Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

April 2023. Vol. 11, No. 2
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 422-433

Projection of Tourist Climate Comfort Level Period 2031-2050 in Caldera Toba Geopark

[1,2] Alfonsius Chrisandy Pratama Siregar, [1*] Erna Frida, [1,3]Marzuki Sinambela, [1]Marhaposan Situmorang, [1]Syahrul Humaidi, [3]Yahya Darmawan

[1] Department of Physics, Faculty of Mathematics and Natural Sciences – Universitas Sumatera Utara, Jl. Dr. T. Mansur No.9, Padang Bulan, Kec. Medan Baru, Kota Medan, Sumatera Utara, Indonesia. Postal code: 20222

[2] BMKG – North Sumatera Climatology Station, Jl. Meteorologi Raya No.17, Kec. Percut Sei Tuan, Kab. Deli Serdang, Sumatera Utara, Indonesia. Postal code: 20371

[3] School of Meteorology, Climatoly and Geophysics (STMKG), Jl. Perhubungan I No.5, Pd. Betung, Kec. Pd. Aren, Kota Tangerang Selatan, Banten, Indonesia. Postal code: 15221

*Corresponding Author e-mail: ernafridatarigan@usu.ac.id

Received: March 2022; Revised: March 2023; Published: April 2023

Abstract

Tourism is one of the economic sectors that is developing relatively rapidly and has the potential to become a source of foreign exchange due to an increase in the number of tourists. Caldera Toba Geopark is one of the UNESCO-owned Geoparks in Indonesia as a tourist destination that depends on natural potential to be vulnerable to climate change. The relationship between climate and tourism from the comfort index is needed in determining tourist comfort. Climate parameters that become the calculation of the climate comfort index such as air temperature, rainfall, wind speed, length of sunshine and cloud cover are part of the thermal, physical and aesthetic aspects of climate comfort weighting. Climate projection data in this study is the RCP 4.5 scenario with the ACCESS 1-3 model. Using the TCI and HCI methods, the results of the temporal pattern analysis on the climate comfort index for the period 2031-2050 have a 'Bimodal - Shoulder Peak' distribution pattern. Based on the results of the spatial pattern analysis, the level of tourist climate comfort for the period 2031-2050 both with TCI and HCI methods is dominated by the comfortable category index where the peak comfort occurs in December with a very comfortable category. The lowest comfort level with the TCI method occurs in June in the comfortable category, while the HCI method in July with a comfortable category. In the end, the results of this study provide recommendations for the best tourist time in the Caldera Toba Geopark from September to December. The recommended geosite locations are Simanindo - Batu Hoda and Hutatinggi - Sidihoni geosites.

Keywords: Climate change, tourism climate comfort, Caldera Toba Geopark

How to Cite: Siregar, A., Frida, E., Sinambela, M., Situmorang, M., Humaidi, S., & Darmawan, Y. (2023). Projection of Tourist Climate Comfort Level Period 2031-2050 in Caldera Toba Geopark. *Prisma Sains : Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram, 11*(2), 422-433. doi:https://doi.org/10.33394/j-ps.v11i2.7756

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INTRODUCTION

Tourism is one of the economic sectors that is currently experiencing relatively rapid development and has the potential to become one of the leading sources of foreign exchange for the country due to the increasing trend in the number of tourists (Iwan Setiawan, 2019). Lake Toba, which is included in the five UNESCO Geoparks in Indonesia, is the largest volcanic lake in the world with a length of 100 km, width of 30 km, and water depth of 500 m (Kemenparekraf RI, 2022b). Lake Toba as a tourist destination that relies on natural potential is vulnerable to climate change (Wibowo, 2013a).

Weather and climate characteristics are one of the important factors in determining the importance of tourism (de Freitas, 2003). Therefore, the development of the Lake Toba Region urgently needs to pay attention to climate conditions and projections of future climate change to help adaptation and mitigation to climate change in tourism (Aldrian & Ratri, 2007). Scott et al. (2016) in their research explained that a climate index approach is one way for researchers to determine the nature of the variety of climate components for tourism.

Several climate comfort indices have been developed to highlight the diversity of climate resources for tourism (Anđelković et al., 2016). Climate comfort is characterized as the level of satisfaction with the climatic conditions in the environment where people take part in tourism activities. While comfort conditions vary by type of tourism, the presentation of certain threshold values and directories can ensure a clearer picture of the comfort level associated with environmental climatic conditions (Öztürk & Göral, 2018). Therefore, it is very important to develop this index to provide an assessment of tourism climate suitability that can be used as the best decision maker by tourists or tourism managers.

Based on the above background, the topic of the problem discussed in this study is how the temporal pattern and spatial pattern on the projection of the level of tourist climate comfort in the period 2031-2050 and recommendations for when the best time and location to make tourist visits in the Caldera Toba Geopark. This also helps the government in developing and determining tourism management strategies in the Caldera Toba Geopark area as well as long-term planning in developing tourism potential in the area.

METHOD

The scope of this research area is the Caldera Toba Geopark tourist area with 16 Geosites spread across 7 district administrative areas in the Lake Toba region. The data used in this study are RCP 4.5 scenario climate projection model data obtained from The Fifth Phase of The Coupled Model Intercomparison Project (CMIP5) which is data widely used by IPCC-AR5. CMIP5 data with ACCESS 1-3 models with a resolution of 1.25° x 1.875° includes parameters of air temperature, maximum temperature, minimum temperature, precipitation, wind, and solar radiation. The time period of projection data used is 2031 - 2050.

