http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 9 No 3 2024

RESEARCH ARTICLE

Drought Management in Batam using Combined NDVI-TCT Algorithm to Create a Classification Level Map

Sudra Irawan[1]*, Tita Fitriania[1], Luthfiya Ratna Sari[1], Suci Dayanti Natali[1], Satriya Bayu Aji[1], Sismanto[2]

[1] *Geomatics Engineering Study Program, Politeknik Negeri Batam, Ahmad Yani Street Batam Center, Kota Batam, Indonesia.*
[2] *Geophysics Engineering Study Program, Universitas Gadjah Mada, Bulaksumur, Yogyakarta, Indonesia*

* Corresponding author : sudra@polibatam.ac.id
Tel.:+81-72-867-1686; fax: +81-72-867-1658
Received: Jun 01, 2023; Accepted: Aug 01, 2024.
DOI: 10.25299/jgeet.2024.9.3.13033

Abstract

Drought constitutes a significant natural disaster with profound implications for agricultural productivity, economic stability, and ecological balance. Batam is one of the cities experiencing a high level of drought. At the end of 2022, Batam is actually on the verge of drought. The purpose of this study is to find out information on the distribution of potential for drought in Batam and the dominant factors affecting the potential for drought occurred using NDVI and TCT algorithms. This research employed remote sensing and GIS techniques, using Landsat 8 images to acquire parameters from NDVI, TCT, and Rainfall data, which are then processed through scoring and overlaying. The final step was to validate the vegetation index parameter by taking the coordinates. The final result is a map of the potential for drought in Batam, consisting of 5 classes of potential for drought. The area with a very low potential for drought was located mostly in Sagulung, with an area of 2.661,89 Ha. The areas with low potential for drought were mostly located in Nongsa, Batam Center, Batu Ampar, Bengkong, Lubuk Baja, and Batu Aji, with an area of 7.175,22 Ha. The areas with a very high potential for drought were mostly located in Galang, Bulang, and Belakang Padang, with an area of 19.744,76 Ha. The area with moderate potential for drought was mostly located in Sungai Beduk, with an area of 22.122,71 Ha. The areas with high potential for drought were mostly located in Galang and Bulang, with an area of 35.663,89 Ha. It is concluded from the results of this research that the collective classification of high and very high drought potential levels covers up to 64% of the entire research area.

Keywords: Urban Drought, Spatial Distribution, NDVI-TCT Algorithm, Spatial Assessment

1. Introduction

Batam is the largest city in Riau Islands, Indonesia. Batam includes the Batam island itself, Galang, Rempang, and other small islands located between Singapore Strait and Strait of Malacca. Batam, Rempang, and Galang islands are connected by Barelang Bridge. Rempang Island, the second largest island in Batam, is connected by six parts of Barelang Bridge, with the coordinate of 0°2' north and 10°13' east. Galang, part of the administrative area of Batam, is the third largest group of the islands, which is also connected by the bridge, with the coordinate of 0°5′ north and 10°1′ east (BPS Batam City, 2022).

Drought is one of the major natural disasters and some of the effects of drought are losses in food production, economy, and the environment (Shahpari et al., 2022). Therefore, it is necessary to solve these problems by understanding the climatic characteristics of each region to develop a strategic plan during the time of drought in these regions, which can last from several months to several years (Zamroni et al., 2022). In other words, drought can be interpreted as the relationship between the amount of water and its availability for survival, agriculture, economic activities, and the environment (Kuswandi et al., 2020).

According to the records from Badan Nasional Penanggulangan Bencana, from 2002 to 2022, based on the average disaster incidence in Indonesia, drought was ranked second (Ilham et al., 2023). Batam is one of the cities experiencing a high level of drought. At the end of 2022 Batam was on the verge of drought. Shifts in seasons and a decrease in rainfall make water reserves in several reservoirs continue to decline, resulting in drought.

Judging from the wind cycle, Batam is a city that has a tropical climate, with a sea area of 2,950 km^2 and a land area of 1,040 km^2. The wind characteristic in Batam involves parameters related to changes in global climate seasons in tropical areas (Amin et al., 2023). Between January to February and July to November, the maximum wind speed is 18-26 knots and the average wind speed is 3-9 knots, between February to November. Based on observations at Airport Meteorological Station of Hang Nadim, from December to April, the wind predominantly blows from north and northeast, while in May it varies, from south, southeast, and west. From October to November, the wind moves southeast and west, causing irregular seasonality in Batam.

