Preliminary Exploration of Refined Constructability Analysis Method Based on Cold Islands Value Evaluation: Taking Nanjing Eastern Central District as an Example

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Abstract. Under the concept of sustainable development, researching and evaluating the "constructability" of urban land is an important starting point for the harmonious coexistence of artificial and natural environment. Territorial planning provides the basic suitability assessment for a certain land use of the entire city in macro scale, which can be classified into suitable, restricted, and prohibited construction scopes. However, as the urban design tends to be more refined, when considering at the meso-micro scale, there still be a large number of natural ecological elements such as vegetation and water bodies in the suitable construction scopes. These elements have potential value as natural cold-sources for reducing the summer energy consumption and carbon emission but may be destroyed due to different intensities of artificial constructions. From the perspective of meso-micro scale, we proposed an optimized refined classification method of the suitability assessment by introducing cold island value evaluation through thermal and humid environment analysis technology, so as to provide land layout guidance for different development intensity in urban design. Subsequently, the method was applied to Nanjing Eastern Central District, which effectively realizes the goal of cold islands reservation, summer energy consumption reduction, sustainable development and ecological protection.

Keywords: green city; constructability; cold island value; urban design; refinement.

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1 INTRODUCTION

1.1 Background

The urban climatic characteristics has a non-negligible relationship with the urban energy system and the comfort of human settlements. The quality of urban environmental performance and carbon emissions depend on whether the urban physical space is adapted to the climatic characteristics.

Land suitability assessment is a method seeking the best land planning schemes for urban physical space through analysing the suitability and limiting factors of the land for a certain land use objective. At the macro scale, the land suitability assessment in territorial planning defined the rigid ecological bottom line and construction capacity. It also provided basic land use suitability reference which can be classified into suitable, restricted, and prohibited construction scopes. However, at the meso-micro scale, the suitable construction areas are still different in terms of constructability due to different conditions such as topography, vegetation distribution, historical accumulation, and other physical environment elements. Notably, the vegetation and water bodies that are not included in the restricted or prohibited scopes may have important cold-source value. Therefore, it is necessary to take further scientific assessment so as to clarify the protection and utilization strategies of such physical environment elements.

Based on the thermal and humid environment analysis technology, the method of refined constructability analysis was explored through identifying and evaluating the value of vegetation and water bodies cold islands within the research range, and superimposing it with the basic constructability analysis. The method provided the refined land layout reference for different development intensity in urban design, and promote the formation of energy-saving cities.

1.2 Previous Research

Research on Cold Island.

Climatological scholars have found that thermal environment is one of the important indicators for evaluating urban space after in-depth studies of urban climate. The cold-source reservation and the increase of the proportion of vegetation and water bodies have been proved to reinforce the influence scopes of cold islands, alleviate high temperature and air pollutants accumulation, and improve the urban microclimatic environment. Su proposed that cold islands were formed by green vegetation and water bodies.[1] The cold island effect has positive significance for alleviating the adverse effects of UHI and protect urban ecosystem[2] such as cooling and affecting the surrounding built-up areas[3] and balancing urban temperature[4], and is more effective in the inland areas[5]. The Normalized Difference Vegetation Index (NDVI) is an important indicator for evaluating vegetation growth status and coverage. The NDVI value has been demonstrated being negatively correlated with urban surface temperature[6] [7], and the negative correlation becomes more obvious when the value is greater than a certain threshold. [8]

The focus of urban physical environment research has shifted from the climatology field to the interdisciplinary application in urban planning in recent years. Koch proposed the concept of "Klimaatlas" which includes cold islands evaluation as one of the core themes[9], and then has been combined with the urban spatial design in Germany, Canada, Japan, Hong Kong and other regions. Several qualitative planning measures have been proposed to enhance the alleviation effects of vegetation and water bodies cold islands on UHI.[10] More methods such as MSPA, MCR[11] and CT[12] have been demonstrated applicable to cold islands network construction in urban design. In the Qianhai New District and Liaodong Bay projects, the planners combined various methods, including the identification of heat and cold islands to facilitate and guide the organization of open space structures. [13] [14]

Research on Land Suitability Assessment.

The land suitability assessment is an internationally common analysis method in urban planning with rich theoretical researches and practical experiences. It is usually aimed at one certain land use, such as cultivated land[15], wind farm[16], urban development[17], etc., and solves the distinction between suitable and unsuitable construction scopes within the entire city. In the assessment of agriculture and animal husbandry land use at urban or region scales, further classification of the suitable construction scopes has gradually emerged, for example the research of five agricultural suitability classes in 14 EU and 7non-EU countries.[18]

Over the past 50 years, the scholars have carried out a great number of researches on land suitability assessment and have established abundant methods. McHarg first proposed the assessment method of land ecological suitability, emphasizing the rational use of land.[19] Subsequently, AHP, TOPSIS, BWM, MCDA and other methods have been introduced in the land suitability assessment and applied to many cities.[20] [21]

Chinese scholars have gradually realized that land suitability assessment provides the bottom line for ecosystem protection and socio-economic security, and plays an important role in the field of urban planning. The development of land suitability assessment in China started from adopting the international experience, and gradually expands from urban to region scale.[22] [23] [24] Various methods such as single-norm and comprehensive evaluation[25], GIS multi-factor superposition analysis[26], etc. had been formed during the time to provide a basis reference for land use.