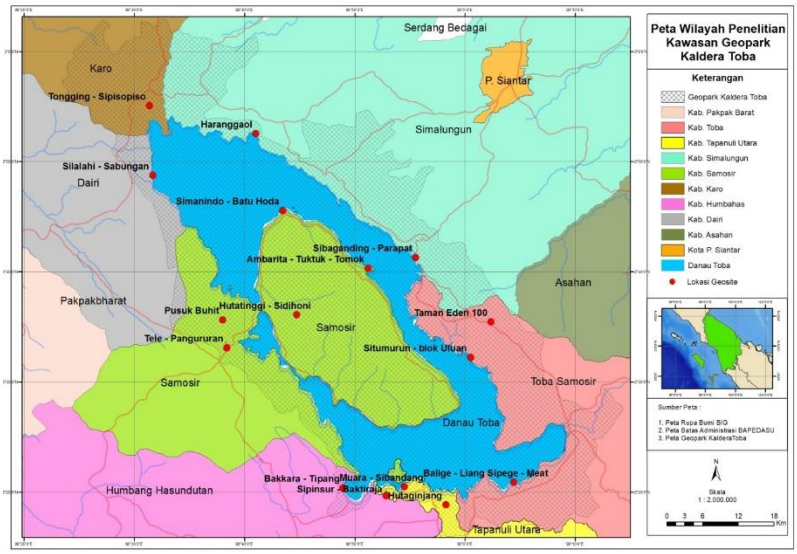

Figure 1. Research Area in Caldera Toba Geopark Region

This study uses several calculations of climate parameter indices such as effective temperature calculation, rainfall projection calculation, calculation of projected sunshine duration, calculation and projection of cloud cover. While the method in calculating the climate comfort index uses the Tourism Climate Index (TCI) method and the Holiday Climate Index (HCI) method.

Climate projection data with a large enough resolution comparison to the research area needs to be downscaled to get a small resolution which is then corrected using the delta method (Faqih, 2016) to produce more accurate data. At this stage, the corrected air temperature data will be used as input for the calculation of the Normal Effective Temperature value (Blazejczyk, 2011). Relative humidity data and wind speed data used are based on projection data that has been regrid according to the scope of the research area. The calculation of rainfall projections is taken from the precipitation flux data formed from diabatic heating of the atmosphere which is closely represented by the vertical convergence flux energy. The projected value of solar irradiance length is obtained from the surface solar radiation value obtained from the CMIP5 projection value. The length of solar irradiation is known as the Angstrom correlation which can be written in the form of the following equation (Utomo,2017, Besharat, F, Dehghan, A.A. dan Faghih, A.R, 2013):

$$\frac{Hg}{Ho} = a + b\left(\frac{n}{N}\right) \qquad \text{(equation. 1)}$$

With :

Hg = Global radiation intensity (MJ.m-2.day-1)

Ho = Extraterresterial radiation intensity (MJ.m-2.day-1)

a dan b = Regression coefficients which for the tropics have values of a = 0.25 and b = 0.45

n = Sunshine Duration (hour)

N = day length (hour)

Cloud cover projections use values of surface solar radiation obtained from CMIP5 projection values. The calculation of cloud cover has many models by developing empirical calculations between solar radiation and cloud cover by Kasten and Czplak (1980), which developed calculations of simple solar radiation by analyzing the correlation of radiation with cloud cover and its type. The calculation of Kasten and Czeplak took the calculation of local radiation with the following calculation.

$$\frac{H_g}{H_o} = 1 - 0.75\left(\frac{N}{8}\right)^{3.4} \qquad \text{(equation. 2)}$$

Tourism Climate Index (TCI) is a calculation of climate variables used by tourists as a consideration in traveling to quantitatively evaluate natural and social phenomena representing an index with a rating scheme and relative weight (Scott & McBoyle, 2001). The TCI is calculated based on the sub-indices of climate comfort level aspects contained in Table 1.

Table 1. Weighting of Sub-indices *Tourism Climate Index* (TCI) (Mieczkowski,1985; Scott & McBoyle, 2001)

Aspects	Sub-indices	Monthly Climate Variable	Influence	Weight
Thermal	Daytime Comfort Index	Maximum air temperature and minimum air humidity	Indicates the thermal comfort that occurs during maximum tourist activity	40%
	Daily Comfort Index	Mean air temperature and humidity	Demonstrate 24-hour thermal comfort, including during sleep	10%
Physics	Rainfall	Rainfall	Represents negative values related to outdoor activities	20%
	Wind	Average wind speed	Variables that have an effect on temperature	10%
Aesthetic	Sunshine	Sunshine Duration	Rated as a positive in tourism, but can be a negative due to solar radiation and discomfort during hot conditions	20%

In calculating the Tourism Climate Index (TCI), it is adjusted to the weighting based on the ranking table of each variable. From the TCI calculation, the division of values is divided into 11 categories contained in table 2. The TCI calculation is designed to assess the suitability of the climate for tourism activities by taking into account comfort based on subjective analysis of the literature that has been researched. The assessment scheme is relative to each tourist-related variable composed of three independent climate variables and bioclimatic combinations (Dewani, 2013). The calculation of the Tourism Climate Index (TCI) is as follows:

$TCI = 2 \times (4CID + CIA + 2R + 2S + \mathrm{W})$ (equation. 3)

With :

TCI = Tourism Climate Index
CID = Daytime Comfort Index
CIA = Daily Comfort Index
R = Rainfall (mm)
S = Sunshine duration (hour)
W = Wind Speed (km/jam)