Normalized Difference Vegetation Index (NDVI) is a commonly used remote sensing index that quantifies the health and abundance of green vegetation in a given area. It is calculated using reflectance measurements acquired from satellite or aerial Imagery (Huang et al., 2021). NDVI is widely used in various applications, including agriculture, forestry, ecology, and land management. It provides valuable information about vegetation growth, biomass estimation, crop monitoring, drought detection, and land cover classification (Kattimani et al., 2015).

Tasseled Cap Transformation (TCT) is a technique used in remote sensing and image analysis to transform multispectral data, typically from satellite imagery, into a set of orthogonal indices known as tasseled cap components. The TCT was originally developed for Landsat satellite data but has been applied to other sensors as well. By applying the TCT, analysts can extract meaningful information from satellite imagery and perform various tasks such as land cover classification, vegetation monitoring, and change detection (Zhai et al., 2022). The resulting tasseled cap components can be analyzed and interpreted to gain insights into land surface characteristics, identify land cover types, detect changes in vegetation health, and assess environmental conditions.

From the problems above, this study aims to find out information on the distribution of potential drought in Batam and the dominant factors that affect the potential for drought using NDVI and TCT algorithms.

2. Material and Method

2. 1. Data and Research Locations

The data used in this study are 2018 Administrative Map of Batam (Figure 1), 2021 Landsat 8 Images**,** 2021 Rainfall data**.** The research was conducted in Batam, Riau Islands, Indonesia. The method used in this study also consists of literature study, which includes the process of collecting relevant theoretical references to solve the problem. The following is the flow chart of this study.

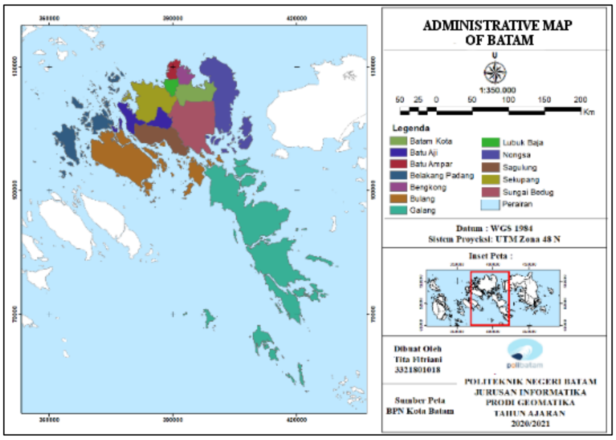

Fig 1. Research Location

2. 2. Research Method and Stage

In this study, the data were analyzed using satellite image data processing to correct possible geometric errors in the images using Landsat 8 Image data downloaded from USGS (https://ers.cr.usgs.gov/) in January 2021. The data were then processed using NDVI and TCT Algorithms (Figure 2). Cropping is carried out in certain areas of study to obtain the image with the appropriate size during the analysis. The RGB bands used in the compositing process are Band 1-5 and Band 7 with a band order of 432.

Radiometric correction converts data values from Digital number (DN) format to radians and then to reflective. This process is useful to correct values that have errors. To convert the digital number value to radiance, the following formula is used (Arunachalam et al., 2023).

$$L\lambda = ML * Qcal + AL \quad (1)$$

with $L\lambda$ is spectral reflectan in watts/(meter squared*ster* µm), ML is reflectan_Mult_Band_x, where x is the band number, AL is reflectan_Add_Band_x, where x is the band number, and Qcalis quantized and calibrated standard product pixel values (DN).

