Analysis of Urban Land Use and Its Effects on Air Environment in Chengdu, Western China from 1992 to 2008

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Abstract Large-scale development of urban land use has led to change of a variety of natural processes and ecological processes, resulting in complex eco-environmental consequences. The objective of this study was to analyze the urban land use and its impact on air environment effect in Chengdu, western China from 1992 to 2008 following the RS (Remote Sensing) and GIS technique. The environmental effects data of urban land use was extracted and analyzed by overlaying layers of urban land use and the density of nitrogen dioxide and total suspended particulate matter in sampling points data concerning to the air quality of the environment in Chengdu based on GIS spatial analysis method. The results show that the main feature of urban land use change was substantial reduction of cultivated land and construction land and forest land increased significantly within the study area from1992 to 2008. The temporal-spatial change was notable in study period time. Land use has a significant impact on urban air environment, the chroma change of nitrogen dioxide derived from forest land was obvious, the area occupied by different nitrogen dioxide chroma was the largest. The urban land use impact on the highest class chroma of total suspended particulate matter was notable and its area was the greatest. The results show also the spatial distribution of nitrogen dioxide chroma and total suspended particulate matter chroma in study area is reduced following from Qingbaijiang District – Xindu District-downtown to both sides. The spatial distribution of industry, mining and traffic land is basically the same chroma spatial distribution. Therefore, the results of this study provide a scientific basis for improvement air environment quality, the urban sustainable development and a scientific response for decisions from the municipal governments.

Key words Urban land use, Air environment, Effects, RS (Remote Sensing), GIS

Land use and land cover (LULC) changes have largely changed the process of the Earth's living beings, energy and water (Chen, 1996; Kennedy Okello *et al.*, 2010; Grimm N B *et al.*, 2008). This change has been an important component and reason in global environmental change (Liu Jiyuan *et al.*, 2010; Chen, 2003; Liu, 1996; Li, 1996;), and has affected human sustainable development (Shi, 1999; Zhang, 1997; Zeledon E B *et al.*, 2009). Since the reform and opening-up, with the fast development of socio-economic and the acceleration of urbanization process, the large-scale urban land use development has become one of the main human activities changing the natural environment. This urban land use has resulted in sharp growth for natural resource, the remarkable change of land use and land cover from the natural and ecological processes (Zhou, 2000). This development has affected the socio-economic and sustainable development, leading to complex ecological environmental consequences (Turner B L *et al.*, 2008), and even ecological security problems in China (Ge, 2000).

It is well known that land as an important part of the ecosystem provides the habitat for animals and plants, which involves all the factors that affect the physical and biologic environment of land use (Liu, 2010). Urban land use changes have led to the results of human activities frequently, intervention intensity greatly, fragile ecosystem (Michelsen O, 2008), and thus, the environmental issues are highlighted (Wu G F, 2008), and this change has become the main limiting factor restraint of the social, economic and sustainable development in Chengdu City. Chengdu City is situated at Sichuan basin, and the special climatic conditions such as still wind is high frequency, gradient intensity of inversion temperature and so on, formed disadvantageous and polluting meteorological conditions, that is the air transport to be impeded, the hindrance air pollutant spread and the migration, resulting in the threaten seriously of air environment quality in Chengdu City. The ecological environmental protection in Chengdu City is not only extremely important for the socio-economic development in Sichuan Province, but also has the important strategic position for the ecological and environmental protection in the upstream of Yangtze River and Three Gorges Reservoir Region (Chen, 2001).

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Climate change is one of the greatest social, economic and environmental challenges of our time (Long, 2007). Human activity is causing the climate to change (Li, 2010). This, in turn, is having an impact on Chengdu City's rainfall, temperatures, health, heritage and biodiversity for current and future generations.

The air environment quality in Chengdu City depends mainly on the concentration of sulphur dioxide, concentration of nitrogen dioxide and concentration of total suspended particulate matter, and so on three indicators. In this paper, we consider that the pollution of nitrogen dioxide derived mainly from the exhaust gas of motor vehicles, dioxide pollution derived mainly from the coal by industrial and domestic, total suspended particulate matter derived mainly from the dust of the building sites, municipal sites, demolition sites, the vacant land and road dust. Therefore, urban land use has an important impact on the environment of air quality in Chengdu City. The air environmental effects of different urban land use in Chengdu City was analyzed based on the sampling points concentration of the nitrogen dioxide and total suspended particulate matter and through the Inverse Distance Weighted interpolation for its spatial distribution, then layer of urban land use and urban air quality is overlapped based on GIS spatial analysis method. It should provide the scientific basis of making decisions for sustainable urban development and for urban governments.

