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Analysis of Eco-Tourism Climate Resources in Xingwen, China Based on the Comfort Index and the Negative Air (Oxygen) Ion

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Abstract

The present work investigates an analysis of Eco-Tourism Climate Resources in Xingwen, China based on the Comfort Index and Negative Air (Oxygen) Ion ("NAI" for short in this article) concentration. The daily temperature, precipitation, wind speed, sunshine hours, and relative humidity data of the Xingwen National Meteorological Station from 1999 to 2018, as well as the NAI data of Feiwu Cave station and Shoushan Lake station in Xingwen of 2018 were used in this study. Based on the analysis of the characteristics of basic meteorological elements, the index of climate comfort of human living environment and the NAI variation in Xingwen, the eco-tourism climate resources in this area were evaluated comprehensively. The results show that: The climate is mild, the precipitation is abundant and the seasonal variation trend of precipitation and heat is similar in the study area. The annual average temperature of this area is 17.8˚C, the annual average precipitation is 1096 mm, the annual average precipitation days are 186 days, the annual average relative humidity is 81%, the annual average wind speed is 1.3 m/s, and the annual average sunshine hours are 999 h. The living environment comfort level reaches the "comfort" level for 6 months per year. In addition, the concentration of NAI in Xingwen remains at the highest level 7 throughout the year, and the rate of good air quality is extremely high. Overall, the study area has high-quality ecological climate resources that are conducive to the development of forest recuperation, leisure and vacation and other ecological tourism activities.

Keywords

Climate Resources, Eco-Tourism, Comfort Index, NAI

1. Introduction

Temperature, sunshine, wind speed, relative humidity, rainfall, air freshness and other conditions have a comprehensive impact on the experience of tourists. In recent years, the public meteorological services are not only limited to the forecast of meteorological elements, but also related to the human feelings of the forecast and service. The comfort index evaluates the comfortable feeling of human body in different climatic conditions. Considering the comprehensive effect of temperature, humidity, wind speed and other meteorological factors on human body, the general population's feelings towards the external meteorological environment can be quantitatively described with an index. Many experts and scholars (Hougthton & Yaglou, 1923; Siple& Passel, 1945; Thom, 1959; Terjuny, 1966; Gagge et al., 1970; Kalkstein & Valimont, 1986; Zhou, 1999) began to study the human comfort index since the early last century. Thom proposed the discomfort index in 1959 (Thom, 1959). Terjuin proposed the concept of climate comfort index (Terjuny, 1966). Nikolopoulou & Lykoudis studied the thermal comfort of cities in different European countries (Nikolopoulou & Lykoudis, 2006). Barradas used the temperature and relative humidity series to calculate the comfort index of 5 parks in Mexico City and their surroundings (Barradas, 1991). Wang et al. designed a calculation method for human comfort based on the golden section method (Wang et al., 2013). Xu & Zhu made a detailed analysis of body surface temperature, discomfort index and clothing index (Xu & Zhu, 2000). Yan & Shen proposed seven design methods for environmental meteorological index and human comfort index (Yan & Shen, 2005). The above different comfort index calculation methods have their own advantages and disadvantages. We selected the Index of climate comfort of human living environment for calculation, which is actually commonly used by the China Meteorological Administration in recent years.

The research area Xingwen is located in the southeast of Sichuan Province, China, which is a golden tourism node and transportation hub in Sichuan, Yunnan, Guizhou and Chongqing. Xingwen has a long history and is the place where the ancient Bo people multiplied and eventually died out. It is also an area where the Miao people in Sichuan Province are concentrated, with ethnic minorities accounting for 11% of the total population. The Xingwen landform is a typical basin and mountain topography. Xianfeng Mountain divides the whole area into the north and south in the middle, and the altitude ranges from more than 200 meters to 1800 meters. The area has a large vertical gradient and remarkable three-dimensional climate characteristics. Studying the suitability of eco-tourism climate resources in this area is of great significance for guiding tourists to travel, developing and improving tourism products, and expanding the health and tourism market.

