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A Comprehensive Assessment of Sustainable Development of Urbanization in Hainan Island Using Remote Sensing Products and Statistical Data

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Abstract: In the "2030 Agenda for Sustainable Development" proposed by the United Nations, there are several Sustainable Development Goals (SDGs) related to the sustainable development of urbanization. Therefore, this paper combines remote sensing products and statistics data; uses the entropy weight method to construct a comprehensive assessment framework for the sustainable development of urbanization in Hainan Island based on 11 SDGs; and conducts a spatial and temporal analysis of Hainan Island from 2011 to 2020. The assessment scores of the study area are distributed spatially in a pattern that scores high in the north and south and low in the middle and west. In terms of SDGs' progress, each region faces its own challenges and needs to develop under its own status. For Wuzhishan City and Ding'an County, which scored low in the assessment, newly increased fixed assets, per capita public green areas and the rate of science and technology expenditures to local government expenditures are the main factors affecting the assessment scores.

Keywords: sustainable development of urbanization; Sustainable Development Goals; Hainan Island; spatial and temporal evolution

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1. Introduction

Urbanization is a necessary path for a country's development and plays an important role in promoting coordinated regional development and improving people's livelihood. However, the challenges of resources, environment and urban construction brought about by the process of urbanization cannot be ignored. At the turn of the century, the Millenium Development Goals (MDGs) were put forward to promote a better urban future, whereas the MDGs seemed insufficient to intercept the new challenges taking place in the global situation [1]. To address these issues, in 2015, the United Nations approved "The 2030 Agenda for Sustainable Development" at the Sustainable Development Summit, proposing 17 Sustainable Development Goals (SDGs) and 169 targets, which aim to build an agenda that stresses cohesion and balance between economic, social and environmental ambitions [2]. Among them, Sustainable Development Goal 11 (SDG11)—"Make cities and human settlements inclusive, safe, resilient and sustainable"—proposed a series of targets and requirements for the development of future cities, covering basic public services and facilities, transportation, energy and so on [3]. The establishment of this goal shows that analyzing the sustainable development of urbanization has become a crucial issue.

The clear and meaningful measurement methods for urbanization in a particular area have yet to be unified [4]. According to the number of indicators used, there are two main types of measurement methods in the existing studies: the single indicator method and the composite indicator method. The single indicator method mainly uses the proportion of urban population to total population to measure the development of urbanization. Some studies have used this indicator to analyze the development of urbanization, including 31 regions in China and 124 countries or regions [5] and countries along the Belt and Road [6]. Some studies have also analyzed urbanization using other single indicators. Using population density as a measure of urbanization development, Qadeer [7] analyzed the population density of rural areas in the Third World and found that it was equal to or exceeded the threshold of population density in some cities. Some studies have also considered land use change as a reflection of the urbanization process and thus used the ratio of built-up land area to total land area as an evaluation indicator of urbanization. For example, Xu et al. [8] used built-up land expansion to reflect land urbanization and analyzed its effect on the carbon sequestration of urban vegetation; Qiu et al. [9] used an impervious area to evaluate the urbanization process and studied the effect of urbanization on the loss of cropland.

However, urbanization is a complex systemic process, and the use of a single indicator approach would ignore the influence of other aspects of the urbanization process, such as economic factors and social factors [10]. Therefore, some studies have used multiple indicators to comprehensively evaluate the urbanization situation. Wang et al. [11] selected four urbanization structural elements: economic urbanization, demographic urbanization, social urbanization and spatial urbanization. They used the Analytic Hierarchy Process (AHP) method to determine the weights of each index and to construct an index system for urbanization. Wang et al. [12] used the PESS model to comprehensively evaluate the urbanization development level of the Beijing–Tianjin–Hebei urban agglomeration from four dimensions: population growth, economic development, life improvement and spatial expansion. As can be seen, different studies have a different selection of indicators and methods when constructing composite indicators for urbanization evaluation, so it is difficult to evaluate and analyze the results of different studies in a uniform manner.

Compared with the traditional assessment of urbanization, the sustainable development of urbanization holds a more holistic view, taking more into account the sustainability and coordinated development of human society, resources and the environment, involving social, economic, environmental and humanistic aspects [13,14]. It emphasizes that the development of urbanization must meet the needs of present and future generations and the development needs of modern society [15]. The SDGs proposed in the "2030 Agenda for Sustainable Development" are a more comprehensive and specific blueprint for global sustainable development, based on the consolidation of the existing achievements of the MDGs, and are universal in nature [2]. Studies have been conducted to analyze the relationship between the SDGs and sustainable development from the perspective of specific meanings and practical applications. For example, Klopp et al. [16] described what the Urban Sustainable Development Goals (USDGs) in the 2030 SDGs entailed and analyzed the problems and prospects of using them as a tool for improving urban development; the Republic of Montenegro has incorporated some indicators of the SDGs in the National Sustainable Development Strategy [17]. This shows that the SDGs play a guiding role in achieving sustainable development, and there have been relevant studies based on this framework to select the corresponding development goals and indicators to analyze and assess the sustainable development of urbanization. For example, Xu et al. [3] constructed an index system of urban sustainability assessment based on SDG11 to assess the sustainability level in the Yangtze River Delta of China. Integrating earth observation (EO) and statistical data, Wang et al. [18] monitored "The ratio of land consumption rate to the population growth rate (LCRPGR)" in SDG11 and analyzed the spatial heterogeneity and dynamic trends of urban expansion and population growth in mainland cities in China from 1990–2010. Ghazaryan et al. [19], based on Landsat data, analyzed the expansion of urban areas in North Rhine–Westphalia, Germany from 1985–2017 and integrated it with population dynamics data to estimate the progress towards SDG11 in the study area.

Although SDG11 is the most relevant goal to the development of cities in SDGs, the analysis for sustainable development of urbanization should not focus only on it. Since the "2030 Agenda for Sustainable Development" is not just a collection of goals and targets but a system of interacting components, the achievement of one goal requires the collaboration of other SDGs [20]. In addition to SDG11, other SDGs also reflect the sustainable development relationship of economic, social and resource environment elements involved in the process of urbanization, such as sustainable urban water management, which contributes to SDG 11 and SDG 6 (Clean water and Sanitation) [21]. Similarly, energy-efficient buildings, which are essential for sustainable urban development, contribute directly to SDG7 (Affordable and Clean Energy) and SDG13 (Climate Action) [22]. Therefore, it is necessary to conduct a comprehensive assessment of the sustainability of urbanization in conjunction with other SDGs.

Based on the existing research results, it can be seen that most current studies focus on larger spatial scales, such as economically developed urban agglomerations [3,23,24], with fewer studies targeting sub-level areas. On the other hand, most current studies use different indicators and data for urbanization assessment and focus mainly on SDG11, with limited links to other SDGs. Hainan Province, as China's Special Economic Zone and Pilot Free Trade Zone, has a good ecological environment, obvious location advantages and many conditions for sustainable development. It is also a key node of the 21st Century Maritime Silk Road and is at the forefront of China's maritime interactions with Southeast Asia, South Asia, the Middle East and other countries. Therefore, the sustainable development of urbanization in this region is of great importance to China. Many current studies on urbanization in Hainan Island have been conducted based on multiple indicators [25–27], but few studies evaluate the sustainable development of urbanization in this region based on multiple SDGs. This paper takes Hainan Island in Hainan Province as the study area, using statistical data and remote sensing products to carry out: (1) a sustainable development assessment index system for Hainan Island using the entropy weight method that integrates SDGs indicators with localized indicators and (2) a spatial and temporal analysis of the sustainable development of urbanization in the study area from 2011 to 2020. Although SDGs were proposed in 2015, in order to better analyze the sustainable development of urbanization in Hainan Island over a longer period, this paper chose the period from 2011 to 2020 after considering the availability of data. This research period covers the years before and after the formulation of SDGs, thus this study can provide a data reference for the sustainable development of urbanization in Hainan Island during this period and can also provide a reference for the sustainable development of urbanization in other regions.

2. Study Area and Data

2.1. Study Area

The study area of this paper is Hainan Island (Figure 1), located in the south of China (18°09′–20°10′ N and 108°37′–111°03′ E), which is part of Hainan Province, China. Hainan Island includes 18 cities and counties, while Sansha City in Hainan Province is not included in this study area because of its small land area, small resident population and lack of data. According to the Hainan Statistical Yearbook [28], by the end of 2020, Hainan Province already had a resident population of 10,123,400, including 6,114,000 urban residents, with a per capita GDP reaching CNY 55,131. Figure 1 also shows the percentage of urban population among resident population in 2020, which was calculated based on the urban resident population and the total resident population in the Hainan Statistical Yearbook [28].

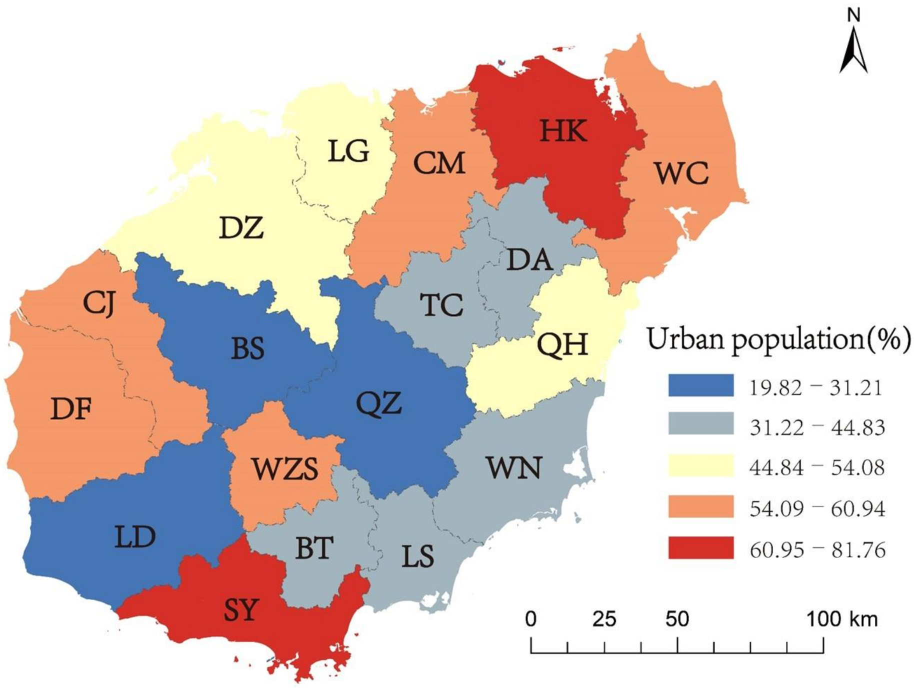

Figure 1. Study area and percentage of urban population among resident population in 2020. Abbreviations: HK: Haikou City, SY: Sanya City, DZ: Danzhou City, WZS: Wuzhishan City, QH: Qionghai City, WC: Wenchang City, WN: Wanning City, DF: Dongfang City, DA: Ding'an County, TC: Tunchang County, CM: Chengmai County, LG: Lingao County, BS: Baisha Li Autonomous County, CJ: Changjiang Li Autonomous County, LD: Ledong Li Autonomous County, LS: Lingshui Li Autonomous County, BT: Baoting Li and Miao Autonomous County, QZ: Qiongzhong Li and Miao Autonomous County.