1 Overview of the study area

Chengdu is the capital of Sichuan Province in southwest China, located at 102°54′ – 31°26′E, 30°5′ – 31°26′N. The municipality covers a total area of 12,390 sq kilometers, extending for 192 km from the east to the west and 166km from the south to the north. It is adjacent to Deyang City in the northeast and Ziyang City in the southeast, bordering on Ya'an City in the southwest, Aba Zang and Qiang Autonomous Prefecture in the northwest, and Leshan City in the south. Under its jurisdiction, it has 10 districts, 6 counties and 4 county-level cities: Jinjiang District, Qingyang District, Jinniu District, Wuhou District, Chenghua District, Gaoxin District, Longquanyi District, Qingbaijiang District, Xindu District and Wenjiang District, Dujiangyan City, Pengzhou City, Qionglai City and Chongzhou City, Jintang County, Shuangliu County, Pixian County, Dayi County, Pujiang County and Xinjin County.

Chengdu City terrain is divided into the mountains, plains and hills from west to east. The west region is Longmen mountain and Qionglai mountain, elevation is mostly more than 3 000 m, and the vertical distribution of the elevation is more obvious. The central region is Chengdu plain, which has a half of total city area, and the altitude is 450 – 720 m, whose topography is slightly inclined from the northwest to the southeast. Eastern region is Longquan mountain and the western edge of the hills is located in central Sichuan basin, with the elevation less than 1 000 m.

This region is characterized by a subtropical humid climate with mild weather, clearly four seasons and ample rainfall year-round which is favorable for agricultural production. This research area in this paper involves Chenghua District, Wuhou District, Qingyang District, Jinjiang District, Jinniu District, Gaoxin District, Longquanyi District, Qingbai Jiang District, Xindu District, Wenjiang District, Shuangliu County and Pi County, which covers a total area of 3.7×10^4 hm^2 (Fig. 1). In 2008, the GDP per capita in study area was more than 4.435×10^4 yuan, and the total population of in study area reached 8.224 million.

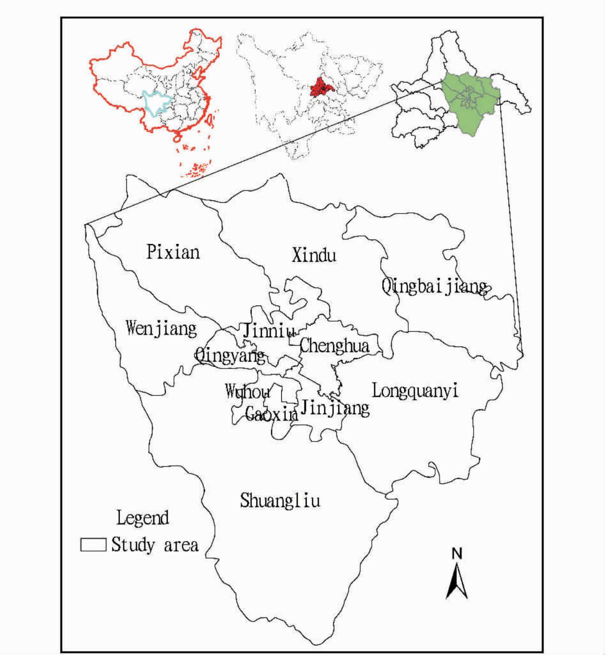


Fig. 1 The location of study area

2 Data and Methodology

2.1 Data The various types of data used in this study are the sampling points concentration of the nitrogen dioxide and total suspended particulate matter, remotely sense data, 1:5000 scale topographic map, 1:5000 land use map in study area. The remotely sense data in this paper adopted are TM/ETM + imagery, and the image quantity is good. TM/ETM + image resemble time is August 16, 1992, November 2, 2000, April 30, 2008, respectively. Imagery WRS is 129/039, all images is single wave band primitive data, which from satellite earth stations of the Chinese Academy. Besides, the Statistical Yearbook of Chengdu since1992 and GPS data is required here.

2.2 Methodology

2.2.1 Remote sensing data processing. The primitive TM/ETM + image of study area is read into the computer and processed for geometric correction. Geometric rectification was carried out on the 1992 TM image using 1:5000 scale topographic maps applying for polynomial function method, Albers shadow way, the degree central longitude is 105° E, original adopting 0° E, 0° N, northern and northern standard latitude line is 25° N and 47° N distinguish, Peking 1954 for the earth level, error is no more than 0.5 pixel. The gray levels value is transformed from the original image pixels to gray scale values after image correction following the most nearby re-sampling method. TM, ETM + imagery in 2000 and 2008 are geometric corrected based on the standard reference image of TM imagery corrected in 1992, respectively, the registration RMS error is less than 0.5 pixel.

2.2.2 Image classification. Land use was categorized into 7 types in this paper based on signature of the images, such as forest land (FL), paddy field (PF), dry land (DL), town land (TL), industry, mining and traffic land (IMTL), rural homestead land (RHL) and water field (WF). The method of maximum likelihood (ML) procedure was chosen as classification method based on its ready availability and the fact that it did not require an extended training process. The ML was processed in ERDAS 8.5. Further, ARCGIS 9.0 is used to provide a suitable platform for data analysis, update and retrieval. Land use can be captured both in terms of geographic location and absolute area. We created characteristic picture spots of land cover type as training sample data on the ground and then train TM or ETM + bands 4, 3 and 2 images to recognize them. Then, information of construction land, vegetation, cultivated land, water field and others land were extracted by independent supervised classification of images, using a Gaussian maximum likelihood classifier, employing TM or TM or ETM + bands 2, 3 and 4 images as standard data and 1:5000 scale topographic map in this area as reference data. To do this, a simple supervised multi-date k-means clustering of stable and changed land cover classes will be employed.