Accounting into the urban climate deterioration, natural landscape destruction and ecological function degradation caused by rapid urban expansion, urban planning scholars have taken physical environment elements into consideration in land suitability assessment recently. Some special factors, such as carbon balance[27], green ventilation[28], ecological protection[29] and other factors have been progressively included in the land suitability assessment index.

Conclusions.

The protection of cold islands in urban design is a beneficial factor for improving the human settlements environment. Methods such as MCR and CT which incorporat-

ing cold island protection into urban planning tend to be macroscopic and have not been applied internationally. The land suitability assessment is a more general approach in the field of urban plan, and the inclusion of the cold island protection will not only increase the implementation of cold islands protection, but also improve the comprehensiveness of the land suitability assessment.

The suitability assessment is to distinguish between suitable and unsuitable construction scopes according to a certain land use, which is the analysis and judgement of the entire city in macro scale. Nowadays, as urban design tends to be refined, what is needed is to seeking the differences in intervention intensity of artificial construction on natural base within the suitable construction scopes in meso-micro scale, which cannot be obtained from current land suitability assessment. Thus, it is necessary to optimising the suitability assessment into a method which can be used to classify the land for different development intensity in suitable construction scopes and applicable to meso-micro scale.

1.3 Objectives

The core objective of this study was to establish an optimization method for refined constructability analysis suitable for meso-micro scale urban design based on cold island value assessment. This objective can be broken down into the following two subgoals:

(1) To propose a quantitative value evaluation method of vegetation and water bodies cold islands;

(2) To establish an optimization method of the suitability assessment to classify the land for different development intensity levels within suitable construction scopes in meso-micro scale urban design.

2 RESEARCH OBJECT AND ANALYTICAL TOOLS

2.1 Application Case

The urban design of Nanjing Eastern Central District was selected as the application case. Nanjing is located in the hilly area of the middle-lower Yangtze River, which belongs to the northern subtropical humid climate and the hot-summer and cold-winter climate zone, with four distinct seasons and abundant rainwater. From the meteorological data (Figure 1), it can be known that Nanjing has high temperature and high humidity in summer and low temperature and high humidity in winter. Since air conditioning cannot be completely relied on in such area, the comfortable thermal environment mainly depends on scientific urban planning and architectural design strategies.

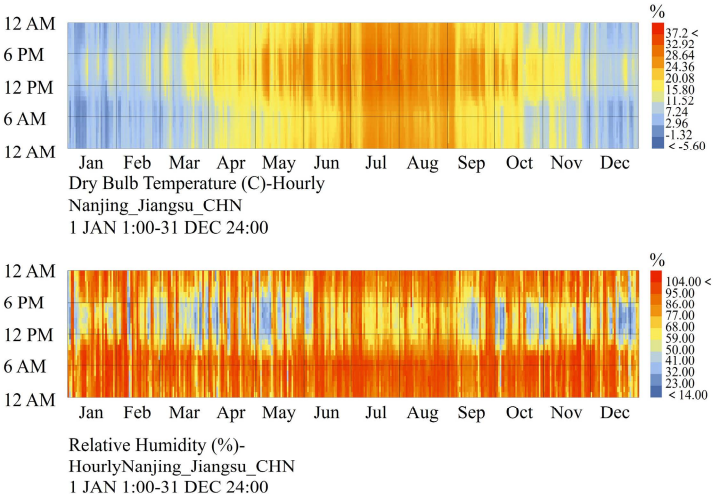

Fig. 1. Area thermal and humidity maps.

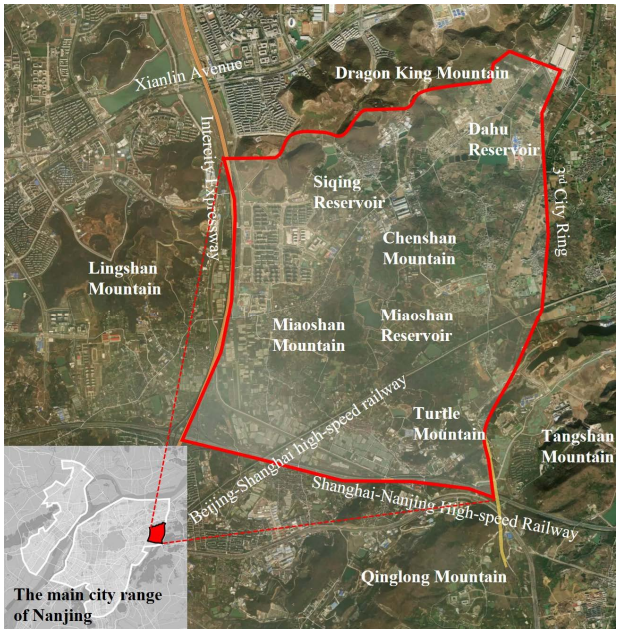

Fig. 2. Location of the research range.

