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Effects of Different Land Cover Types on Urban Surface Temperature —— A Case Study of Busan, Republic of Korea

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Abstract: Taking Busan, Republic of Korea as the research object, the temporal and spatial pattern changes of different land cover types in 2010-2020 were analyzed, and the urban surface temperature of Busan, a typical area of rapid urbanization, was inversed, and the difference of surface temperature of different land use types and the relationship between surface temperature and NDVI were analyzed. The results show that the average surface temperature in Busan metropolitan area is generally the trend of construction land > grassland > cultivated land > forestland in 2011, which is basically consistent with the trend in 2015 and construction land > grassland > forestland > cultivated land in 2019. Generally speaking, from 2011 to 2020, the spatial distribution of urban thermal environment in Busan is basically consistent with the spatial distribution of urban construction land. Construction land has become the main factor affecting the intensity of urban heat island.
Keywords: Land cover types, Temporal and spatial pattern, Surface specific radiation, Land surface temperature

I. INTRODUCTION

In 2022, the world experienced an unprecedented hot summer, and the temperature in southern Europe, western Asia and eastern China was extremely rare. The temperature in many places reached a record high, and the rainfall was obviously less than in previous years. In the summer of 2022, the northern hemisphere was extremely hot, and continuous high temperature weather appeared in Europe, North Africa, the Middle East, Asia and North America, which affected the lives of nearly 5 billion people and led to mountain fires in many countries. The extreme heat wave, drought and wildfire in 2022 affected all parts of the world and caused billions of dollars in losses. In the past five years (2018-2022), Republic of Korea experienced some extreme high temperature weather events, which had a great impact on Republic of Korea's society and economy. In the summer of 2018, Republic of Korea was hit by high temperature and drought, which led to water shortage in many cities and rural areas, affecting crop production and drinking water supply. In the summer of 2019, Republic of Korea was affected by one of the highest temperatures in history, which caused many people to die of heatstroke, which had a serious impact on the environment and health. In 2020, Republic of Korea was hit by high temperature and floods, which led to flooding and landslides in many cities and rural areas, causing great economic losses and casualties. In the summer of 2021, Republic of Korea was once again affected by high temperature and drought, which led to crop failure, water shortage and environmental damage. Republic of Korea's national average temperature in early July 2022 (1-10) was 27.1 degrees Celsius, and the highest temperature reached 32 degrees Celsius, both of which set a record for the highest temperature in the same period since 1973. The average temperature in Republic of Korea in July was 25.9 degrees Celsius, 1.3 degrees Celsius higher than the average in the same period from 1991 to 2020. In addition, the average number of high temperature days in July reached 5.8 days, 1.7 days more than the same period of last year. The number of tropical nights is 3.8 days, one day more than the same period of last year. At the same time, the extreme high temperature in the whole northern hemisphere caused the strongest rainstorm in Republic of Korea metropolitan area in the past 100 years, causing serious waterlogging. More than 10 people were killed and more than 7,000 people were forced to leave their homes.

On March 25th, 2022, Republic of Korea's Basic Law on Carbon Neutralization and Green Development (Referred to as Carbon Neutralization Law) came into effect. The law stipulates specific measures to achieve carbon neutrality and national independent contribution (NDC) in 2030, with the goal of achieving carbon neutrality and reducing greenhouse gas emissions by 40% by 2050. Republic of Korea has thus become the 14th country to legalize the goal of carbon neutrality. The implementation of this law will help promote the sustainable development of Korea and build an environment-friendly society.

But how to grasp the long-term spatial-temporal pattern evolution at the macro level? How to actively deal with extreme high temperature under the premise of urban ecological sustainable development? How to build an active and sound coping mechanism for extreme high temperature? These problems need to be evaluated and discussed systematically and theoretically. By analyzing the evolution characteristics of spatio-temporal pattern in different time and space, the spatio-temporal change pattern of land use and vegetation cover, urban surface temperature and extreme high temperature are systematically calculated and evaluated(Srivastava et al., 2023). Combining the analysis results with urban ecological security theory, landscape ecological security pattern theory and urban surface temperature and thermal environment remote sensing theory(Ullah et al., 2023), we strive to get a new idea of urban sustainable development to adapt to the new era and establish a powerful mechanism to deal with extreme climate such as extreme high temperature phenomenon(Mortey et al., 2023).