The post-classification change detection method was to be the most suitable for detecting land use change. In the post-classification technique, two images from different dates are independently classified (Jensen, J. R. 1981; Singh, A. 1989). Accurate classification was imperative to insure precise change detection results (Foody. G. M, 2001). Preliminary classification was performed on the 1992 and 2008 images. The classification in 1992 and 2008 images with the highest overall accuracy were used in the change detection process. However, image classification and post-classification techniques are iterative and require further refinement into order to produce more accurate change detection results.

2.2.3 Accuracy assessment. To validate the maps of land use change, the third phase involves ground-based accuracy assessment. Validating the maps is critical to improve methodology, improve area estimates, and understand biases in analysis (Pathan. S. K, 1991). All field observations were georeferenced using GPS to validate the change of land cover based on remote sensing image to support the interpretation of statistical analysis. An accuracy assessment for the land use change map is summarized in Table 1. The overall producer's accuracy and user's accuracy of the land use change map are greater than 90 %, and the Kappa value is 0.612 during 1992 – 2008. As a result, the accuracy of classification is satisfactory.

Table 1 Accuracy assessment for the classification of land use in study area (1992 – 2008) Unit: %

Land use types	1992		2000		2008		1992 – 2008	
	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy
WF	100	99.737	96.640	94.671	98.553	97.986	98.398	97.465
TL	99.328	94.911	90.365	94.444	87.711	95.167	92.468	94.840
PF	99.897	98.471	100.000	98.558	100.000	100.000	99.966	99.010
DL	74.097	91.829	100.000	99.511	63.445	84.515	79.181	91.952
RHL	48.291	91.870	79.268	98.485	88.380	91.681	71.980	94.012
IMTL	96.573	97.792	99.585	98.361	96.473	89.148	97.544	95.100
FL	95.874	88.167	94.503	95.717	94.289	89.889	94.889	91.258
Accuracy	87.723	94.682	94.337	97.107	89.836	92.627	90.632	94.805
Kappa	0.617		0.638		0.581		0.612	

Note: Forest land-FL, Paddy field-PF, Dry land-DL, Town land-TL, Industry, mining and traffic land-IMTL, Rural homestead land-RHL, Water field-WF.

2.2.4 Analysis of air environment effect on land use. The land use change transfer matrix is established using software of Erdas or ArcGIS in research area during 1992 – 2008, then the characteristic of tempo-spatial evolution for urban land use is analyzed. The air environment effect for urban land use is analyzed based on spatial method following the urban land use layer and the density layer in study area.

The method of Inverse Distance Weighted interpolation is used to map density values of nitrogen dioxide and total suspended particle matter decreases influence with distance of sampled location.

The Inverse Distance Weighted interpolation in interpolation to raster has a Fixed or Variable search radius type. The search radius type is Variable in this paper. With a variable radius, the count represents the number of points used in calculating the value of the interpolated cell. A Power of 2 is used in this paper. The search radius setting is that the number of points is 20 in study area and the maximum distance is 2000 meters. The output cell size is 30 meters as resolution in TM/ETM + data.