The Nanjing Eastern Central District is located around the Qinglong Mountain Range to the east of the main city of Nanjing, covering an area of about 22 square kilometres (Figure 2). There are a large number of mountains, vegetation, and water bodies in the site.

2.2 Analytical Tools

In this research we mainly used ENVI-met platform, ArcGIS platform and AutoCAD platform. The thermal environment simulation was based on the ENVI-met platform, and the local meteorological data was used in the pre-processing process of the calculation. In ENVI-met, the urban environment and buildings were modelled with the materials mainly being buildings, roads, vegetation and water. The thermal environment was simulated according to typical summer at 14: 00 noon.

According to the requirements of the constructability analysis, various types of data were obtained from the government planning department, including terrain data, reservoirs, built rivers, national ecological red line, ecological control areas, suburban green space, basic farmland, other non-construction land and railways and stations. The Landsat satellite images were obtained from the USGS Earth Explorer

3 METHODOLOGY AND CASE STUDY

At meso-micro scale, the constructability-related factors obtained from the macro land suitability assessment were summarized. The conclusion of land suitability assessment was taken as the basic constructability scopes of this study. From the previous summary, the vegetation boundaries were generally fuzzy and the NDVI value is one of the important indicators to describe the vegetation. Thus, the valid vegetation patches ware extracted based on NDVI value. Compared with the vegetation, the water bodies had clearer boundaries and were more convenient to acquire in terrain data. Therefore, the valid water patches were extracted based on AutoCAD platform. Because the water bodies and vegetation usually have different mean value and range in temperature, different methods were adopted to classify the vegetation and water bodies respectively.

In the optimization of refined constructability analysis method based on cold islands value evaluation, there are four main steps. First, the basic constructability analysis was conducted to generate the basic constructability scopes. Secondly, the vegetation and water bodies cold island value were assessing and superimposed with the basic constructability scopes to obtain the refined scopes. Thirdly, the refined scopes were applied in the actual project according to different development intensity guidance of different scope levels. Finally, the urban design after deepening were verified to determine whether the method can guide the urban design to shape a more sustainable and ecological human settlement.

3.1 Basic Constructability Analysis Method

The land suitability assessment is applicable to territorial planning. All kinds of restrictions obtained from the assessment have entered into the statutory plan, which are unbreakable rigid factors in urban design. Based on the above, the meso-micro scale basic constructability analysis method includes the classification of rigid factors and the generation of basic constructability scopes.

Classification of Rigid Factors.

First, the rigid constructability-related factors are extracted from the government planning department, and are classified and summarized according to several criteria. In the case, we classified the factors according to the rigid physical factors and rigid artificial factors, and continue to subdivide them into water body, vegetation, others and infrastructure facilities (Table 1).

Table 1. Rigid constructability-related factors summary.

Rigid Physical Factors			Rigid Artificial Factors
Water Body	**Vegetation**	**Others**	**Infrastructural Facilities**
Reservoirs	National Ecological Red Line	Basic Farmland	Railways and Stations
Built Rivers	Ecological Control Areas	Other Non-construction Land	
	Suburban Green Space		

Generation of Basic Constructability Scopes.

All rigid factors' areal maps (Figure 3) are superimposed in the GIS platform to generate the basic constructability scopes. The superimposed coloured patches form the basic un-constructable scope, and the remaining white parts within the research range are the basic constructable scopes (Figure 4).