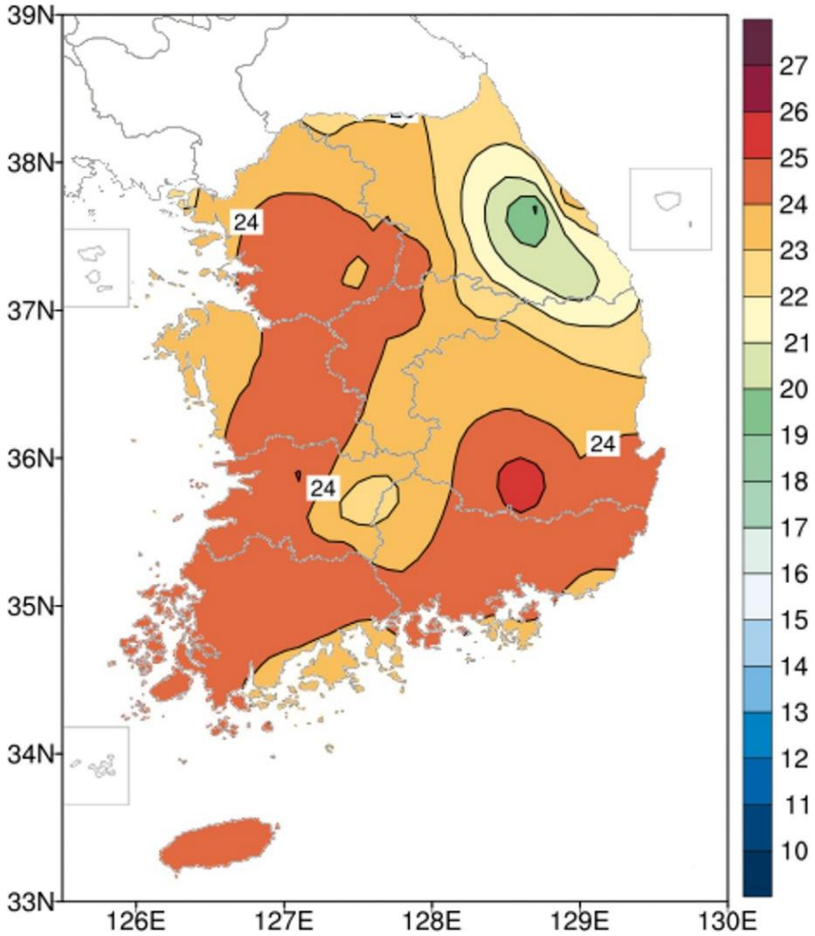

Figure 1 : *(1991~2020) Distribution of Average Summer Temperature in Korea (average temperature ℃)*

Previous studies have shown that there is a correlation between the change of land surface temperature in Korea and the change of urban land types, while the land surface temperature of green land and water body is obviously lower than that of other land uses. Therefore, taking Busan as an example, this study will focus on different land cover types, analyze the coupling relationship with the change of surface temperature, and study the correlation between the change of vegetation coverage and the rise and fall of surface temperature, so as to determine the causes of surface high temperature and effective cooling methods(Jaiswal et al., 2023).

II. METHODOLOGY

Using ArcGIS10.8 platform and MCD12Q1 version 6.1 data product, the temporal and spatial pattern changes of different land cover types in Busan from 2010 to 2020 were analyzed. This product is obtained by supervised classification of Terra and Aqua reflectance data from MODIS. Land cover types come from international geosphere-biosphere plan (IGBP), University of Maryland (UMD), leaf area index (LAI), biota-biogeochemical cycle (BGC) and plant function type (PFT) classification schem(Zou et al.) . Then, supervised classification carries out additional post-processing, which combines previous knowledge and auxiliary information to further improve specific categories. The Land Cover Classification System (LCCS) of Food and Agriculture Organization (FAO) provides additional layers for land cover, land use and surface hydrology. MODIS Land Cover Product (MCD12Q1) provides a set of scientific data sets (SDSs) to draw the global land cover with 500 meters spatial resolution for six different land cover legends in annual time step(Cetin et al., 2023).

These maps are spectrometers (MODIS) created by classification of spectral time features from medium resolution imaging data(Tali et al.).

