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Supplement of

A 28-time-point cropland area change dataset in Northeast China from 1000 to 2020

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Supplement: 2.2.1 Reconstruction of the cropland area from 1000 to 1600

The main algorithm applied in the Liao Dynasty (1000 and 1100) is as follows:

$$F_{ihCroparea} = F_{iMan} \times A_{ManCroparea} \quad (1)$$

$$H_{ikCroparea} = H_{ikhousehold} \times A_{kCroparea} \quad (2)$$

$$L_{iCroparea} = F_{ihCroparea} + H_{ikCroparea} \quad (3)$$

where $L_{iCroparea}$ denotes the total cropland area in *i* Dao; $F_{ihCroparea}$ denotes the cropland area of the agricultural population in *i* Dao; $H_{ikCroparea}$ denotes the cropland area of the non-agricultural population in *i* Dao; F_{iMan} denotes the number of Man of the agricultural population in *i* Dao; $A_{ManCroparea}$ denotes the average annual potential cropland area per Man of the agricultural population (0.93 hm^2); $H_{ikhousehold}$ denotes the number of households of the non-agricultural population in *i* Dao; and $A_{kCroparea}$ *is* the average cropland area per household in the non-agricultural population (0.13 hm^2).

The main algorithm applied in the Jin Dynasty (1200) is as follows:

$$H_{imCroparea} = H_{im} \times AC_m \quad (4)$$

$$F_{ihCroparea} = F_{ih} \times A_{ManCroparea} \quad (5)$$

$$J_{iCroparea} = H_{imCroparea} + F_{ihCroparea} \quad (6)$$

where $J_{iCroparea}$ denotes the total cropland area in *i* Lu; $H_{imCroparea}$ denotes the cropland area of the non-agricultural population in *i* Lu; H_{im} denotes the number of households in the non-agricultural population in *i* Lu; AC_m is the average cropland area per household in the non-agricultural population (3.02 hm^2); $F_{ihCroparea}$ denotes the cropland area of the agricultural population in *i* Lu; F_{ih} denotes the number of Man of the agricultural population in *i* Lu; and $A_{ManCroparea}$ denotes the average annual potential cropland area per Man for the agricultural population (0.93 hm^2).

The main algorithm applied in the Yuan Dynasty (1300) is as follows:

$$F_{ihCroparea} = F_{iMan} \times A_{ManCroparea} \quad (7)$$

$$H_{imCroparea} = H_{imhousehold} \times A_{mCroparea} \quad (8)$$

$$G_{iCroparea} = G_{isoldier} \times A_{SCroparea} \quad (9)$$

$$Y_{iCroparea} = F_{ihCroparea} + H_{imCroparea} + G_{iCroparea} \quad (10)$$

where $Y_{iCroparea}$ denotes the total cropland area in *i* province; $F_{ihCroparea}$ denotes the cropland area of the agricultural population in *i* province; $H_{imCroparea}$ denotes the cropland area of the non-agricultural population in *i* province; $G_{iCroparea}$ denotes the cropland area of the garrison soldiers in *i* province; F_{iMan} denotes the number of Man of the agricultural population in *i* province; $A_{ManCroparea}$ denotes the average annual potential cropland area per Man of the agricultural population (0.93 hm^2); $H_{imhousehold}$ denotes the number of households of the non-agricultural population in *i* province; and $A_{mCroparea}$ *is* the average cropland area per household in the non-agricultural population (0.13 hm^2); $G_{isoldier}$ denotes the number of garrison soldiers in *i* province; $A_{SCroparea}$ denotes the average cropland area per soldier (6.67 hm^2).