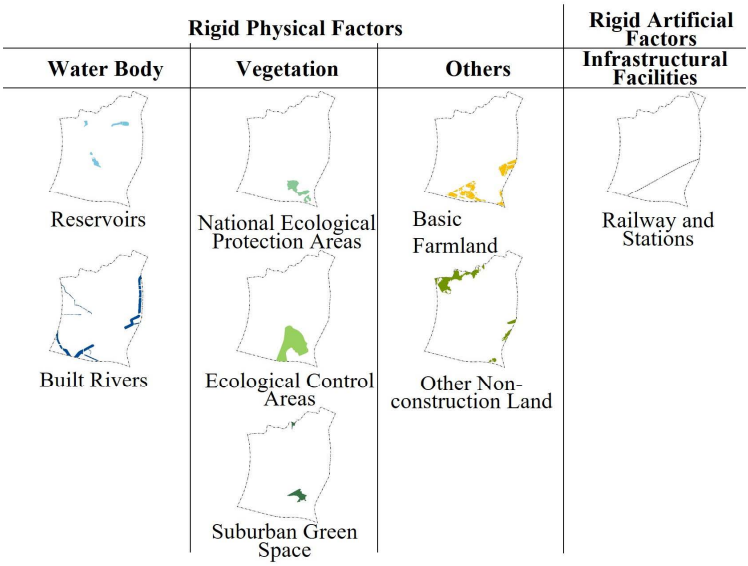

Fig. 3. Rigid factors areal maps summary.

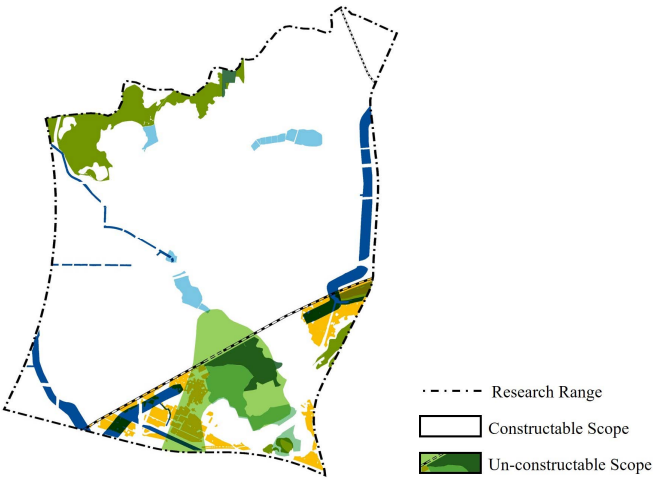

Fig. 4. Basic constructability scopes.

3.2 Superimpose Cold Island Value Assessment

There are usually a large number of vegetation and water bodies cold islands which have nonnegligible positive effects on urban climatic regulation within the research range. It is necessary to superimpose the cold island value assessment in the basic analysis, so as to improve the cold island protection and classify the different development intensity levels of land for meso-micro scale urban design. The processing specifically includes extracting valid vegetation and water patches, assessing cold island value, and optimizing basic constructability scopes.

Extract Valid Vegetation and Water Patches.

The basic vegetation and water patches are obtained in different ways. The basic vegetation patches are the area within the selected NDVI value based on the ENVI-met platform. The NDVI data was obtained based on the Landsat satellite images, and the efficient NDVI value was selected between 0.48 and 1. The basic water patches are obtained according to the terrain file.

Then the valid vegetation and water patches are extracted by intersecting the basic vegetation and water patches with the basic constructable scopes.

In the case study, the basic vegetation patches were the areas with NDVI value greater than 0.48, the basic water patches were obtained from the terrain data. As shown in Figure 5, we extracted the valid vegetation and water patches according to the steps mentioned above.

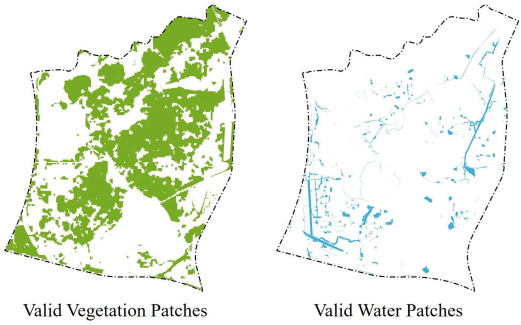

Fig. 5. Valid vegetation and water bodies patches.

Assessing Cold Island Value.

Taking each patch as the centre, the patch boundary offsets outward at an interval of 30 meters to a distance of 600 meters from the patch boundary. A temperature change line chart of each patch and its expansion range was drawn based on each offset boundary line's average temperature which is calculated by superimposing the boundary lines and the surface temperature image. The surface temperature image was generated from the LST file based on the Landsat satellite images. In each line chart, the offset boundary line which is the closest to the patch and the slope is closest to 0 is the vegetation or water body's cooling range. The average surface temperature of all cooling range boundaries is extracted and calculated to distinguish the vegetation and water bodies cold islands.

According to the area and the average surface temperature of the water bodies cold islands range, the k-means clustering is carried out by using the Euclidean distance measurement formula. Based on the average surface temperature in each category, the clustering results are set as three zones: low, medium and high.

The average surface temperature in the vegetation cold islands range is calculated by using the mean-standard deviation classification method (Table 2). According to the T value, the vegetation cold islands are divided into three value zones: high, medium and low.

Table 2. Mean-standard-deviation-grading method used to classify value zones of cold islands.

