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MODELING *FOREST* AND LAND FIRE VULNERABILITY IN BANJAR DISTRICT USING *RANDOM FOREST* CLASSIFICATION METHOD IN 2023

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ABSTRAK

Kebakaran hutan dan lahan (karhutla) merupakan salah satu permasalahan lingkungan utama di Kabupaten Banjar, Kalimantan Selatan, dengan luas area terdampak mencapai 1.812,80 ha pada tahun 2023. Penelitian ini bertujuan untuk memodelkan tingkat kerawanan kebakaran hutan dan lahan menggunakan algoritma *Random Forest* berbasis data penginderaan jauh. Data yang digunakan berupa citra satelit Landsat 8 sepanjang tahun 2023 dengan ekstraksi indeks spektral seperti NDVI, NBR, NDWI, MSI, dan BAI, serta data titik kebakaran dari BPBD Kabupaten Banjar. Model dilatih menggunakan data bulan Juni hingga pertengahan September, dan divalidasi dengan data dari pertengahan September hingga November 2023. Hasil pemodelan menunjukkan bahwa wilayah utara dan tengah Kabupaten Banjar memiliki tingkat kerawanan tertinggi terhadap karhutla. Peta kerawanan diklasifikasikan ke dalam lima zona berdasarkan probabilitas kebakaran. Uji akurasi menggunakan confusion matrix menghasilkan akurasi keseluruhan sebesar 71,64% dan nilai indeks Kappa sebesar 40,81%. Temuan ini menunjukkan bahwa metode *Random Forest* cukup efektif untuk mengidentifikasi wilayah prioritas mitigasi karhutla dengan efisiensi tinggi dan input data minimal. Hasil ini dapat digunakan sebagai dasar pengambilan keputusan dalam upaya pencegahan dan penanganan karhutla yang lebih tepat sasaran.

ABSTRACT

Forest and land fires are a major environmental concern in Banjar Regency, South Kalimantan, with a burned area of 1,812.80 ha recorded in 2023. This study aims to model fire susceptibility levels using the Random Forest algorithm based on remote sensing data. The data utilized include Landsat 8 imagery from 2023 with extracted spectral indices such as NDVI, NBR, NDWI, MSI, and BAI, along with fire hotspot data from the Banjar Regency Disaster Management Agency. The model was trained using data from June to mid-September and validated with data from mid-September to November 2023. Results indicate that the northern and central areas of Banjar Regency exhibit the highest fire susceptibility. The susceptibility map was categorized into five zones based on fire probability. Accuracy assessment using a confusion matrix yielded an overall accuracy of 71.64% and a Kappa coefficient of 40.81%. These findings demonstrate that the Random Forest method is effective in identifying fire-prone areas with high efficiency and minimal input data. This model provides a valuable tool for spatially targeted fire prevention and mitigation planning.

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INTRODUCTION

Forest and land fires (karhutla) are one of the most destructive and complex ecological disasters in Indonesia. This phenomenon not only causes widespread ecosystem degradation, but also incurs huge losses in the economic, health and social sectors. Areas in Indonesia characterized by peatlands such as Sumatra and Kalimantan are highly vulnerable to forest and land fires, especially during the long dry season influenced by global climate phenomena such as El Niño (KLHK, 2024; Badri et al., 2018). One of the areas with a high level of vulnerability is Banjar District in South Kalimantan Province. In 2023, the district recorded a fire area of 1,812.80 ha, making it the region with the highest frequency of forest and land fires in the last decade in the province (Diskominfo Provinsi Kalimantan Selatan, 2024).

In principle, fire incidents can be explained through the concept of the fire triangle, which consists of three main elements, namely fuel, oxygen, and heat. These three interact with each other to create and sustain a flame (Chakrabarty et al., 2016). In Indonesia, heat sources generally come from anthropogenic activities such as land clearing by burning (Mareta et al., 2020). This indicates that most forest and land fires can be prevented through appropriate mitigation approaches based on data and technology.