The main algorithm applied in the Ming Dynasty (1400) is as follows:

$$F_{ihCroparea} = F_{iMan} \times A_{ManCroparea} \quad (11)$$

$$H_{itCroparea} = H_{ithousehold} \times A_{tCroparea} \quad (12)$$

$$G_{iCroparea} = G_{isoldier} \times A_{SCroparea} \times 0.3 \quad (13)$$

$$M_{iCroparea} = F_{ihCroparea} + H_{itCroparea} + G_{iCroparea} \quad (14)$$

where $M_{iCroparea}$ denotes the total cropland area in *i* province; $F_{ihCroparea}$ denotes the cropland area of the agricultural population in *i* province; $H_{itCroparea}$ denotes the cropland area of the non-agricultural population in *i* province; $G_{iCroparea}$ denotes the cropland area of the garrison soldiers in *i* province; F_{iMan} denotes the number of Man of the agricultural population in *i* province; $A_{ManCroparea}$ denotes the average annual potential cropland area per Man of the agricultural population (0.93 hm^2); $H_{ithousehold}$ denotes the number of households of the non-agricultural population in *i* province; and $A_{tCroparea}$ *is* the average cropland area per household in the non-agricultural population (0.13 hm^2); $G_{isoldier}$ denotes the number of garrison soldiers in *i* province; $A_{SCroparea}$ denotes the average cropland area per soldier (3.07 hm^2).

The main algorithm applied in the Ming Dynasty (1500 and 1600) is as follows:

$$F_{ihCroparea} = F_{iMan} \times A_{ManCroparea} \quad (15)$$

$$H_{itCroparea} = H_{ithousehold} \times A_{tCroparea} \quad (16)$$

$$G_{iCroparea} = G_{isoldier} \times A_{SCroparea} \times 0.3 + G_{isoldier} \times A_{ManCroparea} \times 2.7 \quad (17)$$

$$M_{iCroparea} = F_{ihCroparea} + H_{itCroparea} + G_{iCroparea} \quad (18)$$

where $M_{iCroparea}$ denotes the total cropland area in *i* province; $F_{ihCroparea}$ denotes the cropland area of the agricultural population in *i* province; $H_{itCroparea}$ denotes the cropland area of the non-agricultural population in *i* province; $G_{iCroparea}$ denotes the cropland area of the garrison soldiers in *i* province; F_{iMan} denotes the number of Man of the agricultural population in *i* province; $A_{ManCroparea}$ denotes the average annual potential cropland area per Man of the agricultural population (0.93 hm^2); $H_{ithousehold}$ denotes the number of households of the non-agricultural population in *i* province; and $A_{tCroparea}$ *is* the average cropland area per household in the non-agricultural population (0.13 hm^2); $G_{isoldier}$ denotes the number of garrison soldiers in *i* province; $A_{SCroparea}$ denotes the average cropland area per soldier (3.07 hm^2).

Supplement: 2.2.2 Reconstruction of the cropland area from 1700 to 1900

When reconstructing the cropland data for the three provinces in Northeast China during this period, Ye (Ye et al., 2009) primarily utilized historical documents such as *General Chorography of Shengjing* and statistical data from the late Qing Dynasty's land survey (A, 1997; Li, 1991; Li et al., 2005; Ji et al., 2002; Yang et al., 1990). The methods employed for processing the cropland data include 4 aspects: (1) conversion and standardization of measurement units; (2) correction of the hidden percentage of cropland area in the historical records; (3) estimation of property of mu used in Northeast China; (4) estimation of cropland area based on population data. Among these, (1) conversion and standardization of measurement units: Converting the diverse measurement units used for different regions and types of cultivated land in the Northeast China during