Category	Classification Method
Average Temperature	μ
Standard Deviation of Temperature Change	std
High-value Zone	$T < \mu$-2std
Medium-value Zone	μ-2std$\leq T \leq \mu$+2std
Low-value Zone	$T > \mu$+2std

In the case study, as mentioned above, the vegetation and water bodies cold islands were distinguished according to the average temperature of all cooling range boundaries as 28°C. According to the surface temperature of the vegetation cold island and the classification method in Table 2, the high value area's temperature is less than 24 °C, the medium value area's temperature is greater than 24 °C and less than 30 °C,

and the low value area's temperature is greater than 30 °C. Then we screened out the high-value and medium-value zones of vegetation and water bodies cold islands (Figure 6).

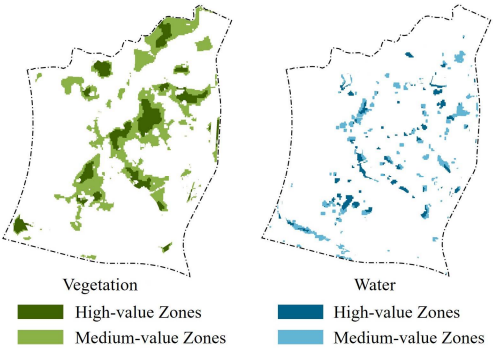

Fig. 6. Vegetation and water bodies cold islands zones after value evaluation and classification

Optimizing Basic Constructability Scopes.

By superimposing with the high-value and medium-value zones of vegetation and water bodies cold islands, the basic constructability scopes can be optimized into refined constructability scopes.

In the case study, after the superposition, three scope levels were classified as shown in Figure 7. The third-level scopes were the intersection set of high-value vegetation and water bodies cold islands which were suitable for low intensity development. The second-level scopes were the intersection set of medium-value vegetation and water bodies cold islands which were suitable for medium intensity development. The first-level constructable scopes were the remaining white parts which were most suitable for high intensity construction and did not contain high-value or medium-value vegetation and water bodies cold islands.

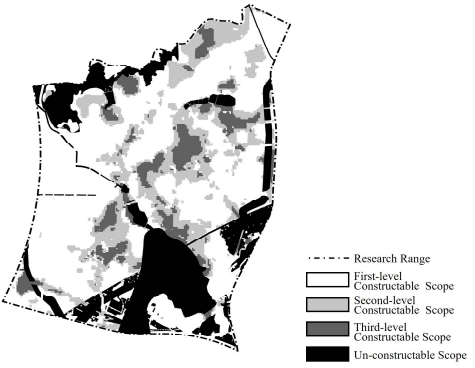

Fig. 7. Refined constructability scopes.

3.3 Application of Refined Constructability Scopes

Combined with the needs of development and the design concept, different types of land use are arranged in different constructable scopes. Firstly, open spaces should mainly adopt the vegetation and water bodies actively retained or rebuilt within the third-level constructable scopes and connected by green spaces. Thus the open spaces can expand the positive efficiency of high-value cold islands. Secondly, the land with high floor-area ratio (FAR) should be preferentially distributed within the first-level constructable scopes, and the FAR of these lands can be increased as much as possible subjected to other conditions. If the total amount of construction is insufficient after the arrangement within the first-level constructable scopes, the remaining land can be distributed within the second-level constructable scopes. And so on, the remaining land can be distributed within the third-level constructable scopes.

In the case study, in terms of the land layout, the land with FAR greater than 0.8 was distributed within the first-level constructable scopes. Open spaces such as parks had given priority to the use of the original vegetation and water bodies retained in the third-level constructable scopes and un-constructable scopes (Figure 8). Subsequently, the open spaces formed the clover-shaped central green vein and several green corridors, which divided the construction area into three groups. The two CBD hearts were selected and determined based on the refined constructability scopes, in addition with the urban landscape and traffic organization, etc. (Figure 9). Then after the deepening of urban design, we obtain the master plan as shown in Figure 10.

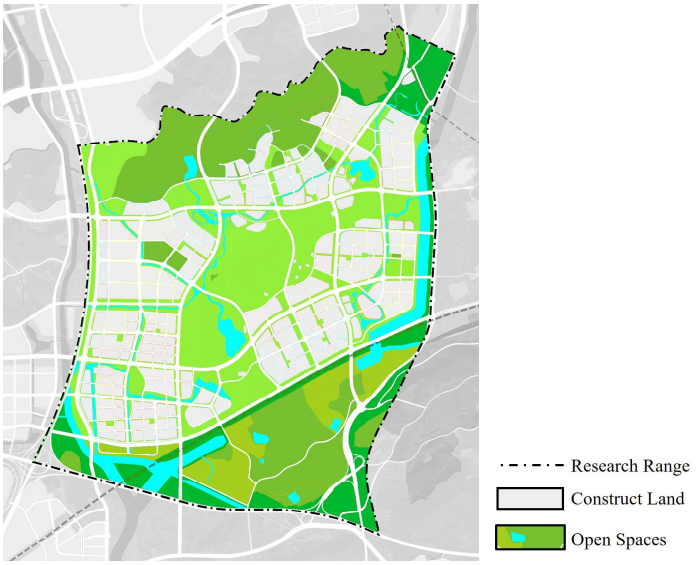

Fig. 8. Land layout based on refined constructability scopes.