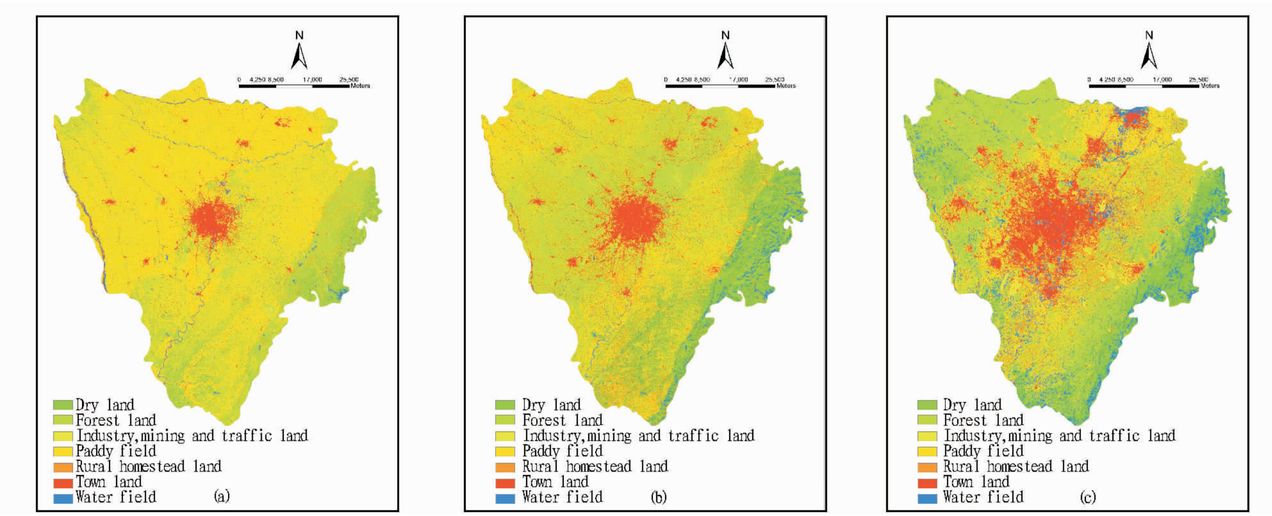
3 Results and discussion

3.1 Urban land use changes Urban land uses from 1992 to 2008 are mapped in Fig. 2, respectively. Urban land use change is significant over the period from 1992 to 2008 in Chengdu City (Table 1). According to Table 1, the main characteristic of urban land use changes is significant decrease of cultivated land (paddy land) and significant increase of construction land (town land, work and traffic land) during 1992 – 2008, the decrease quantity amounts to $17.794\,6 \times 10^4$ hm^2, the increase quantity amounts to $4.651\,8 \times 10^4$ hm^2, respectively. The land area for industrial and traffic and rural homesteads increased by 1.386 4 $\times 10^4$ hm^2 and 1.573 4 $\times 10^4$ hm^2 over 16 years, respectively. The area for forest land and water land increased by 3.195 2 $\times 10^4$ hm^2, 2.645 5 $\times 10^4$ hm^2, respectively.

From 1992 to 2000, the cultivated land area decreased significantly by 11.080 6 $\times 10^4$ hm^2 and by 29.908%. In contrast, town land, rural homesteads land, work and traffic land, forest land and water land increased by 1.467 8 $\times 10^4$ hm^2, 1.274 7 $\times 10^4$ hm^2, 1 932.96 hm^2, 3.309 1 $\times 10^4$ hm^2 and 4 485.81 hm^2, respectively, in the same period (Table 1).

These trends continued in the period from 2000 to 2008 except for the change of forest land and dry land (Table 1). The change trend of forest land and dry land is reversed, decreasing by 1.138 hm^2 and by 1.658 3 $\times 10^4$ hm^2 from 2000 to 2008, respectively. The cultivated land (paddy field, dry land) decreased by 5.372 4 $\times 10^4$ hm^2 and by 14.501%, respectively, the decrease speed is less than that of last period. The construction land (town land, work and traffic land) increased by 2.990 6 $\times 10^4$ hm^2 and by 8.072%, respectively, the increase speed is more than that of last period in 1992 – 2000. The area of water land was continued to increase, reached by 2.192 $\times 10^4$ hm^2, but the increased area and speed was low speed than 1992 – 2000.

The transfer matrix of urban land use in 1992 – 2008 was obtained through Tabulate area module of spatial analysis in ArcGIS and maps operating of urban land use types from 1992 to 2008, respectively (Table 3, 4).



Note: (a)1992; (b)2000; (c)2008.

Fig.2 Urban land use from 1992 to 2008 in study area

Table 2 Urban land use change Unit: hm^2

Land use types	1992	2000	2008	1992 – 2000	2000 – 2008	1992 – 2008
FL	109 371.26	142 462.89	141 323.96	33 091.63	–1 138.93	31 952.70
PF	196 365.42	85 559.78	48 418.62	–110 806	–37 141.2	–147 946.80
DF	14 906.81	58 774.99	42 191.90	43 868.18	–16 583.1	27 285.090
TL	11 343.80	26 022.45	43 997.88	14 678.65	17 975.43	32 654.080
IMTL	13 397.33	15 330.29	27 261.63	1 932.96	11 931.34	13 864.30
RHL	19 529.17	32 276.93	35 263.91	12 747.76	2 986.98	15 734.74
WF	5 580.73	10 066.54	32 035.95	4 485.81	21 969.41	26 455.22
Total area	370 493.87	370493.87	370 493.87	0	0	0

Note: Forest land-FL, Paddy field-PF, Dry land-DL, Town land-TL, Industry, mining and traffic land-IMTL, Rural homestead land-RHL, Water field-WF.

Table 3 The transfer matrix of urban land use in 1992 – 2000 Unit: hm^2

Types	FL	WF	PF	DL	TL	IMTL	RHL	1992
FL	32 324.06	3 493.16	28 160.79	34 038.39	2 669.38	1 755.27	6 930.20	109 371.25
WF	757.10	2 422.13	344.56	148.97	1 098.24	267.07	542.66	5 580.73
PF	97 387.48	1 160.71	49 178.89	12 055.66	6326.45	10 652.50	19 603.73	196 365.42
DL	2 521.39	483.78	2 420.26	8 334.09	14.46	12.18	1 120.01	14 906.17
TL	895.91	301.51	161.80	62.54	9 015.98	536.41	369.65	11 343.80
IMTL	3 205.38	1 055.93	1 809.12	1 040.09	3340.95	1 284.33	1 661.54	13 397.33
RHL	5 371.57	1 148.03	3 484.39	3 096.54	3 557.01	822.48	2 049.14	19 529.17
2000	142 462.88	10 065.24	85 559.82	58 776.28	26 022.46	15 330.24	32 276.95	370 493.87

Note: Forest land-FL, Paddy field-PF, Dry land-DL, Town land-TL, Industry, mining and traffic land-IMTL, Rural homestead land-RHL, Water field-WF.

