



Supplement of

Spatial patterns of sandy beaches in China and risk analysis of human infrastructure squeeze based on multi-source data and ensemble learning

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Supplementary Figures

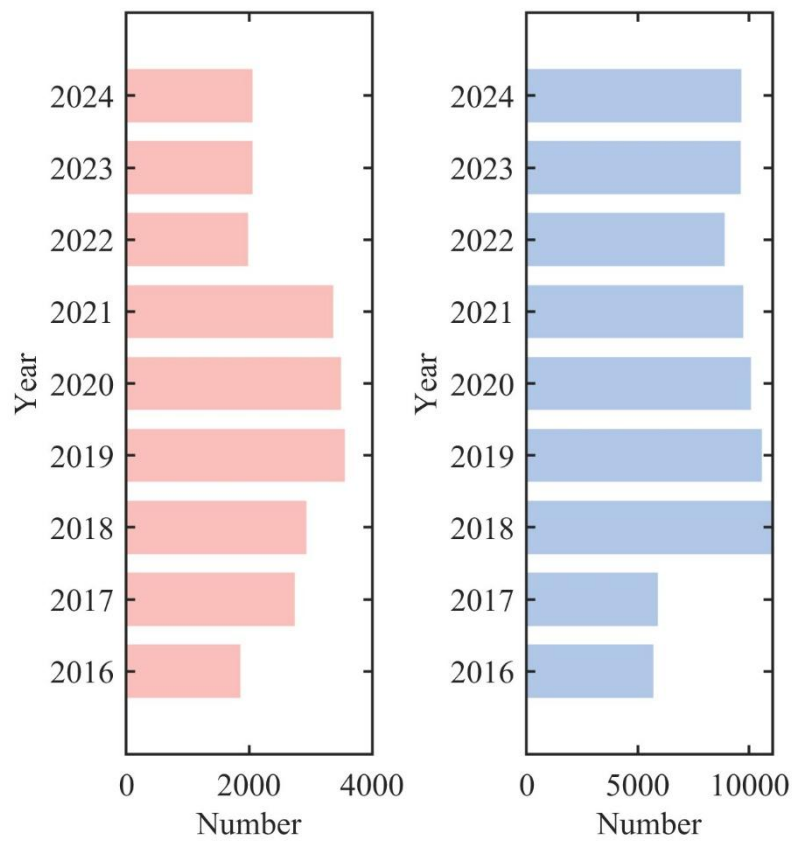


Figure S1. Image count from 2016 to 2024: (a) Image count of Sentinel-1, (b) Image count of Sentinel-2.