2. Materials and Methods

2.1. Data

The meteorological data of Xingwen national automatic meteorological station

from 1999 to 2018 were used in the study. We selected daily data of temperature, precipitation, wind speed, relative humidity and sunshine hours for statistical analysis. The NAI data of Feiwu Cave station and Shoushan Lake station in Xingwen of 2018 were also used (Table 1).

2.2. Methodology

Season Division

According to the classification of climate statistics in China, we define March to May as spring, June to August as summer, September to November as autumn, and December to February as winter.

Index of Climate Comfort of Human Living Environment

The provisions of the "People's Republic of China National Standard GBT27963 2011 Human Living Environment and Climate Comfort Evaluation" were used in this research, the calculation method and the classification standard of human living comfort level are as follows (Table 2).

The Temperature-Humidity Index (I) is an index that describes the human body's comprehensive perception of environmental temperature and humidity. Among them, temperature is the main factor. When the temperature is suitable, the influence of humidity on the comfort of the human body is not significant, and when the temperature is too high, the influence of humidity on the human body tends to be significant. The Temperature-Humidity Index (I) is calculated as follows (Tang et al., 2008):

Table 1. Stations information.

Station Name	Latitude (˚N)	Longitude (˚E)	Altitude (m)	Station Type
Xingwen	28.32	105.23	399	Meteorological station
Feiwu Cave	28.55	105.14	930	NAI station
Shoushan Lake	28.31	105.05	998	NAI station

Table 2. Index Grade of climate comfort of human living environment.

Grade	Body feeling	Temperature-Humidity Index (I)	Wind-Efficiency Index (K)	Description of the Feeling of Healthy People
1	Freeze	<14.0	<−400	Feel very cold and uncomfortable
2	Chill	14. 0 - 16. 9	−400 - −300	Feel chill and less comfortable
3	Comfortable	17. 0 - 25. 4	−299 - −100	Feel comfortable and acceptable
4	Hot	25. 5 - 27. 5	−99 - −10	Feel a bit hot and less comfortable
5	Stuffy Hot	>27. 5	>−10	Feel stuffy hot and uncomfortable

$$I = T - 0.55 \times (1 - RH) \times (T - 14.4)$$

In the formula, I represents the temperature and humidity index, T is the average temperature (˚C) in a certain evaluation period and RH is the average air relative humidity (%) in a certain evaluation period.

The Wind-Efficiency Index describes the human body's overall perception of wind, temperature and sunlight. Wind efficiency index is calculated by the following formula (Tang et al., 2008):

$$K = -(10 + 10.45 - V) \times (33 - T) + 8.55S$$

In the formula, K is the Wind-Efficiency Index, T is the average temperature (˚C) in a certain evaluation period, V is the average wind speed (m/s) in a certain evaluation period and S is the average sunshine duration (h/d) in a certain evaluation period.

The degree of climate comfort was evaluated by I and K. When the two indexes are inconsistent, K should be used in the winter half year, and I should be used in the summer half year (Ma et al., 2011).

3. Results and Analysis of Eco-Tourism Climate Resources

3.1. Basic Meteorological Elements

Temperature and Precipitation

Temperature is one of the most sensitive meteorological elements that affect the human body. It plays an important role in the regulation of human body temperature and is one of the most concerned meteorological elements in people's daily life. The average annual temperature in Xingwen is 17.8˚C based on the daily temperature observation data in the past 20 years. The coldest month of the year is January with an average temperature of 7.6˚C while the hottest month is July with an average temperature of 27.1˚C.

The average seasonal temperature of spring, summer, autumn and winter in Xingwen is 18.1˚C, 26.1˚C, 18.3˚C and 8.9˚C while the temperature difference between adjacent seasons is basically around 8˚C. The seasonal differences of maximum and minimum temperatures are similar to the seasonal differences in the average temperature. Xingwen is affected by the monsoon climate with four distinct seasons.