The main feature of urban land use transfer from the Table 3 in 1992 – 2000 is as follows: the area transferred mainly from cultivated land to forest land is 97 387.48 hm^2, and then major forest land is converted to rural homestead land and cultivated land with about 6.219×10^4 hm^2, 6 930.2 hm^2, respectively. New increased water land transferred mainly from forest land is about 3 493.16 hm^2, and then the majority water land is converted to construction land and forest land, the area converted is about 1 098.24 hm^2, 757.10 hm^2, respectively. The much of paddy field area was transferred to forest land and construction land (town land, industry, mining and traffic land, rural homestead land), the area converted is about 9.738×10^4 hm^2, 3.658×10^4 hm^2, respectively, its area is more than the additional paddy field area by 11.08×10^4 hm^2, which causes the paddy land area in study area decrease. The new increased area of dry land was more than area converted to other land use types by 4.387×10^4 hm^2, which much of area from cultivated land (paddy field) is about 3.403×10^4 hm^2. The new increased area of town land was main from the conversion of paddy land with 6326.45 hm^2, The new increased area of rural homestead land was main from the conversion of paddy field and forest land with 1.96×10^4 hm^2, 6 930.2 hm^2, respectively.

According to Table 4, the main feature of urban land use transfer from 2000 to 2008 is as follows:

Table 4 The transfer matrix of urban land use in 2000 – 2008 Unit: hm^2

Types	FL	WF	PF	DL	TL	IMTL	RHL	2008
FL	59 128.70	1 251.68	44 889.61	19 853.34	1 820.98	2 938.80	11 440.04	141 323.16
WF	8 912.08	5 830.04	5 239.17	5 731.15	2 104.27	975.59	3 243.63	32 035.95
PF	23 690.26	501.24	11 763.80	3 070.95	1 457.91	2 494.58	5 439.88	48 418.63
DL	7 379.81	1 778.62	5 414.60	24 356.07	67.17	102.59	3 093.05	42 191.91
TL	15 521.05	195.18	3 372.71	267.47	1 6837.70	4 853.92	2 949.85	43 997.88
IMTL	12 118.26	241.73	6 008.55	2 735.09	14 38.82	1 741.22	2 978.76	27 262.43
RHL	15 712.72	266.75	8 871.37	2 762.20	2 295.61	2 223.53	3 131.82	35 263.99
2000	142 462.88	10 065.24	85 559.81	58 776.29	26 022.46	15 330.24	32 277.03	370 493.94

Note: Forest land-FL, Paddy field-PF, Dry land-DL, Town land-TL, Industry, mining and traffic land-IMTL, Rural homestead land-RHL, Water field-WF.

The majority of forest land was converted to cultivated land (paddy land) and the construction land (rural homestead land) with 2.369×10^4 hm^2, 43.352×10^4 hm^2, respectively, the new increased forest land which mainly comes from the cultivated land (paddy field and dry land) is about 6.474×10^4 hm^2. The majority of water land area converted to the dry land is about 1 778.02 hm^2, the new water increased land area which comes from the forest land and the cultivated land (paddy field and dry land) is about 8 912.086 hm^2, 1.097×10^4 hm^2, respectively. The area of paddy field converted to the forest land and the construction land (town land, industry, mining and traffic land, rural homestead land) is about 4.488×10^4 hm^2, 1.825×10^4 hm^2, respectively, and the area of newly increased paddy field which mainly comes from the forest land is about 2.369×10^4 hm^2. The area of dry land converted to the forest land and the construction land (rural homestead land) is about 1.985×10^4 hm^2, 5 764.76 hm^2, respectively. The additional dry land which mainly comes from the forest land and the cultivated land (paddy field) is 7 379.81 hm^2, 5 414.6 hm^2. The new increased town land area mainly comes from land use adjustment of the forest land and the cultivated land (paddy field) with about 1.552×10^4 hm^2, 3 372.71 hm^2, respectively. The additional area of industry, mining and traffic land mainly comes from the transformation of the cultivated land (paddy field, dry land), the area converted is about 8 743.64 hm^2, the new rural homestead land mainly comes from land use transformation of the cultivated land (paddy field, dry land) and the forest land with 1.163×10^4 hm^2 and 1.571×10^4 hm^2, respectively.