The use of remote sensing technology is crucial for modeling the risk of forest and land fires. It enables efficient monitoring of large areas and provides multi-temporal data useful for analyzing vegetation and soil moisture conditions. Landsat 8 satellite imagery, with its various spectral indices such as Normalized Difference Vegetation Index (NDVI), Normalized Burn Ratio (NBR), Normalized Difference Water Index (NDWI) and Moisture Stress Index (MSI) has proven effective in detecting and monitoring environmental conditions related to fire potential (Fang, 2024; Rahimi & Jung, 2024). However, the limited accuracy of a single index is often an obstacle in producing consistent predictions, as shown by the variation in accuracy in previous studies (Sivrikaya et al., 2024; Rotjanakusol & Laosuwan, 2023).

To address these challenges, this research utilizes the Random Forest method, a machine learning algorithm capable of classifying fire vulnerability with high accuracy and tolerance to overfitting. This method works by combining multiple decision trees and utilizing the advantages of historical data to identify spatial patterns that could potentially cause fires (Husen et al., 2022; Thanh Noi & Kappas, 2017). The utilization of Random Forest in the Google Earth Engine (GEE) platform also enables faster and more computationally efficient analysis on a large scale.

Considering the high incidence of forest and land fires in Banjar Regency and the

great potential of remote sensing technology and classification algorithms in assisting mitigation, this research was conducted to develop a Random Forest classification-based forest and land fire vulnerability mapping model. The results of this research are expected to be a reference in decision-making by the government and related institutions for more effective and spatially-based prevention and handling of forest and land fires.

RESEARCH METHODS

Description of the Research Area

The study area in this research is Kabupaten Banjar, which is located in South Kalimantan Province at coordinates 3° 0' N - 3° 30' N and 114° 30' East - 115° 0' East. The district has an area of approximately 4,668.50 km² and consists of 20 sub-districts. Geomorphologically, the region is dominated by peatlands and shrubs that have a high potential to catch fire, especially during the dry season. In addition, the pressure of land use change and unsustainable land clearing activities increase the vulnerability to fire. The location map and Landsat 8 imagery of Banjar District can be seen in Figure 1 below.

