Agricultural climate change based on GIS and remote sensing image and the spatial distribution of sports public services

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Abstract

Comprehensively promoting the comprehensive improvement of my country’s agriculture, accelerating the restoration of agricultural functions, and improving the quality and efficiency of agricultural development and utilization have become important decisions to comprehensively promote the development of modern ecologically civilized rural areas and reduce the distance between cities and villages. In the process of restoring agricultural functions and promoting agricultural development, GIS technology plays a very critical role. Using GIS technology, we can easily carry out on-site surveys, sort out survey data, and perform statistical analysis to achieve the purpose of providing an auxiliary role for environmental decision-making. GIS is the abbreviation of geographic information system, using this system we can easily collect the required geographic data. The geographic location of a sports-related company will greatly affect the company’s total sales and turnover. This article mainly analyzes the relationship between the geographical distribution of some sports companies and their development by consulting related documents. During the investigation, the documents borrowed in this article mainly include the “Statistical Classification of the National Sports Industry” and a list of sports enterprise information compiled by the Ministry of Sports in 2019.

Keywords Remote sensing image · Agricultural climate · Public service · Spatial distribution

Introduction

GIS is the abbreviation of geographic information system, which involves the knowledge of geography, information engineering and hydrology, and is widely used in many fields. They usually use GIS system to look up, collect, save, statistic, and analyze geographic information. The main body of GIS system is the geographic information and data processing system based on the information space system. We cannot only use the system to detect the information of a place but also look up the detailed data of a certain area according to the huge database of the system. It is also because of the strong data processing and storage capacity of GIS system that the system will be widely used in many fields including geological environment survey, mineral resources and water resources exploration.

Application of GIS and remote sensing image in agriculture

GIS can effectively predict and control disasters

The Earth’s climate is unpredictable, and people have suffered from various extreme weather since ancient times. Whether it is flood, drought, acid rain, debris flow, or hail, it will bring great losses to agricultural development. Therefore, the effective prediction and prevention of all kinds of severe weather plays a very important role in agricultural development. In the development of these years, meteorologists have made great achievements in weather prediction and reducing the loss caused by bad weather by effectively combining GIS, GPS, and RS technology. Even if the meteorological disasters cannot be effectively predicted, meteorologists can accurately calculate the area and degree of disaster of crops suffering from meteorological disasters through GIS technology, which provides great help for disaster management and agricultural economic recovery after disasters (Egbueri et al. 2020). At the
same time, meteorologists can also use GIS technology to analyze the meteorological data of a certain area in a long period of time, and according to the analysis results, calculate the possible losses caused by the meteorological disasters in the region and provide corresponding countermeasures.

GIS technology can effectively analyze soil erosion

GIS technology has a very effective analysis effect on soil erosion and can be combined with RS technology reasonably. Scientists mainly use RS technology to take images of a certain area, and use GIS technology to analyze and process the images, input the analyzed data into the GIS system, and establish the collection system of soil erosion (Hussain et al. 2010). Through the perfect data analysis, it provides scientific data reference for the effective analysis of the later ecological status.

Application of GIS technology in soil and water conservation monitoring

In the monitoring work of soil and water conservation of land, GIS technology can be more effective, dynamic, and scientific for real-time monitoring of soil and water conservation in the monitoring area. Through scientific and effective monitoring, specific soil treatment scheme for monitoring land in this area can be formulated to avoid more serious damage to the land due to ignorance of the actual situation and blind management of the land. However, due to the short development time of GIS technology in China and the obvious geographical differences in different regions of China, it is difficult to make great progress in soil and water conservation monitoring in China.

Application of GIS in investigation and management of agricultural resources

Agricultural resources refer to all kinds of resources that agricultural workers need to use in the process of agricultural production or agricultural related economic activities. The investigation of agricultural resources is the investigation and statistics of various means of production involved in agricultural production. The monitoring and protection of ecological environment plays an important role. It is an important way to study the quality of ecological environment and establish the evaluation standard system of ecological environment quality research in China (Hydrological Division 2007). These data mainly come from soil analysis map and climate analysis map of monitoring area and some professional statistical data reports. GIS technology can combine graphics and database more intuitively, so that people cannot only get detailed data but also quickly get the required information according to the chart. This not only facilitates the storage and extraction of agricultural resources data but also makes the management and service of agricultural resources more humanized.

Application of GIS in agricultural adaptability evaluation

To vigorously promote the construction of rural ecological environment is inseparable from the monitoring of rural environmental quality. Through the investigation of water quality conditions, hydrological information, pollution and air quality, and the laws of climate and environment, relevant staff comprehensively collect and master the rural environmental quality status, and make a reasonable evaluation of agricultural adaptability. The evaluation of agricultural land adaptability refers to the comprehensive identification and monitoring of the inherent attributes of cultivated land through scientific and reasonable technical means, which are also many elements of land composition. Through the identification of the inherent attributes of cultivated land and the evaluation and classification of monitoring land according to certain standards, it can help the staff to better determine the crops suitable for different grades of land, which is an important work of land use decision-making.

Application of GIS in agricultural ecological environment research

The research on agricultural ecological environment is beneficial to the further development of agriculture in China in the new period. Through the treatment of agricultural ecological environment, we can intuitively feel the changes of agricultural production and surrounding ecological environment before and after the treatment. Good agricultural ecological environment makes the rural environment more comfortable and pleasant. In the process of harnessing agricultural production environment in rural areas, GIS technology plays a very important role. Technical personnel can establish ecological model through GIS technology, and analyze the most appropriate control measures for agricultural ecological environment in monitoring area by comparing daily monitoring data of monitoring area environment. Targeted governance work is conducive to the better development of agricultural ecological environment (Italconsult 1979). Regular monitoring can accurately help the staff to understand the current situation of rural environment, so that environmental planning can be more effective, the environmental quality of rural areas will be improved, and the construction of rural ecological civilization can be better developed.

Assessment method of agricultural disaster loss by satellite remote sensing

When evaluating the loss of crops caused by natural disasters by remote sensing technology, the staff not only
used computer technology but also applied biological principles. According to the biological characteristics of different crops, the staff will monitor the growth of these crops, and compare the parameters of these crops before and after the disaster according to the relevant standards, so as to evaluate the disaster loss degree of different crops and predict the yield, which mainly includes three important contents: extraction of classified distribution area of crops, growth monitoring, and disaster loss assessment (Camp and Roobol 1989). During the growing period of crops, the spectral characteristics of crops will change due to the influence of environmental factors (such as drought, flood, diseases, and insect pests). In this paper, the statistical model of vegetation index is used. Using spectral vegetation index and the statistical data of the plant growth process, the statistical relationship between the yield of the crop in a certain period of time and the vegetation index in this period is established, so as to count the loss of crop yield. Firstly, the land ownership data and high-resolution remote sensing data of the target monitoring area are used to complete the accurate positioning and information collection of the target area (Nosrati and Van Den 2012). At the same time, the data processing is carried out to classify the crops and extract the planting area. Then, according to the growth model of the target crop, the multi-stage crop growth monitoring in the target area is carried out (Al-Shaibani 2008). Combined with the meteorological and disaster monitoring information, the disaster damage level of the target area is evaluated. According to the classification results, the on-site sampling points are selected to obtain the on-site sampling measurement yield data, and the crop yield formula is used to calculate the total crop yield. The accuracy of the data was corrected by sampling data, and the precision of yield reduction was evaluated by comparing with the historical standard yield of crops. The specific process is shown in Fig. 1.