2.2. Data

In this paper, statistical data and remote sensing product data were integrated to provide a comprehensive evaluation of the sustainable development of urbanization in Hainan Island based on SDGs. The research objects of this paper are the cities and counties of Hainan Island (18 regions in total). Regarding the selection of indicators, this study selected the indicators of economic, social, infrastructure construction, resources and the environment concerning the existing studies [10,12]. After that, these indicators were corresponded to SDGs based on the specific contents of SDGs [29]. The indicators of economic, social, infrastructure construction, resources and the environment aligned with the UN SDGs of each city and county were used to evaluate the sustainable development of urbanization in the study area. The final selected indicators and their corresponding SDGs are shown in Table 1. The effect direction of indicators is divided into positive and negative, with a "+" indicating that the greater the indicator, the better the level of sustainability, and vice versa.

The remote sensing product data used to construct the assessment system included land use data, $PM_{2.5}$ data and average temperature data. Among them, the land use data is the annual China's Land-Use/Cover Datasets (CLCD) from 1990 to 2020 published by Yang et al. [30], which has a spatial resolution of 30m. $PM_{2.5}$ data is the ChinaHigh$PM_{2.5}$ dataset published by Wei et al. [31,32], which is a big data-derived seamless (spatial coverage = 100%) daily, monthly and yearly 1 km ground-level $PM_{2.5}$ dataset in China from 2000 to 2021. The mean temperature data were obtained from the High-spatial-resolution monthly temperatures dataset, published by Peng et al. [33–37], including monthly minimum, maximum and mean temperatures from 1901.1 to 2020.12, covering the main land area of China. The vector map data used in this study was obtained from the

National Earth System Science Data Center, National Science & Technology Infrastructure of China [38].

Table 1. Relevant data of Comprehensive Assessment Index System for Sustainable Development of Hainan Island Urbanization.

System Layer	Sub-System Layer	SDGs Indicators	Index Layer	Effect Direction	Data Source
Assessment of Sustainable Urbanization Development	Economic urbanization	SDG1	Average wages of staff and workers	+	Statistical Yearbook [28]
		SDG8	Per capita GDP	+	Statistical Yearbook [28]
		SDG8	The ratio of secondary and tertiary industries to total GDP *	+	Statistical Yearbook [28]
		SDG8	Total retail sales of consumer goods as a percentage of GDP *	+	Statistical Yearbook [28]
		SDG8	Newly increased fixed assets	+	Statistical Yearbook [28]
		SDG8	Total number of overnight tourists	+	Statistical Yearbook [28]
	Social urbanization	SDG3	Number of hospital beds per 10,000 people *	+	Statistical Yearbook [28,39]
		SDG3	Number of traffic deaths per 100,000 people *	–	Statistical Yearbook [28]
		SDG4	Per capita expenditure of local government on education *	+	Statistical Yearbook [28]
		SDG4	Number of students enrolled from elementary to high school per 10,000 population *	+	Statistical Yearbook [28]
		SDG9	Rate of science and technology expenditures to local government expenditures *	+	Statistical Yearbook [28]
		SDG10	Urban–rural income gap *	–	Statistical Yearbook [28]
		SDG11	Rate of urban population to resident population *	+	Statistical Yearbook [28]
		SDG11	Impervious area as a percentage of total land area	+	Remote sensing product data [30]
	Urban infrastructure construction	SDG6	Coverage rate of urban population with access to tap water	+	Statistical Yearbook [28]
		SDG6	Number of public lavatories per 10,000 people*	+	Statistical Yearbook [28]
		SDG7	Coverage rate of urban population with access to gas	+	Statistical Yearbook [28]
		SDG11	Per capita public green areas	+	Statistical Yearbook [28]
		SDG11	Per capita area of paved roads	+	Statistical Yearbook [28]
	Resources and environment	SDG11	Green covered area of built districts	+	Statistical Yearbook [28]
		SDG11	$PM_{2.5}$ concentration	–	Remote sensing product data [31,32]
		SDG13	Intensity of heat island in summer	–	Remote sensing product data [33–37]
		SDG15	Forest area as a percentage of total land area	+	Remote sensing product data [30]

Notes: SDG1: No poverty; SDG3: Good health and well-being; SDG4: Quality education; SDG6: Clean water and sanitation; SDG7: Affordable and clean energy; SDG8: Decent work and economic growth; SDG9: Industry, innovation and infrastructure; SDG10: Reduced inequalities; SDG11: Sustainable cities and communities; SDG13: Climate action; SDG15: Life on land. * means the indicator was obtained from the raw statistical data after calculation and processing.

The data used for the remaining indicators are statistical data of each city and county, sourced from the Hainan Statistical Yearbook [28] and the China Statistical Yearbook (County-Level) [39], with some missing data supplemented, according to the statistical communique on economic and social development in each city and county, or replaced by average values of the recent years.

3. Methods

3.1. Data Preprocessing

3.1.1. Remote Sensing Product Data Preprocessing

For remote sensing product data, this study used the land use dataset (CLCD) to calculate the two indicators in Table 1: Impervious area as a percentage of total land area and Forest area as a percentage of total land area. Although impervious surface area is not directly equivalent to urban built-up area and urban area, it is one of the indicators used to understand and assess urbanization [40]. The vector map data of each region was used as a mask to divide the raster data of Hainan Island to obtain the indicator values of each city and county.

The yearly $PM_{2.5}$ data (ChinaHigh$PM_{2.5}$ dataset) was used to calculate the indicator in Table 1: $PM_{2.5}$ concentration. The vector map data of each region was used as a mask to divide the $PM_{2.5}$ data and to find the annual average of $PM_{2.5}$ in each region.

Due to the large size of Hainan Island and the roughly flat terrain around the island with a high center, the temperature varies from season to season and from region to region. Considering the relatively high mean temperatures in June, July and August based on the dataset (High-spatial-resolution monthly temperatures dataset), this study used the mean temperatures data from June to August to calculate the index of intensity of heat island in summer in Table 1. For the division of heat island regions, this study refers to the results of existing studies and divides them according to the mean and standard deviation of regional temperatures, as shown in Table 2 [41], where T is the value of the mean temperature dataset; μ is the mean value of the study area; and std is the standard deviation. The heat island intensity was calculated as shown in Formula (1), and the calculation results of the three summer months (June, July and August) were arithmetically averaged to obtain the intensity of the heat island in summer for each region.

Table 2. Classification criteria for heat island areas.

Categories	Range
Non-heat island region	$T \leq \mu + 0.5$ std
Heat island region	$T > \mu + 0.5$ std

$$P = T_H - T_V \tag{1}$$

As in Formula (1), P is the intensity of the heat island in summer; T_H is the average value of temperature in the heat island region; and T_v is the average value of temperature in the non-heat island region.

3.1.2. Statistical Data Preprocessing

The indicators marked with * in Table 1 were obtained from the raw statistical data after calculation and processing. Among them, the urban–rural income gap is the ratio of per capita disposable income of urban households to per capita disposable income of rural households; the rate of urban population to resident population is the proportion of the population living in urban areas to the resident population in the corresponding year. Population-related indicators were all derived from the revised resident population data published in Hainan Statistical Yearbook 2021 [28], such as the number of hospital beds per 10,000 people, traffic accident fatality rate per 100,000 people, per capita financial expenditure on education, primary and secondary school students per 10,000 people and public lavatories per 10,000 people.

3.2. Entropy Weight Method

There are two main methods widely used in the comprehensive evaluation of composite indicators: the subjective weighting method and the objective weighting method [42,43]. The subjective weighting method depends on the subjective preference of the evaluator and the evaluation of each indicator and therefore tends to lack objectivity [44]. The objective weighting method, on the other hand, determines the weights based on the information provided by the value of each indicator, and the results can better meet the needs of studies [45,46]. Therefore, this study uses the entropy weight method to calculate the index weights in the comprehensive assessment index system for the sustainable development of Hainan Island urbanization and then derives the comprehensive score for the sustainable development level of urbanization in Hainan Island according to the obtained weights. The entropy weight method belongs to the objective weighting method, which determines the indicator weights according to the dispersion of values on the same indicator [47]. It can reduce the subjective analysis bias caused by the subjective weighting method to a certain extent. The main steps are as follows [44,48].

Because of the different units and dimensions among indicators, it is necessary to standardize the indicators first, and the processing methods are shown below, according to positive and negative indicators.

$$y_{\theta ij} = x_{\theta ij} / x_{max} \tag{2}$$

$$y_{\theta ij} = x_{min} / x_{\theta ij} \tag{3}$$

Positive indicators are normalized using Formula (2), and negative indicators are normalized using Formula (3). $x_{\theta ij}$ is the jth indicator for region i in year θ; x_{min} and x_{max} represent the minimum and maximum values of the jth indicator in all study regions and years, respectively. $y_{\theta ij}$ is the result obtained after normalization.

Calculate the proportion of the jth indicator for region i in year θ:

$$z_{\theta ij} = y_{\theta ij} / \sum_{\theta}^{r} \sum_{i}^{n} y_{\theta ij} \tag{4}$$

where r is the length of the study period and n is the number of study regions.