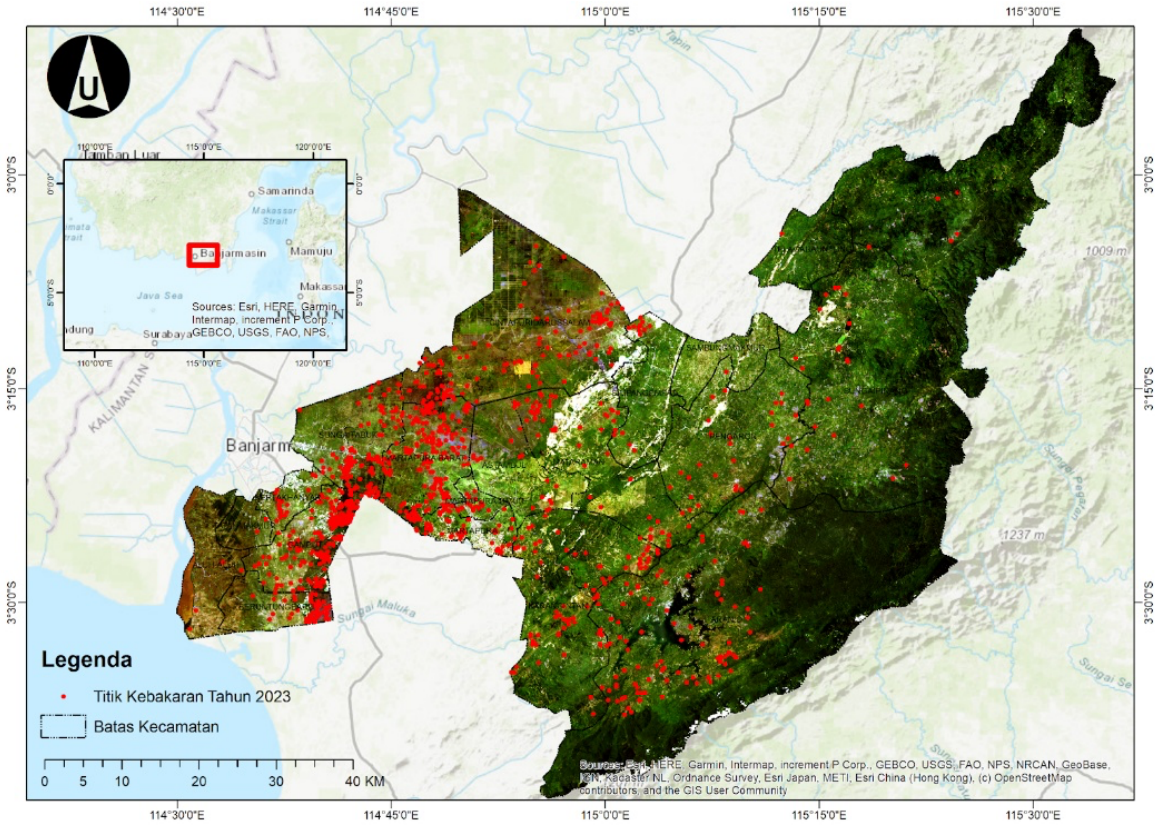


Figure 1. Location Map of Banjar District and Fire Spots with Landsat 8 Original Color Composite Imagery 2023 as Background.

Data Used

This research uses two main types of data, namely:

1. Landsat 8 OLI/TIRS satellite imagery with a spatial resolution of 30 meters, downloaded through Google Earth Engine (GEE). The data used is monthly imagery from January to December 2023. From this image, several spectral indices related to fire susceptibility were extracted, namely:
   - Normalized Burn Ratio (NBR)
   - Normalized Difference Vegetation Index (NDVI)
   - Normalized Difference Water Index (NDWI)
   - Moisture Stress Index (MSI)
   - Burned Area Index (BAI)
2. Fire Data for 2023, obtained from BPBD Banjar Regency, which includes the location and time of fire incidents. This data is used as a label in training the classification model and validating the prediction results.

Random Forest

Random Forest is used as a classification algorithm to model forest and land fire vulnerability. Random Forest works by building a large number of decision trees from a randomly drawn subset of training data (bagging), and then generating predictions based on the majority voting of all trees. In the context of this research, a model was developed to classify the region into five fire vulnerability probability classes, namely: zone 1 - zone 5.

The training process was conducted using imagery and fire data from June 1 to September 15, 2023, while data from September 16 to November 30, 2023 was used for model validation. The model was developed and run using the Google Earth Engine (GEE) platform, which can be used for efficient processing of large-scale spatial data.

Fire Vulnerability Modeling

Land and forest fire vulnerability modeling was conducted using a machine learning approach using the Random Forest (RF) algorithm, which is capable of handling multivariate data and has high classification capabilities. The model was built by utilizing the channel and spectral index transformation results from the 2023 Landsat 8 imagery and fire data from BPBD Banjar District. All data were transformed into a 30-meter resolution grid format, then used as classification input in the Google Earth Engine (GEE) platform.

The Random Forest model produces a probability value for each pixel in the range of 0-1, indicating the vulnerability of forest and land fires. These probability values are then classified into five vulnerability zone classes (Karurung et al., 2025) as follows:

- Zone I (Very Low): 0.00 - 0.20
- Zone II (Low): 0.20 - 0.40
- Zone III (Medium): 0.40 - 0.60
- Zone IV (High): 0.60 - 0.80
- Zone V (Very High): 0.80 - 1.00

This zone division is used to simplify map interpretation and assist stakeholders in determining priority areas for forest and land fire mitigation. Each zone indicates an area's vulnerability to fire based on biophysical characteristics and historical fires from 2023.

The application of this probability-based classification is also in line with the approach in the study by Karurung et al. (2025), which emphasizes the importance of quantitative spatial risk representation to support more precise and adaptive fire mitigation and management planning.

Accuracy Test

The accuracy test is conducted using the confusion matrix method, which produces several evaluation metrics, including:

- Overall Accuracy: the percentage of correct classifications out of the total validation data.
- Kappa Coefficient: an index that measures the consistency of the classification by considering the possibility of random fit.

Table 1. Kappa Index Classification (Fleiss et al. 2023)

Kappa Index Value	Interpretation
< 0.40	Bad
0,40 - 0,75	Fair - Good
> 0,75	Very good

The evaluation was conducted by comparing the classification results with the actual fire points from the test data. This accuracy test is the basis for assessing the performance of the model in representing actual conditions.