Table 2. Categories of Tourism Climate Index (TCI) (Mieczkowski ,1985)

TCI Value	Category	Description
(-10) – (-30)	Impossible	Uncomfort
9 – (-9)		
10 – 19	Very Extreme	
20 – 29	Very bad	
30 – 39	Bad	
40 – 49	Marginal	Comfort
50 – 59	Acceptable	
60 – 69	Good	
70 – 79	Very Good	Very Comfort
80 – 89	Excellent	
90 – 100	Ideal	

Scott et al (2016a) stated that the Holiday Climate Index (HCI) is a tourism climate index developed to more accurately assess climate suitability for tourist destinations. The Holiday Climate Index (HCI) climate index is specifically designed for outdoor recreational tourism activities calculated using daily climate data. The Holiday Climate Index (HCI) is a development of the CIT index design (de Freitas et al., 2008). The Holiday Climate Index (HCI) uses five climate variables related to three important aspects in calculating the comfort level of tourism climate which include thermal, aesthetic, and physical comfort. (Scott et al., 2008). The weighting of the results of each aspect of the climate component can be seen in Table 3..

Table 3. Component Weighting of Holiday Climate Index (HCI) (Tang, 2013)

Aspects	Climate Variable	Index weighting
Thermal Comfort	Maximum Temperature (°C)	40 %
	Relative Humidity (%)	
Aesthetic	Cloud cover (%)	20 %
Physics	Rainfall (mm)	30 %
	Wind Speed (km/jam)	10 %

Calculation of the Holiday Climate Index (HCI) based on references from tourists used as a calculation of outdoor recreation activities by taking into account the climatic parameters that combine in the calculation of comfort aspects that are weighted in each aspect. The HCI value is calculated based on the weighting of climate variables used in the following equation:

$HCI\ urba = (T \times 4) + (A \times 2) + [(R \times 3) + (\mathrm{W} \times 1)]$ (equation. 4)

$HCI\ beach = (T \times 3) + (A \times 3.5) + [(R \times 2.5) + (W \times 1)]$ (equation. 5)

with:

HCI = Holiday Climate Index
T = Effective temperature (°C)
A = Cloud cover (%)
R = Rainfall (mm)
W = Wind Speed (km/jam)

From the HCI calculation above, the division of the HCI category value is divided into 10 parts as in table 4 below.

Table 4. Categories of Holiday Climate Index (HCI) (Mieczkowski,1985 dan Scott, 2016)

HCI Index	Category	Description
0 – 9	Dangerous	Uncomfort
10 – 19		
20 – 29	Unacceptable	
30 – 39		
40 – 49	Marginal	Comfort
50 – 59	Acceptable	
60 – 69	Good	
70 – 79	Very Good	
80 – 89	Excellent	Very Comfort
90 – 100	Ideal	

RESULTS AND DISCUSSION

Temporal Pattern Analysis of Tourist Climate Comfort Level for the period 2031-2050 in Caldera Toba Geopark

Temporal pattern analysis on the projection of the level of climate comfort with the TCI method for the period 2031-2050 in the Caldera Toba Geopark area has a 'Bimodal - Shoulder Peak' distribution pattern where the value of the comfort index has 2 (two) peaks of comfort levels that occur in May and December (Figure 2). The maximum TCI value at several geosites in the Caldera Toba Geopark area is dominated in November to December with a value range of 80 - 89 which is included in the very comfortable category of the extraordinary subcategory. While the minimum TCI value predominantly occurs from June to August ranging from 50 - 59 included in the comfortable category of acceptable subcategory. Based on the location of the geosite, the highest level of comfort is at the Sipinsur - Baktiraja geosite with a TCI value of 86 included in the Very Comfortable category of the excellent subcategory. While the geosite with the lowest comfort level is the Sibaganding - Parapat geosite in June with a TCI value of 47 with the category Comfortable marginal subcategory.

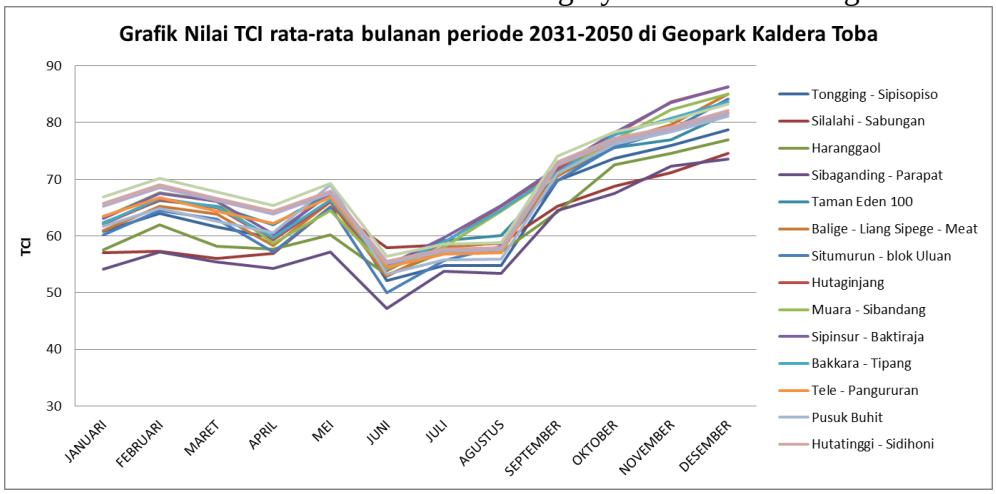

Figure 2. Graph of monthly average TCI values for 2031-2050 in Caldera Toba Geopark

Temporal pattern analysis on the projection of climate comfort levels with the HCI method for the period 2031-2050 in the Caldera Toba Geopark area has a 'Bimodal - Shoulder Peak' distribution pattern (Figure 3) where the value of the comfort index has 2 (two) peaks in comfort levels that occur in May and December. The maximum HCI value at several geosites in the Caldera Toba Geopark area is dominated in November to December with a value range of 80 - 89 which is included in the very comfortable category of the extraordinary subcategory. While the minimum TCI value predominantly occurs from June to August ranging from 50 - 59 included in the comfortable category of acceptable subcategory.