the Qing Dynasty into a unified area measurement unit. Additionally, the conversion of Qing Dynasty area measurement units to km^2 was performed based on proportional relationships (Wu, 1984). (2) Correction of the hidden percentage of cropland area in the historical records: Historical literature from the Qing Dynasty and the government's published cropland data may contain concealment or inaccuracies (Buck, 1941; Shi, 2000). Hence, a correction of 20% was applied to the original cropland data. (3) Estimation of property of mu used in Northeast China: By analyzing the tax system in Northeast China, it is found that the taxation was different in the same area of cropland in high, middle and low productivity. That means the cropland area recorded in the historical document was the real amount, and the problem of tax mu could be ignored in Northeast China. (4) Estimation of cropland area based on population data: In cases where exact cropland area was unavailable, the minimum requirement of 3 mu (0.2 hm^2) per capita were used to estimate and interpolate cropland area based on population data (Fang et al., 2006). In reconstructing cropland data for the east of Inner Mongolia during this period, Tian (Tian, 2005) primarily relied on historical documents such as local gazetteers and official government records. The methods employed for processing cropland data include 4 aspects: (1) historical data summarization; (2) proportional estimation; (3) population-based estimation; (4) linear interpolation. Among these, (1) historical data summarization: By extensively collecting data, the scrutinized and analyzed data were directly used as the historical cropland area. (2) Proportional estimation: In the absence of exact cropland area, the cropland within a region was proportionally distributed to sub-regions based on the ratio of historical and contemporary cropland area, or the cropland area in some regions was used to estimate the overall cropland area. (3) Population-based estimation: Based on the proportional relationship between the number of farmers and the cropland area in the region during historical periods, cropland area was estimated using population data. (4) Linear interpolation: In cases where the trend of cropland change in the study area did not exhibit significant variations, linear interpolation was applied using the already reconstructed cropland area results for various time sections, ultimately generating cropland areas for multiple time sections.

Supplement: 2.2.3 Reconstruction of the cropland area from 1910 to 1980

In the published results used in this study, CNEC data primarily utilized government files or investigation reports, Japanese and Russian survey data, official statistical data and survey data (Committee Of Science And Technology In Northeast China, 1946; National Bureau Of Statistics, 1989; Heilongjiang Provincial Bureau Of Statistics, 1997; Jinlin Provincial Bureau Of Statistics, 1997; Liaoning Provincial Archives et al., 1988; Liaoning Provincial Bureau Of Statistics, 1997; Xin et al., 1999; Xiong, 1933; Ye et al., 2006; Middle East Railway Economic Survey, 1931; Committee Of Integrative Survey Of Natural Resources and Committee Of National Planning Of Chinese Academy Of Sciences, 1989). The methods employed for processing the cropland data include 2 aspects: (1) standardization of multi-sourced data; (2) correlation analysis between statistical data and survey data. (1) Standardization of multi-sourced data: The study area scope of different datasets was determined, measurement units were standardized, and data from different sources during the same period were cross-verified

and compared at the county-level. (2) Correlation analysis between statistical data and survey data: Analyzing the correlation between statistical data and survey data for each county in the study area during the same period, then calculating their linear regression equations and explanatory variances. When reconstructing cropland data for the Eastern of Inner Mongolia during the same period, Ye's data (Ye and Fang, 2012) mainly consisted of government statistical reports and Japanese survey reports (Committee Of Science And Technology In Northeast China, 1946; South Manchuria Railways Co., 2015; Ministry Of Agricultural And Commercial, 1919). The methods employed for processing the cropland data include 2 aspects: (1) conversion and standardization of measurement units; (2) correlation analysis between statistical data and survey data. These two data processing methods have been introduced in the previous sections. In the reconstruction of cropland data for the east of Inner Mongolia during this period, Tian (Tian, 2005) primarily used local gazetteers, statistical data and survey data (Cropland Research Group, 1992; Ho, 1988). The methods employed for processing the cropland data mainly involved a comparative analysis of statistical data and survey data: Comparing the obtained statistical data on cropland area at different time points with survey data at the county-level, assessing the accuracy of the data used in the reconstruction.

