Analysis of Climate Comfort for Tourism in Kunming under Background of Healthy Living Destination

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Abstract. Climate comfort is an important index for evaluating the liveability of a region, and it is also the basis for building a healthy living destination. Quantitative analysis of tourism climate comfort index was built in this paper through average temperature, relative humidity, wind speed and other climatic factors in Kunming, using Fuzzy Analytic Hierarchy Process to evaluate the tourism comfort of Kunming. The results show that Kunming has a pleasant perennial climate, a long tourism cycle and a great advantage in tourism climate comfort. The conclusions can provide scientific basis for the related work of healthy living destination.

1. Introduction

"Healthy Living Destination" is one of the three brands that Yunnan Province spare no effort to create, which embodies the development concept of innovation, coordination, green and opening in Yunnan Province, and embodies the unique environmental and resource advantages of Yunnan Province. Regional climate comfort not only greatly affects local residents, but also determines the attractiveness to tourists for Kunming. As a tourist city, it is important to implement the provincial strategy of building “A Healthy Living Destination” by utilizing the unique meteorological resources. Tourism climate exerts influences on tourism activities besides the integrated comfort during the trip; hence climatic environment has become an important determinant while people choose tourism destinations. On assessment of regional tourism climate comfort, three determine indicators are temperature, humidity, and wind speed. However, single factor could not be treated as the standard criterion of evaluation of human comfort; effective climate comfort analysis needs a holistic environmental climatic data. Terjuug proposed the concept of Comfort Index and Wind Effect Index[1], Oliver created the temperature-humidity Index and Wind chill Index[2], Steadman in 1979 put forward the concept of Apparent Temperature[3], and Commission for Climatology, World Meteorological Organization (CCI, WMO) created Universal Thermal Climate Index (UTCI) in 2012[4]. At present, such researches have been applied in human comfort forecasting, tourism climate comfort assessment and city planning. Researches of domestic climate comfort started in the 1980s, based on unique climatic environment of Grand Jiu Zhaigou Scenic Area, Zhou et al. created a multi-suitability index by factors such as temperature, humidity, solar radiation intensity, wind speed, and obtained tourism suitability in high altitude area [5]. Wang et al. conducted a tourism comfort analysis by utilizing FAHP model [6]. Climate comfort has become a hotspot research field with growth of tourism industry and ongoing of Healthy China Initiative, however there are only few tourism suitability recommendations on building health living destination.
2. Material and Methods

2.1. Introduction to study area

As a gateway of China to Southeast and South Asia, and located in central part of Yungui plateau, Kunming is one of the Chinese important touristic cities with the fame of “the Spring City”. Climatically, it belongs to the low latitude mountain plateau monsoon climate in north subtropical zone, with an average temperature of 16.5 °C and participation of 1450 mm. The frost-free period of the year reached 278 days. It appears a typical climatic characteristic of alternation of dry/rainy seasons. Monthly statistics of tourists and tourist income from Kunming Municipal Tourism Development Commission (http://lfw.km.gov.cn/ghfz/lytj/) showed that Kunming’s tourism income has been increasingly growing at a average speed of 18%, and laid the foundation for implementation of the health living destination.

2.2. Data Source and Analysis

Data source of this paper are 10-year successive regular climatic data from ground observatory with average wind speed, average relative humidity and average temperature. Evaluations on climate comfort mainly focus on Human Comfort Index (H CI), Temperature-Humidity Index (THI), Wind Chill Index (WCI) and Index of Clothing (ICL) (Table 1).