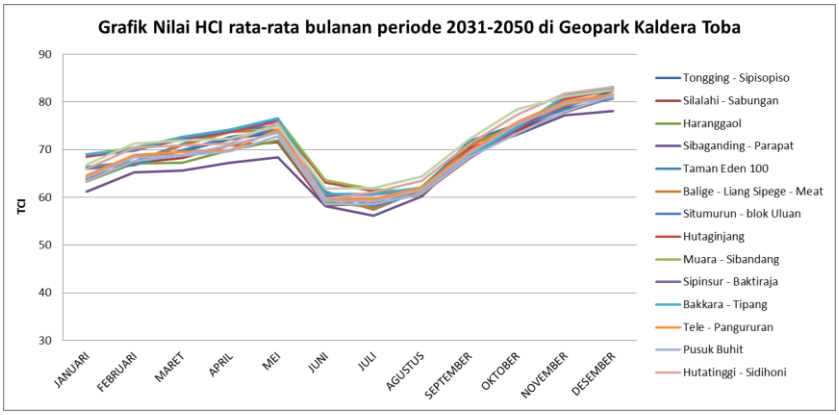

Figure 3. Graph of monthly average HCI values for 2031-2050 in Caldera Toba Geopark

Spatial Pattern Analysis of Tourism Climate Comfort Level for the period 2031-2050 in Caldera Toba Geopark

Based on the results of calculations and data processing processed by the IDW interpolation method, the condition of the tourist climate comfort level with the TCI index in January for the period 2031-2050 is in the comfortable category with a value range of 50 - 69. While using the HCI index, all geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 60 - 69 (Figure 4).

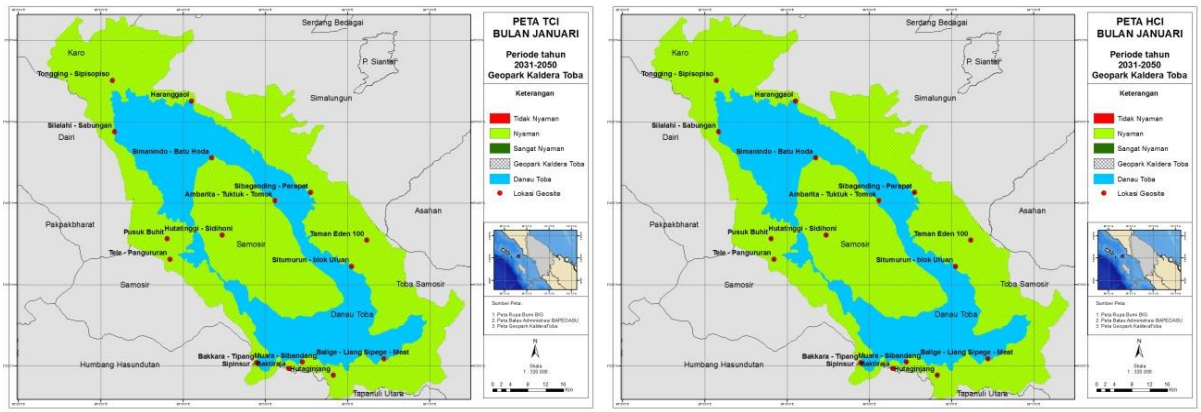

Figure 4. Map of Projected Average Tourist Climate Comfort in January with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level with the TCI index in February is in the comfortable category with a value range of 50 - 69. The geosite that is in the very comfortable category is the Simanindo - Batu Hoda geosite. When using the HCI index, most geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 60 - 69. There are geosites that are in the very comfortable category with a value range of 70 - 79, namely Muara - Sibandang, Hutatinggi - Sidihoni and Simanindo - Batu Hoda geosites. (Figure 5).