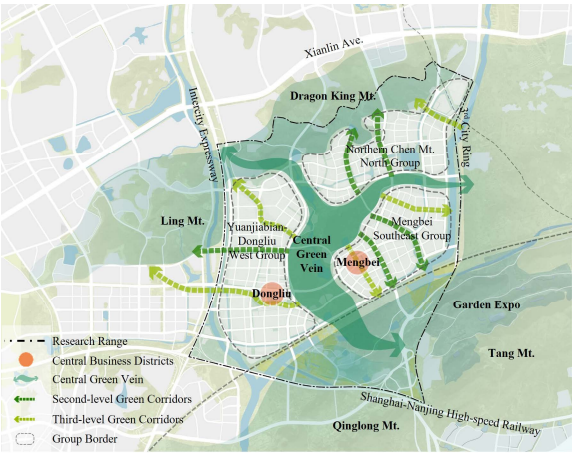

Fig. 9. Urban design spatial hierarchy diagram.

Fig. 10. Urban design master plan.

3.4 Verification

Thermal environment simulations were carried out for the case designed based on refined constructability scopes and other same-level built-up central areas in Nanjing. The average temperatures of other central areas were analysed and obtained by using remote sensing thermal infrared data and the lowest was 35.10 °C (Figure 11).

The average temperature of the research range was simulating by using the meteorological data of the same day, and the data was 33.06 °C (Figure 12). Compared with other central areas' average temperature in Nanjing, research range had a more comfortable and pleasant thermal environment in summer noon while ensuring the total amount of construction.

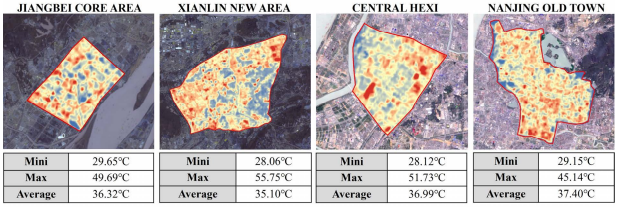

Fig. 11. Thermal environment simulation conclusions of other same-level built-up central areas in Nanjing.

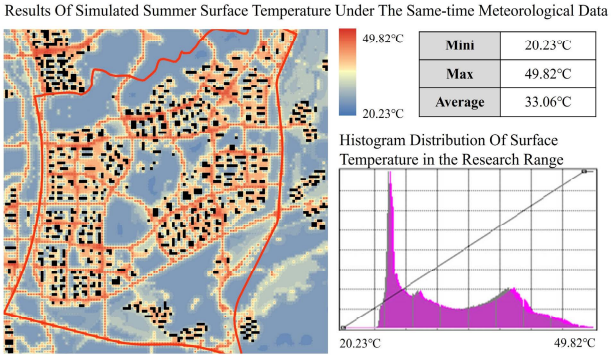

Fig. 12. Thermal environment simulation of the site.

4 CONCLUSION AND DISCUSSION

Through the case study of Nanjing Eastern Central District, we studied the interaction between cold island and urban design. The method of optimizing and classifying the macro scale basic suitable construction scopes was proposed. Through introducing the cold island value evaluation, the lack of refined classification land scopes for different development intensity in meso-micro scale and the difficulty of effectively bringing the cold island protection into urban design were made up.

Responding to objective1, a quantitative evaluation method of vegetation and water bodies cold island was proposed. It assisted in judging the retention significance of vegetation and water bodies which are not within the rigid factors' range. Thus, the natural ecological elements were saved from being destroyed by relying solely on the subjective choice of the designers.

Moreover, two issues require further consideration. First, the fineness of the input water bodies data needs to be adjusted according to the specific project. When the water bodies were a large closed area in CAD and has quite different temperature within the range, it may be classified as a worthless cold island due to the use of average temperature. Therefore, it is necessary to finely divide the water bodies in practical projects. Second, the classification standard of vegetation and water bodies cold islands need to be discussed. When sorting the vegetation and water bodies cold is-

lands in different standards, the results are different. The high-value water bodies may lack protection potential compared to high-value vegetation. When adopting the same standards in practical application, the average temperature of water bodies and vegetation cold islands can be very different, resulting in the number of cold islands in one category being significantly greater than the other when filtrating for valuable cold islands.