Research Flow Chart

The following flowchart explains the stages of the research methodology, starting from data collection, feature extraction, model training, vulnerability classification, to validation of results:

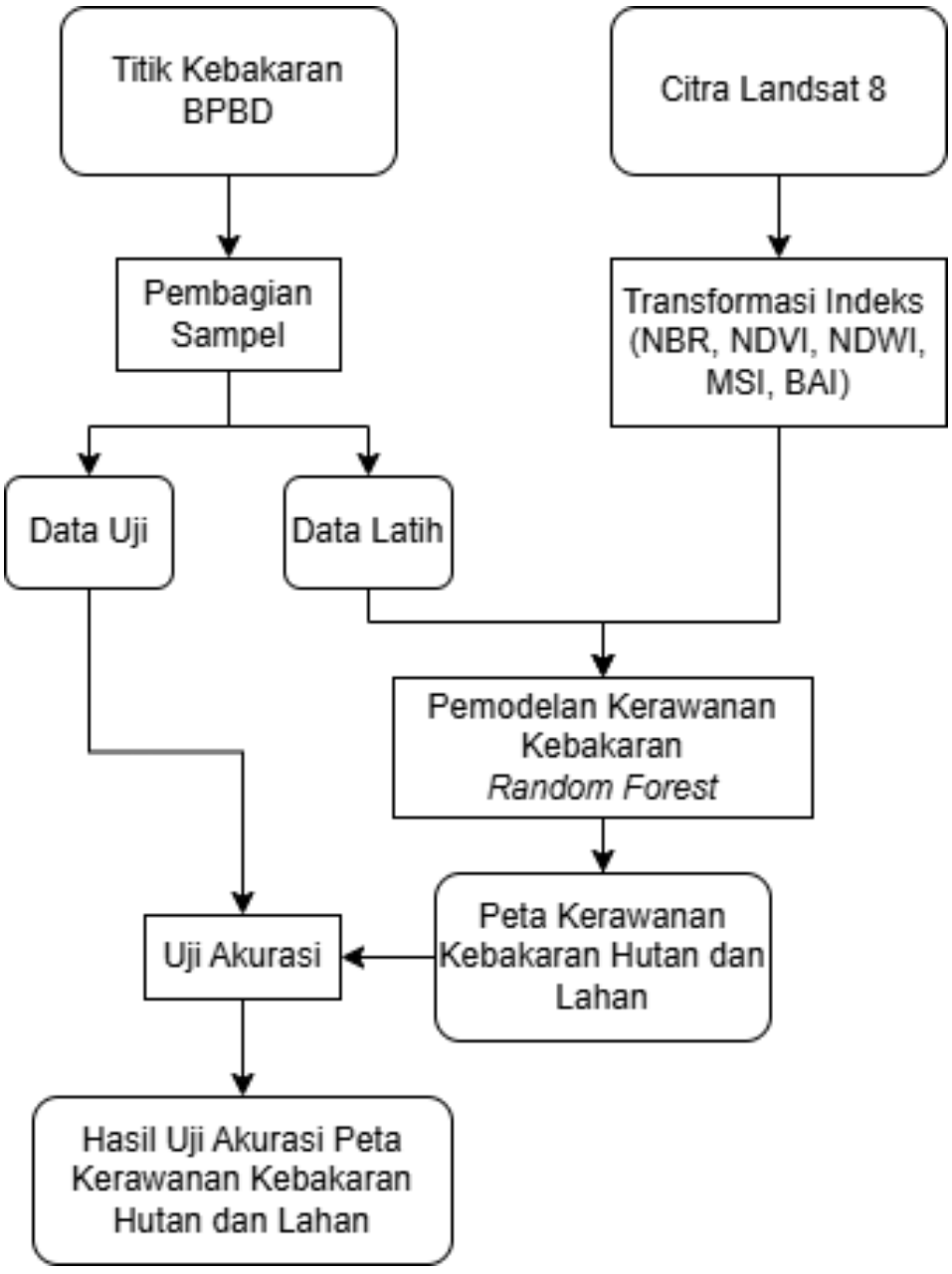
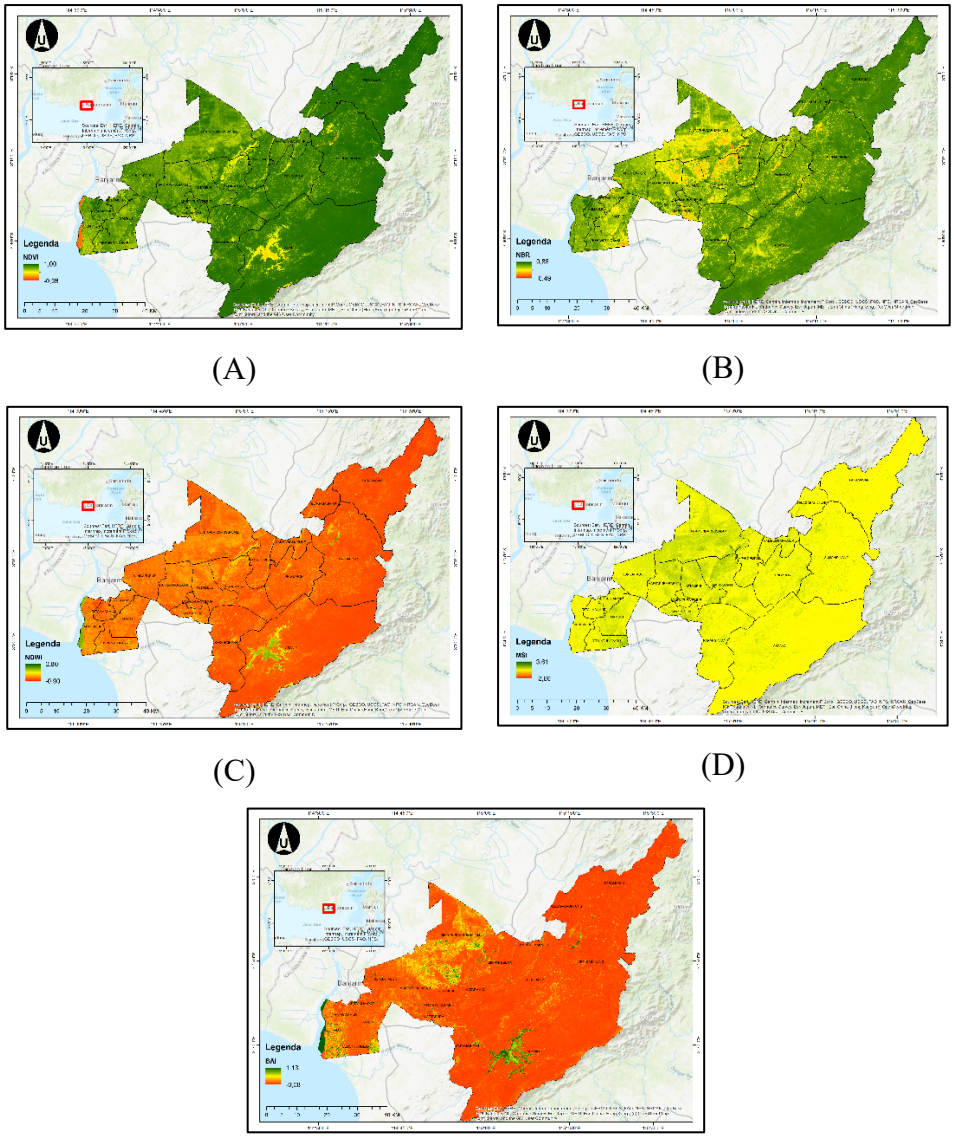