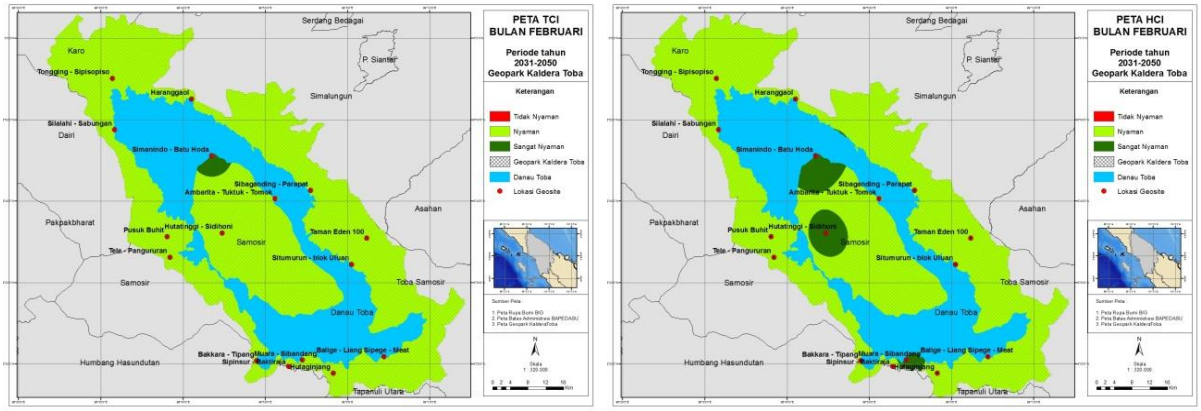

Figure 5. Map of Projected Average Tourist Climate Comfort in February with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in March with the TCI index is in the comfortable category with a value range of 50 - 69. When using the HCI index, most geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 60 - 69. There are geosites that are in the very comfortable category with a value range of 70 - 79, namely the Taman Eden 100 geosite, Balige - Liang Sipege - Meat, Hutaginjang, Muara - Sibandang, Sipinsur - Baktiraja, Bakkara - Tipang, Hutatinggi - Sidihoni and Simanindo - Batu Hoda. (Figure 6).

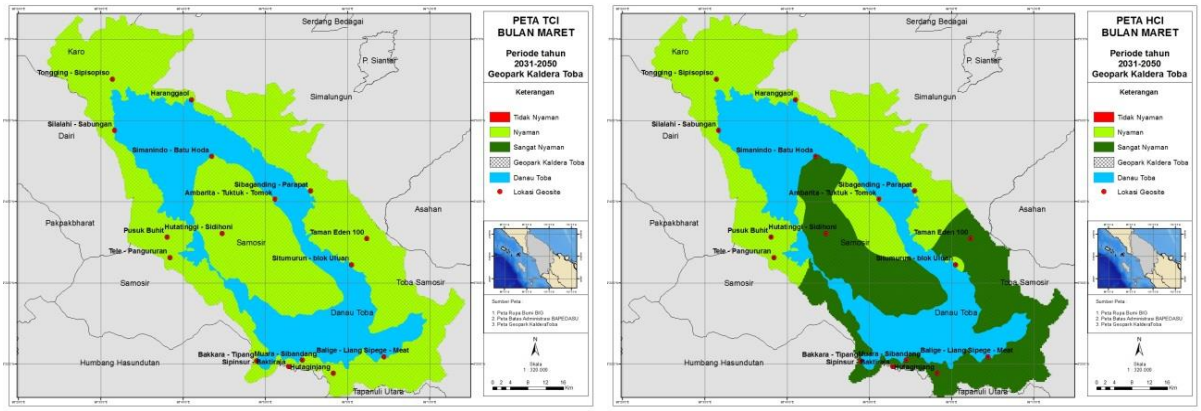

Figure 6. Map of Projected Average Tourist Climate Comfort in March with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in April using the TCI index, in general all geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 50 - 69. When using the HCI index, most geosites in the Caldera Toba Geopark area are in the very comfortable category with a value range of 70 - 79. There are geosites that are in the comfortable category with a value range of 60 - 69, namely the Haranggaol, Sibaganding - Parapat, Tele - Pangururan and Pusuk Buhit geosites (Figure 7).

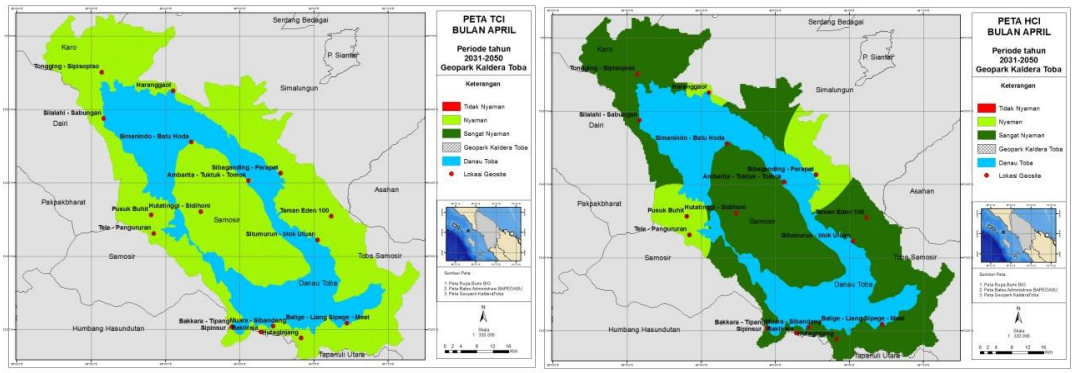

Figure 7. Map of Projected Average Tourist Climate Comfort in April with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in May using the TCI index, in general all geosites in the Caldera Toba Geopark area in May were in the comfortable category with a value range of 50 - 69. When using the HCI index, most geosites in the Caldera Toba Geopark area are in the very comfortable category with a value range of 70 - 79. There is a geosite that is in the comfortable category with a value range of 60 - 69, namely the Sibaganding - Parapat geosite (Figure 8).