Calculate the entropy value of the jth indicator:

$$e_j = -k \times \sum_{i}^{n} \sum_{\theta}^{r} (z_{\theta ij} \times \ln z_{\theta ij}),\ k = 1/\ln(rn) \tag{5}$$

Calculate the weight of the jth indicator:

$$w_j = d_j / \sum_{j}^{m} d_j,\ d_j = 1 - e_j \tag{6}$$

where m is the number of indicators.

Finally, the comprehensive assessment score of the sustainable urbanization development for region i in θ year can be obtained according to the entropy theory and the weighted sum method. The assessment formula is as follows.

$$S_i = \sum_{j}^{m} w_j \times y_{\theta ij} \tag{7}$$

3.3. Local Spatial Autocorrelation

Spatial autocorrelation is a measure of the spatial correlation of variables based on the first law of geography: "All things are related, but nearby things are more related than distant things" [49]. In this study, local spatial autocorrelation is used to discuss the sustainable development of urbanization in the study area. The local spatial autocorrelation index is calculated as shown in Equations (8)–(10) [50].

$$I_i = \frac{Z_i}{S^2} \sum_{j \neq i}^{n} \omega_{i,j} Z_j \tag{8}$$

$$Z_i = y_i - \bar{y}\,,\ Z_j = y_j - \bar{y} \tag{9}$$

$$S^2 = \frac{1}{n} \sum_{i=i}^{n} \left(y_i - \bar{y} \right)^2 \tag{10}$$

where I_i is the local Moran's I index of region i and n is the total number of studied regions. $\omega_{i,j}$ is a weight which is equal to 1 when region i is adjacent to region j and 0 otherwise. Z_i and Z_j are the degree of deviation from the mean value in regions i and j, respectively. When I_i is a high positive value, it means that the location under study has similar high or low values with its neighboring locations, and thus these locations are spatial clusters, including high–high clusters (high values in high value neighborhoods) and low–low clusters (low values in low value neighborhoods); when I_i is a high negative value, it means that the studied location has significant differences with its surrounding locations, thus forming spatial outliers, including high–low (high values in low value neighborhoods) and low–high (low values in high value neighborhoods) outliers [51].

4. Results

4.1. Sustainable Development of Hainan Island Urbanization

According to the formula of the entropy weight method, the assessment results of sustainable urbanization development of cities and counties in Hainan Island from 2011 to 2020 were obtained, as shown in Table 3.

Table 3. Comprehensive Assessment Index System for Sustainable Development of Hainan Island Urbanization.

System Layer	Sub-System Layer	SDGs Indicators	Index Layer	Weight
Assessment of Sustainable Urbanization Development	Economic urbanization	SDG1	Average wages of staff and workers	0.0119
		SDG8	Per capita GDP	0.0206
		SDG8	The ratio of secondary and tertiary industries to total GDP *	0.0078
		SDG8	Total retail sales of consumer goods as a percentage of GDP *	0.0182
		SDG8	Newly increased fixed assets	0.1865
		SDG8	Total number of overnight tourists	0.2273
	Social urbanization	SDG3	Number of hospital beds per 10,000 people *	0.0284
		SDG3	Number of traffic deaths per 100,000 people *	0.0221
		SDG4	Per capita expenditure of local government on education *	0.0131
		SDG4	Number of students enrolled from elementary to high school per 10,000 population *	0.0012
		SDG9	Rate of science and technology expenditures to local government expenditures *	0.1345
		SDG10	Urban–rural income gap *	0.0013
		SDG11	Rate of urban population to resident population *	0.0084
		SDG11	Impervious area as a percentage of total land area	0.1065
	Urban infrastructure construction	SDG6	Coverage rate of urban population with access to tap water	0.0004
		SDG6	Number of public lavatories per 10,000 people *	0.0735
		SDG7	Coverage rate of urban population with access to gas	0.0006
		SDG11	Per capita public green areas	0.0193
		SDG11	Per capita area of paved roads	0.0174
	Resources and environment	SDG11	Green covered area of built districts	0.0036
		SDG11	$PM_{2.5}$ concentration	0.0037
		SDG13	Intensity of heat island in summer	0.0856
		SDG15	Forest area as a percentage of total land area	0.0083

Notes: * means the indicator was obtained from the raw statistical data after calculation and processing.

The results are presented in a boxplot to show the median values of the urbanization sustainability assessment in the study area and the variation between regions (Figure 2).

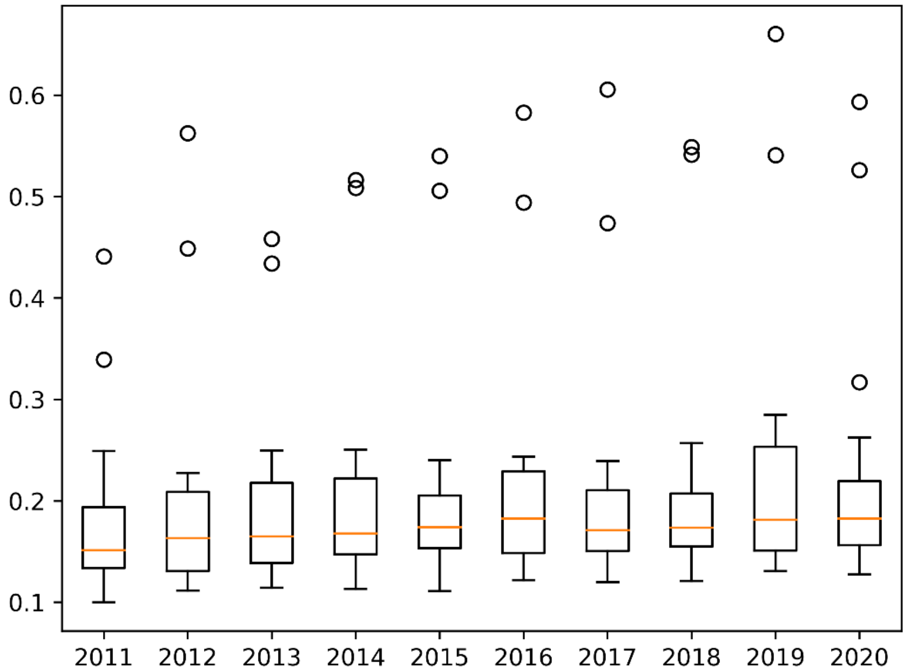

Figure 2. The assessment boxplot of sustainable development of Hainan Island urbanization.

In general, the sustainable development of urbanization in cities and counties in Hainan Island showed an upward trend, with the median value increasing from 0.151 in 2011 to 0.182 in 2020. In terms of the degree of variation in the study area, Haikou City and Sanya City always took the leading position in the evaluation, and their assessment results had a large gap with other cities and counties. This is because Haikou City is the capital city and the political, economic and cultural center of Hainan Province, China. Sanya City is a famous tourist city with tropical seaside scenery and a well-developed tourism industry. In 2020, Chengmai County's urbanization sustainability assessment results also gaped with other cities and counties, becoming an outlier along with Haikou City and Sanya City. The length of the boxes in Figure 2 is the interquartile range of the assessment results, and its variation reflects the fluctuation of the assessment results of each city and county during the study period. In 2019, the interquartile range of the assessment results reached the largest, indicating a large difference in the assessment results of the cities and counties in that year.

Except for Haikou City and Sanya City, Wenchang City had higher urbanization sustainability assessment results than other regions in 2011 and 2015, due to its better performance in terms of resources and environment (Figures 3 and 4). The urbanization sustainability assessment scores of Chengmai County and Sanya City in 2020 were significantly higher compared to 2015, which were both mainly due to the increase in sustainability scores in terms of social urbanization. As a result, Chengmai County overtook Wenchang City to rank third in Hainan Island in the 2020 urbanization sustainability assessment. Some regions had a decrease in their comprehensive assessment scores of urbanization sustainability compared 2020 to 2015, mainly due to lower scores in economic urbanization. In 2011 and 2015, Ledong County's urbanization sustainability assessment scores were the lowest of the study area. In 2020, Ledong County's scores in economic urbanization and urban infrastructure construction increased compared to previous years, resulting in Ledong County's urbanization sustainability assessment score ranking higher within the study area in that year, while Baoting County's urbanization sustainability assessment score decreased to the lowest value within the study area.

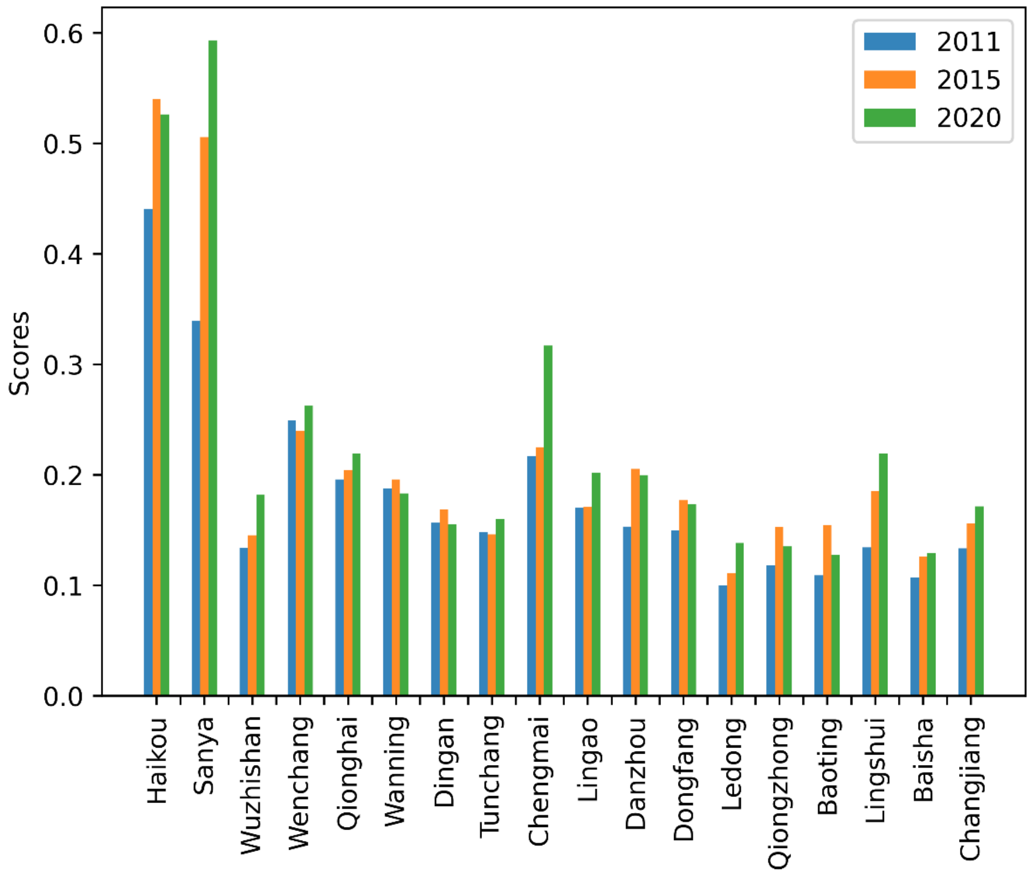

Figure 3. Score chart for cities and counties of Hainan Island in 2011, 2015 and 2020.