| Range          | XHCI              | XTHI   | Range      | WCI                | Range      | XICL         | C   | A   |
|----------------|-------------------|--------|------------|--------------------|------------|--------------|-----|-----|
| <25            | Very cold, extremely uncomfortable | <40  | >1000      | Very cold, extremely uncomfortable | >2.5       | Thick sweater plus down jacket | e   | 1   |
| 25~38          | Cold, very uncomfortable | 40~45 | 800~1000   | Cold, very uncomfortable | 1.8~2.5    | Thick sweater plus padded jacket | d   | 3   |
| 38~50          | Cool, uncomfortable | 45~55 | 600~800    | Cool, uncomfortable | 1.5~1.8    | Sweater plus jacket | c   | 5   |
| 50~58          | Slightly Cool, relatively comfortable | 55~60 | 300~600    | Slightly Cool, relatively comfortable | 1.3~1.5    | Sweater plus coat | b   | 7   |
| 58~70          | Neutral, Most comfortable | 60~65 | 200~300    | Neutral, Most comfortable | 0.7~1.3    | Casual wear | A   | 9   |
| 70~75          | Warm, relatively comfortable | 65~70 | 50~200     | Warm, relatively comfortable | 0.5~0.7    | Long sleeve shirt | B   | 7   |
| 75~79          | Slightly Warm, uncomfortable | 70~75 | -80~50     | Slightly Warm, uncomfortable | 0.3~0.5    | short sleeve shirt | C   | 5   |
| 79~85          | Hot, very uncomfortable | 75~80 | -160~80    | Hot, very uncomfortable | 0.1~0.3    | T shirt and summer clothe | D   | 3   |
| ≥85            | Very Hot, extremely uncomfortable | ≥80  | ≤160       | Very Hot, extremely uncomfortable | ≤0.1       | T shirt and shorts | E   | 1   |

We made an overall evaluation on subjects constrained by multiple climatic factors by Fuzzy Analytic Hierarchy Process (FAHP), which transform qualitative evaluation to quantitative evaluation based on fuzzy mathematic membership function theory [7]. We established a priority relationship matrix \( F = (f_{ij})_{n \times m} \), \( F \) means fuzzy reciprocal matrix:

\[
(f_{ij}) = \begin{cases} 
0.5, & s(i) = s(j) \\
1.0, & s(i) > s(j) \\
0, & s(i) < s(j)
\end{cases}
\]

In equation, \( s(i) \) and \( s(j) \) indicate relative importance of factor i and j. We established a comparison matrix based on the secondary indicators.
A-B=
\[
\begin{bmatrix}
0.5 & 1 & 1 & 0 \\
0 & 0.5 & 1 & 0 \\
0 & 0 & 0.5 & 0 \\
1 & 1 & 1 & 0.5 \\
\end{bmatrix}
\]

And established the corresponding fuzzy consistent comparison matrix according to comparison matrix.

\[
R_{ij} = \begin{bmatrix}
0.5 & 0.625 & 0.75 & 0.375 \\
0.375 & 0.5 & 0.625 & 0.25 \\
0.25 & 0.375 & 0.5 & 0.125 \\
0.625 & 0.75 & 0.875 & 0.5 \\
\end{bmatrix}
\]

By using normalizing rank aggregation (NRA) find the ranking vector= (0.29 0.21 0.15 0.35)
And we get a Climate Comfort Index (CCI):
\[
T_{CCI} = 0.29X_{HCI} + 0.21X_{WCI} + 0.15X_{ICL} + 0.35X_{THI}
\]

In equation, HCI, WCI, ICL and THI indicate Human Comfort Index, Temperature-Humidity Index, Wind Chill Index and Index of Clothing, and weight coefficients are 0.29,0.21,0.15 and 0.35. According to the result of model calculation and the grade assignment of each index, the criteria of tourism climate comfort determined in this paper are as follows: 7< TCCI ≤9 is most comfortable; 5< TCCI ≤7 is relatively comfortable; 3< TCCI ≤5 is relatively uncomfortable and 1≤ TCCI ≤3 is uncomfortable.