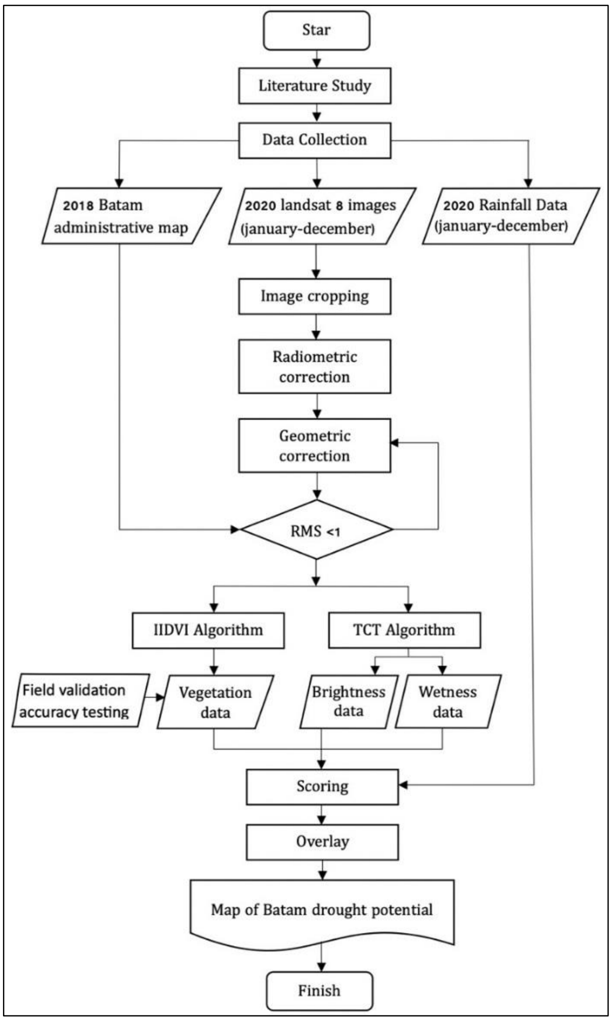

Fig 2. Research Flow Chart

Radiometric correction converts data values from Digital number (DN) format to radians and then to reflective. This process is useful to correct values that have errors. To convert the digital number value to radiance, the following formula is used (Arunachalam et al., 2023).

$$L\lambda = ML * Qcal + AL \quad (1)$$

with $L\lambda$ is spectral reflectan in watts/(meter squared*ster* µm), ML is reflectan_Mult_Band_x, where x is the band number, AL is reflectan_Add_Band_x, where x is the band number, and Qcal is quantized and calibrated standard product pixel values (DN).

The ToA calculation results are recalculated to eliminate differences in DN values using the following formula (Teng at al., 2023).

$$\rho\lambda^* = \frac{\rho\lambda}{\cos(\theta sz)} = \frac{\rho\lambda}{\sin(\theta se)} \quad (2)$$

with $\rho\lambda^*$ is TOA (Top of Atmoshpere, sun-corrected, $\rho\lambda$ is TOA (Top of Atmoshpere), without sun angle correction, θse is sun_elevation, local sun angle, θsz is local zenit angle of the sun;

$$\theta sz = 90^o - \theta se \quad (3)$$

Geometric correction aims to correct an image so that the coordinates of the image correspond to the geographical coordinates referring to a certain coordinate system, with a value of less than 1. If the RMSE is more than 1, it will be repeated until it meets the geometric correction conditions. The data used to make geometric corrections are image data from January 6, 2021, using Batam City SHP reference at 7 points with an RMSE value of 0.0025.

Normalized Difference Vegetation Index (NDVI) Algorithm is a method to obtain the value of vegetation greenery level by comparing NIR with red waves using the following formula (Martinez et al., 2023).

$$NDVI = (NIR - RED)/\ (NIR + RED) \quad (4)$$

With NIR is Channel 5 and RED is Channel 4

Tasseled Cap Transformation (TCT) is used to obtain the greenery, brightness, and wetness indices in this study. To obtain brightness and wetness indices, researchers only use 6 bands of TCT, which are Band 1-5 and Band 7. From these calculations, the brightness index is related to the lands. The wetness index is related to the amount of water. The following formula was used in the research (Deng et al., 2023).

$$Brightness = (0{,}3037 \times B1) + (0{,}2793 \times B2) + (0{,}474 \times B3) + (0{,}5585 \times B4) + (0{,}508 \times B5) + (0{,}1863 \times B7)$$

$$Wetness = (0{,}1509 \times B1) + (0{,}19731 \times B2) + 0{,}3279 \times B3) + (0{,}3406 \times B4) - (0{,}711 \times 2B) - (0{,}4572 \times B7)$$

This study used the 2021 rainfall data downloaded from BMKG (https://dataonline.bmkg.go.id/). The data were processed using IDW interpolation from three stations in Batam, which are Hang Nadim Station (Batam), Raja Haji Fisabilillah Meteorological Station (Tanjung Pinang), and Raja Haji Abdullah Meteorological Station (Karimun). Scoring parameter used to obtain areas with the potential for drought in Batam for each parameter based on each class, with a score of 1 for the lowest class and 5 for the highest. The data processing for each parameter was done in ArcGIS 10.3.

The value of the vegetation index ranges from -1 to 1. The closer the value to 1, the higher the greenery index. On the other hand, the closer the value to -1, the lower the greenery index. From these values, the lower the value of the vegetation index, the drier the surface. If there is no vegetation, the condition of the land is not humid (Rhymee et al., 2023).

Table 1. Vegetation index scoring

Vegetation index	Classification	Score
-1 - (-0.03)	Very low	1
-0.03 – 0.15	No vegetation	2
0.15 – 0.25	Low	3
0.26 – 0.35	Low	4
0.35 -1	High	5

Brightness index is a transformation used to assess or interpret the brightness level of an object. The higher the brightness index value, the brighter the object (Mousania et al., 2023). In this study, the high brightness value indicates that the object is dry.