Most of the average annual precipitation in Sichuan is between 400 and 1200 mm. The basin area is generally between 800 to 1200 mm. And Xingwen is located in the southern part of the basin where the annual precipitation is abundant.

According to the statistics of precipitation data, Xingwen has abundant precipitation and the number of precipitation days is also large. The average annual precipitation is 1095. 8 mm. February and December have the lowest average rainfall of 31 mm while July has the highest average rainfall of 191.3 mm. The maximum one-day precipitation was 161.2 mm which occurred on August 29, 2009. The average annual rain days are 185.6 days, with the most (20.3 days) in

October and the least (12.8 days) in August.

Xingwen not only has abundant precipitation, but also has excellent allocation of rain-heat resources (precipitation and temperature) on the time scale. The distribution of temperature and precipitation in each month of the year is generally changing simultaneously (Figure 1). The greatest advantage of year-round heat and rain configuration is in the spring. As the temperature in spring exceeds 10˚C and increases gradually, the precipitation also gradually increases significantly. The average precipitation in February is 31 mm, March 50.1 mm, April 78.9 mm, and in May the precipitation increased to 119.6 mm. This provides excellent rain and heat conditions for natural plant growth in the spring, and there is very little drought during the spring.

Wind, Relative Humidity and Sunshine Hours

The annual average wind speed in Xingwen is 1.3 m/s, and the monthly average wind speed is stable around the average. Due to the influence of topography, the frequency of quiet winds in Xingwen reaches 36%.

Xingwen is located in the southern edge of Sichuan Basin, which is under the water vapor channel that from the Indian Ocean and the South China Sea to the inland. The annual average relative humidity is 81%, and the relative humidity varies from 76% to 87% in each month. The humidity in this area is higher in the winter because there is less sunshine and autumn rain often occurs. In the spring and after it, the humidity gradually decreases as the temperature rises and the sunshine increases.

The annual average sunshine hours in Xingwen are 999.2 h, of which the sunshine hours in January-March and October-December are less than 80 h. There are more sunshine hours from April to September, with an average of over 100 h per month (Figure 2).

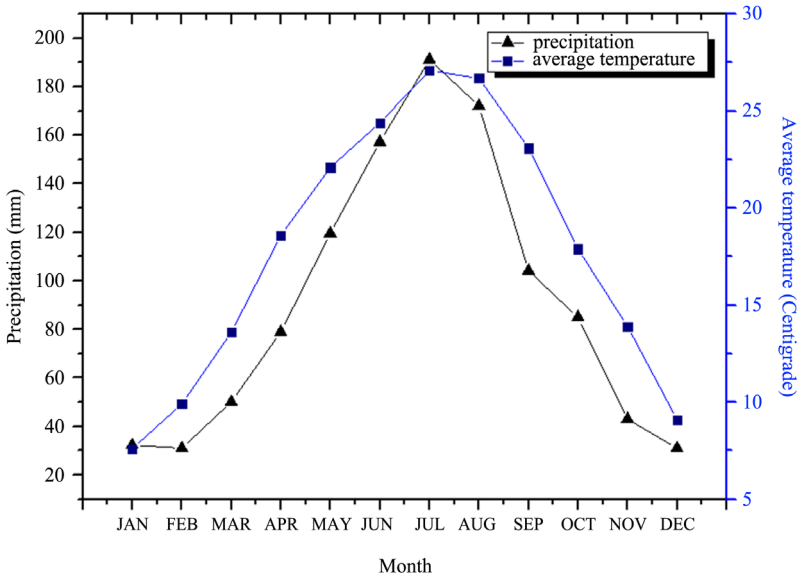

Figure 1. Monthly average precipitation and temperature.