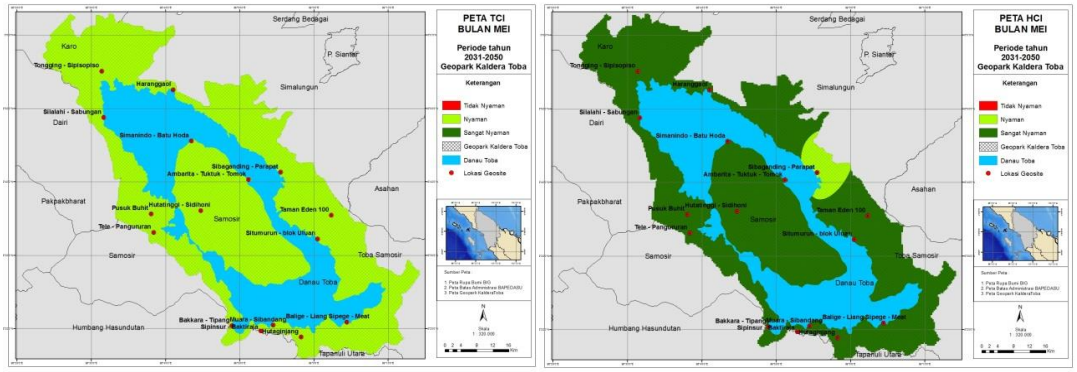

Figure 8. Map of Projected Average Tourist Climate Comfort in May with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in June using the TCI index, in general all geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 40 - 69. When using the HCI index, all geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 50 - 59 (Figure 9).

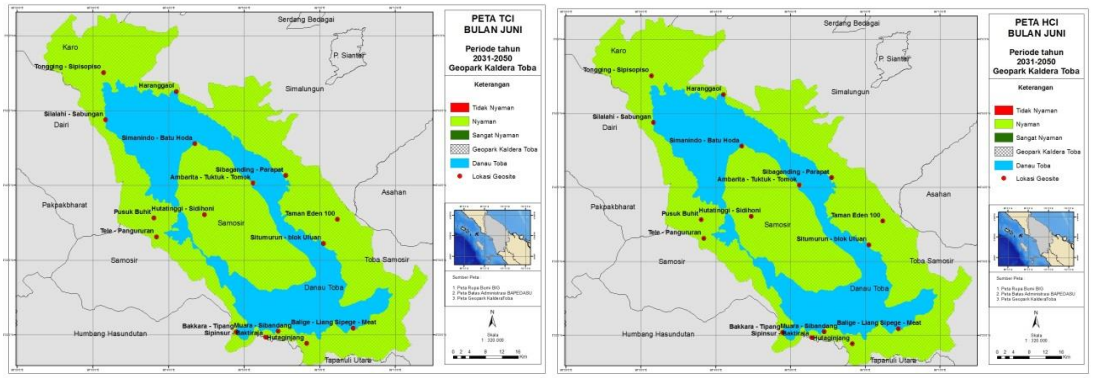

Figure 9. Map of Projected Average Tourist Climate Comfort in June with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in July using the TCI index, in general, all geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 50 - 59. When using the HCI index, all geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 50 - 69 (Figure 10).

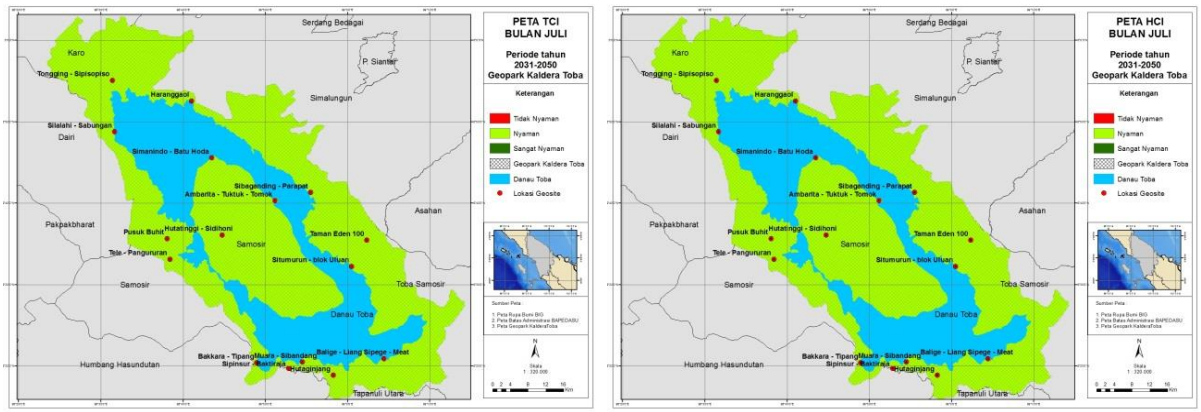

Figure 10. Map of Projected Average Tourist Climate Comfort in July with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in August using the TCI index, in general all geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 50 - 69. When using the HCI index, all geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 60 - 69 (Figure 11).