Figure 5 shows the spatial distribution of urbanization sustainability assessment results of cities and counties in Hainan Island for some years during the study period, and all the assessment results during the study period are divided into five levels in this paper. As shown in Figure 5, fewer regions broke through the low-value zone of the comprehensive urbanization sustainability assessment in 2011–2015, and they were mainly located in the south and north of Hainan Island. The assessment scores of Haikou City, Sanya City, Wenchang City and Chengmai County were relatively stable, while the assessment score of Qionghai City fluctuated. As the capital city of Hainan Province, Haikou City and its neighboring regions (Chengmai County and Wenchang City) scored well in the assessment, reflecting Haikou City's promotion to the surrounding areas during this period. The assessment scores of Sanya City were relatively well in Hainan Island for this period, but the scores of other areas adjacent to Sanya City were in the low-value zone ($\leq$0.212), which shows that, as a famous tourist city, the development of Sanya City does not bring sufficient promotion to the surrounding areas during this time.

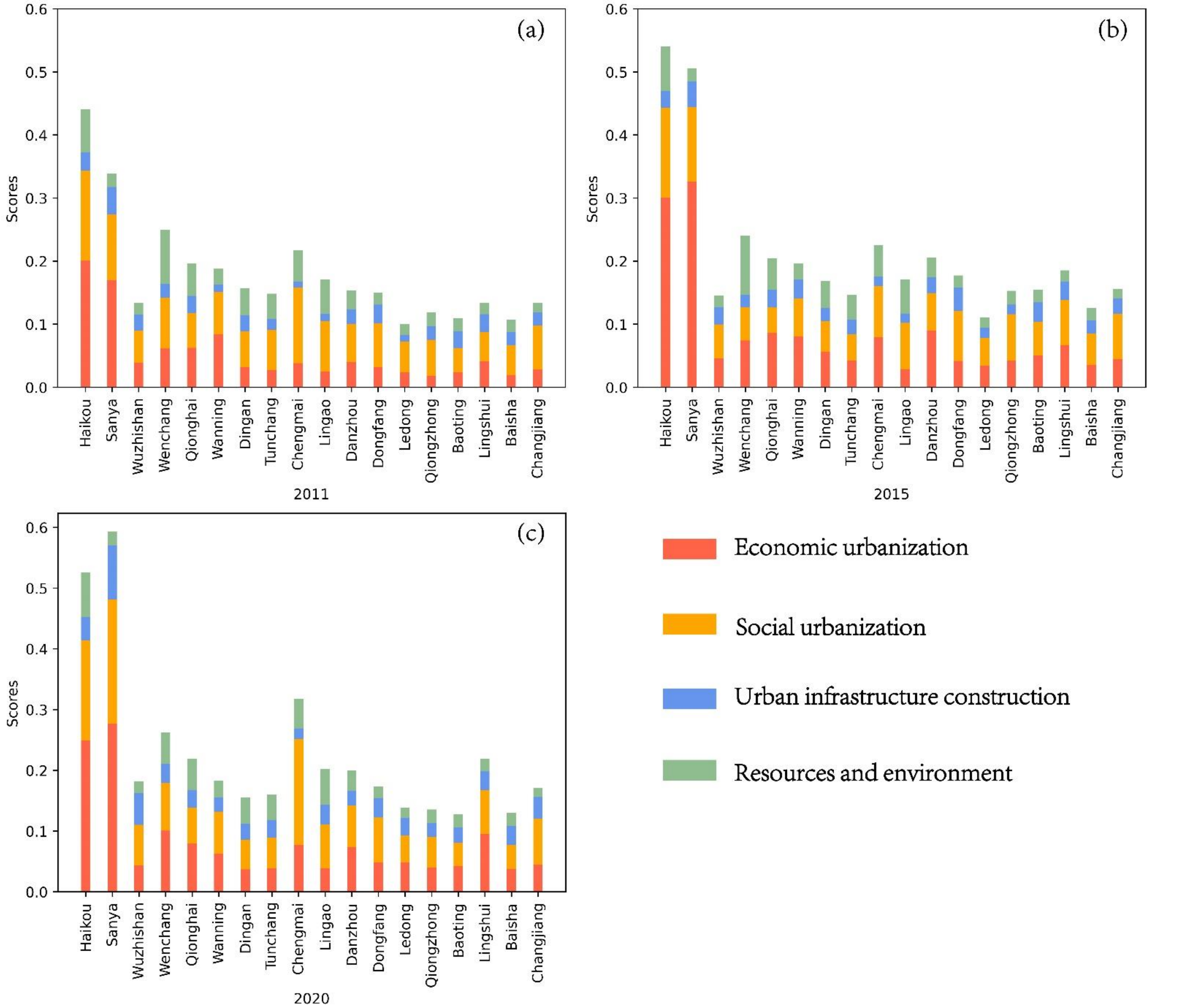

Figure 4. Sub-system layer score chart for cities and counties of Hainan Island in 2011, 2015 and 2020: (**a**) sub-system layer scores in 2011; (**b**) sub-system layer scores in 2015; (**c**) sub-system layer scores in 2020.

In 2015, the 17 Sustainable Development Goals (SDGs) proposed by the United Nations guided the future development direction of countries. China, as the world's largest developing country, insists on development as its top priority. In 2016, China released "China's National Plan on Implementation of the 2030 Agenda for Sustainable Development", which sets out specific plans for implementing the 17 SDGs in the coming period. In recent years, Hainan has also been promoting the construction of the "Haikou-Chengmai-Wenchang-Ding'an" and " Greater Sanya" economic circles, interpreting the concept of sustainable development with a series of measures. After 2015, the number of cities and counties breaking through the low-value zone of comprehensive urbanization sustainability assessment increased, and the eastern region continued to develop (Figure 5). In 2020, Haikou City and Sanya City were still at the top of the study area in terms of sustainable urbanization development, while the radiating effect of these two cities was reflected, and some of the surrounding areas have broken through the low-value zone of urbanization sustainability assessment. However, the urbanization sustainability assessment score of the central part of Hainan Island remained in the low-value range, mainly because some of these areas used to belong to poor areas, and therefore were lagging behind in economic development, such as Qiongzhong Li and Miao Autonomous County and Baoting Li and Miao Autonomous County, which were lifted out of poverty in April 2019, and Baisha Li Autonomous County in February 2020, with room for further development in the future.

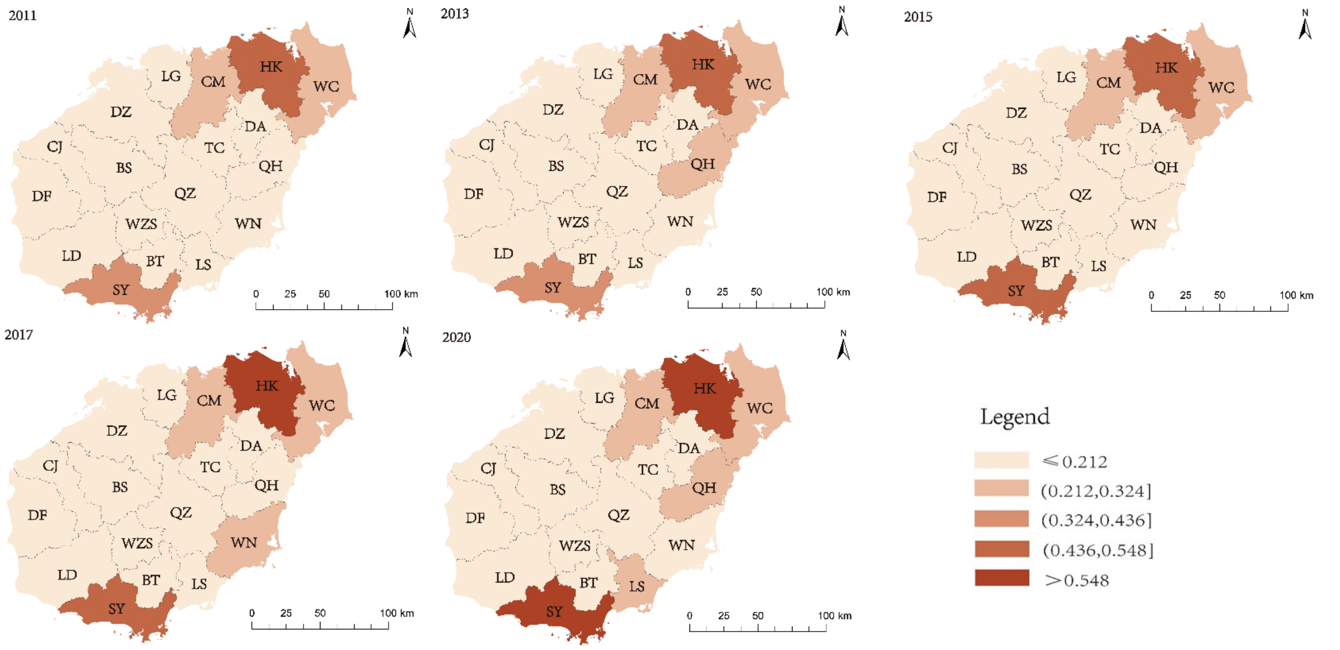

Figure 5. Spatial distribution of sustainable development of Hainan Island urbanization.