### Data processing

Because the meteorological data and geographical data observed by the weather station are very large, it is very difficult to calculate and count directly by hand, and it is easy to make mistakes. Therefore, the relevant staff will import all the data into excel table, classify all the data according to different data types, and then conduct statistical processing and calculation respectively (Jankowski and Acworth 1997). When importing the data, the staff found that there were obvious errors in the meteorological data of individual months in some years, and some months did not include meteorological and geographical data. If the data with large errors are deleted directly and the months without data are ignored, the final calculated average, median, and extreme value will have large errors. Therefore, the staff use statistical analysis software and spatial interpolation method to restore the missing data and modify the data with large error. When data restoration and data modification are completed, the average, median, and extreme value of all data are calculated. And because the database cited in this paper is relatively old, the software system in the computer will not be able to read part of the data (Bodrud-Doza et al. 2016). Therefore, the staff will use the file data conversion function of relevant software to convert these data into an acceptable format.

### Calculation of temporal and spatial variation of climate resources

A large number of mathematical parameters can reflect the temperature changes in the studied area. In this paper, we will mainly select several parameters with high correlation as the research content, such as median, average value, maximum value, minimum value, variance, and standard deviation

\[
S_c = \sqrt{\frac{\sum_{i=1}^{n} (c_i - \bar{c})^2}{n-1}}
\]  

(1)

In the above formula, \(s\) represents the standard deviation of the annual temperature in the region, \(C\) represents the daily temperature in the region in a year, and \(N\) represents the days of statistical temperature in the year.

\[
P_c = \frac{C_{\text{max}} - C_{\text{min}}}{\bar{c}}
\]  

(2)

In the above formula, \(P\) represents the variation range of temperature in the region in a year, \(C_{\text{max}}\) and \(C_{\text{min}}\) represent the highest and lowest temperature in the region in a year, respectively.
The $A$ in the above formula represents the change range of temperature in a certain region of the region in a year, and its magnitude is equal to the difference between the annual average temperature of a certain region in the region and the annual average temperature of the whole region divided by the annual average temperature.

$$CV = \frac{S}{\overline{C}}$$

CV in the above formula represents the coefficient of variation of temperature variation in the region within a year, which is equal to the standard deviation of the temperature in the region in a year divided by the annual average temperature of the area (Khan et al. 2020) (Figs. 2, 3, 4, and 5).

### Calculation of spatial distribution of sports public service

#### Literature method

According to the needs of the research, this study searched the papers and journals related to the research content from 2010 to 2020 by inputting keywords such as sports industry, geographical location, spatial distribution, regional industrial planning, and industrial development.

#### Location quotient

From the perspective of industrial economics, the characteristics of industrial distribution can be expressed from the perspectives of intensity, balance, and diversity of industrial distribution. This paper selects the most relevant index location quotient to express the industrial layout characteristics. The concept of location quotient was first put forward by American economist Haggett in 1860s. This scholar thinks that we can analyze the connection degree, cooperation situation, and development characteristics of the industrial structure between different regions of an enterprise by statistical analysis of the industrial distribution, industrial scale, and industrial specialization degree in different regions of an enterprise. The location quotient is calculated as follows:

$$LQ_{ij} = \frac{x_{ij}}{x_i/x}$$

In the above formula, $LQ$ represents the changes in the number of industries and the number of employees of an enterprise in the region in a year. This paper mainly studies the development and changes of various sports industries and the
total number of employees of the sports enterprises in this area in a year (El Maghraby et al. 2013). By calculating the location quotient of the sports enterprise, we cannot only get the specialization degree of the enterprise in different regions but also get the comparison between the development level of the enterprise and the development level of all enterprises in the whole region, and the proportion of the total number of employees of the sports enterprise in the total number of employees of all enterprises in the region (Hydrological Division 2007). The larger the location quotient, the higher the degree of specialization; the smaller the location quotient, the lower the degree of specialization (Abderrahman and Al-Harazin 2008). And if the location quotient of the wrong calculation is greater than one, it means that the industry development level of the sports enterprise is higher than the average development level of all enterprises in the region; if the location quotient is less than one, it means that the industry development level of the sports enterprise is lower than the average.
Fig. 4 Dynamic degree analysis of temporal and spatial changes of plant area in different stages (a 2001–2007, b 2007–2014, and c 2014–2019)

Fig. 5 Comparison of dynamic degree area and proportion of plant area (a dynamic degree area change and b dynamic degree proportion change)
development level of all enterprises in the region; if the location quotient is equal to one, it indicates the sports industry (Sakakibara et al. 2019). The development level of the industry is basically the same as the average development level of the enterprises in the region.

**Exploratory spatial data analysis**

The difference between exploratory spatial data analysis and traditional analysis is that it integrates a lot of geographical knowledge and spatial planning theory. The analysis objects of this data analysis mainly include local area and whole area.

**Global spatial autocorrelation analysis**

Global autocorrelation mainly represents the degree of association between all the research objects in the whole research area (Rogerson 2001). This kind of analysis method generally involves a wide range of contents, which can show the distribution characteristics and correlation characteristics of all research objects in the whole research area. Its disadvantage is that it cannot show readers the position and proportion of a specific object in the whole area. In the process of global spatial autocorrelation analysis, a mathematical variable is usually introduced to assist the analysis: global spatial autocorrelation statistics. The statistics are calculated as follows:

\[
I = \frac{n}{S_0} \sum_{i} \sum_{j=1}^{n} w_{ij} (x_i - \bar{x})(x_j - \bar{x}) \sum_{i} \left( x_i - \bar{x} \right)^2 
\]  

(6)

In the above formula, different mathematical symbols represent different meanings. Among them, \( X \) represents the observed values of objects in different regions, and \( S \) represents the sum of all observed objects in a certain region. When \( I \) is greater than zero and less than one, the relationship between all objects in the region is positive; when \( I \) is less than zero and greater than \(-1\), the relationship between all objects in the region is negative correlation. If \( I \) value is greater than 1 or less than \(-1\), then the calculated statistics are invalid and need to be checked and recalculated. \( Z \) should be introduced when checking \( I \) (Reddy et al. 2018). The calculation method of \( Z \) is as follows:

\[
Z = \frac{1-E(I)}{\sqrt{\text{VAR}(I)}} 
\]  

(7)

**Local spatial autocorrelation analysis**

Local spatial autocorrelation reflects the degree of association between spatial objects in a specific region in the whole region. Although the scope of regional spatial autocorrelation analysis is not as comprehensive as that of global spatial autocorrelation analysis, local analysis can effectively reflect the key changes between spatial objects caused by different regions (Garrels and Mackenzie 1967). At the same time, regional analysis can also show us the region of each spatial object and compare the spatial objects between different regions.

**Results**

**Average temperature change based on GIS and remote sensing image**

**Ten-day average temperature**

The spatial variability is mainly based on the administrative division map to divide the studied Heilongjiang Province into 13–27 10-year periods and collect the maximum, minimum, average, standard deviation, and relative variability of the annual temperature in different 10-year areas (index. see the table below for specific data) (Tables 1 and 2, Figs. 6, 7, 8, 9, and 10).

From the above table, it is not difficult to see that in all the 10-day regions, the temperature variation in the northwest is relatively large, and the temperature variation in the northeast is relatively small. Among them, the most obvious performance is that the variation of city D is large, and the variation of city B is small (Singh and Bhakar 2020).

From the table, we find that the temperature changes in different cities are different, among which the temperature changes in M, G, K, D, B, and other places are relatively large, while the changes in other areas are small.

**Spatial variability of monthly mean temperature**

The temperature changes in each month of a year in different regions are shown in the following table (Tables 3, 4, and 5):

From the above table, we find that the temperature change range in summer is not large, but in spring and autumn.

