density 2016
Hohhot	HH	0.47	0.25	0.54	0.00	HH	1.00	0.97	1.00	0.23
	WC	0.00	0.36	0.00	0.07	WC	0.02	0.07	0.01	0.05
	TKT	0.86	0.11	0.65	0.34	TKT	0.15	0.78	0.09	0.68
	TMZ	0.66	0.24	0.69	0.22	TMZ	0.15	0.86	0.12	0.85
	QSH	0.73	0.00	0.75	0.35	QSH	0.04	0.15	0.02	0.13
	HL	0.71	0.02	0.65	0.14	HL	0.07	0.53	0.04	0.54
Baotou	BT	0.60	0.78	0.72	0.40	BT	0.53	0.68	0.78	0.54
	TMY	0.67	0.33	0.89	0.22	TMY	0.14	1.00	0.09	1.00
	GY	0.17	0.86	0.30	0.45	GY	0.04	0.11	0.02	0.13
	DMJ	0.31	1.00	0.09	0.50	DMJ	0.00	0.00	0.00	0.00
Ordos	DS	0.71	0.40	0.81	0.10	DS	0.31	0.02	0.24	0.02
	HJ	0.86	0.97	0.80	0.61	HJ	0.00	0.06	0.00	0.08
	DLT	0.92	0.54	0.82	0.28	DLT	0.04	0.41	0.03	0.43
	ZGE	0.89	0.22	0.79	0.32	ZGE	0.05	0.06	0.04	0.04
	YJHL	0.75	0.63	0.79	0.13	YJHL	0.06	0.07	0.06	0.06
	WS	0.94	0.46	0.88	0.49	WS	0.01	0.13	0.01	0.14
	ETKQ	1.00	0.57	1.00	1.00	ETKQ	0.00	0.04	0.00	0.08
	ETK	0.88	0.87	0.94	0.77	ETK	0.00	0.04	0.00	0.03

(c) Economic driver group

County/league	County	GDP Density 2010	Primary Industry GDP Density 2010	Secondary Industry GDP Density 2010	Tertiary Industry GDP Density 2010	GDP Density 2020	Primary Industry GDP Density 2020	Secondary Industry GDP Density 2020	Tertiary Industry GDP Density 2020
Hohhot	HH	0.54	1.00	0.23	0.84	0.91	0.86	0.59	1.00
	WC	0.01	0.05	0.01	0.01	0.00	0.09	0.00	0.01
	TKT	0.14	0.92	0.20	0.04	0.10	0.85	0.10	0.06
	TMZ	0.06	0.90	0.05	0.05	0.06	0.78	0.06	0.04
	QSH	0.01	0.11	0.01	0.01	0.02	0.11	0.02	0.01
	HL	0.04	0.42	0.05	0.02	0.05	0.36	0.06	0.03
Baotou	BT	1.00	0.62	1.00	1.00	1.00	0.68	1.00	0.90
	TMY	0.09	0.96	0.08	0.08	0.07	1.00	0.06	0.05
	GY	0.01	0.15	0.02	0.00	0.01	0.15	0.01	0.00
	DMJ	0.01	0.03	0.01	0.00	0.00	0.02	0.01	0.00
Ordos	DS	0.35	0.05	0.28	0.44	0.34	0.02	0.31	0.34
	HJ	0.00	0.03	0.00	0.00	0.00	0.05	0.00	0.00
	DLT	0.04	0.22	0.05	0.03	0.03	0.29	0.04	0.02
	ZGE	0.10	0.06	0.12	0.07	0.09	0.07	0.17	0.05
	YJHL	0.09	0.07	0.11	0.06	0.12	0.07	0.21	0.05
	WS	0.02	0.04	0.02	0.01	0.02	0.06	0.04	0.01
	ETKQ	0.00	0.03	0.00	0.00	0.00	0.04	0.01	0.00
	ETK	0.01	0.00	0.02	0.00	0.01	0.00	0.03	0.00