Local spatial autocorrelation analysis (Figure 6) was conducted on the results of urbanization sustainability assessment of the study area to analyze whether there were local spatial clusters. In 2011, the central and western regions of Hainan Island showed low–low clusters. Sanya City's urbanization sustainability assessment result was significantly higher than those of the surrounding areas and therefore was judged to be a high–low outlier. Wenchang City's urbanization sustainability assessment score showed a significant high–high cluster with the surrounding areas and played a positive role in the sustainable development of urbanization in the surrounding areas, while Ding'an County, which is adjacent to it, was identified as a low–high outlier area due to its low urbanization sustainability assessment result compared with the surrounding areas. In 2013–2015, there were still significant low–low clusters in the central part of Hainan Island, but the number has decreased compared to previous years. The significant relationship between the cities of Sanya and Wenchang and their surrounding areas changed, while the assessment of urbanization sustainability in Ding'an County remained significantly lower than the surrounding areas. In 2020, the spatial autocorrelation of urbanization sustainability assessment scores between Ding'an County and the surrounding areas became insignificant, and Baisha Li Autonomous County and Wuzhishan City were still judged to be statistically significant low–low outliers, and there were no significant clusters in other areas.

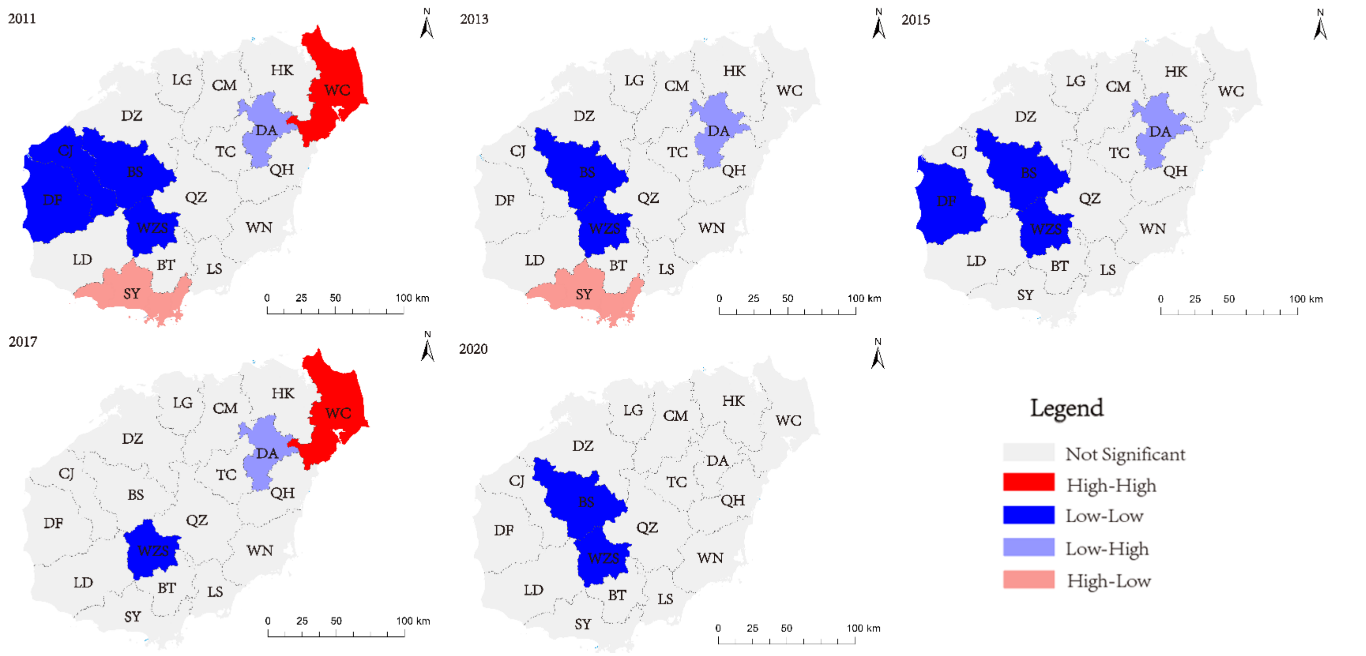

Figure 6. Hotspot areas of sustainable development of Hainan Island urbanization.

4.2. Monitoring the Performance of SDGs in Hainan Island

The SDGs were proposed by the United Nations in 2015. Therefore, we would like to discuss the performance of SDGs in Hainan Island between the starting year (2015) and the year when the latest data are available (2020). The ranking of the SDGs scores of cities and counties in Hainan Island for 2015 and 2020 is shown in Table 4. Haikou City and Sanya City, as the two cities with excellent performance in urbanization sustainability assessment scores, had failed to fully achieve some SDGs. For example, Haikou City ranked low on SDG4 (Quality education) and SDG15 (Life on land), which indicates that Haikou City still needs to pay more attention to environmental protection and investment in education in the process of sustainable development of urbanization. As a famous tourist city, Sanya City ranked high in the study area in several SDGs, among which SDG6 (Clean water and sanitation) and SDG8 (Decent work and economic growth) contained indicators closely related to tourism, and Sanya City had the highest scores in the study area in both 2015 and 2020, demonstrating its strength in tourism attractiveness, however, in SDG10 (Reduced inequalities), Sanya City ranked lower and remained unchanged in 2015 and 2020.

In terms of spatial distribution, the central cities and counties of Hainan Island (Wuzhishan City, Ding'an County, Tunchang County, Qiongzhong Li and Miao Autonomous County, Baoting Li and Miao Autonomous County, and Baisha Li Autonomous County), which contain several nature reserves, ranked high in SDG15 (Life on land), and there was no major change in rankings between 2015 and 2020. However, their SDG11 rankings were all low. The western regions of Hainan Island (Chengmai County, Lingao County, Danzhou City, Dongfang City, Ledong Li Autonomous County, and Changjiang Li Autonomous County) performed worse overall in SDG3 (Good health and well-being) and had larger internal ranking gaps in other SDGs, such as Danzhou City and Chengmai County ranking better than other cities and counties of the western regions in SDG8 (Decent work and economic growth). Ledong Li Autonomous County in SDG10 (Reduced inequalities) ranked first, but Changjiang Li Autonomous County's ranking in 2020 was 17.

Table 4. Ranking the assessment scores of Sustainable Development Goals in Hainan Island in 2015 and 2020.

	SDG1		SDG3		SDG4		SDG6		SDG7		SDG8	
Area/Year	2015	2020	2015	2020	2015	2020	2015	2020	2015	2020	2015	2020
Haikou	10	5	3	3	16	18	9	3	1	6	2	2
Sanya	4	3	10	10	4	15	1	1	5	9	1	1
Wuzhishan	6	4	2	1	1	6	3	2	16	5	11	12
Wenchang	3	9	14	17	18	8	13	5	2	1	7	3
Qionghai	13	8	16	5	17	14	4	12	4	2	4	5
Wanning	14	17	13	2	13	16	5	16	6	8	5	8
Ding'an	17	18	7	8	11	17	14	17	14	17	9	17
Tunchang	12	16	8	6	15	9	8	6	18	12	14	15
Chengmai	1	1	17	9	7	5	18	13	8	4	6	6
Lingao	15	15	4	11	14	12	16	4	9	14	18	16
Danzhou	5	7	12	14	12	11	11	15	10	3	3	7
Dongfang	8	12	18	7	8	10	2	8	3	7	15	9
Ledong	9	6	11	16	9	13	17	18	12	13	17	10
Qiongzhong	16	10	5	13	5	1	10	14	13	18	13	14
Baoting	11	13	1	15	6	3	7	10	7	11	10	13
Lingshui	7	11	6	4	3	4	12	11	17	16	8	4
Baisha	18	14	9	12	10	2	15	9	15	15	16	18
Changjiang	2	2	15	18	2	7	6	7	11	10	12	11
	SDG9		**SDG10**		**SDG11**		**SDG13**		**SDG15**			
Area/Year	2015	2020	2015	2020	2015	2020	2015	2020	2015	2020		
Haikou	9	5	13	14	1	1	2	1	17	17		
Sanya	1	1	12	12	2	2	10	10	6	8		
Wuzhishan	11	8	14	15	16	13	17	17	2	2		
Wenchang	15	3	7	8	8	8	1	3	18	18		
Qionghai	16	17	2	2	11	12	5	4	7	6		
Wanning	8	7	5	3	10	10	9	9	9	10		
Ding'an	14	13	9	9	12	14	6	6	10	9		
Tunchang	12	18	4	4	15	15	7	7	5	5		
Chengmai	3	2	6	6	7	9	4	5	8	7		
Lingao	13	15	8	7	5	3	3	2	15	14		
Danzhou	18	9	3	5	4	5	8	8	12	11		
Dongfang	4	11	10	11	3	4	11	11	16	16		
Ledong	17	14	1	1	13	11	16	15	11	12		
Qiongzhong	2	6	17	16	18	18	12	13	1	1		
Baoting	10	12	18	18	14	17	15	16	3	4		
Lingshui	7	16	11	10	6	7	13	12	14	15		
Baisha	6	10	16	13	17	16	14	14	4	3		
Changjiang	5	4	15	17	9	6	18	18	13	13		

The ranking of some SDGs changed significantly between 2015 and 2020, for example, Baoting Li and Miao Autonomous County's ranking in SDG3 (Good health and well-being) decreased due to the increase of the number of traffic deaths per 100,000 people in 2020 compared to 2015, while Lingao County's ranking in SDG6 (Clean water and sanitation) increased due to the growth of the number of public lavatories per 10,000 people. The rankings of cities and counties in SDG10 (Reduced inequalities), SDG11 (Sustainable cities and communities), SDG13 (Climate action) and SDG15 (Life on land) did not change significantly between 2015 and 2020.

Figure 7 shows the weights of the SDGs. It can be seen that the weight of SDG8 (Decent work and economic growth) has the largest proportion of 46.03%; the weight of SDG11 (Sustainable cities and communities) has the second largest ratio of 15.89%; and SDG7 (modern energy access and efficiency) has the smallest (0.06%). Although only one indicator—"Rate of science and technology expenditures to local government expenditures"—corresponds to SDG9 (Industry, innovation and infrastructure), the entropy weight method yields a larger weight due to the large variation among regions in this indicator. The proportion of SDG9′s weight is 13.45%, ranking third among all SDGs.