This study is based on the classification standard of leaf area index (LAI)(Rahman et al., 2023). In landscape ecology, LAI is an important structural parameter of ecosystem, which is used to reflect the number of plant leaves, canopy structure changes(Perez-Planells et al., 2022), plant community vitality and its environmental effects, provide structured quantitative information for the description of material and energy exchange on plant canopy surface, and play an important role in ecosystem carbon accumulation, vegetation productivity, energy balance among soil, plants and atmosphere, and vegetation remote sensing(Yan et al.). Choosing the classification standard of leaf area index (LAI) can more intuitively show the evolution trend of urban construction land and urban green space pattern mainly caused by human activities, and more objectively evaluate the influence between land cover type change and urban temperature change caused by human activities(Rahman et al., 2023).

II. RESULTS AND DISCUSSION

3.1 Evolution of temporal and spatial pattern of land cover types

Table 1 reflects the time pattern evolution of different land cover types in Busan from 2010 to 2020. Among them, the area of urban construction land increased year by year, and the area expanded by 9km2 in ten years, reaching 377km2 in total, accounting for 48.97% of the total area of Busan, while the areas of evergreen broad-leaved forest and evergreen coniferous forest decreased by 42.86% and 22.22% respectively, indicating that Busan.

Table 1: Evolution of time pattern of different land cover types (km^2)

Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Water Bodies	16	16	16	16	16	16	16	16	16	16	16
Grasslands	81	78	75	71	74	78	71	74	79	76	74
Broadleaf Croplands	13	17	15	14	10	10	10	7	8	11	11
Savannas	85	86	91	97	97	87	89	92	91	90	95
Evergreen Broadleaf Forests	14	13	12	11	11	7	6	5	5	7	8
Deciduous Broadleaf Forests	177	178	177	176	173	182	186	183	178	181	176
Evergreen Needleleaf Forests	18	16	16	15	18	18	20	19	19	15	14
Deciduous Needleleaf Forests	1	1	1	1	1	1	1	1	1	1	2
Urban and Built-up Lands	368	368	370	372	373	374	374	376	376	376	377

Combined with the spatial pattern (Figure 2), in the past 10 years (2010-2020), although the area of urban construction land has been increasing, the change rate is only 2.45%, which has little influence on the overall spatial pattern of the city. At the same time, with the increase of green areas such as sparse grassland and deciduous coniferous forest, the influence brought by this change has been effectively compensated.

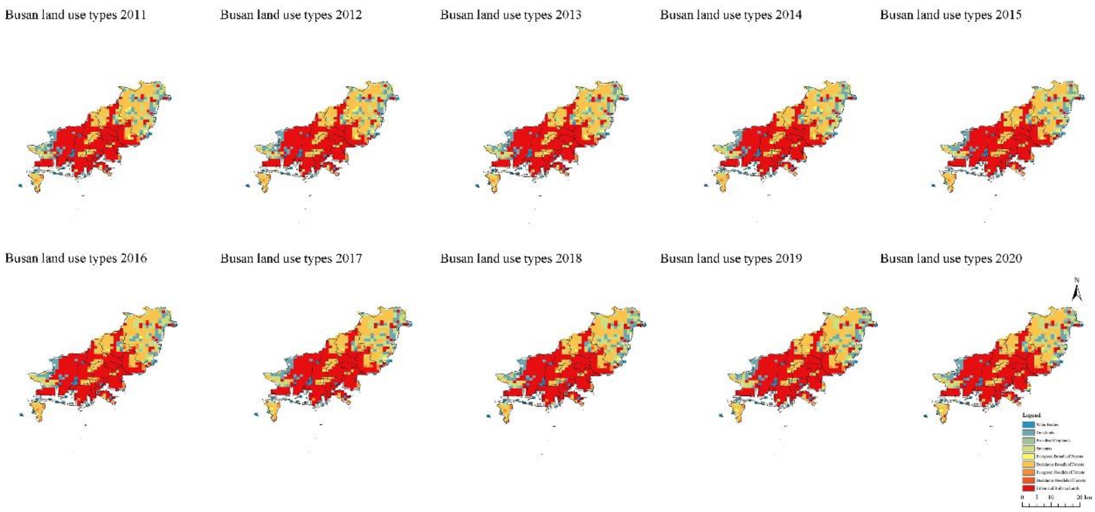

Figure 2: *Spatial pattern evolution of different land cover types*

The area transfer of different land cover types in Busan in 2011-2015 and 2015-2020 are counted respectively. The results show that the biggest change in 2011-2015 is that grassland is transformed into construction land and deciduous broad-leaved forest is transformed into sparse grassland, both of which are 6 km2, indicating that urban construction has invaded some urban green spaces in the past five years, while some woodlands have been destroyed and trees have been planted. In 2015-2020, this situation will be somewhat reduced, and only grassland and sparse grassland will be transformed into construction land, which are 2 km2 and 1 km2 respectively. However, 11 km2 of deciduous broad-leaved forest will still be transformed into sparse grassland, which is also an important manifestation of forest land destruction, which should not be underestimated.