Fig. S1 Supplementary information showing the three types of verification points used in this study

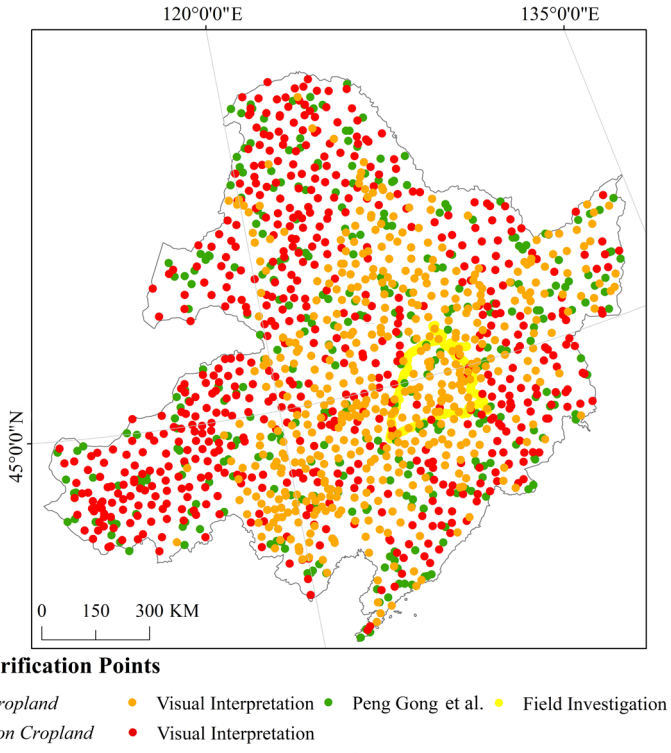

Figure S1. Spatial distribution of verification points. The green points derived from FROM-GLC within the study area (Gong et al., 2013); The yellow points obtained through field investigations conducted by the authors in April 2023 within the study area; The orange and red points were randomly generated within the study area.

Fig. S2 Supplementary information showing change in the cropland area, population and settlements of Northeast China during Liao, Jin, Yuan, and Ming Dynasties (1000-1600)

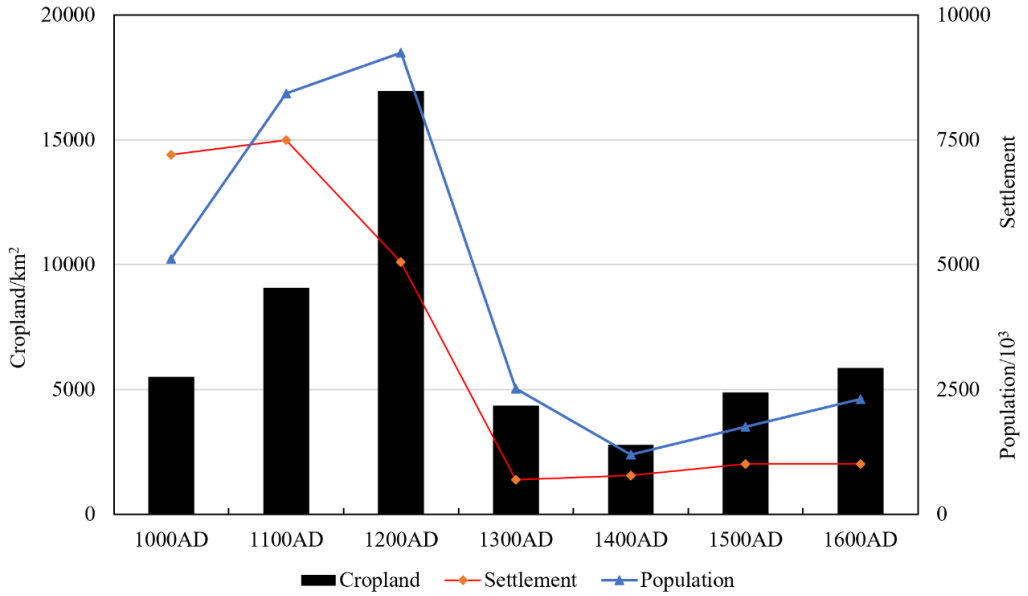

Figure S2. Graphs showing change in the cropland area, population and settlements of Northeast China from 1000 to 1600. The settlement relics and the administrative division points derived from Jia et al. (2018) and the *Historical Atlas of China* (Tan, 1982a; Tan, 1982b). The population data was revised and derived from the *History of Population in China* (Wu and Ge, 2005a; Cao and Ge, 2005b).