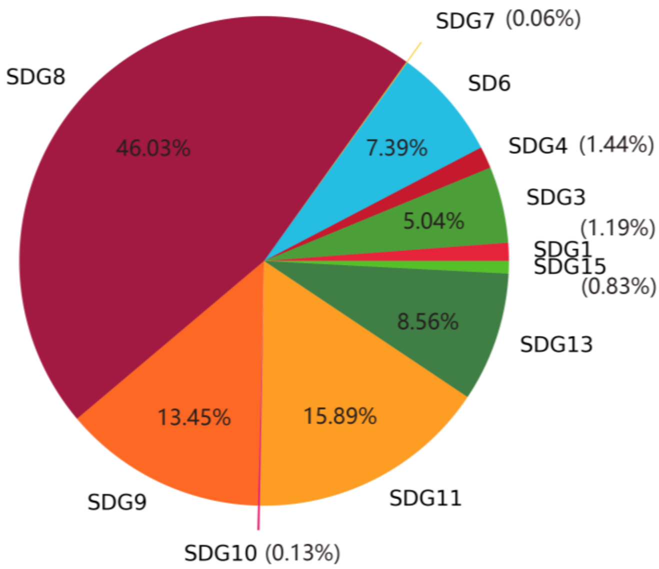

Figure 7. The percentage of Sustainable Development Goals' weights.

As shown in Figure 7, the scores of each region in SDG8, SDG11 and SDG9 have a major impact on the final urbanization sustainability assessment results. Therefore, it is necessary to analyze the SDG8, SDG11 and SDG9 scores of some regions with lower assessment scores. Combining the previous results of this paper, the comprehensive assessment of urbanization sustainability in Ding'an County had been at a low value for a long time compared with the surrounding areas (Figure 6), while Wuzhishan City, a county-level city located in the middle of Hainan Island, had been at a low value in the comprehensive assessment of urbanization sustainability (Figure 5) and had formed a statistically significant low–low cluster with the surrounding areas (Figure 6). Thus, Ding'an County and Wuzhishan City were selected for further analysis and discussion of their completion in SDG8, SDG11 and SDG9, as shown in Figures 8 and 9.

Figure 8 shows the specific scores of Ding'an County in SDG8, SDG11 and SDG9. In SDG8, the per capita GDP of Ding'an County maintained a stable growth trend from 2011 to 2020, and the ratio of secondary and tertiary industries to total GDP as well as the total retail sales of consumer goods as a percentage of GDP fluctuated during the study period but generally showed an upward trend. The newly increased fixed assets had changed significantly, accounting for 43.37% of the total SDG8 score in 2015; it continued to fluctuate afterwards and dropped to the lowest in 2020. The assessment score of the total number of overnight tourists increased steadily from 2011 to 2018 and then began to decline. In SDG11, the SDG11 assessment score of Ding'an County in 2011 was 0.040, which was the closest to the average of the study area, but the SDG11 score of Ding'an County continued to fluctuate in subsequent years, with a gap to the average. Most of the indicators did not change much during the study period and were a stable driving force for Ding'an County to promote SDG11. However, there were overall fluctuations in the sustainability assessment scores of per capita public green areas and per capita area of paved roads, of which the per capita public green areas were the main reason for the SDG11 fluctuation in Ding'an County. The SDG9 scores of Ding'an County showed an overall decreasing trend and a large gap with the average of the study area.

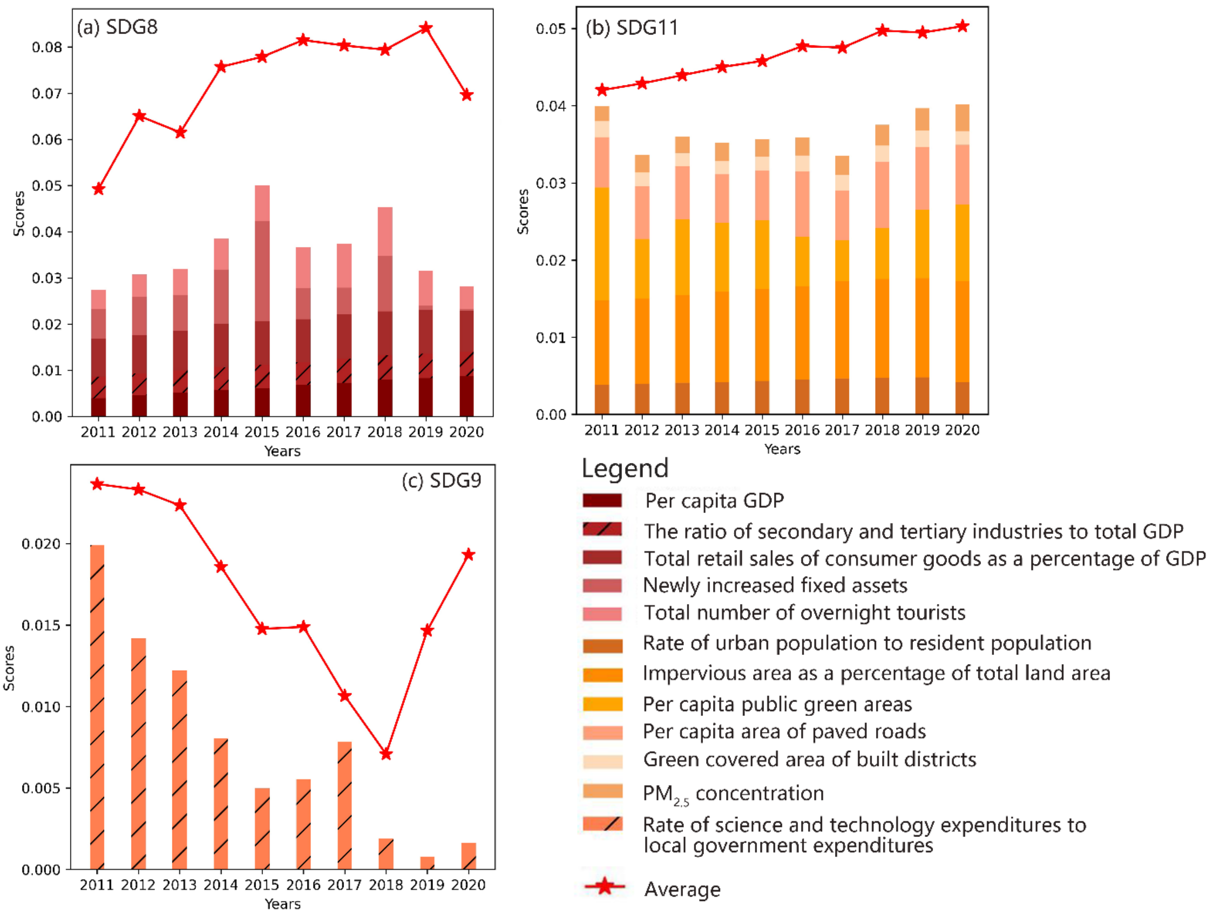

Figure 8. The assessment scores of Ding'an County in SDG8, SDG11 and SDG9.

As can be seen from Figure 9, in SDG8, the sustainability score of newly increased fixed assets in Wuzhishan City fluctuated greatly between 2011 and 2020 and dropped to the lowest value in 2018, while the sustainability score of the total number of overnight tourists rose to the highest value in that year, thus making the SDG8 score of Wuzhishan City in 2018 show no major fluctuations. The sustainability scores of other indicators in SDG8 showed an overall upward trend, with relatively stable changes in scores during the study period. In SDG11, Wuzhishan's SDG11 score fluctuated within a certain range from 2011 to 2019, while the score in 2020 increased significantly, mainly due to the increase in the sustainability score of per capita area of paved roads in that year. In addition, the change in the score of per capita public green areas was one of the reasons for the fluctuation of SDG11 score in Wuzhishan City. In terms of SDG9, the trend in Wuzhishan City's sustainability score was generally consistent with the change in the average within the study area.