Responding to objective 2, an optimization method of the suitability assessment to classify the land for different development intensity levels within suitable construction scopes in meso-micro scale urban design was established. The elements obtained from the macro suitability assessment were taken as the rigid factors to generate the basic constructability scopes. The vegetation and water bodies cold islands were the superimposed elements to optimize and generate refined constructability scopes. The method can be used in areas where the vegetation and water bodies cold islands are effective in alleviating UHI effects, especially in inland areas. It not only graded the suitable constructability scopes into different levels, but also incorporated the cold islands protection into the universal methodology. The refined constructability scopes provided a more accurate and reasonable judgment basis and land layout guidance for different development intensity in meso-micro scale urban design. The inclusion of cold island protection had great significance for the formation of energy-saving cities with comfortable wind and thermal environment.

Moreover, one issue requires further discussion. In the case mentioned above, the data used in cold island value evaluation was NDVI value obtained based on the satellite maps. The NDVI value was most accurate in vegetation growing seasons and received a great impact from temperature, moisture and terrain. However, in the actual project, it was not certain whether can obtain the satellite map of growing seasons, nor the humidity and the temperature of the moment the satellite map was taken. Thus, more methods should be introduced to correct the NDVI value, so as to ensure the optimized refined constructability analysis method more scientific and accurate.

REFERENCES

1. Su, C.X., Hu, Q.Y. (1987) Cold Island Effect of the Oasis and Lake. Chinese Science Bulletin, 10: 756-758.
2. Qiu, K.B., Jia, B.Q., Cheng, F.J. (2017) Cool Island Effect of Urban Parks and its Influencing Factors within the Fifth Ring in Beijing. Chinese Journal of Ecology, 36(07): 1984-1992. https://doi.org/ 10.13292/j.1000-4890.201707.027.
3. Bouketta, S. (2023) Urban Cool Island as a sustainable passive cooling strategy of urban spaces under summer conditions in Mediterranean climate. Sustainable Cities and Society, 99: 104956. https://doi.org/10.1016/j.scs.2023.104956.
4. Wang, L.P., Tan, W., Wang, Z.J. (2009) Responses of Urban Green Land to the Temperature in Heat and 'Cold' Island Effect. Journal of Mountain Agriculture and Biology, 28(03): 225-229.
5. Žgela, M., Herceg-Bulić, I., Lozuk, J., Jureša, P. (2024) Linking land surface temperature and local climate zones in nine Croatian cities. Urban Climate, 54: 101842. https://doi.org/10.1016/j.uclim.2024.101842.
6. Nse, O.U., Okolie, C.J., Nse, V.O. (2020) Dynamics of land cover, land surface tempera-