3. Results and Analysis

3.1. Integrated Analysis of Meteorological Elements

![Analysis of Main Meteorological Elements in Different Areas of Kunming](image)

There are many factors that influence regional climate comfort, and the influences differ due to different factors. Relevant literatures points out that temperature, humidity, wind speed and sunshine duration are determinants for climate comfort. Therefore this paper analysis climate comfort on
monthly basis. Figure (1) demonstrated that temperature in Kunming is relatively comfortable on yearly basis, with the coldest temperature in January and hottest in July. Temperature in spring is higher than in autumn, year-round temperature curve is relatively smooth. Year-round relative humidity is highest in July and August and lowest in April and May. Wind speed is higher in April and May and lower in August and September due to Kunming’s typical Monsoon climate. Sunshine duration is longer in May and June due to low precipitation and part cloudy and clean weather, and rainy days are increasing in July which causes reduction of sunshine duration.

3.2. Tourism Climate Comfort Index

Results from FAHP analysis indicate that tourism climate comfort assessment index in February, April, October and November are all above 7, which means the most comfortable, and most suitable for tourism. Tourism climate comfort index in rest of the year is between 5 and 7, indicates that the climate is relatively comfortable and suitable for tourism (Table 2). We have also found that there is no index below 5, which means touristic period in Kunming is long and four seasons are all pleasant. The most comfortable days of tourism in Kunming in recent 10 years account for a high proportion of the whole year, and there are no uncomfortable months of tourism in the whole year. Both comprehensive evaluation and secondary index evaluation have shown good results, indicating that the region has its own prominent advantages in tourism climate.

### Table 2. Tourism Climate Comfort Index in Kunming

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|
| XTHI  | 58.3 | 66.6 | 59.2 | 70.6 | 73.1 | 72.2 | 73.2 | 73.3 | 71.5 | 66.9 | 63.5 | 58.9 |
| XWCI  | 432.5 | 315.4 | 426.6 | 232.5 | 194.1 | 197.1 | 198.4 | 193.5 | 229.4 | 297.5 | 338.4 | 424.6 |
| XICL  | 1.2 | 0.8 | 1.1 | 0.6 | 0.6 | 0.6 | 0.6 | 0.7 | 0.9 | 1.1 | 1.3 | |
| XHCT  | 48.8 | 55.5 | 58.3 | 61.2 | 77.6 | 74.1 | 75.1 | 65.3 | 76.7 | 58.8 | 55.9 | 49.39 |
| TCCI  | 6.7 | 7.7 | 6.9 | 7.3 | 6.3 | 6.3 | 6.3 | 6.8 | 6.7 | 8.3 | 8.1 | 6.7 |

3.3. Relationship between Climate Comfort and Volume of Tourists

As one of the key attractions for tourists, climate has become more and more important. The volume of tourists to Kunming reaches peak at Februarys, Augests and Octobers in resent 10 years, indicating monthly volume of tourists to Kunming are positively correlated with tourism comfort index in Kunming, with little deviation in Aprils and Novembers due to vacation period has not yet come, notwithstanding there are the most climate comfortable months (Figure 2). This result is coherent with Chen’s research [8].

![Relationship between Climate Comfort and Monthly Volume of Tourists in Kunming](image-url)
4. Conclusion and Discussion
Tourism Climate Comfort in Kunming is generally good for the whole year and suitable for tourism with a long period of climate comfort, on basis of meteorological elements and climate comfort analysis in Kunming for the last 10 years. Marches, Aprils, Octobers and Novembers are most suitable for tourism, which coincided with the fame of “Spring City”.

Climate comfort is one of the key factors that attract people outside the region to spend their holidays. Richness of tourism resources, good ecological environment, diverse ethnic cultures and excellent climate resources in Yunnan Province have laid a good foundation for construction of tourist destinations. However, in order to create a "Healthy Living Destination", we must give full play to the advantages of climate resources, and transform the advantages of ecological environment into social and economic opportunities so as to attract more people to Yunnan for vacation, business and settlement. Through the conservation of ecological environment, maintenance of resources balance and the utilization of climate resources, great effort must put to construct a world-class "Healthy Living Destination" for Yunnan Province, and to provide theoretical support for the implementation of "Plan of Health China 2030 ". And at last bidirectional conversion between "lucid waters and lush mountains" and " invaluable assets" is realized.

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