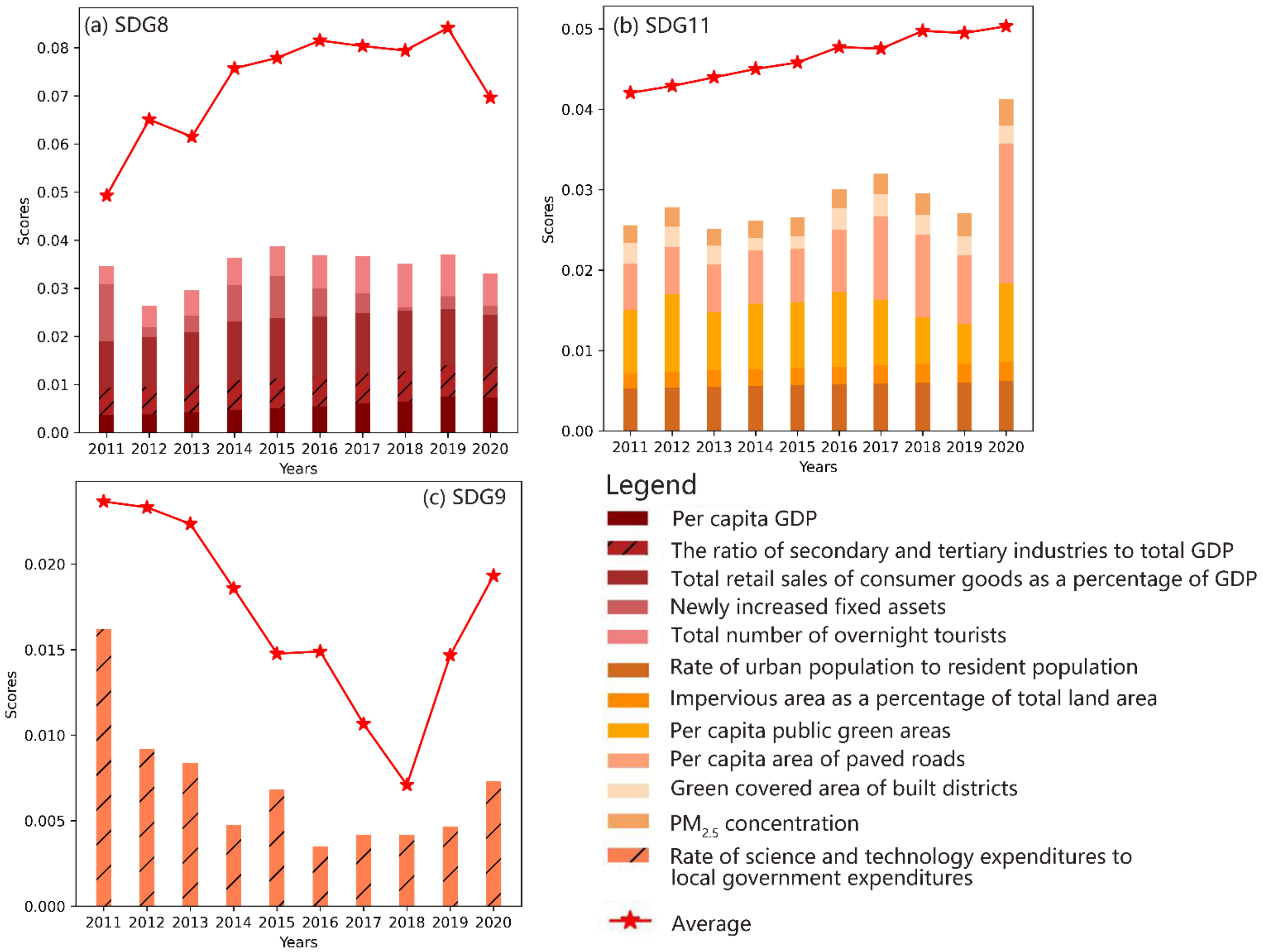

Figure 9. The assessment scores of Wuzhishan City in SDG8, SDG11 and SDG9.

5. Discussion

Most of the existing studies have developed indicators for the study area based on SDG11 [23,27,52], while this study considers that the sustainable development of urbanization is closely related to other SDGs and therefore integrates 23 indicators corresponding to 11 SDGs to construct a comprehensive assessment index system for the sustainable development of Hainan Island urbanization. In contrast with previous studies, Zhang et al. [27] collected relevant indicators based on SDG11 to build an urban sustainable development assessment framework for Hainan Province from 2010–2018, and the results showed that Haikou City and Sanya City were about to achieve the SDGs, while other cities and counties fell behind, and the development level of Hainan Province was high in the north and south and low in the middle and west. This finding is consistent with the results obtained in this paper, which found that Haikou City and Sanya City were the top cities in Hainan Island in terms of the comprehensive assessment of sustainable development of urbanization from 2011 to 2020, pulling away from the rest of Hainan Island. Haikou City and Sanya City need to strengthen their promotion to the surrounding areas to enable the cities and counties of Hainan Island to achieve synergistic development. Meanwhile, the development of SDG4 (Quality education) and SDG15 (Life on land) must be given priority in the urbanization sustainability process of Haikou City. Haikou City has achieved outstanding achievements in economic urbanization, thus creating a certain attraction for the population in less developed areas. The resident population of Haikou City in 2020 was 2,886,600, accounting for 28.5% of the total resident population in Hainan Province [28], while the assessment scores of the number of students enrolled per 10,000 population from elementary to high school in Haikou City were not high, which showed that the educational resources in Haikou City had not kept up with the resident population growth trend. Land use changes have a significant impact on the spatial and temporal patterns of ecosystem service functions in cities [53], so Haikou should also pay attention to the rational arrangement of land use to promote ecological construction.

Xu et al. [54] selected 11 indicators corresponding to SDG11 and evaluated the sustainable level of 26 cities in the Yangtze River Delta (YRD) urban agglomeration from 2007 to 2016, and the results showed that the sustainable development of YRD urban agglomeration had made significant progress. However, the sustainable development level of most cities was affected by factors such as the per capita green area, air quality and commercial housing sales area. Similar conclusions were reached in this paper, namely that the assessment scores of urbanization sustainability of cities and counties in Hainan Island continued to increase during the study period, and in the analysis of Ding'an County and Wuzhishan City, the sustainable development scores of the per capita public green areas fluctuated, which had a greater impact on the SDG11 assessment scores.

Earth observation can well support the tracking of SDGs' progress with timely and spatially disaggregated information [55]. In this study, the available statistics data cannot correspond to all the indicators. Thus, Earth observation data were used to fill the vacancies, which shows their important role in assessing the sustainable development of Hainan Island urbanization. However, the number of indicators corresponding to some SDGs, especially those related to ecological environment, was limited, and the statistical data had problems such as missing data for some years and regions. In future work, it is necessary to supplement data concerning the ecological environment and to give consideration to using more Earth observation data to build a comprehensive assessment system for urbanization sustainability.

The study area in this paper includes county-level areas, and it is difficult to obtain statistics data at this scale. The available statistics can also vary among different provinces and regions. Therefore, if the methods in this paper would be implemented in other study areas, the challenges of data acquisition need to be taken into account. The assessment system and the method of constructing multiple indicators in this paper may provide a reference for similar studies in the future.

6. Conclusions

This study integrated remote sensing product data and statistical data; selected 23 indicators corresponding to 11 SDGs considering the actual situation of Hainan Island; and used the entropy weight method to construct the comprehensive assessment index system for the sustainable development of urbanization in Hainan Island so as to assess the spatial and temporal situation of the sustainable development of urbanization in Hainan Island from 2011 to 2020, as well as the progress of SDGs in each city and county. The following conclusions are drawn: (1) From 2011 to 2020, the assessment scores of cities and counties in Hainan Island continued to improve, with Haikou City and Sanya City performing prominently, and Chengmai County showing a better growth in recent years. The sustainable development scores of urbanization showed a spatial pattern with high scores in the north and south and low scores in the central and western regions. In particular, Wuzhishan City and Baisha Li Autonomous County had low sustainable development scores of urbanization, and the local spatial autocorrelation results for these two areas were classified as low–low clusters for most years in the study period. (2) Overall, Haikou City needs to focus on SDG4 (Quality education) and SDG15 (Life on land), while SDG11 (Sustainable cities and communities) in the central region of Hainan Island and SDG3 (Good health and well-being) in the western region ranked low and are areas that need more efforts to advance the sustainable development process. (3) The scores of SDG8, SDG11 and SDG9 have a great impact on the comprehensive score of sustainable development of urbanization. For these three SDGs, the corresponding indicators of Ding'an County and Wuzhishan City were analyzed, and it is found that the fluctuations of the newly increased fixed assets, the per capita public green areas and the rate of science and technology expenditures to local government expenditures are the main factors affecting sustainable development.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Arslan, T.V.; Durak, S.; Aytac, D.O. Attaining SDG11: Can sustainability assessment tools be used for improved transformation of neighbourhoods in historic city centers? *Nat. Resour. Forum* **2016**, *40*, 180–202. [CrossRef]
2. Allen, C.; Metternicht, G.; Wiedmann, T. National pathways to the Sustainable Development Goals (SDGs): A comparative review of scenario modelling tools. *Environ. Sci. Policy* **2016**, *66*, 199–207. [CrossRef]
3. Xu, X.; Zhang, Z.; Long, T.; Sun, S.; Gao, J. Mega-city region sustainability assessment and obstacles identification with GIS–entropy–TOPSIS model: A case in Yangtze River Delta urban agglomeration, China. *J. Clean. Prod.* **2021**, *294*, 126147. [CrossRef]
4. Fernando, M.; Samita, S.; Abeynayake, R. Modified Factor Analysis to Construct Composite Indices: Illustration on Urbanization Index. *Trop. Agric. Res.* **2012**, *23*, 327. [CrossRef]
5. Chen, M.; Huang, Y.; Tang, Z.; Lu, D.; Liu, H.; Ma, L. The provincial pattern of the relationship between urbanization and economic development in China. *J. Geogr. Sci.* **2013**, *24*, 33–45. [CrossRef]
6. Liu, H.; Fang, C.; Miao, Y.; Ma, H.; Zhang, Q.; Zhou, Q. Spatio-temporal evolution of population and urbanization in the countries along the Belt and Road 1950–2050. *J. Geogr. Sci.* **2018**, *28*, 919–936. [CrossRef]
7. Qadeer, M.A. Urbanization by implosion. *Habitat Int.* **2004**, *28*, 1–12. [CrossRef]
8. Xu, Q.; Dong, Y.-X.; Yang, R. Influence of land urbanization on carbon sequestration of urban vegetation: A temporal cooperativity analysis in Guangzhou as an example. *Sci. Total Environ.* **2018**, *635*, 26–34. [CrossRef]
9. Qiu, B.; Li, H.; Tang, Z.; Chen, C.; Berry, J. How cropland losses shaped by unbalanced urbanization process? *Land Use Policy* **2020**, *96*, 104715. [CrossRef]
10. Zhou, C.; Wang, S.; Wang, J. Examining the influences of urbanization on carbon dioxide emissions in the Yangtze River Delta, China: Kuznets curve relationship. *Sci. Total Environ.* **2019**, *675*, 472–482. [CrossRef]
11. Wang, S.; Gao, S.; Li, S.; Feng, K. Strategizing the relation between urbanization and air pollution: Empirical evidence from global countries. *J. Clean. Prod.* **2019**, *243*, 118615. [CrossRef]
12. Wang, Z.; Liang, L.; Sun, Z.; Wang, X. Spatiotemporal differentiation and the factors influencing urbanization and ecological environment synergistic effects within the Beijing-Tianjin-Hebei urban agglomeration. *J. Environ. Manag.* **2019**, *243*, 227–239. [CrossRef] [PubMed]
13. Egger, S. Determining a sustainable city model. *Environ. Model. Softw.* **2006**, *21*, 1235–1246. [CrossRef]
14. Zhong, L.; Li, X.; Law, R.; Sun, S. Developing Sustainable Urbanization Index: Case of China. *Sustainability* **2020**, *12*, 4585. [CrossRef]
15. Yigitcanlar, T.; Teriman, S. Rethinking sustainable urban development: Towards an integrated planning and development process. *Int. J. Environ. Sci. Technol.* **2014**, *12*, 341–352. [CrossRef]
16. Klopp, J.M.; Petretta, D.L. The urban sustainable development goal: Indicators, complexity and the politics of measuring cities. *Cities* **2017**, *63*, 92–97. [CrossRef]
17. Galli, A.; Đurović, G.; Hanscom, L.; Knežević, J. Think globally, act locally: Implementing the sustainable development goals in Montenegro. *Environ. Sci. Policy* **2018**, *84*, 159–169. [CrossRef]
18. Wang, Y.; Huang, C.; Feng, Y.; Zhao, M.; Gu, J. Using Earth Observation for Monitoring SDG 11.3.1-Ratio of Land Consumption Rate to Population Growth Rate in Mainland China. *Remote. Sens.* **2020**, *12*, 357. [CrossRef]