Table S1. Supplementary information showing the revisions to the CNEC dataset

Counties where cropland is missing or inconsistent	**Year**	**Adjacent counties for interpolation or based on the number of settlements**
Dashiqiao City	1683	Haicheng City, Yingkou City, Gaizhou City, Panjin City
Tieling County	1683, 1735, 1780	Faku County, Tieling City, Diaobingshan City
Suizhong County	1683	Huludao City, Jianchang County
Xingcheng City		Huludao City, Jianchang County
Liaoyuan City	1683, 1735, 1780, 1908	Dongliao County
Xifeng County	1735, 1780	Changtu County, Siping City, Dongfeng County, Dongliao County
Jiaohe City	1735, 1780, 1914	Interpolated based on Shulan City, Yongji County, and Jilin City in 1735 and 1780; Linear interpolation in 1914 using data from 1908 and 1931
Meihekou City	1735, 1780	Interpolated based on multiplying the number of settlements and the cropland area owned by unit settlement in this region 1735 and 1780.
Fuxin Mongolian Autonomous County	1780, 1914	Interpolated based on Fuxin City and Beipiao City in 1780; Linear interpolation in 1914 using data from 1908 and 1931
Huadian City		Interpolated based on Dunhua City, Jingyu County, and Fusong County in 1780; Linear interpolation in 1914 using data from 1908 and 1931

Shulan City	1780	Jilin City, Changchun City, Jiaohe City, Wuchang City
Panshi County		Huadian City, Dongliao County, Dongfeng County, Meihekou City, Huinan County
Yushu City		Interpolated based on multiplying the number of settlements and the cropland area owned by unit settlement in this region in 1780
Manchu Autonomous County of Yitong		
Songyuan City		
Changling County		
Fuyu City		
Siping City	1780, 1914	Interpolated based on multiplying the number of settlements and the cropland area owned by unit settlement in this region in 1780; Linear interpolation in 1914 using data from 1908 and 1931
Lishu County		
Gongzhuling City		
Shuangliao City		
Jianchang County	1908, 1914	Interpolated based on Lingyuan City, Kalaqinzuoyi Mongolian Autonomous County, Suizhong County and Xingcheng County in 1908; Linear interpolation in 1914 using data from 1908 and 1931
Zhenlai County	1908	Baicheng City, Da'an City, Ulan Hot City
Tailai County		Jalaid Banner, Qiqihar City, Longjiang County
Dorbod Mongolian Autonomous County		Qiqihar City, Daqing City, Lindian County
Fuxin City	1914	Linear interpolation based on cropland fraction in 1908 and 1931
Chaoyang City		
Chaoyang County		
Jianping County		
Kalaqinzuoyi Mongolian Autonomous County		
Beipiao City		
Lingyuan City		
Baishan City		
Fusong County		
Jingyu County		
Korean Autonomous County of Changbai		
Qian Gorlos Mongolian Autonomous County		
Qian’an County		
Antu County		
Mohe City		
Qiqihar City	1940, 1950	Revised according to Qiqihar Agricultural Annals

Table S2. Supplementary information showing the county's determination of initial cultivation between 1780 and 1908