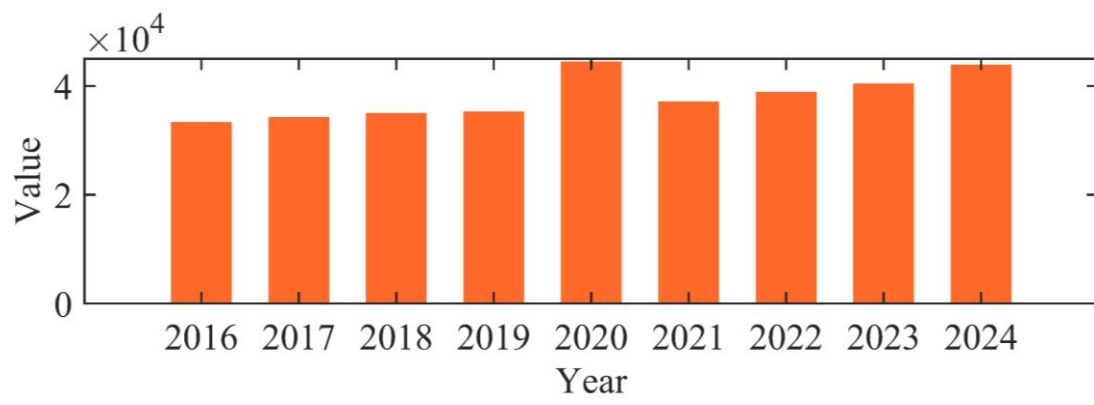


Figure S2. The sample set for each year

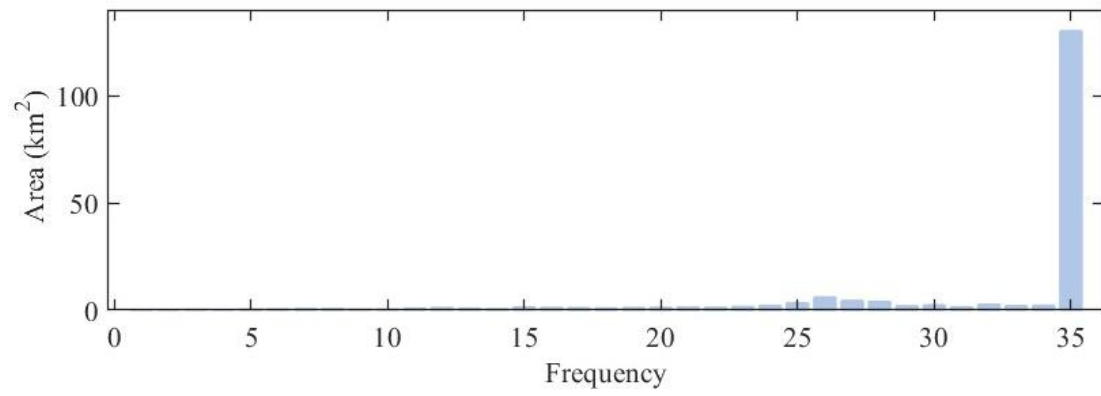


Figure S3. Frequency of human infrastructure squeeze risk.

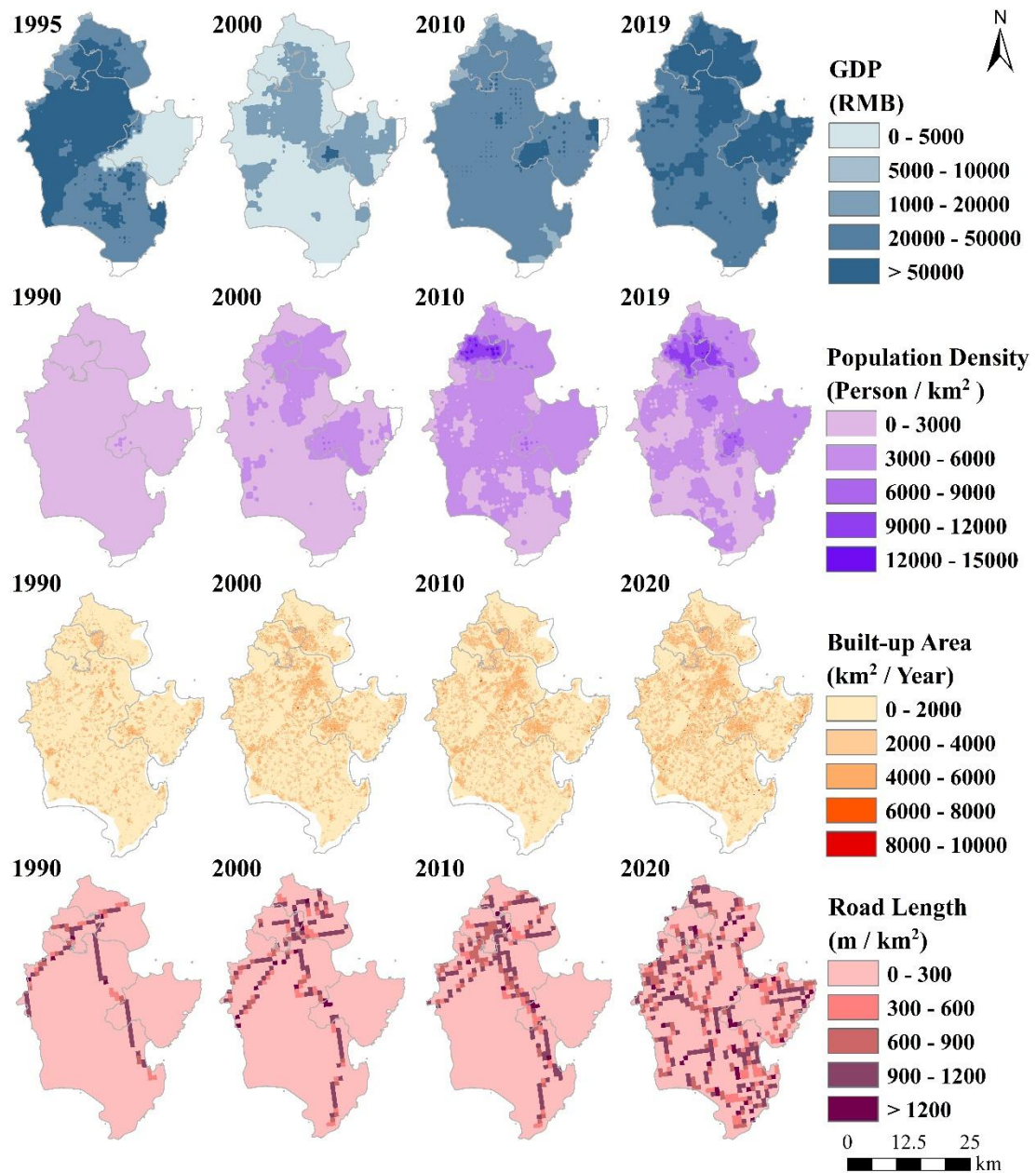


Figure S4. Changes in indicators such as GDP, population density, built-up area, and road length.