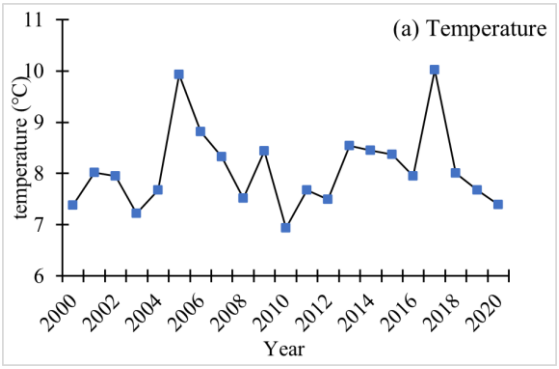
(d) Urbanization driver group

County/league	County	Distance to Urban 2010	Distance to Rural 2010	Distance to Road 2010	Distance to Mine 2010	Distance to Urban 2020	Distance to Rural 2020	Distance to Road 2020	Distance to Mine 2020
Hohhot	HH	0.97	0.98	0.83	0.91	1.00	0.99	0.97	1.00

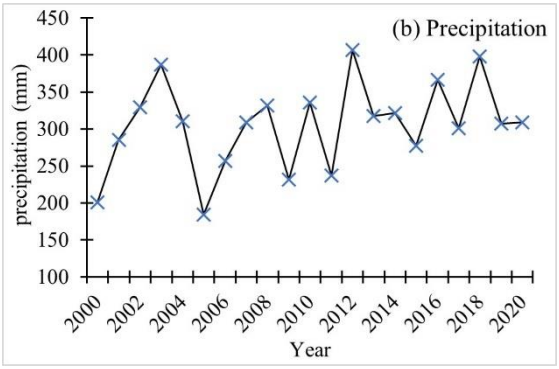
	WC	0.71	1.00	0.88	0.37	0.71	1.00	0.78	0.79
	TKT	0.80	0.98	0.81	0.55	0.84	0.97	0.89	0.83
	TMZ	0.90	0.96	0.90	0.35	0.90	0.97	0.82	0.89
	QSH	0.77	0.81	0.85	0.67	0.74	0.84	0.75	0.74
	HL	0.67	0.97	0.82	0.42	0.79	0.98	0.74	0.79
Baotou	BT	1.00	0.87	1.00	1.00	0.99	0.92	1.00	0.99
	TMY	0.92	0.98	0.96	0.80	0.89	0.97	0.71	0.88
	GY	0.44	0.94	0.78	0.43	0.77	0.94	0.84	0.74
	DMJ	0.13	0.64	0.00	0.70	0.23	0.70	0.00	0.71
Ordos	DS	0.86	0.83	0.98	0.98	0.83	0.81	0.96	0.94
	HJ	0.00	0.29	0.42	0.53	0.12	0.31	0.02	0.39
	DLT	0.35	0.82	0.30	0.83	0.42	0.86	0.56	0.84
	ZGE	0.55	0.79	0.43	0.86	0.56	0.81	0.66	0.88
	YJHL	0.58	0.32	0.76	0.85	0.56	0.49	0.79	0.87
	WS	0.30	0.24	0.05	0.72	0.27	0.48	0.56	0.49
	ETKQ	0.16	0.00	0.55	0.44	0.00	0.00	0.52	0.28
	ETK	0.03	0.05	0.59	0.00	0.14	0.08	0.25	0.00

Table S6. Livestock-dominant chain (2010–2020).

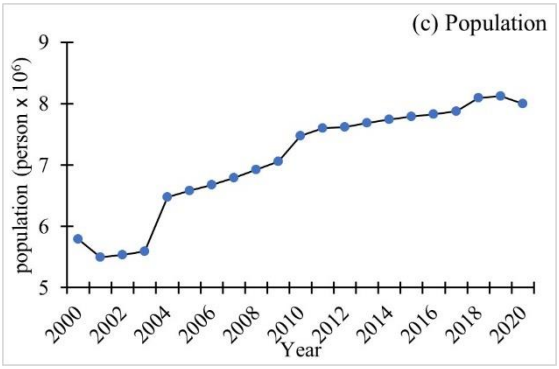
No	chain
1	ETK→WC→GY→QSH
2	ETK→ETKQ→HJ→GY→QSH
3	ETK→WC
4	ETK→ETKQ→HJ→WS
5	ETK→WC→GY→QSH→DLT→HL→TKT→TMZ
6	ETK→ETKQ→HJ→GY→QSH→DLT→HL→TKT→TMZ
7	ETK→ETKQ→HJ→WS→DLT→HL→TKT→TMZ
8	HL→TKT→TMZ
9	ETK→WC→GY→QSH→DLT→HL
10	ETK→ETKQ→HJ→GY→QSH→DLT→HL
11	ETK→ETKQ→HJ→WS→DLT→HL
12	ETK→WC
13	ETK→WC→GY→QSH→DLT→HL→TMY
14	ETK→ETKQ→HJ→GY→QSH→DLT→HL→TMY
15	ETK→ETKQ→HJ→WS→DLT→HL→TMY