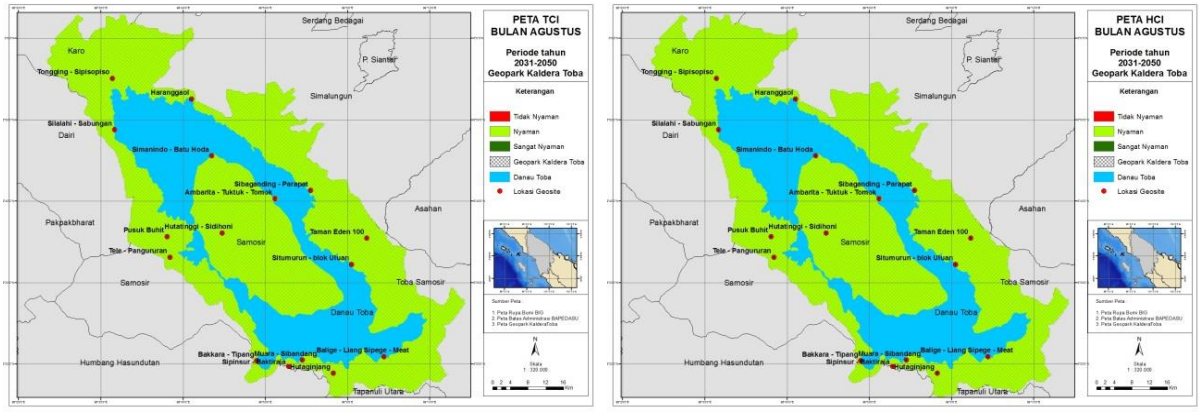

Figure 11. Map of Projected Average Tourist Climate Comfort in August with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in September using the TCI index, in general, most geosites in the Caldera Toba Geopark area are in the very comfortable category with a value range of 70 - 79. The geosites that are in the comfortable category with a value range of 60 - 69 are the Tongging - Sipisopiso geosite, Silalahi - Sabungan, Haranggaol, Sibaganding - Parapat and Situmurun - Uluan block. When using the HCI index, most geosites in the Caldera Toba Geopark area are in the comfortable category with a value range of 60 - 69. There are geosites that are in the very comfortable category with a value range of 70 - 79, namely the Silalahi - Sabungan geosite, Haranggaol, Taman Eden 100, Balige - Liang Sipege - Meat, Hutatinggi - Sidihoni and Simanindo - Batu Hoda (Figure 12).

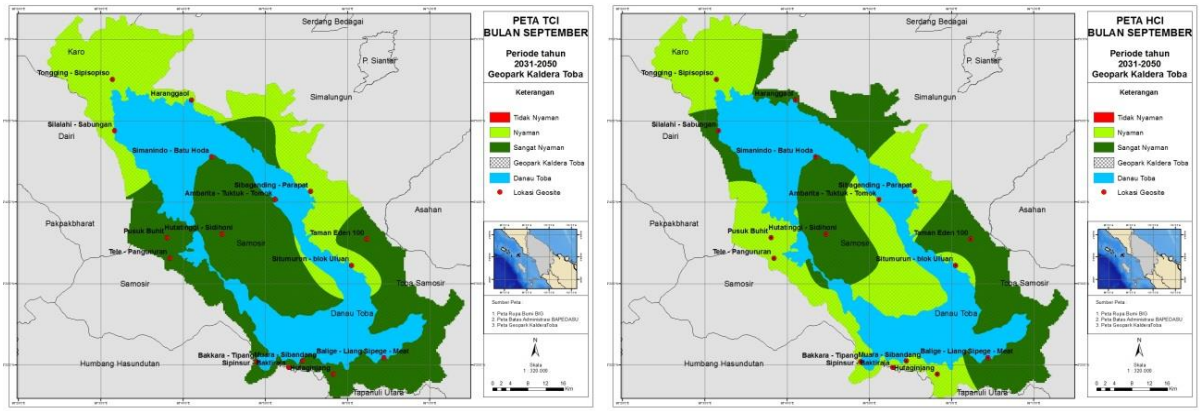

Figure 12. Map of projected average tourist climate comfort in September using TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in October using the TCI index, in general, most geosites in the Caldera Toba Geopark area are in the very comfortable category with a value range of 70 - 79. The geosites that are in the comfortable category with a value range of 60 - 69 are Silalahi - Sabungan and Sibaganding - Parapat geosites. When using the HCI index, all geosites in the Caldera Toba Geopark region are in the very comfortable category with a value range of 70 - 79 (Figure 13).

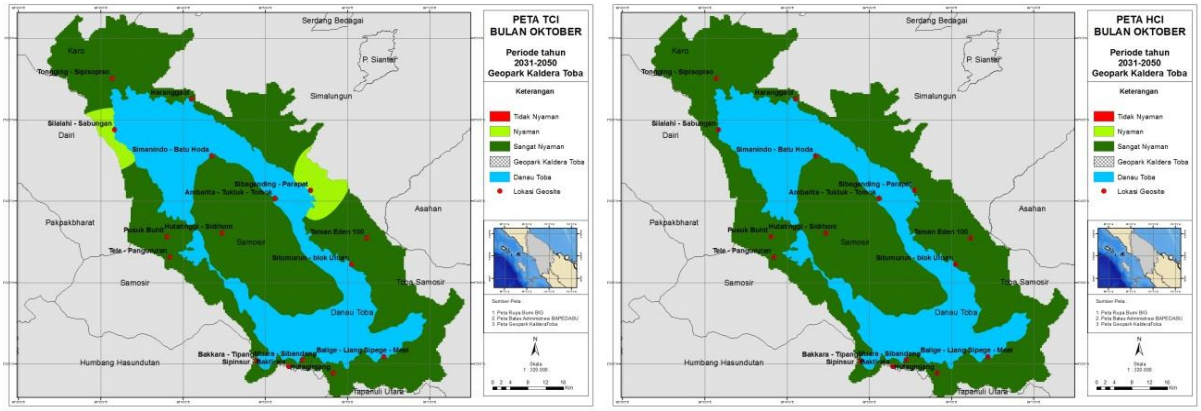

Figure 13. Map of Projected Average Tourist Climate Comfort in October with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in November using the TCI index, in general all geosites in the Caldera Toba Geopark area are in the very comfortable category with a value range of 70 - 89. When using the HCI index, all geosites in the Caldera Toba Geopark area are in the very comfortable category with a value range of 70 - 89 (Figure 14).