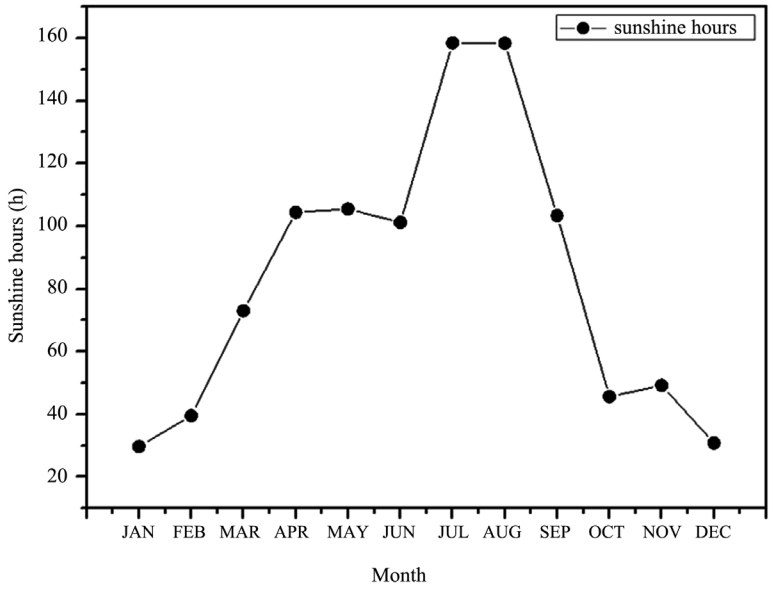

Figure 2. Monthly sunshine hours in Xingwen.

3.2. Index of Climate Comfort

By calculating the Temperature-Humidity Index (I) and Wind-Efficiency Index (K), the comfort level of human living environment in Xingwen can be evaluated in each month (Table 3).

The monthly changes of Index Grade of Climate Comfort of Human Living Environment were analyzed (Table 3). According to the Index Grade of Climate Comfort of Human Living Environment (Table 2), there are 6 months in which the Index of Climate Comfort of Xingwen reached Grade 3 (comfortable). The average comfortable period is from April to June and from August to October. The I value ranges from 17.6 to 25.2 and the K value ranges from −281 to −90 that indicating that healthy people feel comfortable at those period. In midsummer July, the Index of Climate Comfort level of Xingwen is Grade 4 (hot). However the I value is 25.7 which is close to and slightly higher than Grade 3 (comfortable). Also compare to other places there is not any Stuffy Hot month in Xingwen which indicates that the healthy people felt a little heat but not too uncomfortable at that month there. March and November are early spring and late autumn, and the value of I is between 13.7 and 13.9 and the value of K is between −379 and −367. In those months the Index of Climate Comfort of Xingwen is Grade 2 (chill) that the overall feeling is chill and less comfortable. From December to February, the I value is between 8. 2 and 10.3 and the K value is between −496 and −455. In winter the Index of Climate Comfort of Xingwen is Grade 1 (cold) that the overall feeling is cold and uncomfortable. Therefore, according to the comfort level, tourists feel the most comfortable from April to June and from August to October each year while march, July and November follow. In these months, the body feeling is more comfortable and the climate is very suitable for tourism.

Table 3. Monthly index grade of climate comfort and how body feels in Xingwen.

	JAN	FEB	MAR	APR
I	8. 2	10. 3	13. 7	18
K	−496	−455	−379	−273
Index Grade	Grade 1	Grade 1	Grade 2	Grade 3
Body feeling	Cold	Cold	Chill	Comfortable
	MAY	JUN	JUL	AUG
I	21. 1	23. 4	25. 7	25. 2
K	−198	−148	−81	−90
Index Grade	Grade 3	Grade 3	Grade 4	Grade 3
Body feeling	Comfortable	Comfortable	Hot	Comfortable
	SEP	OCT	NOV	DEC
I	22. 2	17. 6	13. 9	9. 5
K	−176	−281	−367	−463
Index Grade	Grade 3	Grade 3	Grade 2	Grade 1
Body feeling	Comfortable	Comfortable	Chill	Cold

3.3. NAI Concentration

The negative oxygen ions (NAI) in the atmosphere are beneficial to the human body. The human body inhales negative oxygen ions, which can regulate the excitement of the nerve center, promote metabolism and improve blood circulation. Negative oxygen ions are also called "vitamins in the atmosphere". The content of negative oxygen ions in the air is affected by many factors, and the concentration is higher in parks, seashores, lakes, waterfalls and forests. Many studies have shown that the better the quality of the atmospheric environment, the higher the concentration of negative oxygen ions, the more beneficial to health (Table 4). In recent years, natural oxygen zone Eco-Tourism has gradually become a new trend of tourism development.