It is not difficult to find that in most areas, the temperature changes in summer are not very large, but in spring and autumn (Sivakumar et al. 2014). The most obvious performance is in A and B, and in contrast, the temperature changes in C and J are relatively gentle.

**Spatial variability of monthly mean temperature**

The annual average temperature changes in this area are shown in the following table (Table 6, 7, 8, and 9):

From the above table, we find that the order of annual temperature change in this area is A, C, E, B, and D.

From the above table, we find that there is a big difference between the temperature of different cities in this year, among which the annual average temperature of city I is the highest, and that of city m is the lowest.
Change of average precipitation based on GIS and remote sensing image

Spatial variability of 10-day precipitation

1. Spatial variation of mean precipitation in 13–27 days

The precipitation changes in different regions of the province were studied by the same method as the average temperature. The detailed precipitation statistics of each region are shown in the table below (Tables 10 and 11).

From the table, we can see that the order of precipitation in all regions of the province is A, B, C, E, D in descending order.

By analyzing the precipitation changes of different regions in the same quarter in the above table and sorting out the data, we can get the specific change of precipitation and the monthly precipitation data of the region from May to September. See Tables 12, 13, and 14 for detailed data.

By summarizing the data in Tables 11, 12, and 13, we can get the precipitation changes in different regions of the province. The detailed data are shown in Tables 15, 16, and 17.

From the above table, it is not difficult to see that the precipitation fluctuation in area D is very significant, while that in area A, B, and E is relatively stable (Table 18).

The data in the table above show that the difference of precipitation between different regions of the province is not very significant, and the rainfall in the southeast is higher than that in the northwest.

Spatial distribution characteristics of national sports towns based on GIS

Climate is the basic natural factor affecting the ecological environment of a region. Feng Xinling et al. [18] have proved that there are various climatic factors affecting human physiological comfort, among which the most important factors are air temperature, air humidity, wind speed, and sunshine. With

| Land use area name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|--------------------|--------------------|--------------------|----------------|--------------------------|-----------|---------------|-----------------------------|-------------------------|
| A                  | 13.0               | 16.6               | 14.1           | 0.82                     | 3.6       | 25.5          | −19.4                       | 0.06                    |
| B                  | 15.3               | 18.7               | 16.9           | 0.65                     | 3.4       | 20.1          | −3.4                        | 0.04                    |
| C                  | 16.3               | 19.2               | 18.3           | 0.28                     | 2.9       | 15.8          | 4.5                         | 0.02                    |
| D                  | 15.7               | 20.1               | 18.6           | 0.97                     | 4.4       | 23.7          | 6.2                         | 0.05                    |
| E                  | 16.4               | 18.9               | 18.1           | 0.33                     | 2.5       | 13.8          | 3.4                         | 0.02                    |
| Whole province     | 13.0               | 20.1               | 17.5           | 1.66                     | 7.1       | 40.6          | 0.0                         | 0.09                    |

| Place/city name    | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|--------------------|--------------------|--------------------|----------------|--------------------------|-----------|---------------|-----------------------------|-------------------------|
| A                  | 18.2               | 19.6               | 18.7           | 0.41                     | 1.4       | 7.5           | 6.9                         | 0.02                    |
| B                  | 17.2               | 20.1               | 18.8           | 0.68                     | 2.9       | 15.4          | 7.4                         | 0.04                    |
| C                  | 17.8               | 18.8               | 18.1           | 0.17                     | 1.0       | 5.5           | 3.4                         | 0.01                    |
| D                  | 16.4               | 18.3               | 17.7           | 0.47                     | 1.9       | 10.7          | 1.1                         | 0.03                    |
| E                  | 17.5               | 18.9               | 18.3           | 0.32                     | 1.4       | 7.7           | 4.6                         | 0.02                    |
| F                  | 18.8               | 20.0               | 19.7           | 0.23                     | 1.2       | 6.1           | 12.6                        | 0.01                    |
| G                  | 15.3               | 18.3               | 17.0           | 0.67                     | 3.0       | 17.6          | −2.9                        | 0.04                    |
| H                  | 17.7               | 18.7               | 18.2           | 0.19                     | 1.0       | 5.5           | 4.0                         | 0.01                    |
| I                  | 18.4               | 18.8               | 18.5           | 0.08                     | 0.4       | 2.2           | 5.7                         | 0.004                   |
| J                  | 16.3               | 18.9               | 18.2           | 0.29                     | 2.6       | 14.3          | 4.0                         | 0.02                    |
| K                  | 15.7               | 18.1               | 16.9           | 0.41                     | 2.4       | 14.2          | −3.4                        | 0.02                    |
| L                  | 16.8               | 19.7               | 18.5           | 0.70                     | 2.9       | 15.7          | 5.7                         | 0.04                    |
| M                  | 13.0               | 16.6               | 14.1           | 0.82                     | 3.6       | 46.8          | −19.4                       | 0.06                    |
| Whole province     | 13.0               | 20.1               | 17.5           | 1.66                     | 7.1       | 40.5          | 0.0                         | 0.09                    |
the concept of “sports leisure + tourism,” the geographical environment of the small town with sports characteristics is closely related to the natural climate. According to the regional statistics, 56 of the first 96 sports towns in China are distributed in the tropical zone, 37 in the temperate zone, and only 3 in the plateau climate zone. Statistical data show that sports towns are mainly distributed in the tropics, followed by temperate zones (Bamousa 2011). However, due to the difference in the number of distributions in the tropical and temperate zones is not obvious, it can only be inferred that climate has a certain impact on the distribution of sports towns, but not a direct influencing factor, which cannot be identified as the main reason for the distribution of sports characteristic towns, and further analysis is needed.

Among them, the distribution characteristics of middle temperate sports towns are mostly located in the south temperate zone, or in the junction with the southern temperate zone. The number of regional statistics is made into a broken line chart (see Fig. 1). From Fig. 1, it can be seen that the number of sports characteristic towns in each climate zone is
in the shape of “mountain peaks.” In addition to the plateau climate zone, the number of sports characteristic towns is gradually decreasing to the north and south sides with the north subtropical zone as the center. The results show that there is a great relationship between the climate zone and the spatial distribution of sports towns, but according to the broken line chart, there seems to be more critical factors (Georhage 1979; Lloyd and Heathcoat 1985). The climate zone cannot be determined as the direct factor affecting the spatial distribution of sports characteristic towns, and further analysis is needed. Based on this, this study analyzes the characteristics of 9 climatic zones (see Table 1). It can be seen from Table 1 that the climate environment in the plateau climate zone and the north temperate zone is relatively bad, and the perennial temperature in the marginal tropical and middle tropical zone is relatively high, and there are many natural disasters (Bob et al. 2016). Therefore, it is relatively difficult to construct sports characteristic towns, and the investment risk is higher, and the distribution of sports characteristic towns is less. In the middle of China, the climate environment...
of the middle subtropical, north subtropical, and warm temperate zone is relatively stable, and the natural disasters are less, so the distribution number of sports characteristic towns is naturally more. In addition, it can be found in Table 1 that two factors are more prominent—temperature and rainfall. In order to further analysis, based on the distribution of annual average temperature and annual rainfall in China in 2017, 96 sports characteristic towns were set as point elements, which were imported into China’s average temperature map (2017) and China’s average rainfall map (2017) for overlay analysis. From the overlay analysis of 96 individual education characteristic towns and China’s average temperature map, we found that most of the sports characteristic towns are located in the average annual temperature of the site is between 8 and 20 °C (Ukah et al. 2019). On the whole, the number of sports characteristic towns increases with the increase of temperature, and decreases when it reaches a certain temperature critical point. In fact, on the relationship between temperature and development, Burkem et al. of the University of California, USA, conducted statistics on the data of 166 countries from 1966 to 2010, and found that: the economic development rate will rise with the temperature at the beginning, and will gradually decrease when the temperature reaches 13 °C. The higher the temperature, the faster the decline of productivity will be (Carlson et al. 2011) (Table 19).