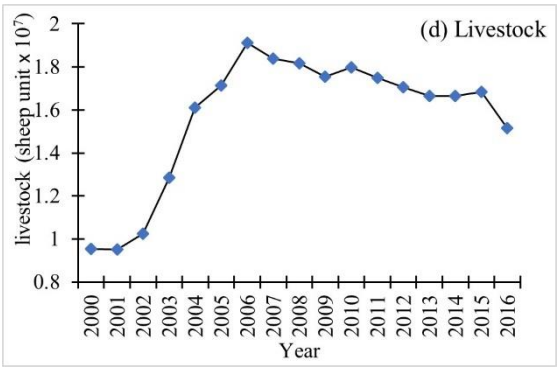
(a) annal temperature



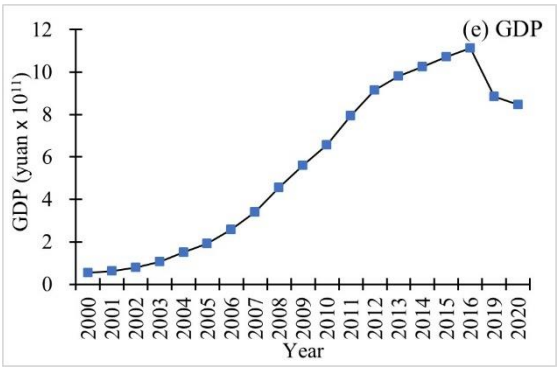
(b) annual precipitation



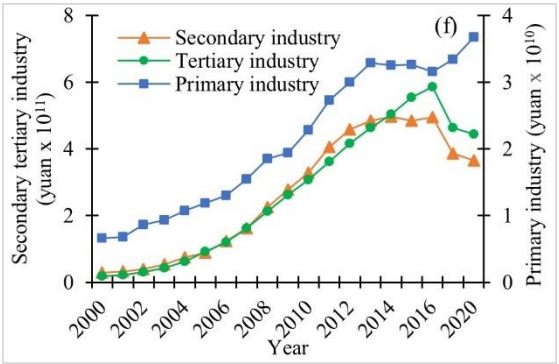
(c) population



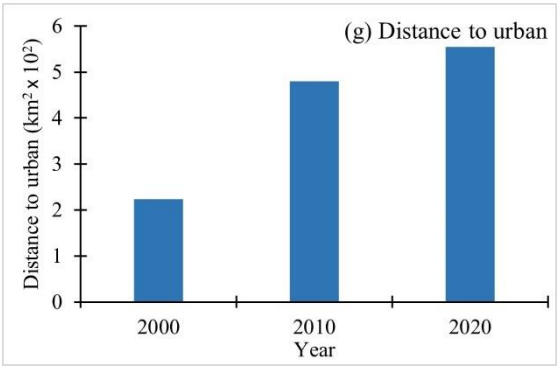
(d) Livestock population



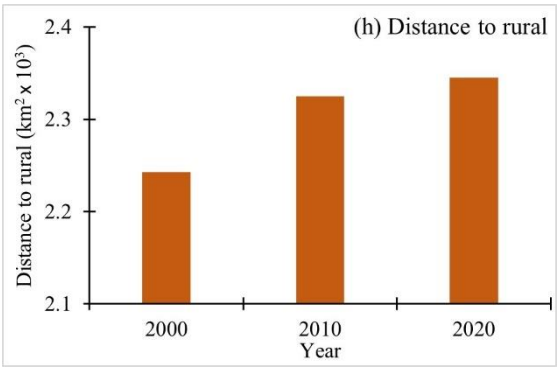
(e) GDP



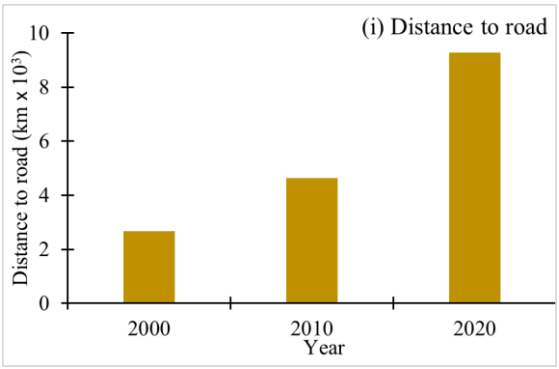
(f) Primary, secondary, tertiary industry