3.2 Air environment effect of urban land use

3.2.1 Nitrogen dioxide effect of urban land use. The density change of nitrogen dioxide is very different from for land use types (Fig.3). The spatial variation of the density nitrogen dioxide during 0.210 – 0.649 9 $\mu g/m^3$ led by urban land use is imbalanced distribution. The spatial analysis results show that the maximum value of the nitrogen dioxide density is Qingbai Jiang district – Xindu district and the Center districts in point or line distribution, its density change reaches 0.561 9 – 0.649 9 $\mu g/m^3$, and the nitrogen dioxide density reduce in turn from the distribution region to both sides region. The minimum value of dioxide nitrogen appears in the southeast region, the density scope of dioxide nitrogen is 0.210 – 0.298 $\mu g/m^3$. So, the distribution region of nitrogen dioxide density change is consistent with town land, the industry, mining and traffic land.

The results of the urban land use and its impact on air environment is computed based on spatial analysis in GIS (table. 4). Though the maximum land use of the density during 0.210 – 0.649 9 $\mu g/m^3$ is forest land with $14.132\,4 \times 10^4$ hm^2, occupying for 38.145% in total research area, the minimum land use types of the density during 0.210 – 0.649 9 $\mu g/m^3$ is industry, mining and traffic land, the area and its proportion is $2.726\,1 \times 10^4$ hm^2, 7.358%, respectively, the land use area in the classification of the density change of nitrogen dioxide density during 0.210 – 0.649 9 $\mu g/m^3$ is very differently. The land use area of the density during 0.386 – 0.474 $\mu g/m^3$ is maximum, its area is $9.489\,7 \times 10^4$ hm^2, occupying for 25.614% in total study area, and the land use area of the density during 0.474 – 0.561 9 $\mu g/m^3$ is minimum, its area is $5.8047 \times 10^4 hm^2$, occupying for 15.668%.

The maximum land use types of the density during 0.209 9 – 0.298 $\mu g/m^3$, 0.298 – 0.386 $\mu g/m^3$ and 0.386 – 0.474 $\mu g/m^3$ is forest land, the area is $1.620\,6 \times 10^4$ hm^2, $4.329\,6 \times 10^4$ hm^2 and $3.605\,2 \times 10^4 hm^2$, respectively, its proportion is 25.347%, 51.758% and 37.991%, respectively. The minimum land use types of the density during 0.209 9 – 0.298 μg/m^3, 0.298 – 0.386 μg/m^3 and 0.386 – 0.474 μg/m^3 is town land, the area is 1 932.961 hm^2, 1 495.744 hm^2 and 3 152.568 hm^2, respectively, its proportion is 3.023%, 1.788% and 3.322%, respectively.

The maximum land use types of the density during 0.474 – 0.561 9 μg/m^3 and 0.561 9 – 0.649 9 μg/m^3 is forest land, the area is 2.616 3 × 10^4 hm^2, 1.960 5 × 10^4 hm^2, respectively, its proportion is 45.072%, and its 28.025%, respectively. The minimum land use types of the density during 0.474 – 0.561 9 μg/m^3 and 0.561 9 – 0.649 9 μg/m^3 is industry, mining and traffic land, the area is 3 212.358 hm^2, 434.102 4 hm^2, respectively, its proportion is 5.534%, 0.621%, respectively.

Table 5 The density change of nitrogen dioxide for different land use Unit: μg/m^3

Urban land use types	Classification of the density change of nitrogen dioxide					Total // hm^2
	0.210 – 0.298	0.298 – 0.386	0.386 – 0.474	0.474 – 0.561 9	0.561 9 – 0.649 9	
FL	16 206.25	43 296.77	36 052.03	26 163.47	19 605.44	141 324
PF	5 905.619	12 127.94	13 394.76	7 763.932	9 226.365	48 418.62
DL	21 481.2	6 071.178	8 094.904	4 158.85	2 385.769	42 191.9
TL	1 932.961	1 495.744	3 152.568	7 041.502	30375.11	43 997.88
IMTL	8 508.407	2 604.614	12 502.15	3 212.358	434.1024	27 261.63
CHL	4 292.998	8 432.674	13 453.95	5 941.202	3 143.088	35 263.91
WL	5 610.099	9 624.112	8 246.972	3 766.509	4 788.258	32 035.95
Total // hm^2	63 937.53	83 653.04	94 897.33	58 047.83	69 958.12	370 493.9

Note: Forest land-FL, Paddy field-PF, Dry land-DL, Town land-TL, Industry, mining and traffic land-IMTL, Rural homestead land-RHL, Water field-WF.