Table 3 Monthly average temperature statistics

| Month | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Coefficient of variation |
|-------|-------------------|--------------------|-----------------|------------------------|-----------|-------------------------|
| 1     | −28.2             | −13.6              | −20.5           | 2.9                    | 14.6      | 71.2                    | 0.14 |
| 2     | −23.3             | −8.6               | −15.0           | 3.1                    | 14.7      | −98.0                   | −0.21|
| 3     | −13.1             | −1.4               | −6.0            | 2.6                    | 11.7      | −195.0                  | −0.43|
| 4     | 0.3               | 8.3                | 5.6             | 1.9                    | 8.0       | 142.9                   | 0.34 |
| 5     | 9.0               | 16.0               | 13.4            | 1.7                    | 7.0       | 52.2                    | 0.13 |
| 6     | 15.1              | 22.1               | 19.3            | 1.5                    | 7.0       | 36.3                    | 0.08 |
| 7     | 18.3              | 24.3               | 21.9            | 1.2                    | 6.0       | 27.4                    | 0.05 |
| 8     | 14.9              | 21.8               | 19.6            | 1.6                    | 6.9       | 35.2                    | 0.08 |
| 9     | 6.8               | 16.2               | 13.1            | 2.2                    | 9.4       | 71.8                    | 0.17 |
| 10    | −3.9              | 6.8                | 3.2             | 2.5                    | 10.7      | 334.4                   | 0.78 |
| 11    | −19.6             | −3.8               | −9.8            | 3.8                    | 15.8      | −161.2                  | −0.39|
| 12    | −26.9             | 11.2               | −18.3           | 3.5                    | 15.7      | −85.8                   | −0.19|
### Table 4  Statistical data of regional average temperature from May to September

| Land use area name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|--------------------|--------------------|--------------------|----------------|-------------------------|-----------|---------------|-----------------------------|-------------------------|
| A                  | 12.9               | 16.4               | 14.0           | 0.82                    | 3.5       | 25.0          | -19.5                       | 0.06                    |
| B                  | 15.2               | 18.6               | 16.8           | 0.64                    | 3.4       | 20.2          | -3.4                        | 0.06                    |
| C                  | 16.2               | 19.1               | 18.2           | 0.28                    | 2.9       | 15.9          | 4.6                         | 3.02                    |
| D                  | 15.6               | 20.1               | 18.5           | 0.97                    | 4.5       | 24.3          | 6.3                         | 0.05                    |
| E                  | 16.4               | 18.8               | 18.1           | 0.33                    | 2.4       | 13.3          | 4.0                         | 0.02                    |
| **Whole province** | **12.9**           | **20.1**           | **17.4**       | **16.6**                | **7.2**   | **41.4**      | **0.0**                     | **0.10**                |

### Table 5  Statistical data of average temperature from May to September in different regions/cities

| Place/city name   | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|-------------------|--------------------|--------------------|----------------|-------------------------|-----------|---------------|-----------------------------|-------------------------|
| A                 | 18.1               | 19.5               | 18.6           | 0.41                    | 1.4       | 7.5           | 6.9                         | 0.02                    |
| B                 | 17.1               | 20.1               | 18.7           | 0.68                    | 3.0       | 16.0          | 7.5                         | 0.04                    |
| C                 | 17.7               | 18.7               | 18.0           | 0.17                    | 1.0       | 5.6           | 3.4                         | 0.01                    |
| D                 | 16.4               | 18.2               | 17.7           | 0.47                    | 1.8       | 10.2          | 1.7                         | 0.03                    |
| E                 | 17.4               | 18.8               | 18.2           | 0.33                    | 1.4       | 7.7           | 4.6                         | 0.02                    |
| F                 | 18.7               | 19.9               | 19.6           | 0.23                    | 1.2       | 6.1           | 12.6                        | 0.01                    |
| G                 | 15.2               | 18.2               | 16.9           | 0.67                    | 3.0       | 17.8          | -2.9                        | 0.04                    |
| H                 | 17.6               | 18.6               | 18.1           | 0.20                    | 1.0       | 5.5           | 4.0                         | 0.01                    |
| I                 | 18.3               | 18.7               | 18.4           | 0.08                    | 0.4       | 2.2           | 5.7                         | 0.004                   |
| J                 | 16.2               | 18.8               | 18.1           | 0.28                    | 2.6       | 14.4          | 4.0                         | 0.02                    |
| K                 | 15.6               | 18.0               | 16.8           | 0.42                    | 2.4       | 14.3          | -3.4                        | 0.03                    |
| L                 | 16.7               | 19.6               | 18.5           | 0.70                    | 2.9       | 15.7          | 6.3                         | 0.04                    |
| M                 | 12.9               | 16.4               | 14.0           | 0.82                    | 3.5       | 25.0          | -19.5                       | 0.06                    |
| **Whole province**| **12.9**           | **20.1**           | **17.4**       | **16.6**                | **7.2**   | **41.4**      | **0.0**                     | **0.10**                |

### Table 6  Statistical data table of regional average temperature

| Land use area name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|--------------------|--------------------|--------------------|----------------|-------------------------|-----------|---------------|-----------------------------|-------------------------|
| A                 | -4.1               | 0.0                | -2.5           | 0.94                    | 4.1       | -164.0        | -213.6                      | -0.38                   |
| B                 | 4.3                | 3.8                | 1.2            | 0.99                    | 4.1       | 341.7         | 45.5                        | 0.83                    |
| C                 | 2.9                | 5.7                | 4.1            | 0.38                    | 2.8       | 68.3          | 86.4                        | 0.09                    |
| D                 | -0.5               | 5.3                | 3.1            | 1.38                    | 5.8       | 187.1         | 40.9                        | 0.45                    |
| E                 | 0.9                | 4.8                | 3.4            | 0.65                    | 3.9       | 114.7         | 54.8                        | 0.19                    |
| **Whole province**| **-4.1**           | **5.7**            | **2.2**        | **2.37**                | **9.8**   | **448.5**     | **0.0**                     | **1.08**                |
### Table 7  
Statistical data table of annual average temperature of each district/city

| Place/city name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|----------------|--------------------|--------------------|-----------------|------------------------|-----------|---------------|-----------------------------|-------------------------|
| A              | 2.8                | 5.0                | 3.9             | 0.55                   | 2.2       | 56.4          | 77.3                        | 0.14                    |
| B              | 1.2                | 5.3                | 3.3             | 1.05                   | 4.1       | 124.2         | 50.0                        | 0.32                    |
| C              | 3.0                | 4.5                | 3.9             | 0.32                   | 1.5       | 38.5          | 77.3                        | 0.08                    |
| D              | 0.9                | 3.7                | 2.7             | 0.64                   | 2.8       | 103.7         | 22.7                        | 0.24                    |
| E              | 2.6                | 4.6                | 3.6             | 0.55                   | 2.0       | 55.6          | 63.6                        | 0.15                    |
| F              | 3.2                | 4.9                | 4.5             | 0.36                   | 1.7       | 37.8          | 104.5                       | 0.08                    |
| G              | −0.1               | 3.5                | 1.6             | 0.92                   | 3.6       | 225.0         | −27.3                       | 0.58                    |
| H              | 2.5                | 4.4                | 3.2             | 0.45                   | 1.9       | 59.4          | 45.5                        | 0.14                    |
| I              | 4.0                | 4.8                | 4.4             | 0.14                   | 0.8       | 182           | 100.0                       | 0.03                    |
| J              | 3.2                | 5.7                | 4.2             | 0.35                   | 2.5       | 59.5          | 90.9                        | 0.08                    |
| K              | −0.5               | 2.4                | 0.80            | 0.48                   | 2.9       | 362.5         | −63.6                       | 0.60                    |
| L              | 1.3                | 4.8                | 3.1             | 0.84                   | 3.5       | 112.9         | 40.9                        | 0.27                    |
| M              | −4.1               | 0.0                | −2.5            | 0.94                   | 4.1       | −164.0        | −213.6                      | −0.38                   |
| Whole province | −4.1               | 5.7                | 2.2             | 2.37                   | 9.8       | 445.5         | 0.0                         | 1.08                    |