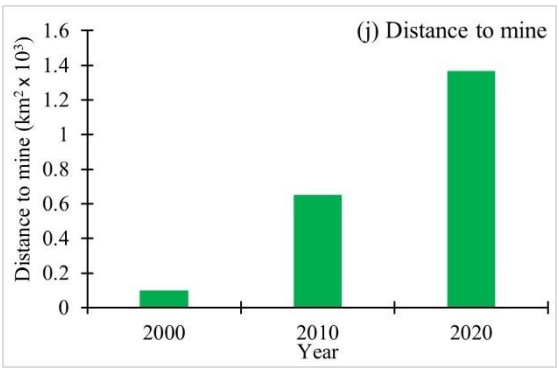
(g) distance to urban



(h) distance to rural



(i) distance to road



(j) distance to mine

Figure S1. All driver changes between 2000 and 2020.

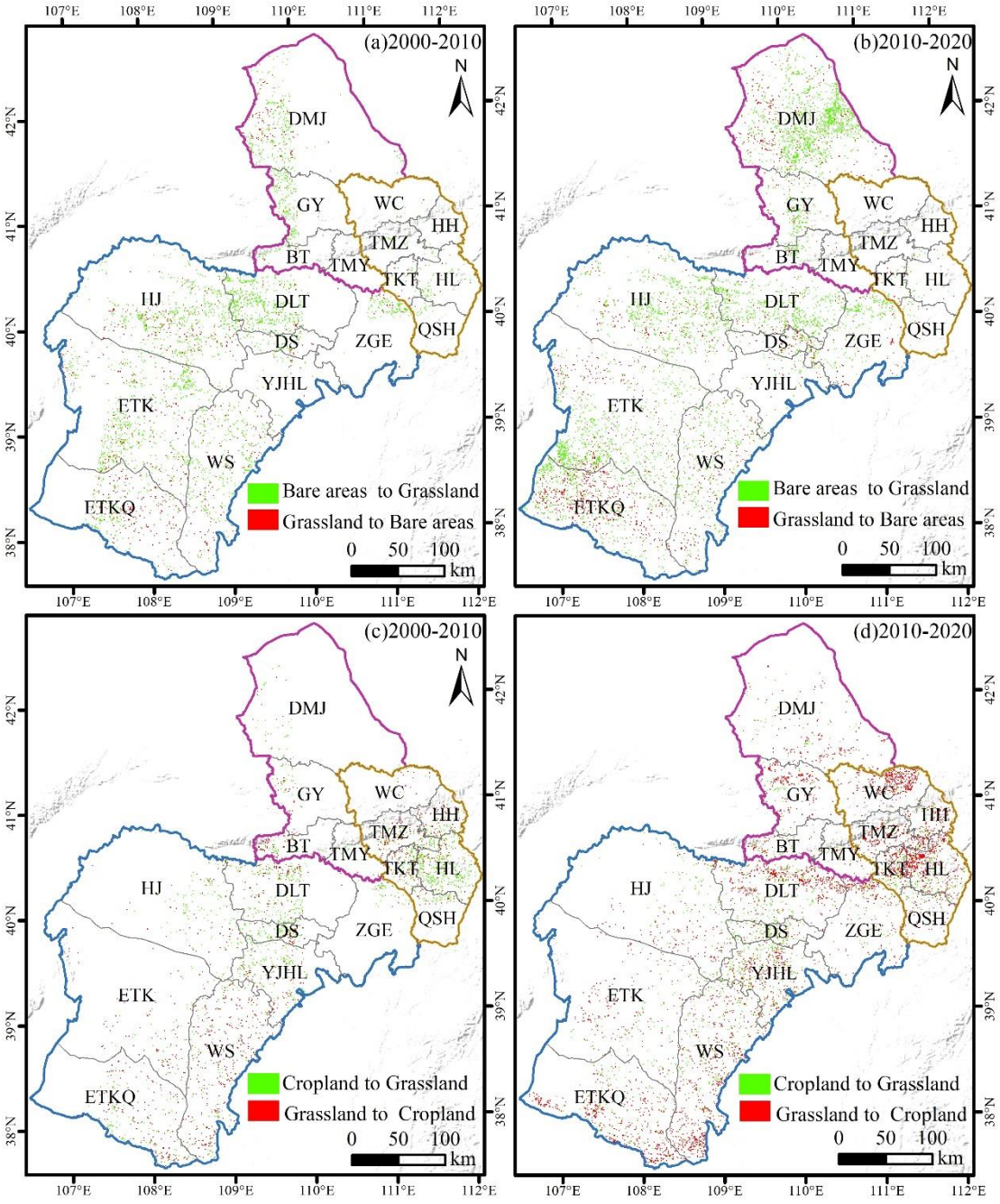


Figure S2. Conversion between cropland and bare areas (2000–2010, 2010–2020). (a) the map of conversion between grassland