ture and NDVI in Uyo City, Nigeria. Scientific African, 10: e00599. https://doi.org/10.1016/ j.sciaf.2020.e00599.
7. Xue, X.Y., He, T., Xu, L.C., Tong, C., Ye, Y., Liu, H.J., Xu, D.Y., Zheng, X.Y. (2022) Quantifying the spatial pattern of urban heat islands and the associated cooling effect of blue–green landscapes using multisource remote sensing data. Science of The Total Environment, 843: 156829.https://doi.org/10.1016/j.scitotenv.2022.156829.
8. Cheng, C.Q., Wu, N., Guo, S.D., Li, S.D., Liu, D.P. (2004) A Study on the Interaction Between Urban Heat Island and Vegetation Theory, Methodology, and Case Study. Research of Soil and Water Conservation, (03): 172-174.
9. Knoch, K. (1951) Uber das Wesen einer Landesklimaaufnahme. Meteorologische Zeitschrift, 5: 173.
10. Du, H.Y. (2018) The Cool Island Effect of Urban Blue-green Spaces and Impact Factors in Mega City: A Case Study of Shanghai. East China Normal University, Shanghai, China. https://kns.cnki.net/kcms2/article/abstract?v=xFzLC8E_KjH1gAChG5LAKtjxEeOEUf8qYw8RPaeLs_Hty_ixW261K8oiydX4fj_BT3JmZoW257z_7stNBCkJyQdbxERXzU9mN2hmLJBFVTZWghKwouVyk-ejo5FWX_T5raN42dMw9jY=&uniplatform=NZKPT&language=CHS.
11. Qiu, J., Li, X.Y., Qian, W.Q. (2023). Optimizing the spatial pattern of the cold island to mitigate the urban heat island effect. Ecological Indicators, 154:110550. https://doi.org/10.1016/j.ecolind.2023.110550.
12. Liu, F., Liu, J., Zhang, Y.Q., Hong, S.P., Fu, W.C., Wang, M.H., Dong, J.W. (2024). Construction of a cold island network for the urban heat island effect mitigation. Science of The Total Environment, 915: 169950. https://doi.org/10.1016/j.scitotenv.2024.169950.
13. Zhang, Y. (2021). Research on Evaluation Methods of Urban Morphology Related to Wind-heat Environment: A Case Study of Guangzhou. South China University of Technology, Guangzhou, China. https://doi.org/10.27151/d.cnki.ghnlu.2020.000058.
14. Zhang, Y., Lu, J., Chen, J. (2021) Exploring the “Morphological Structure” in Contemporary Urban Design Practices. J. Archit, 5: 91–98. https://doi.org/10.19819/j.cnki.ISSN 0529-1399.202105019.
15. Sadiq, F.K., Ya'u, S.L., Aliyu, J., Maniyunda, L.M. (2023) Evaluation of land suitability for soybean production using GIS-based multi-criteria approach in Kudan Local Government area of Kaduna State Nigeria. Environmental and Sustainability Indicators, 20: 100297. https://doi.org/10.1016/j.indic.2023.100297.
16. Tercan, E. (2021) Land suitability assessment for wind farms through best-worst method and GIS in Balıkesir province of Turkey. Sustainable Energy Technologies and Assessments,47:101491. https://doi.org/10.1016/j.seta.2021.101491.
17. Bamrungkhul, S., Tanaka, T. (2022) The assessment of land suitability for urban development in the anticipated rapid urbanization area from the Belt and Road Initiative: A case study of Nong Khai City, Thailand. Sustainable Cities and Society, 83:103988. https://doi.org/10.1016/j.scs.2022.103988.
18. Dornik, A., Cheţan, M.A., Crişan, T.E., Heciko, R., Gora, A., Drăguţ, L., Panagos, P. (2024) Geospatial evaluation of the agricultural suitability and land use compatibility in Europe's temperate continental climate region. International Soil and Water Conservation Research. https://doi.org/10.1016/j.iswcr.2024.01.002.
19. Yang, B., Li, S.J. (2016) Design with Nature: Ian McHarg’s ecological wisdom as actionable and practical knowledge. Landscape and Urban Planning, 155: 21-32. https://doi.org/10.1016/j.landurbplan.2016.04.010.
20. Vasu, D., Srivastava, R., Patil, N.G., Tiwary, P., Chandran, P., Singh, S.K. (2018) A comparative assessment of land suitability evaluation methods for agricultural land use plan-

ning at village level. Land Use Policy, 79: 146-163. https://doi.org/10.1016/j.landusepol.2018.08.007.
21. Ustaoglu, E., Sisman, E., Aydınoglu, A.C. (2021) Determining agricultural suitable land in peri-urban geography using GIS and Multi Criteria Decision Analysis (MCDA) techniques. Ecological Modelling, 455: 109610. https://doi.org/10.1016/j.ecolmodel.2021.109610.
22. Ma, J., Qiu, Y. (2022) Study on Suitability Evaluation of Land Development in Mountainous City Based on GIS. Urban Geotechnical Investigation & Surveying, 5:19-25.
23. Zhao, K., Li, J.L., Xia, Q.Q. (2021) Machine Learning Evaluation Land Ecological Fitting: A Case of the Mountain Traditional Settlement Location Fitting Evaluation. Urban Development Studies, 28(5): 84-92.
24. Du, W.M., Zhao, J.H., Gong, X. (2012) Land Suitability Evaluation in Planning Environmental Impact Assessment: Application for Wuhan Certain Industrial Base PEIA. The Administration and Technique of Environmental Monitoring, 24(6): 67-72.
25. Wang, Z.Y. (2020) Research Progress of Land Suitability Assessment in China. Agriculture and Technology, 40(4): 36-41. https://doi.org/ 10. 19754 /j. nyyjs. 20200229010.
26. Liu, H., Song, Y.C., Li, L., Zou, K., Lu, Y. (2021) Research on Development Adaptability Analysis and Comprehensive Judgment Method from the Perspective of Urban Design. Contemporary Architecture, 12:36-42.
27. Yang, L., Hao, J.M., Ai, D., Lei, S.X., Shuang, W.Y. (2011) Adjustment of Land Use Structure Based on Regional Carbon Balance: A Case Study in Quzhou County, Hebei Province. Resources Science, 33(12): 2293-2301.
28. Luo, X., Yang, J., Sun, W., He, B.J. (2021) Suitability of human settlements in mountainous areas from the perspective of ventilation: A case study of the main urban area of Chongqing. Journal of Cleaner Production, 310: 127467. https://doi.org/10.1016/j.jclepro.2021.127467.
29. Qi, T.Y., Li, Y., Huang, M., Luo, B.Y., Peng, Z., Wang, W.Y., Li, S.S., Allan Degen, A., Shang, Z.H. (2024) Land intensification use scenarios based on urban land suitability assessment of the national park. Sustainable Cities and Society, 102: 105229. https://doi.org/10.1016/j.scs.2024.105229.