Counties where cropland need to be supplemented	**Year**	**Adjacent counties for interpolation or based on the number of settlements**
Nong'an County	1800, 1850	Revised according to local gazetteer of Nong'an County
Yongji County		Based on the historical origin of this region and Jilin City, revised according to the average proportional relationship between the two regions in 1908, 1914, 1931 and 1940
Huadian City		Dunhua City, Jingyu County, Fusong County
Shulan City		Jilin City, Changchun City, Jiaohe City, Wuchang City
Panshi City		Huadian City, Dongliao County, Dongfeng County, Meihekou City, Huinan County
Mulan County		Bayan County, Tonghe County, Bin County
Fuyu County		Yi'an County, Nehe City, Lindian County, Qiqihar City, Gannan County
Bei'an City		Kedong County, Wudalianchi City, Hailun City
Jiaohe City		Interpolated based on multiplying the number of settlements and the cropland area owned by unit settlement in this region in 1800 and 1850 respectively
Changling County		
Hunchun City		
Dunhua City		
Siping City		
Lishu County		
Yitong Manchu Autonomous County		
Gongzhuling City		
Shuangliao City		
Yanji City	1850	Revised according to local gazetteer of Yanji City
Tonghe County		Yilan County, Mulan County, Fangzheng County
Lanxi County		Suihua City, Zhaodong City, Harbin City, Qinggang County

Table S3. Supplementary information showing the total cropland area of global LUCC datasets, previous representative published studies and our dataset in Northeast China from 1000 to 2020 ($\times 10^4$ km^2).

Period	1000	1100	1200	1300	1400	1500	1600	1661	1685	1700	1724	1750	1753	1766	1800	1812	1820	1840	1850	1870	1887	1890	1900
This Study	0.55	0.91	1.69	0.44	0.28	0.49	0.59			0.96		2.04			3.33				4.36				6.66
HYDE3.2	0.23	0.53	0.57	0.42	0.34	0.37	0.59			0.59		1.29			2.81				4.36				5.63
SAGE										13.61		20.16			26.97				33.80	36.52		38.85	39.97
KK10	25.72	28.26	33.65	14.00	37.90	42.48	43.85			15.49		22.79			26.32				25.93				
PJ	5.58	8.88	9.72	7.27	7.19	9.30	13.53			13.53		20.04			26.80				33.57				39.74
Yu 2021																							16.07
CSY																							
NLS																							
Zhang 1991																2.02			1.21		2.66		
Zhou 2001								0.09			0.16		0.68			20.64		19.71					
Shi 2015								0.00	0.02		1.25			1.95		2.70			4.94		7.27		
Jin 2015								0.43			1.05						3.80				9.82		
Li 2016										0.78					1.23								1.98
He 2023	0.77		3.35		1.51		1.31								4.14								

Period	1910	1914	1920	1930	1933	1940	1946	1950	1952	1960	1965	1970	1978	1980	1985	1990	1995	2000	2005	2010	2015	2020
This Study	10.33		13.44	15.37		17.31		16.63		20.53		22.07		24.28	24.56	23.76	25.87	26.64	27.74	33.37	34.08	37.90
HYDE3.2	6.44		9.08	11.19		10.88		11.76		12.71		13.53		14.37		15.66		15.06	16.38	16.00	16.00	
SAGE	41.11			44.24				48.30				45.21				44.67		31.99				
KK10																						
PJ	40.87		42.37	44.02		46.08		47.92		46.09		44.90		46.08	45.12	44.49						

Yu 2021	18.64		21.21	23.78		24.63		25.56		26.09		30.13		33.61	33.49	33.05	33.55	33.68	32.99	33.50	33.79	
CSY									18.22		17.49		19.18		19.21	19.04	19.66	21.96	23.07	25.79	27.97	32.06
NLS															24.89		24.60			34.03	33.99	37.64
Zhang 1991		8.23					14.17	15.17														
Zhou 2001																						
Shi 2015	10.55																					
Jin 2015					14.71				24.46						25.01							
Li 2016																		4.09				
He 2023																		25.89				