### Table 8  
Statistical table of interannual variation of 10-day mean temperature

| Ten days | Minimum (°C) | Maximum (°C) | Mean value (°C) | Standard deviation (°C) | k | $R^2$ | Ten days | Minimum (°C) | Maximum (°C) | Mean value (°C) | Standard deviation (°C) | k | $R^2$ |
|----------|--------------|--------------|-----------------|------------------------|---|------|----------|--------------|--------------|-----------------|------------------------|---|------|
| 1        | −23.9        | 46.8         | −20.2           | 2.2                    | 0.329 | 0.200 | 19       | 19.8         | 25.4         | 22.2            | 1.9                     | −0.102 | 0.027 |
| 2        | −27.9        | −15.2        | −20.4           | 4.3                    | 0.094 | 0.004 | 20       | 20.1         | 25.5         | 22.8            | 1.5                     | −0.243 | 0.250 |
| 3        | −20.1        | −16.5        | −18.6           | 1.1                    | 0.052 | 0.022 | 21       | 19.9         | 24.3         | 21.0            | 1.4                     | 4.314   | 0.471 |
| 4        | −25.4        | −15.7        | −17.4           | 3.7                    | −0.435 | 0.130 | 22       | 19.6         | 23.9         | 21.6            | 1.5                     | 0.110   | 0.052 |
| 5        | −17.6        | −11.2        | 44.1            | 2.5                    | −0.050 | 0.004 | 23       | 17.6         | 22.7         | 20.5            | 1.6                     | −0.041  | 0.006 |
| 6        | −17.3        | −4.6         | −10.8           | 4.0                    | −0.705 | 0.279 | 24       | 17.3         | 20.2         | 18.8            | 1.1                     | 0.074   | 0.041 |
| 7        | −13.7        | −2.0         | −9.6            | 3.7                    | −0.179 | 0.022 | 25       | 13.4         | 20.1         | 16.6            | 1.7                     | −0.344  | 0.158 |
| 8        | −10.1        | 0.9          | −4.5            | 2.8                    | 0.157 | 0.029 | 26       | 9.8          | 15.9         | 13.5            | 2.1                     | 0.515   | 0.348 |
| 9        | −4.8         | 3.0          | −1.1            | 2.5                    | 0.114 | 0.020 | 27       | 10.5         | 14.4         | 12.6            | 1.4                     | 0.189   | 0.333 |
| 10       | 0.8          | 7.0          | 3.8             | 1.9                    | 0.191 | 0.098 | 28       | 4.0          | 12.0         | 8.6             | 2.0                     | 0.557   | 0.686 |
| 11       | 2.0          | 10.1         | 8.8             | 2.2                    | −0.393 | 0.298 | 29       | 2.1          | 8.4          | 5.0             | 2.2                     | 0.088   | 0.014 |
| 12       | 7.4          | 10.5         | 9.1             | 1.2                    | −0.291 | 0.582 | 30       | −3.2         | 4.3          | 1.0             | 2.1                     | −0.048  | 0.005 |
| 13       | 7.4          | 13.4         | 10.8            | 1.9                    | 1.107 | 0.028 | 31       | −7.0         | 1.0          | −2.4            | 2.5                     | 0.091   | 0.012 |
| 14       | 12.0         | 19.0         | 14.9            | 2.2                    | −0.193 | 0.073 | 32       | −13.3        | −3.4         | −7.3            | 3.3                     | 0.110   | 0.010 |
| 15       | 14.0         | 18.3         | 16.0            | 1.4                    | 0.289 | 0.398 | 33       | −17.5        | −6.7         | −12.6           | 3.8                     | 0.302   | 0.058 |
| 16       | 14.3         | 19.7         | 17.7            | 1.5                    | 0.300 | 0.178 | 34       | −20.2        | −11.3        | −16.0           | 2.7                     | 0.160   | 0.033 |
| 17       | 16.4         | 22.6         | 19.7            | 2.2                    | −0.157 | 0.048 | 35       | −21.2        | −11.6        | −17.0           | 1.8                     | −0.407  | 0.199 |
| 18       | 19.8         | 23.0         | 21.6            | 1.2                    | −0.020 | 0.003 | 36       | −25.7        | −12.7        | −18.1           | 4.0                     | −0.132  | 0.010 |
Table 9  Linear trend line parameters of 10-day interannual temperature moving average

| Ten-day period | Slope $k$ | Intercept $b$ | Correlation coefficient $R^2$ | Ten-day period | Slope $k$ | Intercept $b$ | Correlation coefficient $R^2$ |
|----------------|-----------|---------------|-------------------------------|----------------|-----------|---------------|-------------------------------|
| 26–28          | 0.40      | 9.81          | 0.89                          | 23–25          | −0.15     | 19.39         | 0.52                          |
| 27–29          | 0.31      | 7.34          | 0.88                          | 21–23          | −0.14     | 21.94         | 0.44                          |
| 19–21          | −0.30     | 23.71         | 0.83                          | 16–18          | 0.12      | 19.25         | 0.46                          |
| 15–17          | 0.18      | 17.03         | 0.74                          | 10–12          | 9.17      | 7.05          | 0.32                          |
| 10–13          | 0.22      | 9.67          | 0.58                          | 25–27          | 0.11      | 13.83         | 0.46                          |
| 18–20          | −0.21     | 23.22         | 0.53                          | 17–19          | −0.09     | 21.67         | 0.25                          |
| 12–14          | −0.21     | 12.60         | 0.42                          | 14–16          | 0.09      | 15.82         | 0.17                          |
| 20–22          | −0.20     | 22.97         | 0.43                          | 24–26          | 0.05      | 19.39         | 0.82                          |

Table 10  Statistical data table of regional average precipitation in ten days of 13–27 days

| Land use area name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|--------------------|---------------------|--------------------|-----------------|-------------------------|-----------|---------------|----------------------------|-------------------------|
| A                  | 22.3                | 28.3               | 25.8            | 1.1                     | 6.0       | 23.3          | −9.2                       | 0.04                    |
| B                  | 28.0                | 32.4               | 30.5            | 1.2                     | 4.4       | 14.4          | 7.4                        | 0.04                    |
| C                  | 26.9                | 32.3               | 29.5            | 1.3                     | 5.4       | 8.3           | 3.9                        | 0.04                    |
| D                  | 22.7                | 32.5               | 28.9            | 2.2                     | 9.8       | 33.9          | 1.8                        | 0.08                    |
| E                  | 21.4                | 31.8               | 27.2            | 1.9                     | 10.4      | 58.2          | −4.2                       | 0.07                    |
| Whole province     | 21.4                | 32.5               | 28.4            | 2.3                     | 11.1      | 39.1          | 0.0                        | 0.08                    |