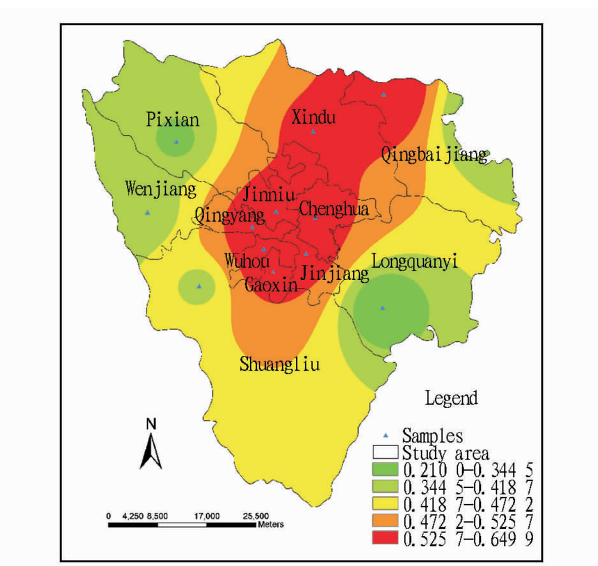


Fig. 3 Density change of nitrogen dioxide for urban land use (μg/m^3)

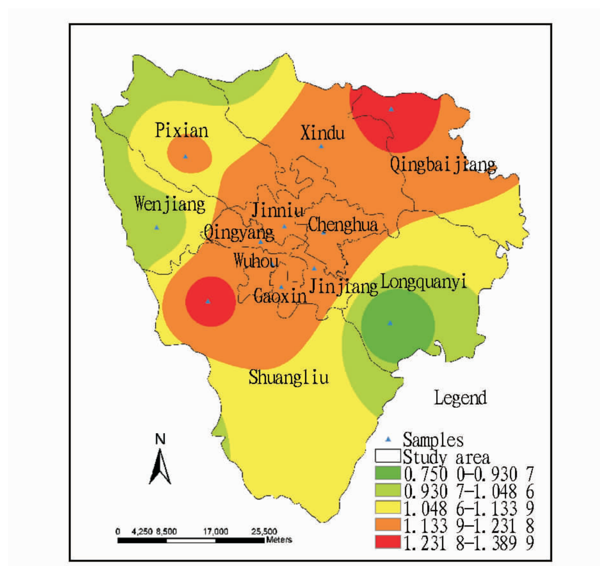


Fig. 4 Density change of total suspended particle matter for urban land use (μg/m^3)

3.2.2 Effect of total suspended particle matter on urban land use. The density change of total suspended particle matter is also very different from for land use types (Fig. 4). The density of area located in north of Qingbaijiang District and Shuangliu County is maximum, by 1.267 – 1.389 μg/m^3, the density from the both sides of the Qingbaiiiang District – Xindu District – Center urban area to peripheral region is gradually lower, the density of area located in southeast region and northeast part in study area is minimum, by 0.750 – 0.878 μg/m^3. The spatial distribution extends from southwest to northeast in study area, and is consistent basically with the land use pattern of industry and mining and transportation land.

The density change of the total suspended particle matter in study area is 0.750 – 1.389 9 μg/m^3, and spatial distribution of the density change is imbalance (Fig. 4). The distribution area of the density change on total suspended particle matter in study area is different, and the land use area of the density change in 1.261 9 – 1.389 9 μg/m^3 is the greatest (8.523 × 10^4 hm^2), accounting for 23% in total study area.

The density change of the total suspended particle matter led by urban land use in study area is different (Table 5). The land use types of the maximum density is town land, its area is 3.488 × 10^4 hm^2, approximately accounting for 9.415% in total area. Though the maximum and the minimum land use types of the density during 0.750 – 1.389 9 μg/m^3 is forest land and industry, mining and traffic land, the area is 14.132 4 × 10^4 hm^2, 2.726 1 × 10^4 hm^2, occupying for 38.145%, 7.358%, respectively, the land use area in the density classification of the total suspended particle matter during 0.750 – 1.389 9 μg/m^3 is very different. The land use area of the density during 1.133 9 –

1.261 9 μg/m^3 is maximum, its area is 4.678 9 ×10^4 hm^2, occupying for 54.108% in total study area, and the land use area of the density during 1.267 1 –1.398 8 μg/m^3 is minimum, its area is 1.866 1 ×10^4 hm^2, occupying for 21.894%.

The greatest land use type of the density during 0.750 –0.878 μg/m^3 is dry land with 2.148 1 ×10^4 hm^2, 37.894%, respectively. The maximum land use types of the density during 0.878 –1.005 9 μg/m^3, 1.005 9 –1.133 9 μg/m^3 and 1.198 7 –1.267 1μg/m^3 is forest land, the area is 2.559 6 × 10^4 hm^2, 3.407 7 ×10^4 hm^2 and 4.6789 ×10^4 hm^2, respectively, its proportion is 41.283%, 42.556% and54.108%, respectively. The minimum land use types of the density during 0.750 –0.878 μg/m^3, 0.878 –1.005 9 μg/m^3 and 1.005 9 –1.133 9 μg/m^3 is town land, the area is 1 886.938 hm^2, 920.457 7 hm^2 and 1 610.861 hm^2, respectively, its proportion is 1.485%, 2.012% and 0.509%, respectively. The greatest land use type of the density during 1.261 9 –1.389 9 μg/m^3 is town land with 3.488 5 ×10^4 hm^2, 40.929%, respectively. The smallest land use type of the density during 1.261 9 –1.389 9 μg/m^3 is industry, mining and traffic land, the area is 434.102 4 hm^2 and the proportion is 0.509%. This shows that the town land use has huge impact on air environment effect.