The abbreviations used in the table are as follows: HYDE3.2 refers to Goldewijk et al. (2017); SAGE refers to Ramankutty et al. (2008) and Ramankutty and Foley. (1999); KK10 refers to Kaplan et al. (2011); PJ refers to Pongratz et al. (2008); Yu 2021 refers to Yu et al. (2021); CSY denotes the Chinese Statistical Yearbook (refer to provincial and prefectural statistical yearbook); NLS denotes the National Land Survey (1985 refer to the first general land investigation (Committee of Integrative Survey of Natural Resources and Committee of National Planning of Chinese Academy of Sciences, 1989); 1995 refers to the first national land survey (Li, 2000); 2010 and 2015 refer to the second national land survey; 2020 refers to the third national land survey (https://gtdc.mnr.gov.cn/Share#/)); Zhang 1991 refers to Zhang (1991); Zhou 2001 refers to Zhou (2001); Shi 2015 refers to Shi (2015); Jin 2015 refers to Jin et al. (2015); Li 2016 refers to Li et al. (2016); He 2023 refers to He et al. (2023).

Table S4. Supplementary information showing the statistical cropland data and land survey cropland data at the prefectural-level in Northeast China in 2010, 2015 and 2020 (km^2).

Period	**2010**		**2015**		**2020**	
	CSY	**NLS**	**CSY**	**NLS**	**CSY**	**NLS**
Hulunbeier City	11980	18545	17812	18651	21172	21172
Xingan League	7969	12691	10940	12637	15440	15413
Chifeng City	10081	14066	14000	14107	18476	18299
Tongliao City	10744	13477	13509	13807	21723	21344
Xilinguole League	2387	2413	2433	2433	3080	3082
Shenyang City	7008	7719	4903	7567	7688	7689
Dalian City	3850	4205	2590	4154	3727	3727
Anshan City	2585	3040	2117	3008	3016	3017
Fushun City	1431	1876	858	1850	1842	1897
Benxi City	677	857	506	842	880	842
Dandong City	2018	2483	1623	2455	2227	2429
Jinzhou City	4855	5117	3517	5060	5052	5478
Yingkou City	1152	1215	1098	1193	1113	1120
Fuxin City	3774	5204	4606	5176	5187	5986
Liaoyang City	1526	1887	1789	1858	1851	1851
Panjin City	1288	1589	1424	1568	1568	1568
Tieling City	6502	6678	6573	6634	6912	6729
Chaoyang City	4785	5505	5297	5493	4767	6140
Huludao City	2553	2938	2605	2914	2900	3122
Changchun City	12244	14598	13016	14457	15651	18210
Jilin City	5841	9281	5965	9247	6736	9122
Siping City	8498	9727	8568	9696	5859	6812
Liaoyuan City	2234	2596	2501	2583	2312	2718
Tonghua City	3058	4054	3227	4070	3165	4064
Baishan City	462	1165	536	1164	950	1094
Songyuan City	10053	12595	12018	12587	12176	13866
Baicheng City	8663	11785	9950	11818	10211	14203

Yanbian Korean Autonomous Prefecture	3601	4373	3840	4371	3816	4578
Harbin City	19650	22866	19774	22744	20066	24531
Qiqihar City	23984	27531	23989	27586	22560	29026
Jixi City	4768	9829	4906	9873	9376	10561
Hegang City	4327	5512	2188	5503	2180	6047
Shuangyashan City	4195	10579	4209	10583	4136	11051
Daqing City	7244	7777	7522	7830	7824	9299
Yichun City	2409	2592	2402	2587	2588	2871
Jiamusi City	12279	20413	16650	20414	18715	21763
Qitaihe City	1752	2799	1660	2782	1949	2865
Mudanjiang City	5874	8840	6531	8817	8879	8879
Heihe City	11084	19203	12257	19196	12708	21874
Suihua City	17637	19977	18904	19961	18973	20935
Daxing'anling Prefecture	879	663	881	665	1161	1161

CSY denotes the Chinese Statistical Yearbook (2010, 2015 and 2020 refer to provincial and prefectural statistical yearbook); NLS denotes the National Land Survey (2010 and 2015 refer to the second National Land Survey; 2020 refers to the third National Land Survey); Daxing'anling Prefecture includes: Mohe City, Huma County, Tahe County.

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