Table 11  Statistical data table of average precipitation in ten days of 13–27 days in different regions/cities

| Place/city name   | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|-------------------|--------------------|--------------------|-----------------|-------------------------|-----------|---------------|----------------------------|-------------------------|
| A                 | 27.3               | 32.3               | 30.9            | 0.9                     | 5.0       | 16.2          | 8.8                        | 0.03                    |
| B                 | 22.7               | 31.4               | 27.4            | 2.2                     | 8.7       | 31.8          | −3.5                       | 0.08                    |
| C                 | 25.0               | 28.7               | 26.5            | 0.8                     | 3.7       | 14.0          | −6.7                       | 0.03                    |
| D                 | 26.4               | 31.2               | 29.2            | 1.2                     | 4.8       | 16.4          | 2.8                        | 0.04                    |
| E                 | 24.4               | 29.2               | 26.1            | 0.9                     | 4.8       | 18.4          | −8.1                       | 0.03                    |
| F                 | 23.7               | 28.5               | 26.2            | 1.0                     | 4.8       | 18.3          | −7.7                       | 0.04                    |
| G                 | 28.3               | 32.4               | 31.1            | 1.1                     | 4.1       | 13.2          | 9.5                        | 0.04                    |
| H                 | 21.4               | 31.6               | 26.9            | 2.2                     | 10.2      | 37.9          | −5.3                       | 0.08                    |
| I                 | 26.4               | 29.9               | 27.9            | 0.9                     | 3.5       | 12.5          | −1.8                       | 0.03                    |
| J                 | 26.9               | 31.1               | 28.8            | 0.9                     | 4.2       | 14.6          | 1.4                        | 0.03                    |
| K                 | 28.0               | 32.1               | 29.8            | 0.9                     | 4.1       | 13.8          | 4.9                        | 0.03                    |
| L                 | 26.2               | 32.5               | 30.2            | 1.6                     | 6.3       | 20.9          | 6.3                        | 0.05                    |
| M                 | 22.3               | 28.3               | 25.8            | 1.1                     | 6.0       | 23.3          | −9.1                       | 0.04                    |
| Whole province    | 21.4               | 32.5               | 28.4            | 2.3                     | 11.1      | 39.1          | 0.0                        | 0.08                    |
### Table 12: Monthly precipitation statistics

| Month | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor Variation (°C) | Coefficient of variation |
|-------|--------------------|--------------------|-----------------|-------------------------|---------------------|--------------------------|
| 1     | 2.1                | 15.3               | 7.7             | 2.7                     | 13.2                | 171.4                    | 0.35 |
| 2     | 0.4                | 9.5                | 3.6             | 1.5                     | 9.1                 | 252.8                    | 0.42 |
| 3     | 2.0                | 18.7               | 10.5            | 4.0                     | 16.7                | 159.0                    | 0.38 |
| 4     | 14.7               | 36.5               | 26.7            | 4.9                     | 21.8                | 81.6                     | 0.18 |
| 5     | 17.3               | 74.9               | 46.6            | 10.4                    | 57.6                | 123.6                    | 0.22 |
| 6     | 39.5               | 98.7               | 74.6            | 10.9                    | 59.2                | 79.4                     | 0.15 |
| 7     | 74.4               | 171.0              | 139.2           | 17.4                    | 96.6                | 69.4                     | 0.13 |
| 8     | 68.4               | 171.9              | 135.6           | 24.0                    | 103.5               | 76.3                     | 0.18 |
| 9     | 14.5               | 45.5               | 38.9            | 6.0                     | 31.0                | 79.7                     | 0.15 |
| 10    | 7.2                | 38.4               | 26.1            | 6.7                     | 31.2                | 119.5                    | 0.26 |
| 11    | 2.0                | 20.2               | 8.7             | 3.3                     | 18.2                | 209.2                    | 0.38 |
| 12    | 2.2                | 8.3                | 8.7             | 1.2                     | 6.1                 | 107.0                    | 0.21 |

### Table 13: Statistical data table of monthly precipitation (average) in the region from May to September

| Land use area name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor Variation (°C) | Relative rate of change (%) | Coefficient of variation |
|--------------------|--------------------|--------------------|-----------------|-------------------------|---------------------|-----------------------------|--------------------------|
| A                  | 66.9               | 84.9               | 77.4            | 3.5                     | 18.0                | −9.3                        | 0.05                     |
| B                  | 84.2               | 97.3               | 91.6            | 3.7                     | 13.1                | 7.4                         | 0.04                     |
| C                  | 80.9               | 96.9               | 83.6            | 4.1                     | 16.0                | 3.9                         | 0.05                     |
| D                  | 68.2               | 97.5               | 86.8            | 6.8                     | 29.3                | 1.8                         | 0.08                     |
| E                  | 64.3               | 95.5               | 81.7            | 5.9                     | 31.2                | 4.2                         | 0.07                     |
| Whole province     | 64.3               | 97.5               | 85.3            | 7.1                     | 33.2                | 0.0                         | 0.08                     |

### Table 14: Statistical data table of monthly precipitation (average) from May to September in each region/city

| Place/city name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor Variation (°C) | Relative rate of change (%) | Coefficient of variation |
|-----------------|--------------------|--------------------|-----------------|-------------------------|---------------------|-----------------------------|--------------------------|
| A               | 81.9               | 96.9               | 92.7            | 2.8                     | 15.0                | 8.7                         | 0.03                     |
| B               | 68.2               | 94.2               | 82.2            | 6.6                     | 26.0                | −3.6                        | 0.08                     |
| C               | 75.0               | 86.3               | 79.7            | 2.4                     | 11.3                | −6.6                        | 0.03                     |
| D               | 79.4               | 93.7               | 87.6            | 3.8                     | 14.3                | 2.7                         | 0.04                     |
| E               | 73.4               | 87.8               | 78.5            | 2.8                     | 14.4                | −8.0                        | 0.04                     |
| F               | 71.3               | 85.5               | 71.6            | 3.2                     | 14.2                | 7.9                         | 0.04                     |
| G               | 85.0               | 97.3               | 93.3            | 3.4                     | 12.3                | 9.4                         | 0.04                     |
| H               | 64.3               | 95.0               | 80.8            | 6.8                     | 30.7                | −5.3                        | 0.08                     |
| I               | 79.2               | 89.9               | 83.7            | 2.8                     | 10.7                | −1.9                        | 0.03                     |
| J               | 90.9               | 93.4               | 86.6            | 2.9                     | 12.5                | 1.5                         | 0.03                     |
| K               | 84.0               | 96.3               | 89.5            | 2.9                     | 12.3                | 4.9                         | 0.03                     |
| L               | 78.6               | 97.5               | 90.6            | 4.9                     | 18.9                | 6.2                         | 0.05                     |
| M               | 66.9               | 84.9               | 77.4            | 3.5                     | 18.0                | −9.3                        | 0.05                     |
| Whole province   | 64.3               | 97.5               | 85.3            | 7.1                     | 33.2                | 0.0                         | 0.08                     |
Table 15  Regional precipitation statistics from May to September

| Land use area name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|--------------------|--------------------|--------------------|----------------|------------------------|-----------|---------------|-----------------------------|------------------------|
| A                  | 334.9              | 424.9              | 387.0          | 17.6                   | 90.0      | 23.3          | −9.3                        | 0.05                   |
| B                  | 421.3              | 486.8              | 458.1          | 18.5                   | 65.5      | 14.3          | 7.4                         | 0.04                   |
| C                  | 404.5              | 484.6              | 443.0          | 20.6                   | 80.1      | 18.1          | 3.9                         | 0.05                   |
| D                  | 341.0              | 487.9              | 434.0          | 34.2                   | 146.9     | 33.8          | 1.8                         | 0.08                   |
| E                  | 321.5              | 477.9              | 408.9          | 29.5                   | 156.4     | 38.2          | −4.1                        | 0.07                   |
| Whole province     | 321.5              | 487.9              | 426.5          | 35.5                   | 166.4     | 39.0          | 0.0                         | 0.08                   |