Table 2. Brightness index scoring

Brightness index	Classification	Score
15.109 – 19.500	Very low	1
19.500 – 24.00	Low	2
24.000 - 28.500	Moderate	3
28.500 - 33.000	High	4
33.000- 103.697	Very high	5

Wetness index is a transformation used to assess the moisture/wetness level of an object. The higher the value of the wetness index, the wetter the object (Yang et al., 2023).

Table 3. Wetness index scoring

Wetness index	Classification	Score
<30	Very dry	1
-30 - (-13)	Dry	2
-13 – 10	Moderate	3
10 – 35	Wet	4
>36	Very wet	5

Rainfall is one of the factors that influence the potential for drought. The greater the rainfall, the smaller the potential for drought. On the other hand, the smaller the rainfall, the greater its dryness potential (Zhu et al., 2023).

Table 4. Scoring for Rainfall

Rainfall	Classification	Score
<2500	Rendah	1
2500 - 3500	Sedang	2

2.3. Weighting and quantification of drought index values

To produce a map of the potential drought in Batam, each parameter was given a predetermined weight. The weighting in this study refers to the previous research (NS et al., 2019), with several modifications so it is in accordance with the parameters used. After the overlay was carried out and the results of each parameter value were obtained, the values on the map were grouped according to the predetermined classes. In this study, there are 5 classes of drought: low, very low, medium, high, and very high.

Table 5. Parameters of Potential for Drought

Parameter	Weight
Rainfall	0.35
Vegetation	0.25
Brightness	0.20
Wetness	0.20

(Mukherjee et al., 2020)

To calculate the value of the level of potential for drought, the following formula is used

$$i = \frac{R}{n} \quad (5)$$

with: I is Kmax – Kmin, R is difference between maximum score and minimum score, and n is number of classes of potential for drought (Ponnusamy at al., 2022).

Table 6. Classes of Potential for Drought

Value of Potential for Drought	Level of Potential for Drought
12,5 – 17,0	Very low
17,5 – 22,5	Low
23,0 – 28,0	Moderate
28,5 – 33,5	High
34,0 – 33,5	Very high

Based on modifications and adjustments in Batam

2.4. Field Validation

Field validatin was performed using handheld GPS to determine the coordinate points of each sample. The number of samples in this study was obtained using slovin formula (Roy et al., 2023). In general, the minimum number of samples for a 1:50,000 mapping scale is 30 samples.

Table 7. Number of samples based on scale

Scale	Minimum Sample Total (MST)
1:25,000	50
1:50,000	30
1:250,000	20

$$A = MST + \left(\frac{Area\ (Ha)}{1500}\right) \quad (6)$$

Where A is Minimum number of samples, and MST is Minimum Sample Total.

Using the formula above, the sample points obtained for this study were 42 points spread across 12 districts in Batam. The 12 sub-districts were divided into 5 samples. Data from smaller sub-districts were combined into the bigger sub-districts. The sample points serve to verify the vegetation index processing results to determine the dominant area of vegetation that has a low level of drought. By acquiring the field data on vegetation conditions, the identification of regions with the potential for drought is possible. The following map is the result of field data validation based on the vegetation index processing.

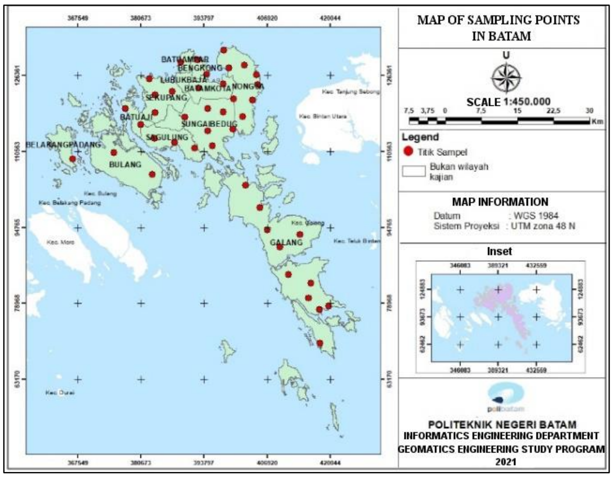

Fig 3. Field Data Validation Map

Of the 42 sample points taken in the field (Figure 3), there were 4 non-conforming sample points and 38 conforming sample points. The conformity results were calculated using the following formula (Pandey et al., 2019).

$$\mathrm{B} = \frac{\sum Conforming\ samples}{\sum\ samples} x\ 100 \quad (7)$$

$$\mathrm{B}\ = \frac{38}{42} x\ 100 = 90{,}48\% \quad (8)$$

The results of field validation used in this study are in accordance with the conditions in the field.