Table 2: Area Transfer of Different Land Cover Types in Busan from 2011 to 2015 (km^2)

Number	2011	2015	Change area/km^2
1	Grasslands	Savannas	12
2	Grasslands	Urban and Built-up Lands	6
3	Broadleaf Croplands	Grasslands	6
4	Broadleaf Croplands	Savannas	1
5	Savannas	Grasslands	11
6	Savannas	Deciduous Broadleaf Forests	5
7	Savannas	Evergreen Needleleaf Forests	2
8	Evergreen Broadleaf Forests	Deciduous Broadleaf Forests	5
9	Deciduous Broadleaf Forests	Savannas	6
10	Deciduous Broadleaf Forests	Evergreen Broadleaf Forests	1
11	Evergreen Needleleaf Forests	Grasslands	1
12	Evergreen Needleleaf Forests	Deciduous Broadleaf Forests	1

Table 3: Area Transfer of Different Land Cover Types in Busan from 2015 to 2020 (km^2)

Number	2015	2020	Change area/km^2
1	Grasslands	Broadleaf Croplands	2
2	Grasslands	Savannas	13
3	Grasslands	Urban and Built-up Lands	2
4	Broadleaf Croplands	Grasslands	2
5	Savannas	Grasslands	10
6	Savannas	Broadleaf Croplands	1
7	Savannas	Deciduous Broadleaf Forests	5
8	Savannas	Urban and Built-up Lands	1
9	Evergreen Broadleaf Forests	Savannas	1
10	Evergreen Broadleaf Forests	Deciduous Broadleaf Forests	1
11	Deciduous Broadleaf Forests	Savannas	11
12	Deciduous Broadleaf Forests	Deciduous Needleleaf Forests	1
13	Evergreen Needleleaf Forests	Grasslands	1

3.2 Temporal and spatial pattern evolution of air temperature and surface temperature

In this study, the annual temperature data published by the National Bureau of Statistics of Korea are used to make a statistical analysis of the evolution of temperature time pattern in Busan from 2010 to 2020.

Using ArcGIS10.8 platform and (MOD11A2) version 6.1 product, the temporal and spatial pattern evolution of land surface temperature (LST) in Busan from 2010 to 2020 was analyzed. MODIS LST products are created as a series of products, starting from a strip (scene), and through the transformation of space and time, daily, 8 days and monthly global grid products. Surface temperature, that is, the temperature of the ground. After the heat energy of the sun is radiated to the ground, part of it is reflected and part of it is absorbed by the ground, which heats the ground. The temperature obtained after measuring the temperature of the ground is the surface temperature. The analysis of surface temperature can further combine the evolution situation of land cover types in time and space, and evaluate urban development and ecological environment more comprehensively, scientifically and objectively.

In the past 10 years (2010-2020), the average temperature, the highest temperature of the draw and the lowest temperature of Busan fluctuated relatively little, and all of them showed an upward trend.