Supplementary Table

Table S1. Comparison of area between different datasets.

Province	Our Dataset	Dataset 1	Dataset 2	Dataset 3
Liaoning	17.78	2.92	8.49	24.14
Hebei	13.89	3.17	8.17	6.98
Tianjin	0.57	0.00	0.23	0.56
Shandong	40.67	16.62	27.31	22.20
Jiangsu	2.26	0.23	1.41	0.00
Shanghai	0.87	0.64	0.48	0.00
Zhejiang	5.95	3.30	1.98	3.51
Fujian	54.57	30.35	29.17	86.60
Guangdong	78.88	20.59	58.35	90.46
Guangxi	7.14	4.72	6.48	28.22
Hainan	51.65	10.50	45.56	49.48
Taiwan	46.60	19.07	25.51	49.35

Table S2. Comparison of perimeter between different datasets.

Province	Our Dataset	Dataset 1	Dataset 2	Dataset 3
Liaoning	699.06	92.74	334.23	2319.39
Hebei	327.70	97.59	231.13	302.53
Tianjin	15.94	0.00	5.16	40.86
Shandong	1186.13	379.73	724.26	1315.41
Jiangsu	96.50	7.48	53.16	0.00
Shanghai	26.52	20.55	19.30	0.00
Zhejiang	204.33	94.59	70.03	310.01
Fujian	1435.89	581.95	756.92	3488.98
Guangdong	2849.39	826.40	1856.62	6020.01
Guangxi	214.05	93.08	81.34	1341.38
Hainan	1977.96	424.35	1574.53	2798.90
Taiwan	1324.98	509.22	906.63	4751.14

Table S3. Comparison of width between different datasets.

Province	Our Dataset	Dataset 1	Dataset 2	Dataset 3
Liaoning	42.57	42.60	29.41	7.34
Hebei	68.77	51.46	40.80	10.67
Tianjin	59.00	0.00	35.85	9.38
Shandong	51.84	55.30	47.44	9.98
Jiangsu	48.95	47.45	51.43	0.00
Shanghai	51.73	35.28	27.93	0.00
Zhejiang	47.43	48.33	34.90	7.17
Fujian	54.91	52.21	45.18	10.20
Guangdong	38.92	20.94	32.58	8.87
Guangxi	40.99	53.66	60.54	9.83
Hainan	41.02	41.59	28.02	8.72
Taiwan	57.17	48.42	27.56	5.61

Table S4. Comparison of number between different datasets.

Province	Our Dataset	Dataset 1	Dataset 2	Dataset 3
Liaoning	310	65	320	21082
Hebei	54	35	86	1165
Tianjin	7	0	4	314
Shandong	386	161	330	6829
Jiangsu	29	7	19	0
Shanghai	14	18	20	0
Zhejiang	163	91	88	3008
Fujian	651	373	427	18814
Guangdong	1096	1056	955	39987
Guangxi	93	42	23	7785
Hainan	322	112	631	14643
Taiwan	225	212	521	50924