3. Result and Discussion

3.1. Vegetation Indeks

As a variable influencing the conditions of potential for drought disasters, the vegetation index is obtained from the processing of Landsat 8 image data using the NDVI algorithm, the classification of vegetation index consists of 5 classes, which are no vegetation, very low, low, moderate, and high, with an index range of -1 to 1. The lowest NDVI value in 2021 was -0.731 and the highest was 0.862 (Figure 4). In Figure 4, the highest distribution of vegetation in Batam was found in Belakang Padang, Bulang, and Galang. Low vegetation was found in Sagulung, Batam Center, Batu Aji, and Bengkong, which were densely populated. Overall, the high vegetation index conditions, which contribute to mitigating the increasing potential for drought, cover 40.82% of the entire research area. The following table shows the area of vegetation index according to its classification.

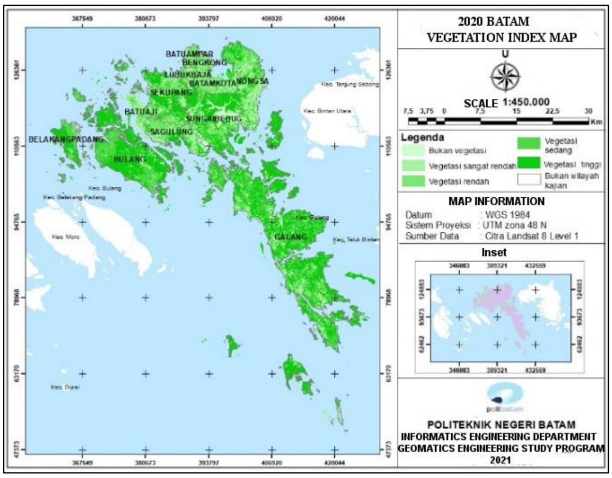

Fig 4. Vegetation Index Map

Table 8. 2021 vegetation index area

Classification	Area (Ha)
Very low	3.333,01
No vegetation	15.020,44
Low	18.381,26
Low	24.219,10
High	42.048,38

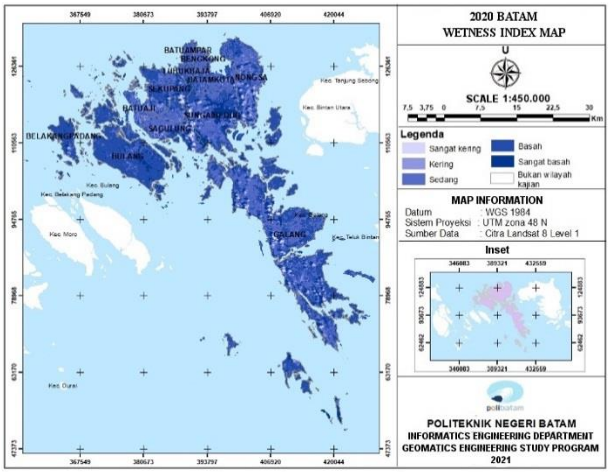

Fig 5. Wetness Index Map

Table 9. 2021 Wetness index area

Classification	Area (Ha)
Very dry	1.346,04
Dry	5.192,38
Moderate	36.323,46
Wet	48.727,39
Very wet	11.459,24

3.2 Wetness Index

Based on the Landsat 8 image data processing results utilizing the TCT algorithm, the wetness index classification, contributing 20% weightage to the processing, comprises five categories: very dry, dry, moderate, wet, and very wet. The spectral value of the wetness index in Batam was -1.920 to 0.217. Based on these spectral values, the lower the spectral value resulting from the transformation on the wetness index, the drier the object. Conversely, the higher the spectral value resulting from the transformation on the wetness index, the wetter the object. From the classification of the wetness index in Batam in Figure 5, very wet objects were found in Sungai Beduk and Sekupang, where reservoirs are. The percentage of areas classified as dry and very dry wetness levels in Batam is only 6%, indicating an unfavourable condition for the formation of drought potential. The following table shows the area of wetness index according to its classification.

3.3. Brightness Indeks

Based on the results of processing using the TCT algorithm, the classification of the brightness index consists of 5 classes, which are very low, low, moderate, high, and very high. The spectral value of the brightness index transformation in Batam was -2.662 to 0.259, which is shown in Figure 6. The higher the brightness index value of an object, the wetter the object. Conversely, if the brightness index value of an object is low, then the object is dry. The classification of the brightness index in Batam can be seen in Figure 6. Batam was mostly moderate in brightness. This means that the spectral value was moderate so the potential drought in the region was moderate because the area was densely populated. The following is the table of the area of the brightness index based on the classification.