Table 16  Statistical data of precipitation from May to September in different regions/cities

| Place/city name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|-----------------|--------------------|--------------------|----------------|------------------------|-----------|---------------|-----------------------------|------------------------|
| A               | 409.9              | 484.6              | 463.7          | 14.0                   | 74.7      | 16.1          | 8.7                         | 0.03                   |
| B               | 341.0              | 471.4              | 411.0          | 33.3                   | 130.4     | 31.7          | −3.6                        | 0.08                   |
| C               | 375.4              | 431.8              | 398.6          | 12.4                   | 56.4      | 14.1          | 4.5                         | 0.03                   |
| D               | 397.0              | 468.5              | 438.2          | 19.4                   | 71.5      | 16.3          | 1.7                         | 0.04                   |
| E               | 367.4              | 439.0              | 392.6          | 14.2                   | 71.6      | 18.2          | −7.9                        | 0.04                   |
| F               | 356.8              | 427.5              | 393.0          | 16.0                   | 70.7      | 18.0          | −7.9                        | 0.04                   |
| G               | 425.2              | 486.8              | 466.9          | 17.2                   | 61.6      | 13.2          | 9.5                         | 0.04                   |
| H               | 321.5              | 475.1              | 404.3          | 34.2                   | 153.6     | 38.0          | −5.2                        | 0.03                   |
| I               | 396.4              | 449.6              | 418.9          | 14.0                   | 83.2      | 12.7          | −1.8                        | 0.03                   |
| J               | 404.5              | 4673               | 433.1          | 14.9                   | 62.8      | 14.5          | 1.1                         | 0.03                   |
| K               | 420.3              | 481.8              | 447.9          | 14.7                   | 61.5      | 13.7          | 5.0                         | 0.03                   |
| L               | 393.1              | 487.9              | 453.3          | 24.9                   | 94.8      | 20.9          | 6.3                         | 0.05                   |
| M               | 334.9              | 424.9              | 387.0          | 17.6                   | 90.0      | 23.3          | −9.3                        | 0.05                   |
| Whole province   | 321.5              | 487.9              | 426.5          | 35.5                   | 166.4     | 39.0          | 0.0                         | 0.08                   |

Table 17  Statistical data table of regional annual precipitation

| Land use area name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|--------------------|--------------------|--------------------|----------------|------------------------|-----------|---------------|-----------------------------|------------------------|
| A                  | 420.5              | 523.2              | 486.2          | 19.3                   | 107.7     | 22.2          | −7.3                        | 0.04                   |
| B                  | 521.8              | 592.3              | 562.8          | 18.4                   | 70.5      | 12.5          | 7.3                         | 0.03                   |
| C                  | 522.7              | 583.7              | 547.2          | 15.7                   | 61.0      | 11.1          | 4.3                         | 0.03                   |
| D                  | 381.1              | 589.5              | 510.9          | 49.4                   | 208.4     | 40.8          | −2.6                        | 0.10                   |
| E                  | 460.8              | 583.3              | 531.1          | 20.4                   | 122.5     | 23.1          | 1.2                         | 0.04                   |
| Whole province     | 381.1              | 592.3              | 524.6          | 40.8                   | 211.2     | 40.3          | 0.0                         | 0.08                   |
Spatial distribution of sports public service

China’s sports enterprises involve many industries, including sports equipment manufacturing industry, sports fitness service industry, sports event performance industry, sports information and media service industry, and sports intermediary service industry (Magdy 2015). Most of the industries are distributed in the eastern and southern regions of China, and the geographical location of sports industry has a very obvious cluster characteristic. In addition, the distribution of industrial structure in different regions of China is quite different (Bhakar and Singh 2019; Yetiş et al. 2019). The sports industry in Northeast and Northwest China is mainly tourism and leisure service industry and fitness activity center, while the central and southern regions are mainly physical training institutions and sports education industry, while the central and western regions are mainly composed of sports buildings and sports venues service industry (Egbueri 2018) (Table 20).

Discussion

Prospect of agricultural climate monitoring based on GIS and remote sensing images

Soil moisture is the result of the comprehensive action of temperature, precipitation and other meteorological factors in a certain time window, and it is the integrator of local meteorological conditions. From this point of view, compared with a single meteorological index, drought monitoring based on soil moisture information has its own advantages (Yidana et al. 2008). The increase of soil moisture observation data sources is more conducive to the direct monitoring of agricultural drought from the perspective of soil drought (Egbueeri and Unigwe 2020).

Suggestions on location layout management of sports industry

This paper describes the challenges and opportunities of agricultural drought monitoring based on soil moisture. The premise of applying soil moisture data to agricultural drought monitoring is to have better timeliness, and at the same time, it needs to have high spatial resolution and accuracy, so as to timely and accurately monitor the farmland soil moisture status at the plot scale (Egbueeri 2020). However, most of the existing operational microwave soil moisture products are resampled to about 25 km, which is difficult to meet the practical application requirements in spatial resolution. At present, the methods to obtain high-resolution soil moisture information include (1) constructing the correlation function of high-resolution data, such as coarse-resolution soil moisture and vegetation index, Bi, st, etc., for downscaling estimation; (2) using synthetic aperture radar (SAR) high-resolution data (such as Sentinel-1) combined with vegetation index, based on Semi empirical models such as water cloud model and change detection model, or improved integration Microwave scattering models such as AIEM are used for inversion; (3) data driven methods such as machine learning are used for calculation. No matter what kind of methods, only relying on physical model or data-driven

### Table 18 Statistical data table of annual precipitation of each region/city

| Place/city name | Minimum value (°C) | Maximum value (°C) | Mean value (°C) | Standard deviation (°C) | Poor (°C) (°C) | Variation (%) | Relative rate of change (%) | Coefficient of variation |
|-----------------|--------------------|--------------------|----------------|------------------------|----------------|--------------|-----------------------------|----------------------|
| A               | 475.8              | 585.8              | 556.3          | 21.8                   | 110.0          | 19.8         | 6.0                         | 0.04                 |
| B               | 381.1              | 560.8              | 477.3          | 46.7                   | 179.7          | 37.6         | -9.0                        | 0.10                 |
| C               | 515.4              | 540.3              | 523.9          | 4.8                    | 24.9           | 4.8          | -0.1                        | 0.01                 |
| D               | 524.3              | 579.3              | 553.7          | 15.4                   | 55.0           | 9.9          | 5.5                         | 0.03                 |
| E               | 508.6              | 550.2              | 519.2          | 7.2                    | 41.6           | 8.0          | -1.0                        | 0.01                 |
| F               | 402.3              | 495.4              | 449.0          | 21.1                   | 93             | 20.7         | -14.4                       | 0.05                 |
| G               | 539.8              | 592.3              | 574.3          | 13.9                   | 82.5           | 9.1          | 9.5                         | 0.02                 |
| H               | 460.8              | 583.3              | 528.6          | 23.3                   | 122.5          | 23.2         | 0.8                         | 0.04                 |
| I               | 514.0              | 555.8              | 529.7          | 10.8                   | 41.8           | 7.9          | 1.0                         | 0.02                 |
| J               | 522.7              | 568.7              | 539.7          | 10.9                   | 46.0           | 8.5          | 2.9                         | 0.02                 |
| K               | 509.5              | 578.9              | 546.2          | 15.9                   | 69.4           | 12.7         | 4.1                         | 0.03                 |
| L               | 448.4              | 589.5              | 533.7          | 37.8                   | 141.1          | 26.4         | 1.7                         | 0.07                 |
| M               | 420.5              | 528.2              | 486.2          | 19.3                   | 107.7          | 22.2         | 0.73                        | 0.04                 |
| Whole province  | 381.1              | 592.3              | 524.6          | 40.8                   | 211.2          | 40.3         | 0.0                         | 0.08                 |
paradigm cannot achieve good soil moisture retrieval effect. Future research will tend to use semi-empirical model or machine learning method with physical mechanism (Bob et al. 2015; Molugaram and Rao 2017). At the same time, as mentioned above, in the global range, active microwave and passive microwave soil moisture products have certain complementarity in different vegetation coverage areas, so improving the accuracy of soil moisture inversion through multi-source data fusion (including active and passive microwave fusion, visible light, and microwave fusion) will also be the focus of future research (Hofmann et al. 2015).