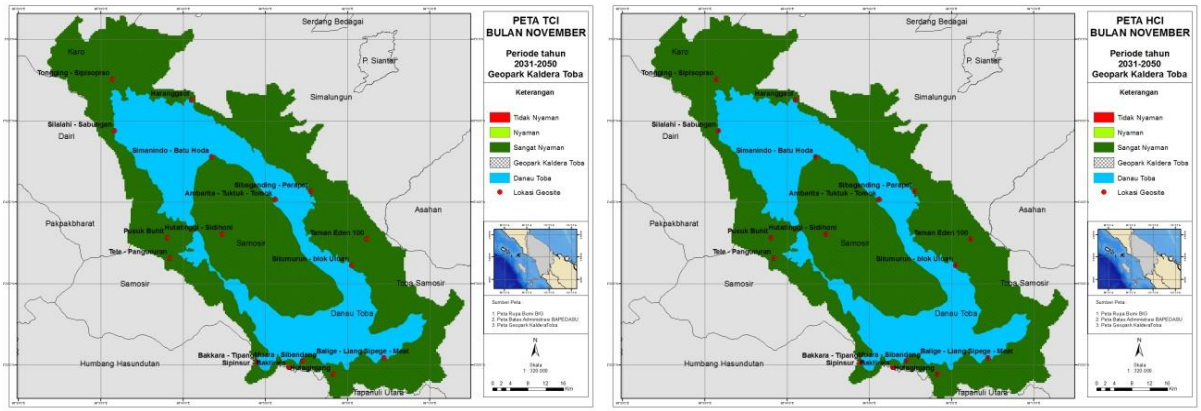

Figure 14. Map of Projected Average Tourist Climate Comfort in November with TCI and HCI methods for the period 2031-2050

The condition of the tourist climate comfort level in December using the TCI index in general, all geosites in the Caldera Toba Geopark area are in the very comfortable category with a value range of 70 - 89. When using the HCI index, all geosites in the Caldera Toba Geopark area are in the very comfortable category with a value range of 70 - 89 (Figure 15).

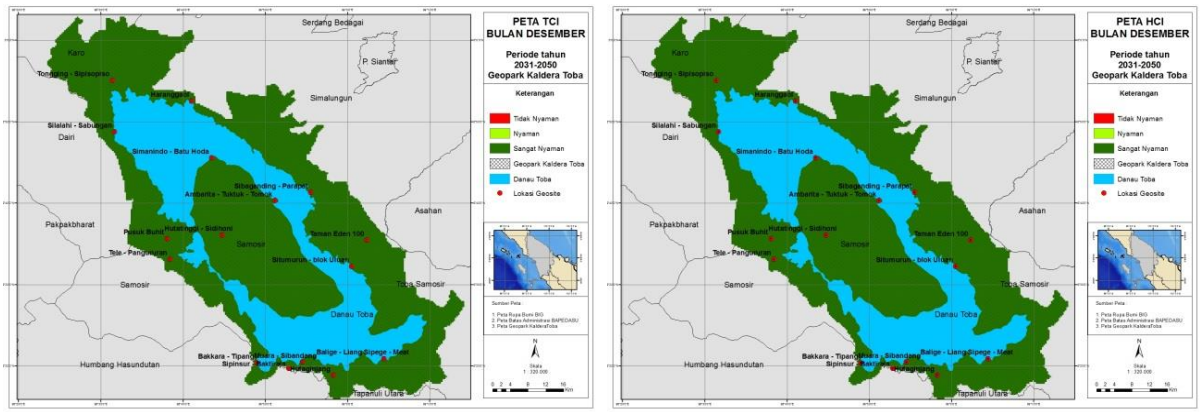

Figure 15. Map of Projected Average Tourist Climate Comfort in December using TCI and HCI methods for the period 2031-2050

Recommended Travel Times and Locations in Caldera Toba Geopark

Based on the results of the analysis of the calculation of the tourist climate comfort level index in the Caldera Toba Geopark using the TCI method in the period 2031-2050, the more recommended time to do tourism is from September to December, where the comfort index is predominantly in the very comfortable category. While the most recommended geosite location for tourism is at the Simanindo - Batu Hoda geosite because it has the most comfortable comfort index throughout the year in February, September to December. While using the HCI method, the more recommended time to do tourism is from October to December and April to May, where the comfort index is dominated in the very comfortable category. While the most recommended geosite locations for tourism are at the Hutatinggi - Sidihoni and Simanindo - Batu Hoda geosites because they have the most comfortable comfort indexes throughout the year in February to May and September to December.

CONCLUSION

Analysis of temporal patterns and spatial patterns in the condition of the level of tourist comfort in the Caldera Toba Geopark for the period 2031-2050 has a 'Bimodal - Shoulder Peak' distribution pattern where the level of comfort is dominated by the comfortable category with the TCI and HCI methods. The highest comfort peak using both TCI and HCI methods occurs in December with a very comfortable category. The lowest comfort level in the TCI method occurs in June with a comfortable category, while in the HCI method also in July with a comfortable category.

In this study, the best time recommendation for tourism in the Caldera Toba Geopark using the TCI method is from September to December, while the HCI method is from April, May, October to December. The recommended geosite locations in this study using the TCI method are Simanindo - Batu Hoda geosite, while the HCI method is Simanindo - Batu Hoda and Hutatinggi - Sidihoni geosite.

RECOMMENDATION

The addition of other tourist climate comfort index research methods is needed so that it can be a better comparison and consideration in determining the level of tourist climate comfort in the Caldera Toba Geopark. In addition, further research needs to be carried out using climate projection data with various models in order to increase the variety of information on the level of climate comfort as an option in determining the best tourism recommendations in the Caldera Toba Geopark.

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