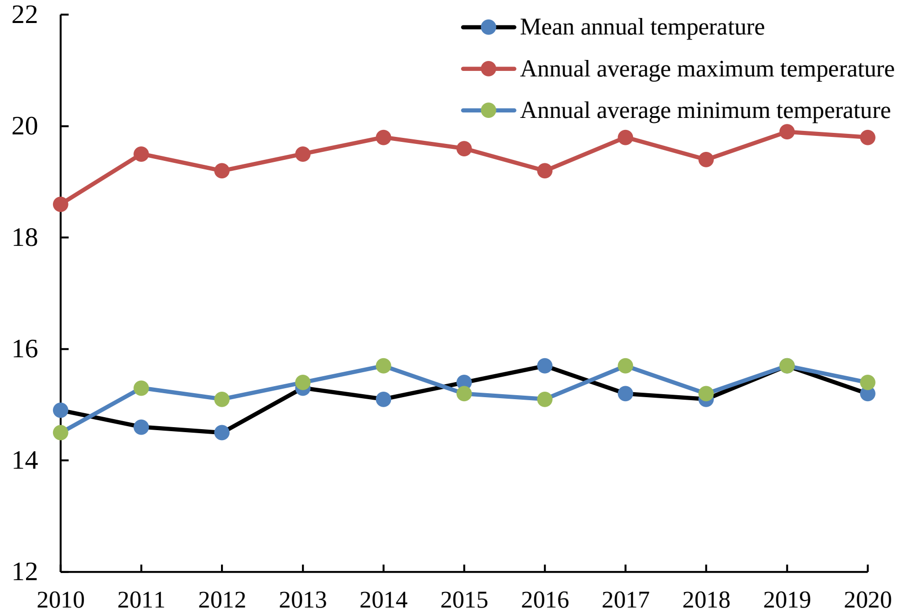

Figure 3: *Changes of average temperature, average maximum temperature and average minimum temperature in Busan from 2010 to 2020.*

Summer, especially August, is the most prone to extreme high temperature. From the changes of average temperature, average maximum temperature and average minimum temperature in Busan from 2010 to 2020 (Figure 4), it can be seen that it experienced a short rise in 2011-2013, and showed a relatively large decline in 2014. From 2014 to 2020, the average temperature, average maximum temperature and average temperature in Busan in August,

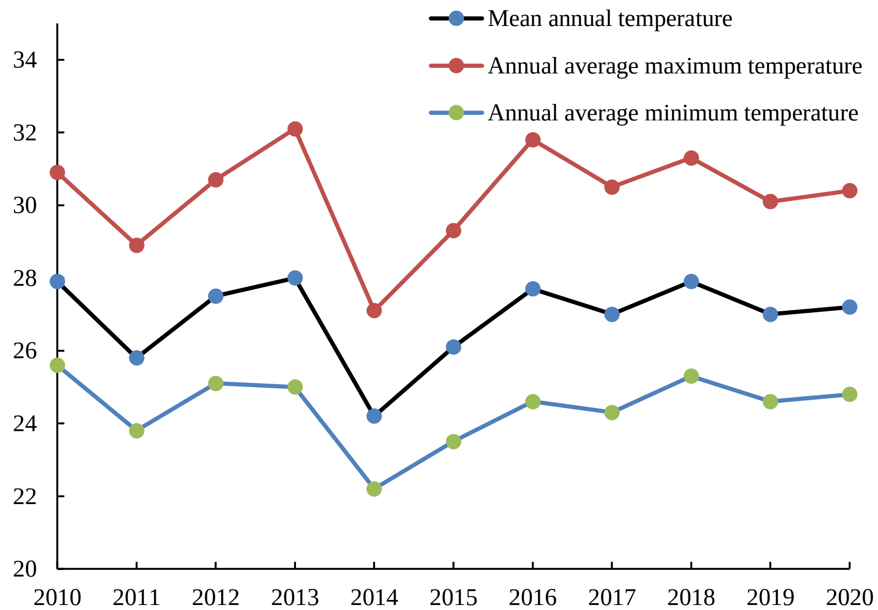

Figure 4: *Changes of average temperature, average maximum temperature and average minimum temperature in Busan from August 2010 to 2020.*

According to the basic data, combined with the single window algorithm, the land surface temperature (LST) of Busan from 2011 to 2020 is inversed, and the inversion result is as follows (Figure 5).