Table 6 The density change of the total suspended particle matter in land use types Unit: μg/m^3

Urban land use types	Classification of the total suspended particle matter					Total//hm^2
	0.750 0 –0.878 0	0.878 0 –1.005 9	1.005 9 –1.133 9	1.133 9 –1.261 9	1.261 9 –1.389 9	
FL	16 189.08	25 596.94	34 077.75	46 798.97	18 661.22	141 324
PL	3 281.83	11 523.59	8 492.782	9 524.746	15 595.67	48 418.62
DL	21 481.2	6 071.178	8 094.904	4 158.85	2 385.769	42 191.9
TL	1 886.938	920.457 7	1 610.801	4 694.334	34 885.35	43 997.88
WTL	8 508.407	2 604.614	12 502.15	3 212.358	434.1024	27 261.63
CHL	1 954.847	6 554.488	9 314.272	10 042.55	7 397.755	35 263.91
WL	3 385.733	8 732.462	5 984.529	8 059.758	5 873.469	32 035.95
Total//hm^2	56 688.03	62 003.74	80 077.19	86 491.56	85 233.33	370 493.9

Note: Forest land –FL, Paddy field –PF, Dry land –DL, Town land –TL, Industry, mining and traffic land –IMTL, Rural homestead land – RHL, Water field –WF.

4 Conclusions

(i) The urban land use change is that the cultivated land area reduces obviously and the construction land area continues to increase, the tempo-spatial conversion speed of the land use types of the cultivated land, the vegetation and construction land, and so on speed up and present the different characteristic from 1992 –2000 to 2000 –2008, and it has the important impact on air environment effect.

(ii) The total quantity of the pollution load caused by vehicles in the central city is actively controlled or cut down through limiting vehicles not having the environmental protection sign to enter the 2nd ring road based on the pollution exhaust of urban vehicle. The raise dust derived from the work sites and the path is a key point. The density of the nitrogen oxide and the total suspended particle matter are reduced effectively, the urban air environment quality is distinct improvement through cleanliness management of the architecture project work site and the idle land or the urban road.

(iii) The complexity of urban land use is manifested in three aspects, such as the scale, the spatial pattern or the land structure of land use. The population growth and urbanization has influenced the land use change, and this change has the major impact on the urban environment. China is faced with issues in the process of urban development, such as the giant resources, the environment, the population, the spatial pressure, and so on. It is of positive significance for the current urban land use, city construction and regional sustainable development to integrate use of remote sensing data and the socio –economic data from theory, method, and practice application.

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farmland into big farmland, separate land into integrated farmland, and waste farmland into good farmland, finally to increase land utilization ratio and yield rate.

2.3 Coastal region of west Guangdong Province This region belongs to tropical monsoon climate zone, the summer is long and winter is warm, heat resource is rich, and average annual temperature is above 22 ℃. The overall quality level is high in this region. Over 90% of farmland has the level of 24 – 27, and over 60% of farmland has the level higher than 26. Advantages of this region in high standard capital farmland construction include abundant heat source and high soil and natural quality; disadvantages include weak foundation of rural economy, bad ecological environment condition, serious soil erosion in Leizhou Peninsula, moderate water depth and volume of underground water, and certain limitation on utilization of underground water resource.

Construction direction: strengthening construction of farmland drainage and irrigation channel system through drilling deep wells, combined with measures such as water delivery pipeline, electricity and road; improving soil and cultivation conditions through project such as protection of natural forest and forests for water supply conservation.

2.4 Northwestern mountain areas of Guangdong Province These areas have higher latitude, short frost-free period, average annual temperature 16 to 20 ℃, and annual rainfall 1 400 to 1 800 mm. Major soil types include red soil, yellow soil, paddy soil, limestone soil, and purple soil, *etc*. Advantages of these areas in high standard capital farmland construction include mature agricultural cultivation technologies, high level of land utilization, and higher level of per unit area yield in some areas; and disadvantages include many agricultural meteorological disasters and large area of middle-and-low-yielding field.

Construction direction: controlling and preventing soil erosion through changing sloping fields to terraced fields; increasing content of organic substance in arable layer, to bring organic matter content in soil over 2.5% for paddy field and higher than 2% for dry field; increasing thickness of arable layer; removing soil obstacle factor and improving main physical and chemical characteristics.

3 Conclusions

When determining key areas of high standard capital farmland construction in Guangdong Province, we preferably selected those factors that can be easily quantified and signify current situation and future potential of high standard capital farmland, and finally selected key areas through calculating the overall score of every region. Extensive interview indicates that 40 key areas of high standard capital farmland are consistent with actual conditions, demonstrating that factors we selected are reasonable and the method of quantification is feasible. This presents another idea for determining key areas of capital farmland construction. Therefore, it provides a reference for determining key areas of high standard capital farmland, and better implementing requirements and tasks of the state for construction of high standard capital farmland.

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