The monthly average NAI monitoring data at Feiwu Cave Station and Shoushan Lake Station were calculated in this study. The average monthly NAI concentration at Feiwu Cave is above 10,000/cm^3, and the average monthly NAI concentration at Shoushan Lake Station is between 4000/cm^3 to 11,000/cm^3. The annual average NAI concentration of Xingwen is 11,415/cm^3. It can be seen that the average concentration of negative oxygen ions in this area far exceeds the standard for clean air (1000 - 1500/cm^3) proposed by the World Health Organization, and it has the effect of enhancing immunity and healing treatment for the human body.

The air is particularly fresh and the annual NAI level of the two monitoring stations in Xingwen is the highest level 7, which is very beneficial to human health (Table 5). Frequent cold air or abundant precipitation indirectly increases the concentration of NAI concentration in the area. Xingwen has superior NAI

Table 4. NAI concentration and air quality level.

NAI Concentration (number/cm^3)	Level	Relationship With Health
≤500	1	Unfavorable
500 - 800	2	Normal
800 - 1100	3	Somewhat Favorable
1100 - 1400	4	Favorable
1400 - 1700	5	Quite Advantageous
1700 - 2000	6	Very Advantageous
≥2000	7	Extremely Advantageous

Table 5. Monthly NAI concentration changes in Xingwen.

Month	Feiwu Cave NAI Concentration	Shoushan Lake NAI Concentration	Level	Air Freshness
JAN	10,087/cm^3	19780/cm^3	7	Extremely Pure and Fresh
FEB	8870/cm^3	17075/cm^3	7	Extremely Pure and Fresh
MAR	8585/cm^3	15789/cm^3	7	Extremely Pure and Fresh
APR	10,348/cm^3	13877/cm^3	7	Extremely Pure and Fresh
MAY	8748/cm^3	14550/cm^3	7	Extremely Pure and Fresh
JUN	8580/cm^3	13516/cm^3	7	Extremely Pure and Fresh
JUL	9509/cm^3	12494/cm^3	7	Extremely Pure and Fresh
AUG	9192/cm^3	12425/cm^3	7	Extremely Pure and Fresh
SEP	5590/cm^3	15055/cm^3	7	Extremely Pure and Fresh
OCT	9711/cm^3	10750/cm^3	7	Extremely Pure and Fresh
NOV	4294/cm^3	15674/cm^3	7	Extremely Pure and Fresh
DEC	6302/cm^3	13164/cm^3	7	Extremely Pure and Fresh

conditions, which is conducive to carrying out ecological tourism activities such as forest recuperation, leisure and vacation. It is a "natural oxygen zone" with the superior natural conditions for building an NAI health care base.

4. Conclusion

The climate is mild, the precipitation is abundant and the seasonal variation trend of precipitation and heat is similar in the study area Xingwen. It is affected by the monsoon climate with four distinct seasons and the average annual temperature in Xingwen is 17.8˚C. The annual average precipitation is 1096 mm, the annual average precipitation days are 186 days, the annual average relative humidity is 81%, the annual average wind speed is 1.3 m/s, and the annual average sunshine hours are 999 h. The results of Index of Climate Comfort show that the tourists feel the most comfortable from April to June and from August to October each year while March, July and November follow. In these months, the body feeling is more comfortable and the climate is more suitable for tourism.

The air is extremely fresh in the study area. The concentration of NAI in Xingwen remains at the highest level 7 throughout the year. Overall, Xingwen has high-quality ecological climate resources that are conducive to the development of forest recuperation, leisure and vacation and other ecological tourism activities.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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