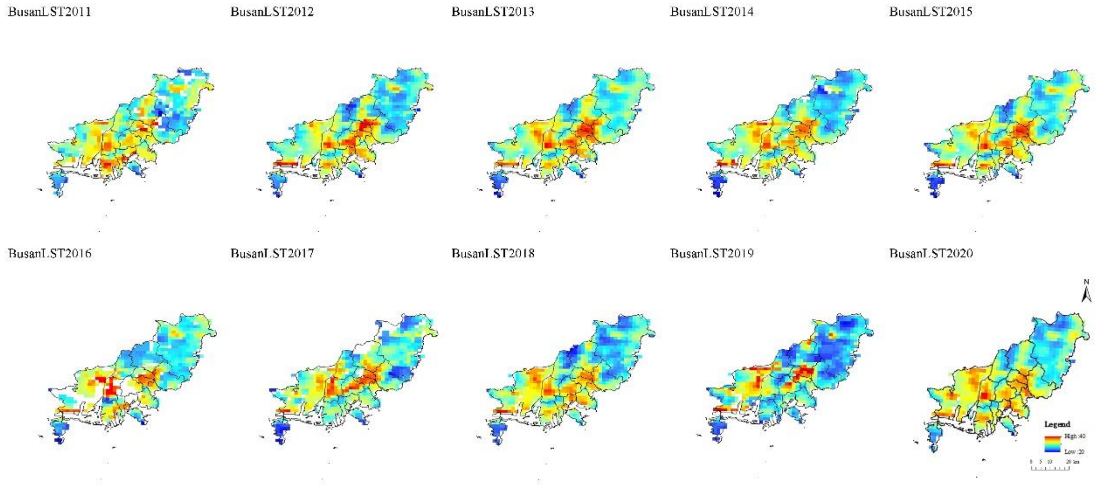

Figure 5: *Land surface temperature (LST) in Busan from 2011 to 2020.*

It can be seen from the figure that the surface temperature of Busan shows obvious spatial differentiation over the years. Among them, the southwest part with Busanjin gu as the core includes Busanjin gu, Yeonje gu, Nam gu, Dong gu, Suyeong gu, Sasang gu, Saha gu, Gangseo gu, Dongnae gu and other regions, and all radiate outward with the highest temperature in the center of each district and county, which is consistent with the layout of urban construction land shown by urban land cover types. Geumjeong gu, Gijang gun, Haeundae gu and other north-eastern regions have lower temperature distribution than the whole area of Busan, which is inseparable from the existence of a large number of different types of urban green space.

3.3 Influence of different land cover types on urban surface temperature

In order to further study the influence of different land cover types on urban surface temperature, the Busan land cover types that have been reversed in 2010-2020 were classified into urban green space and urban construction land by using SPSS 25.0 software. Urban green space includes grassland, cultivated land, sparse grassland, evergreen broad-leaved forest, deciduous broad-leaved forest, evergreen coniferous forest and deciduous coniferous forest. Correlation analysis is made between urban green space, urban construction land area and average temperature in Busan metropolitan area. The results show that the annual average temperature of Busan metropolitan area increases year by year with the increase of years, which is negatively correlated with the urban green space area and positively correlated with the urban construction land area ($p<0.05$).

Table 4：Correlation Analysis of Average Temperature, Urban Green Space and Urban Construction Land in Busan from 2010 to 2020

		year	Urban green space	Urban and built-up lands	Annual average temperature
Annual average temperature	Pearson correlation coefficient	.633*	-.676*	.676*	1
	Sig.（two-tailed test）	0.036468668	0.022369244	0.022369244	
	Number of cases	11	11	11	11

* At the 0.05 level (two-tailed), the correlation is significant.

The results of correlation analysis further confirm that different land cover types do have certain influence on urban surface temperature. The average surface temperatures of different land cover types in Busan in 2011, 2015 and 2020 were classified and counted respectively. The results show that (Table 5), the average surface temperatures in 2011 showed a trend of construction land > grassland > cultivated land > woodland, and the evergreen broad-leaved forest and deciduous broad-leaved forest in woodland had the lowest temperatures in 2011, which were 28.50℃ and 28.27℃, mainly because. 2015 is basically consistent with its trend. In 2020, the order is construction land > grassland > woodland > cultivated land. Compared with before, the change is not particularly obvious. Generally speaking, from 2011 to 2020, the spatial distribution of urban thermal environment in Busan is basically consistent with the spatial distribution of urban construction land. Construction land has become the main factor affecting the intensity of urban heat island.

Table 5: Land cover types and average surface temperature in Busan from 2010 to 2020

Name	Water Bodies	Grasslands	Broadleaf Croplands	Savannas	Evergreen Broadleaf Forests	Deciduous Broadleaf Forests	Evergreen Needleleaf Forests	Deciduous Needleleaf Forests	Urban and Built-up Lands
2011	27.89	31.13	29.84	28.91	28.27	28.50	29.89	29.95	33.37
2015	30.73	32.53	31.54	31.48	30.92	30.90	32.22	32.03	34.26
2020	28.59	31.73	30.25	30.73	30.15	30.34	31.01	30.55	33.30

IV. CONCLUSION

Different land cover types have a certain influence on urban surface temperature. Urban construction land is mainly expanded by encroaching on urban green space. The average temperature of vegetation and water body is lower than the average temperature of regional surface, forming a low temperature zone, which can effectively alleviate the urban heat island effect. Pay attention to greening construction and ecological restoration in urban development planning, so as to further promote the self-regulation of environment and climate, and achieve a sustainable and eco-friendly urban development mode.

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