and bare area from 2000 to 2010; (b) the map of conversion between grassland and bare area from 2010 to 2020; (c) the map of conversion between grassland and cropland from 2000 to 2010; (d) the map of conversion between grassland and cropland from 2010 to 2020;

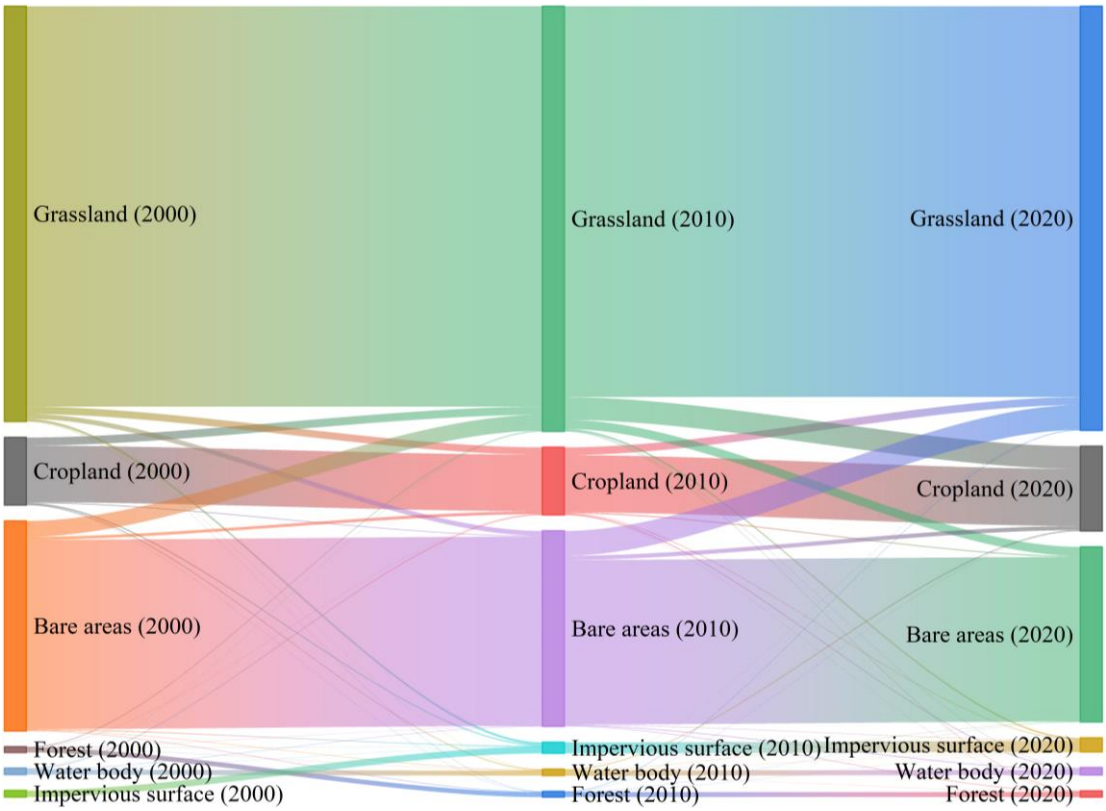


Figure S3. Transition matrix（2000, 2010, 2020）.