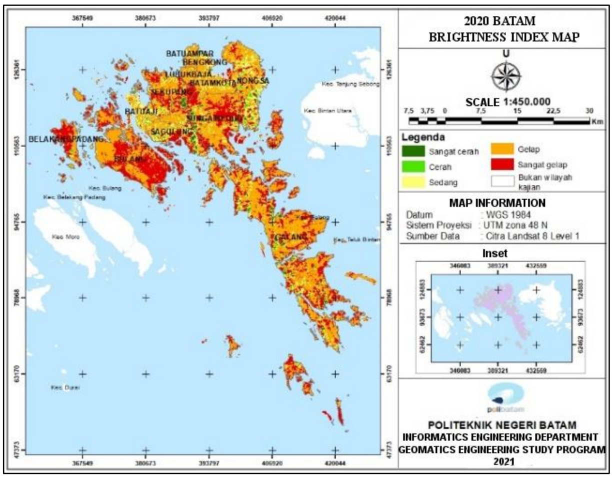

Fig 6. Brightness index Map

Table 10. 2021 vegetation index area

Classification	Area (Ha)
Very low	1.037,52
low	3276,21
Moderate	12.009,05
High	51.795,33
Very high	34.931,75

3.4. Rainfall Map

Based on the analysis of data obtained from BMKG, the average rainfall in 2021 was 2500-3500 mm/year. Figure 7 shows that the rainfall in Batam can be classified into two classes: low and medium. The area of low rainfall consisted of Sungai Beduk, Sagulung, Batu Aji, Sekupang, Batam Center, Nongsa, Lubuk Baja, Bengkong, Batu Ampar, Belakang Padang, and Bulang, while the area of moderate rainfall was Galang. The difference in rainfall intensity values affects 35% of the drought potential weight in the research area, where lower intensities correspond to higher drought potential. The following table shows the area of rainfall according to the classification.

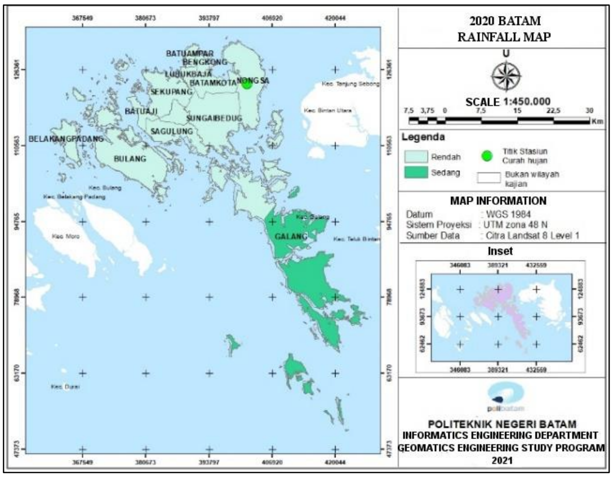

Fig 7. Rainfall Map

Table 11. 2021 Rainfall area

Classification	Area (Ha)
Low	67.080,26
Moderate	20.785,52

3.5. Map of Potential for Drought in Batam

Figure 8 is the result of the overlay and weighting of all parameters: vegetation index, brightness, wetness, and rainfall. The areas of potential for drought in Batam in 2021 were classified into 5 classes, which are low, very low, medium, high, and very high. The area with a very low potential for drought was mostly located in Sagulung, with an area of 2.661,88 Ha. The areas with a low potential for drought were mostly located in Nongsa, Batam Center, Batu Ampar, Bengkong, Lubuk Baja, and Batu Aji, with an area of 7.175,22 Ha. The areas with a very high potential for drought were mostly located in Galang, Bulang, and Belakang Padang, with an area of 19.744,76 Ha. The areas with a moderate potential for drought were mostly located in Sungai Beduk, with an area of 22.122,70 Ha. The areas with a high potential for drought were mostly located in Galang and Bulang, with an area of 35.663,89 Ha.

In general, areas with a very high potential for drought are highlighted in red. It can be observed in Figure 8 that the potential for drought in Batam in 2021 tended to range from high to very high, covering up to 64% of the research area. The following table provides detailed information on the areas classified by their potential for drought in Batam.