**Conclusion**

Agricultural drought has a negative impact on agricultural production, which threatens the food safety of human society. As the most direct characterization variable in agricultural drought monitoring, it is very important to obtain high-quality soil moisture data. In this paper, the soil moisture data observed by stations and microwave remote

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**Table 19**

Analysis on the quantity and climate characteristics of the first batch of national sports characteristic towns distributed in 9 climatic zones

| Climate type         | Climate characteristics                                                                 | Distribution number (small towns at the junction of climatic zones have combined two climates) |
|----------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| Plateau climate zone | Low pressure and hypoxia are prone to altitude sickness, cold and dry, large temperature difference, little rainfall, long sunshine time, strong solar radiation, strong wind, strong winds, thunderstorms and hail. | 3                                                                                              |
| North Temperate      | The four seasons change significantly, and it is affected by polar air masses throughout the year. In winter, the surface water temperature is low, the salinity is low, and the oxygen content is high. | 0                                                                                              |
| Middle temperate zone| Summer temperature, cold winter, long winter, average annual temperature between 2 and 8 °C, distinct dry and wet seasons, high humidity throughout the year, annual average precipitation rate 400–800 mm | 14                                                                                             |
| Warm temperate zone  | The temperature varies greatly in each season, the summer is hot and rainy, and the winter is cold and dry. The four seasons change obviously. The length of day and night varies greatly. The average temperature is about 8 °C–13 °C. The average annual precipitation is 400–1000 mm, and the local area is more than 1000 mm. | 25                                                                                             |
| North Subtropical    | The summer is hot and rainy, and the winter is mild and rainy. The annual average temperature is about 13.5 °C–16.5 °C, the annual accumulated temperature is 4250 °C–5300 °C, and the annual rainfall is 900–1300 mm. | 28                                                                                             |
| Central subtropical  | The annual rainfall is abundant, and the average temperature is 13 °C–20 °C. The annual accumulated temperature is 5000 °C–6000 °C. The annual precipitation is above 1500 mm. | 25                                                                                             |

**Table 19 (continued)**

| Climate type         | Climate characteristics                                                                 | Distribution number (small towns at the junction of climatic zones have combined two climates) |
|----------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| South subtropical    | Affected by typhoons, the frost-free period is more than 300 days. The annual average temperature is above 10 °C. With an annual accumulation of 5000 °C–8000 °C, there is basically no climatological winter. | 9                                                                                              |
| Edge tropical        | In typhoon-prone areas, the annual average temperature is 20 °C–30 °C, the annual average daily temperature is 21 °C, and the annual precipitation is more than 1500 mm. | 2                                                                                              |
| Middle tropical      | Typhoon-prone areas, controlled by subtropical high pressure throughout the year, with an annual accumulated temperature of 9000 °C–10000 °C, and the coldest monthly average temperature ≥ 15 °C. | 1                                                                                              |
sensing are summarized, and three kinds of agricultural drought monitoring indicators are summarized, which are based on long-term soil moisture series, based on soil moisture and soil hydraulic parameters, and based on soil moisture and other multivariable comprehensive drought indicators. Finally, the challenges and opportunities to improve the spatial resolution and retrieval accuracy of soil moisture data, strengthen the research on agricultural drought mechanism, and improve the agricultural drought monitoring system are put forward.

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| Area           | Public service | Market service | Sports construction industry |
|----------------|----------------|----------------|------------------------------|
| East           |                |                |                              |
| Beijing        | 0.0195         | 0.2540         | 0.4192                       | 0.1541 |
| Fujian         | 11.0792        | 1.0712         | 2.7513                       | 4.8105 |
| Guangdong      | 1.1335         | 0.6354         | 2.1108                       | 0.5658 |
| Hebei          | 0.0006         | 0.4010         | 0.3525                       | 0.3309 |
| Jiangsu        | 1.8495         | 0.8976         | 1.1862                       | 2.3485 |
| Shandong       | 0.6214         | 1.1852         | 0.9233                       | 0.1466 |
| Tianjin        | 0.9706         | 0.8215         | 1.5926                       | 2.1589 |
| Weijiang       | 1.7654         | 1.7302         | 1.0528                       | 0.6802 |
| Shanghai       | 0.2004         | 0.3159         | 0.9800                       | 0.5579 |
| Eastern Subtotal | 1.7863         | 0.8798         | 1.4629                       | 1.1369 |
| Central        |                |                |                              |
| Henan          | 0.0930         | 1.2442         | 1.3109                       | 0.5069 |
| Anwei          | 1.5410         | 1.2953         | 0.6769                       | 4.3207 |
| Hubei          | 0.5018         | 0.5233         | 0.7351                       | 3.8906 |
| Xiu             | 0.3117         | 0.9909         | 0.4915                       | 0.3663 |
| Jiangxi        | 0.7623         | 0.5534         | 0.2537                       | 0.0758 |
| Shanxi         | 0.1127         | 0.5904         | 0.2467                       | 0.3529 |
| Central Subtotal | 0.4723         | 0.9214         | 0.7490                       | 1.5011 |
| Northeast      |                |                |                              |
| Heilongjiang   | 0.0201         | 1.7690         | 0.2494                       | 0.0029 |
| Jilin          | 0.0079         | 2.0597         | 0.2507                       | 0.0913 |
| Liaoning       | 0.2819         | 0.5542         | 0.5539                       | 0.5122 |
| Northeast Subtotal | 0.1293         | 1.3199         | 0.3802                       | 0.2430 |
| West           |                |                |                              |
| Inner Mongolia | 0.0024         | 1.0718         | 0.1677                       | 0.0558 |
| Word summer    | 0.0870         | 1.0905         | 0.3938                       | 1.0914 |
| Yuhai          | 0.1179         | 2.2282         | 0.4103                       | 0 |
| Ganno          | 0.0103         | 1.6618         | 0.3878                       | 0.1727 |
| Shaanxi        | 0.0241         | 1.6546         | 0.3696                       | 0.4523 |
| Sichuan        | 0.0258         | 2.4968         | 0.2109                       | 0.0915 |
| Sizo           | 0              | 0.5430         | 0.2595                       | 0 |
| Touch 11       | 0.0104         | 0.3596         | 0.1247                       | 0.1034 |
| Yunnan         | 0.0013         | 0.6231         | 0.1772                       | 0.0511 |
| Chongqing      | 0.0220         | 0.2655         | 0.5797                       | 0.1976 |
| Guangxi        | 0.0783         | 0.7220         | 1.1174                       | 0.9330 |
| Guizhou        | 0.0269         | 0.8355         | 0.348                        | 1.7767 |
| Western Subtotal | 0.0252         | 1.2441         | 0.4031                       | 0.3874 |
Declarations

Conflict of interest The authors declare that they have no competing interests.

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