Table S5. Human infrastructure squeeze risk in each province from 1990 to 2024

Province	Fujian	Guangdong	Guangxi	Hainan	Hebei	Jiangsu
1990	18.3816	22.6548	1.4292	10.2906	6.2847	0.9540
1991	18.7560	23.1723	1.4589	10.3698	6.3054	0.9810
1992	19.1304	23.3739	1.4796	10.4193	6.4314	1.0125
1993	19.8297	23.8383	1.5507	10.5876	6.5943	1.0503
1994	20.0502	24.1830	1.6092	10.7091	6.6069	1.0665
1995	20.5038	25.0200	1.7433	10.9278	6.6519	1.1097
1996	20.9826	25.6554	1.8234	11.0916	6.6726	1.1268
1997	22.1823	27.0198	1.9368	11.6190	6.7023	1.1421
1998	24.2604	28.2051	2.0016	12.0537	6.7194	1.1520
1999	26.2683	30.4380	2.0925	12.9897	6.7455	1.1610
2000	27.2358	31.4622	2.1699	13.4829	6.7707	1.1673
2001	27.4950	32.0652	2.1879	14.1570	6.7473	1.1691
2002	27.9216	32.4900	2.2059	14.5044	6.7725	1.1691
2003	28.2204	32.8131	2.2131	14.7573	6.7770	1.1691
2004	28.5093	33.3108	2.2176	14.9211	6.7716	1.1664
2005	28.7154	33.6879	2.2410	15.0471	6.7662	1.1655
2006	28.9458	33.9984	2.2752	15.0993	6.7428	1.1781
2007	29.2041	34.1847	2.2833	15.1911	6.7509	1.1862
2008	29.5857	34.3782	2.2869	15.2856	6.7851	1.2006
2009	29.9124	34.7364	2.3049	15.4008	6.7698	1.2015
2010	30.4560	35.0784	2.3085	15.5673	6.7878	1.2258
2011	30.4920	35.1918	2.3229	15.6483	6.7995	1.2294
2012	30.6495	35.5392	2.3346	15.8211	6.8076	1.2267
2013	30.8421	36.0018	2.3445	15.9894	6.8445	1.2276
2014	31.1202	36.3429	2.3562	16.1091	6.8553	1.2276
2015	31.2273	36.4500	2.3760	16.1343	6.8679	1.2276
2016	31.3227	36.5463	2.3787	16.2099	6.8841	1.2303
2017	31.5486	36.7614	2.3904	16.2729	6.9417	1.2303
2018	31.7529	37.0080	2.3904	16.3107	6.9480	1.2303
2019	31.9806	37.1538	2.3913	16.3467	6.9462	1.2303
2020	31.9950	37.2258	2.4129	16.3836	6.9507	1.2285
2021	32.0400	37.3176	2.4183	16.4016	6.9480	1.2285
2022	32.0562	37.5102	2.4264	16.3962	6.9489	1.2303
2023	32.1066	37.5534	2.4264	16.4169	6.9489	1.2303
2024	32.1336	37.6173	2.4300	16.4160	6.9453	1.2303

Table S6. Continuation of table S5

Province	Liaoning	Shandong	Shanghai	Taiwan	Tianjin	Zhejiang
1990	13.1571	28.3806	0.6228	29.2680	0.0000	2.9700
1991	13.1913	28.6623	0.6228	29.4066	0.0000	2.9826
1992	13.2507	29.0844	0.6228	29.5839	0.0000	3.0060
1993	13.3164	29.4318	0.6291	29.8962	0.0000	3.0141
1994	13.3857	29.5434	0.6291	30.1662	0.0000	3.0159
1995	13.4568	29.6406	0.6300	30.4209	0.0000	3.0330
1996	13.4919	29.7657	0.6300	30.5496	0.0000	3.0744
1997	13.5720	30.1842	0.6300	30.5757	0.0000	3.1050
1998	13.7043	30.5190	0.6300	30.6324	0.0000	3.1257
1999	13.7853	30.8601	0.6309	30.9159	0.0000	3.2949
2000	13.8465	31.1247	0.6318	31.2057	0.0000	3.3768
2001	13.8555	31.3191	0.6318	31.2507	0.0000	3.4470
2002	13.8582	31.4073	0.6327	31.4082	0.0000	3.4803
2003	13.9140	31.4667	0.6408	31.5081	0.0000	3.5289
2004	13.9509	31.6530	0.6435	31.5927	0.0000	3.5685
2005	13.9761	31.8312	0.6489	31.5513	0.0207	3.5910
2006	14.0166	31.9617	0.6534	31.6962	0.0720	3.6207
2007	14.0445	32.1012	0.6534	31.7826	0.1116	3.6396
2008	14.0544	31.7313	0.6534	31.8267	0.2088	3.6648
2009	14.0670	32.2704	0.6534	31.8429	0.3267	3.6747
2010	14.0877	32.3496	0.6534	31.8483	0.3402	3.6720
2011	14.0634	32.4486	0.6534	31.8339	0.3690	3.6936
2012	14.0742	32.4774	0.6534	31.9302	0.3753	3.7008
2013	14.0931	32.5629	0.6534	32.0697	0.3960	3.7089
2014	14.0994	32.6421	0.6534	32.1273	0.3978	3.7350
2015	14.0949	32.6709	0.6534	32.1390	0.3978	3.7773
2016	14.1084	32.2047	0.6534	32.1741	0.3978	3.7809
2017	14.1336	32.7636	0.6534	32.2290	0.3978	3.7854
2018	14.1480	32.7870	0.6543	32.2911	0.3978	3.7926
2019	14.1552	32.8140	0.6543	32.3433	0.3978	3.8223
2020	14.1588	32.9787	0.6543	32.3928	0.3978	3.8457
2021	14.1597	32.9940	0.6543	32.3982	0.3978	3.8646
2022	14.1597	32.9958	0.6543	32.5044	0.3978	3.8736
2023	14.1678	33.0093	0.6543	32.5296	0.3978	3.8817
2024	14.1750	33.0192	0.6543	32.5233	0.3978	3.8817