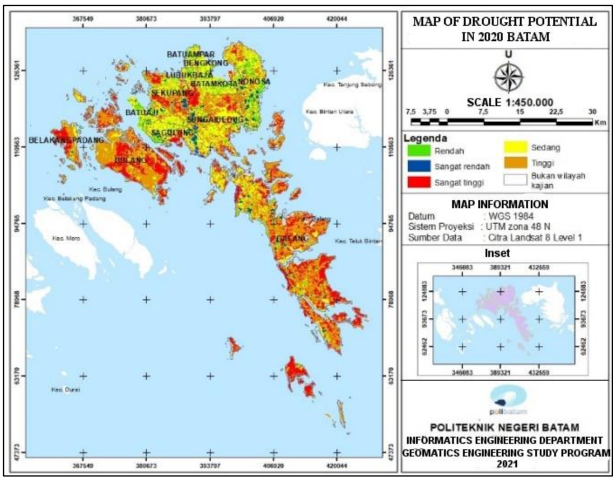

Fig 8. Map of Potential for Drought in Batam

The identification of drought potential phenomena in Batam is achieved through the integration of values and weights of the four variables. Each variable - rainfall, vegetation, brightness, and wetness - contributes to drawing conclusions based on its respective significance. These findings could significantly contribute to Batam's resource management and disaster preparedness endeavours, particularly in addressing and mitigating potential drought occurrences in the future, given that Batam is an island region with limited surface water and aquifer reserves, yet possesses significant potential for industrial development and human resource growth. However, it is imperative to consider the utilization of long-term temporal data to enhance predictive capabilities and improve potential management strategies in the distant future.

Table 12. Area of potential for drought in Batam

Classification	Area (ha)	Percentage
Low	7.175,22	8%
Very low	2.661,88	3%
Very high	19.744,76	23%
Moderate	22.122,70	25%
High	35.663,89	41%

4. Conclusion

Through the utilization of various parameters such as rainfall and vegetation indices processed via the NDVI algorithm, alongside wetness and brightness indices processed using the TCT algorithm, this study employed a comprehensive approach to assess the potential for drought in Batam. By employing scoring/weighting and overlay techniques for each parameter, the overlay results facilitated the creation of a comprehensive map illustrating the potential drought areas in Batam. The integration of TCT and NDVI algorithms proved effective in discerning the distribution and dominant factors influencing drought potential. Specifically, the findings reveal that areas with moderate drought potential primarily encompass Sungai Beduk, comprising an area of 22,122.70 hectares, equivalent to 25% of the total studied area. Conversely, regions with a high potential for drought predominantly include Galang and Bulang, covering an area of 35,663.89 hectares, representing 41% of the total study area. These results underscore the efficacy of employing remote sensing and GIS techniques, emphasizing their utility in assessing and managing drought potential risks in Batam for informed decision-making and sustainable resource allocation.

References

Badan Pusat Statistik Kota Batam. Kota Batam Dalam Angka 2022. Batam: Badan Pusat Statistik Kota Batam https://batamkota.bps.go.id/publication/2022/02/25/be4b5274297b1accccb70a9b/kota-batam-dalam-angka-2022.html

Shahpari, G., Sadeghi, H., Ashena, M., & García-León, D. (2022). Drought effects on the Iranian economy: a computable general equilibrium approach. Environment, Development and Sustainability, 24(3), 4110-412. https://doi.org/10.1007/s10668-021-01607-6

Zamroni, A., Kurniati, A. C., & Prasetya, H. N. E. (2020). The assessment of landslides disaster mitigation in Java Island, Indonesia: a review. Journal of Geoscience, Engineering, Environment, and Technology, 5(3), 124-128. https://doi.org/10.25299/jgeet.2020.5.3.4676

Kuswandi, Y., Erwindi, J., Hadian, M. S. D., & Muslim, D. (2020). Disaster Mitigation for Palu City Residents in Dealing with Liquefaction Disasters in Accordance of Spatial Patterns of Palu City, Central Sulawesi Province, Indonesia. Journal of Geoscience, Engineering, Environment, and Technology, 5(4), 191-197. https://doi.org/10.25299/jgeet.2020.5.4.5653

Ilham, A. P. (2023). The Effect of Natural Disaster on Regional Economic Growth, Unemployment, Poverty, and Human Development Index in Thirty Indonesian Provinces. Journal of Indonesian Applied Economics, 11(1), 40-59. https://doi.org/10.21776/ub.jiae.2023.011.01.4

Amin, M., Prajati, G., Humairoh, G. P., Putri, R. M., Phairuang, W., Hata, M., & Furuuchi, M. (2023). Characterization of size-fractionated carbonaceous particles in the small to nano-size range in Batam city, Indonesia. Heliyon, 9(5). https://doi.org/10.1016/j.heliyon.2023.e15936

Kattimani, J. M., & Renuka Prasad, T. J. (2015). Normalized Difference Vegetation Index (NDVI) Applications in part of South-Eastern Dry Agro-climatic Zones of Karnataka Using Remote Sensing and GIS. International Journal of Advanced Research, 3(12), 1593-1596.