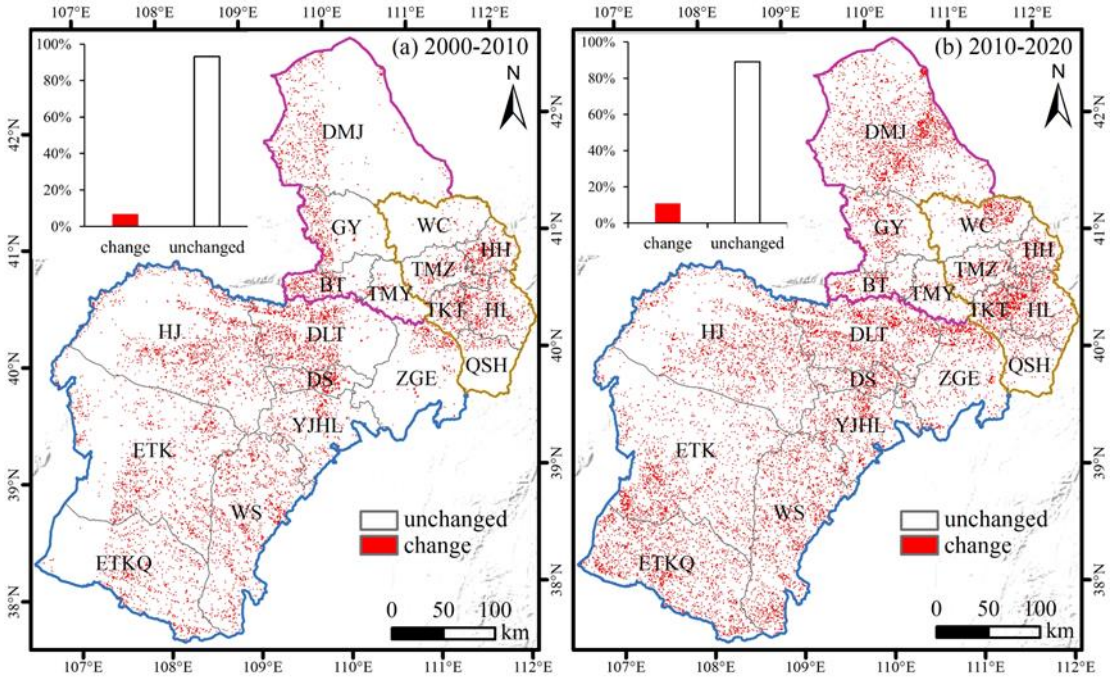
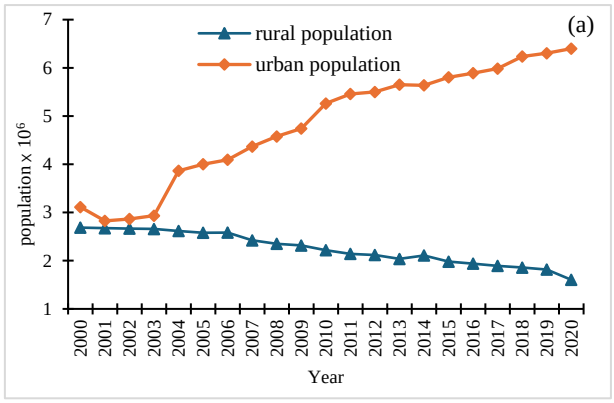
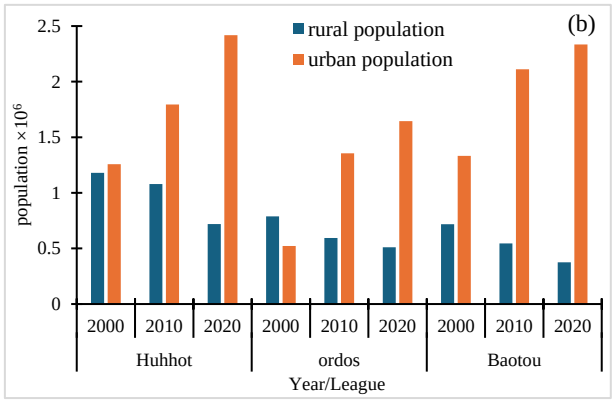


Figure S4. Land-use change in the periods of 2000–2010 and 2010–2020.



(a) Rural and urban population from 2000 to 2020



(b) Population in Huhhot, Baotou and Ordos

Figure S5. Population changes and distribution in the Hohhot–Baotou–Ordos (HBO) region (2000–2020).