19. Ghazaryan, G.; Rienow, A.; Oldenburg, C.; Thonfeld, F.; Trampnau, B.; Sticksel, S.; Jürgens, C. Monitoring of Urban Sprawl and Densification Processes in Western Germany in the Light of SDG Indicator 11.3.1 Based on an Automated Retrospective Classification Approach. *Remote. Sens.* **2021**, *13*, 1694. [CrossRef]
20. Pradhan, P. Antagonists to meeting the 2030 Agenda. *Nat. Sustain.* **2019**, *2*, 171–172. [CrossRef]
21. Herslund, L.; Mguni, P. Examining urban water management practices Challenges and possibilities for transitions to sustainable urban water management in Sub-Saharan cities. *Sustain. Cities Soc.* **2019**, *48*, 101573. [CrossRef]
22. Patiño-Cambeiro, F.; Armesto, J.; Bastos, G.; Prieto-López, J.I.; Barbeito, F.P. Economic appraisal of energy efficiency renovations in tertiary buildings. *Sustain. Cities Soc.* **2019**, *47*, 101503. [CrossRef]
23. Mithun, S.; Sahana, M.; Chattopadhyay, S.; Johnson, B.A.; Khedher, K.M.; Avtar, R. Monitoring Metropolitan Growth Dynamics for Achieving Sustainable Urbanization (SDG 11.3) in Kolkata Metropolitan Area, India. *Remote Sens.* **2021**, *13*, 4423. [CrossRef]
24. Wang, Q.; Liu, C.; Hou, Y.; Xin, F.; Mao, Z.; Xue, X. Study of the spatio-temporal variation of environmental sustainability at national and provincial levels in China. *Sci. Total Environ.* **2021**, *807*, 150830. [CrossRef] [PubMed]
25. Wang, S.; Ma, Z. The Periodicity and Influencing Factors of Hainan Urbanization Process in the New Century. *Areal Res. Dev.* **2013**, *32*, 59–63. (In Chinese)
26. Chen, T.; Chen, Z.; Tian, L. The Spatial Difference Study of Hainan's Urbanization Development in the Post—Crisis Era. *J. South China Norm. Univ. (Nat. Sci. Ed.)* **2017**, *49*, 76–83. (In Chinese)
27. Zhang, C.; Sun, Z.; Xing, Q.; Sun, J.; Xia, T.; Yu, H. Localizing Indicators of SDG11 for an Integrated Assessment of Urban Sustainability—A Case Study of Hainan Province. *Sustainability* **2021**, *13*, 11092. [CrossRef]
28. Hainan Provincial Bureau of Statistics. Hainan Statistical Yearbook. Available online: https://www.hainan.gov.cn/hainan/tjnj/list3.shtml (accessed on 6 June 2022).
29. United Nation General Assembly. *Global Indicator framework for the Sustainable Development Goals and Targets of the 2030 Agenda for Sustainable Development*; United Nation: New York, NY, USA, 2017; Available online: https://unstats.un.org/sdgs/indicators/indicators-list/ (accessed on 20 May 2022).
30. Yang, J.; Huang, X. The 30 m annual land cover dataset and its dynamics in China from 1990 to 2019. *Earth Syst. Sci. Data* **2021**, *13*, 3907–3925. [CrossRef]
31. Wei, J.; Li, Z.; Lyapustin, A.; Sun, L.; Peng, Y.; Xue, W.; Su, T.; Cribb, M. Reconstructing 1-km-resolution high-quality PM2.5 data records from 2000 to 2018 in China: Spatiotemporal variations and policy implications. *Remote. Sens. Environ.* **2020**, *252*, 112136. [CrossRef]
32. Wei, J.; Li, Z.; Cribb, M.; Huang, W.; Xue, W.; Sun, L.; Guo, J.; Peng, Y.; Li, J.; Lyapustin, A.; et al. Improved 1 km resolution PM2.5 estimates across China using enhanced space–time extremely randomized trees. *Atmospheric Meas. Tech.* **2020**, *20*, 3273–3289. [CrossRef]
33. Peng, S. *1-km Monthly Mean Temperature Dataset for China (1901–2021)*; National Tibetan Plateau/Third Pole Environment Data Center: Beijing, China, 2019. [CrossRef]
34. Peng, S.; Gang, C.; Cao, Y.; Chen, Y. Assessment of climate change trends over the Loess Plateau in China from 1901 to 2100. *Int. J. Clim.* **2017**, *38*, 2250–2264. [CrossRef]
35. Peng, S.; Ding, Y.; Wen, Z.; Chen, Y.; Cao, Y.; Ren, J. Spatiotemporal change and trend analysis of potential evapotranspiration over the Loess Plateau of China during 2011–2100. *Agric. For. Meteorol.* **2017**, *233*, 183–194. [CrossRef]
36. Ding, Y.; Peng, S. Spatiotemporal Trends and Attribution of Drought across China from 1901–2100. *Sustainability* **2020**, *12*, 477. [CrossRef]
37. Peng, S.; Ding, Y.; Liu, W.; Li, Z. 1 km monthly temperature and precipitation dataset for China from 1901 to 2017. *Earth Syst. Sci. Data* **2019**, *11*, 1931–1946. [CrossRef]
38. National Earth System Science Data Center, National Science & Technology Infrastructure of China. Available online: http://www.geodata.cn (accessed on 3 December 2021).
39. China Statistical Yearbook (County-Level). Available online: https://data.cnki.net/trade/Yearbook/Single/N2022040099?zcode=Z021 (accessed on 6 June 2022).
40. Liu, Z.; He, C.; Zhou, Y.; Wu, J. How much of the world's land has been urbanized, really? A hierarchical framework for avoiding confusion. *Landsc. Ecol.* **2014**, *29*, 763–771. [CrossRef]
41. Liu, G.; Zhang, Q.; Li, G.; Doronzo, D.M. Response of land cover types to land surface temperature derived from Landsat-5 TM in Nanjing Metropolitan Region, China. *Environ. Earth Sci.* **2016**, *75*, 1–12. [CrossRef]
42. Chen, M.; Lu, D.; Zha, L. The comprehensive evaluation of China's urbanization and effects on resources and environment. *J. Geogr. Sci.* **2010**, *20*, 17–30. [CrossRef]
43. Sahoo, M.; Sahoo, S.; Dhar, A.; Pradhan, B. Effectiveness evaluation of objective and subjective weighting methods for aquifer vulnerability assessment in urban context. *J. Hydrol.* **2016**, *541*, 1303–1315. [CrossRef]
44. Wang, Y.; Li, X.; Kang, Y.; Chen, W.; Zhao, M.; Li, W. Analyzing the impact of urbanization quality on CO2 emissions: What can geographically weighted regression tell us? *Renew. Sustain. Energy Rev.* **2019**, *104*, 127–136. [CrossRef]
45. Zhao, J.; Ji, G.; Tian, Y.; Chen, Y.; Wang, Z. Environmental vulnerability assessment for mainland China based on entropy method. *Ecol. Indic.* **2018**, *91*, 410–422. [CrossRef]
46. Yu, B.; Shi, K.; Hu, Y.; Huang, C.; Chen, Z.; Wu, J. Poverty Evaluation Using NPP-VIIRS Nighttime Light Composite Data at the County Level in China. *IEEE J. Sel. Top. Appl. Earth Obs. Remote. Sens.* **2015**, *8*, 1217–1229. [CrossRef]

47. He, Y.; Jiao, Z.; Yang, J. Comprehensive evaluation of global clean energy development index based on the improved entropy method. *Ecol. Indic.* **2018**, *88*, 305–321. [CrossRef]
48. Li, X.; Wang, K.; Liu, L.; Xin, J.; Yang, H.; Gao, C. Application of the Entropy Weight and TOPSIS Method in Safety Evaluation of Coal Mines. *Procedia Eng.* **2011**, *26*, 2085–2091. [CrossRef]
49. Tobler, W.R. A Computer Movie Simulating Urban Growth in the Detroit Region. *Econ. Geogr.* **1970**, *46*, 234–240. [CrossRef]
50. Anselin, L. The Local Indicators of Spatial Association—LISA. *Geogr. Anal.* **1995**, *27*, 93–115. [CrossRef]
51. Zhang, C.; Luo, L.; Xu, W.; Ledwith, V. Use of local Moran's I and GIS to identify pollution hotspots of Pb in urban soils of Galway, Ireland. *Sci. Total Environ.* **2008**, *398*, 212–221. [CrossRef] [PubMed]
52. Han, L.; Lu, L.; Lu, J.; Liu, X.; Zhang, S.; Luo, K.; He, D.; Wang, P.; Guo, H.; Li, Q. Assessing Spatiotemporal Changes of SDG Indicators at the Neighborhood Level in Guilin, China: A Geospatial Big Data Approach. *Remote Sens.* **2022**, *14*, 4985. [CrossRef]
53. Peng, L.; Zhang, L.; Li, X.; Wang, P.; Zhao, W.; Wang, Z.; Jiao, L.; Wang, H. Spatio-Temporal Patterns of Ecosystem Services Provided by Urban Green Spaces and Their Equity along Urban–Rural Gradients in the Xi'an Metropolitan Area, China. *Remote Sens.* **2022**, *14*, 4299. [CrossRef]
54. Xu, X.; Gao, J.; Zhang, Z.; Fu, J. An Assessment of Chinese Pathways to Implement the UN Sustainable Development Goal-11 (SDG-11)—A Case Study of the Yangtze River Delta Urban Agglomeration. *Int. J. Environ. Res. Public Heal.* **2019**, *16*, 2288. [CrossRef]
55. Prakash, M.; Ramage, S.; Kavvada, A.; Goodman, S. Open Earth Observations for Sustainable Urban Development. *Remote Sens.* **2020**, *12*, 1646. [CrossRef]