Huang, S., Tang, L., Hupy, J. P., Wang, Y., & Shao, G. (2021). A commentary review on the use of normalized difference vegetation index (NDVI) in the era of popular remote sensing. Journal of Forestry Research, 32(1), 1-6. https://doi.org/10.1007/s11676-020-01155-1

Zhai, Y., Roy, D. P., Martins, V. S., Zhang, H. K., Yan, L., & Li, Z. (2022). Conterminous United States Landsat-8 top of atmosphere and surface reflectance tasseled cap transformation coefficients. Remote Sensing of Environment, 274, 112992. https://doi.org/10.1016/j.rse.2022.112992

Arunachalam, M., Joshua, R. M., Kochuparampil, A. J., & Saravanavel, J. (2023). ArcOLITIRS: A Toolbox for Radiometric Calibration and Surface Temperature Estimation from Landsat 8 Products in ArcGIS Environment. Journal of the Indian Society of Remote Sensing, 51(3), 453-468. https://doi.org/10.1007/s12524-022-01636-2

Teng, S., Liu, C., Tan, Z., Li, J., Xu, N., Hu, X., ... & Sohn, B. J. (2023). A multispectral method for retrieving overlapping cloud top heights from passive radiometers. Remote Sensing of Environment, 286, 113425. https://doi.org/10.1016/j.rse.2022.113425

de la Iglesia Martinez, A., & Labib, S. M. (2023). Demystifying normalized difference vegetation index (NDVI) for greenness exposure assessments and policy interventions in urban greening. Environmental Research, 220, 115155. https://doi.org/10.1016/j.envres.2022.115155

Deng, J., Dong, W., Guo, Y., Chen, X., Zhou, R., & Liu, W. (2023). A Novel Remote Sensing Image Enhancement Method, the Pseudo-Tasseled Cap Transformation: Taking Buildings and Roads in GF-2 as An Example. Applied Sciences, 13(11), 6585. https://doi.org/10.3390/app13116585

Rhymee, H., Ratnayake, U., Abdul Rahman, E. K., & Shams, S. (2023, January). Application of normalized difference vegetation index in agriculture to estimate rice yield. In AIP Conference Proceedings (Vol. 2643, No. 1, p. 030022). AIP Publishing LLC. https://doi.org/10.1063/5.0115666

Mousania, Y., Karimi, S., & Farmani, A. (2023). Optical remote sensing, brightness preserving and contrast enhancement of medical images using histogram equalization with minimum cross-entropy-Otsu algorithm. Optical and Quantum Electronics, 55(2), 1-22. https://doi.org/10.1007/s11082-022-04341-z

Yang, P., Xia, J., Chen, Y., Zhang, Y., Li, Z., Zhang, S., & Wang, W. (2023). Dynamic evolution of recent droughts in Central Asia based on microwave remote sensing satellite products. Journal of Hydrology, 620, 129497. https://doi.org/10.1016/j.jhydrol.2023.129497

Zhu, S., Wei, J., Zhang, H., Xu, Y., & Qin, H. (2023). Spatiotemporal deep learning rainfall-runoff forecasting combined with remote sensing precipitation products in large scale basins. Journal of Hydrology, 616, 128727. https://doi.org/10.1016/j.jhydrol.2022.128727

NS, R. (2022). Drought Assessment Using Remote Sensing and Geographic Information Systems (GIS) Techniques (Case Study: Klaten Regency, Indonesia). International Journal of Geoinformatics, 18(5). https://doi.org/10.52939/ijg.v18i5.2393

Mukherjee, I., & Singh, U. K. (2020). Delineation of groundwater potential zones in a drought-prone semi-arid region of east India using GIS and analytical hierarchical process techniques. Catena, 194, 104681. https://doi.org/10.1016/j.catena.2020.104681

Ponnusamy, D., & Elumalai, V. (2022). Determination of potential recharge zones and its validation against groundwater quality parameters through the application of GIS and remote sensing techniques in uMhlathuze catchment, KwaZulu-Natal, South Africa. Chemosphere, 307, 136121. https://doi.org/10.1016/j.chemosphere.2022.136121

Dev Roy, S., & Trivedi, S. (2023). Geospatial Assessment of Long-Term Changes (1937–2019) in Mangrove Vegetation and Shoreline Dynamics of Godavari Estuary, East Coast of India. Journal of the Indian Society of Remote Sensing, 1-19. https://doi.org/10.1007/s12524-023-01698-w

Pandey, P. C., Anand, A., & Srivastava, P. K. (2019). Spatial distribution of mangrove forest species and biomass assessment using field inventory and earth observation hyperspectral data. Biodiversity and Conservation, 28, 2143-2162. https://doi.org/10.1007/s10531-019-01698-8