Figure 2. Research Flowchart

RESULTS AND DISCUSSION

Spectral index transformation is carried out to produce values that will later be used for input variables in the classification of forest and land fire vulnerability using the random forest algorithm. Here are the results of the spectral index transformation.



(A) (B)

(C) (D)

(E)

Figure 3. Spectral Index Maps (A) NDVI, (B) NBR, (C) NDWI, (D) MSI, (E) BAI

The results of this index transformation map are taken spectral values which will later become input for the random forest algorithm. From the results of this transformation, it can be seen that some of the indices used have a correlation such as the NBR index with NDVI, in NBR with a high value, the NDVI value is low, this shows that when there is a fire, the greenness value of the vegetation decreases, this is in line with that if there is a fire, a lot of vegetation is burned which causes the greenness value of the vegetation to decrease due to burned vegetation. The BAI value can also be seen to have a spatial pattern similar to NBR. Likewise, the NDWI and MSI values can be seen to tend to have low values in burned areas, so the results of this transformation can be concluded that the results of these indices are correlated.

The Random Forest algorithm produces a map of forest and land fire vulnerability which can be seen in Figure 3, it can be seen that zone A is the zone with the highest level of vulnerability while zone B is the zone with the lowest level of vulnerability, so this can be a recommendation in mitigating the handling of forest and land fires to related parties, which will be a consideration for the placement of posts and teams for handling forest and land fires in Banjar district, seeing from the results of this model, it can be focused on increasing personnel and posts in zone A of Banjar district which is the zone with the highest fire vulnerability.

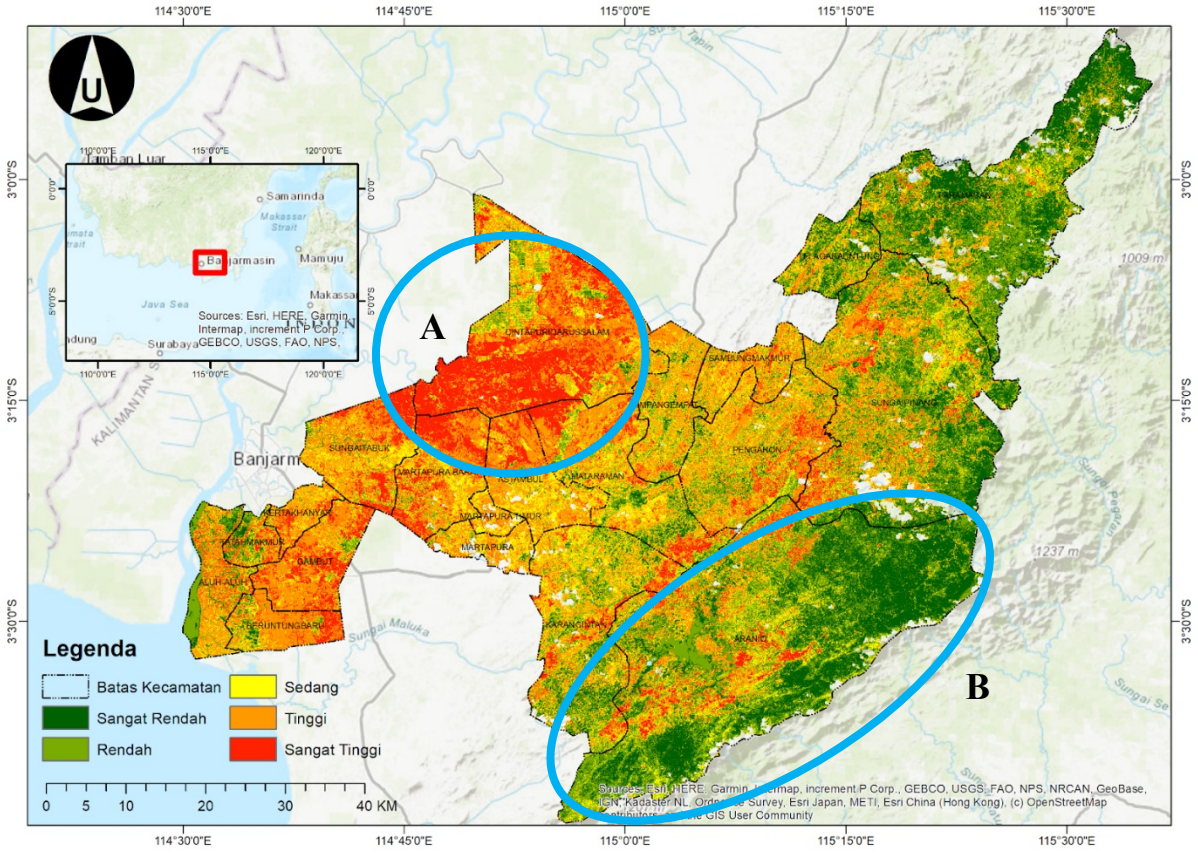


Figure 4. Land and Forest Fire Vulnerability Map of Banjar Regency in 2023

Table 2. Table of fire area by class

Class	Area (Hectares)
Very Low (0.0-0.2)	81.798,48
Low (0.2-0.4)	99.327,42
Medium (0.4-0.6)	79.944,66
High (0.6-0.8)	125.692,5
Very High (0.8-1.0)	63.396,36

From the visualization results obtained, it can be seen that the high fire class has an area of 125,692.5 hectares, this figure makes the high fire class the most extensive class of fire occurrence which can be concluded that in this study area there are quite high and extensive fires. This is in line with the explanation that zone A is the zone most prone to fires.

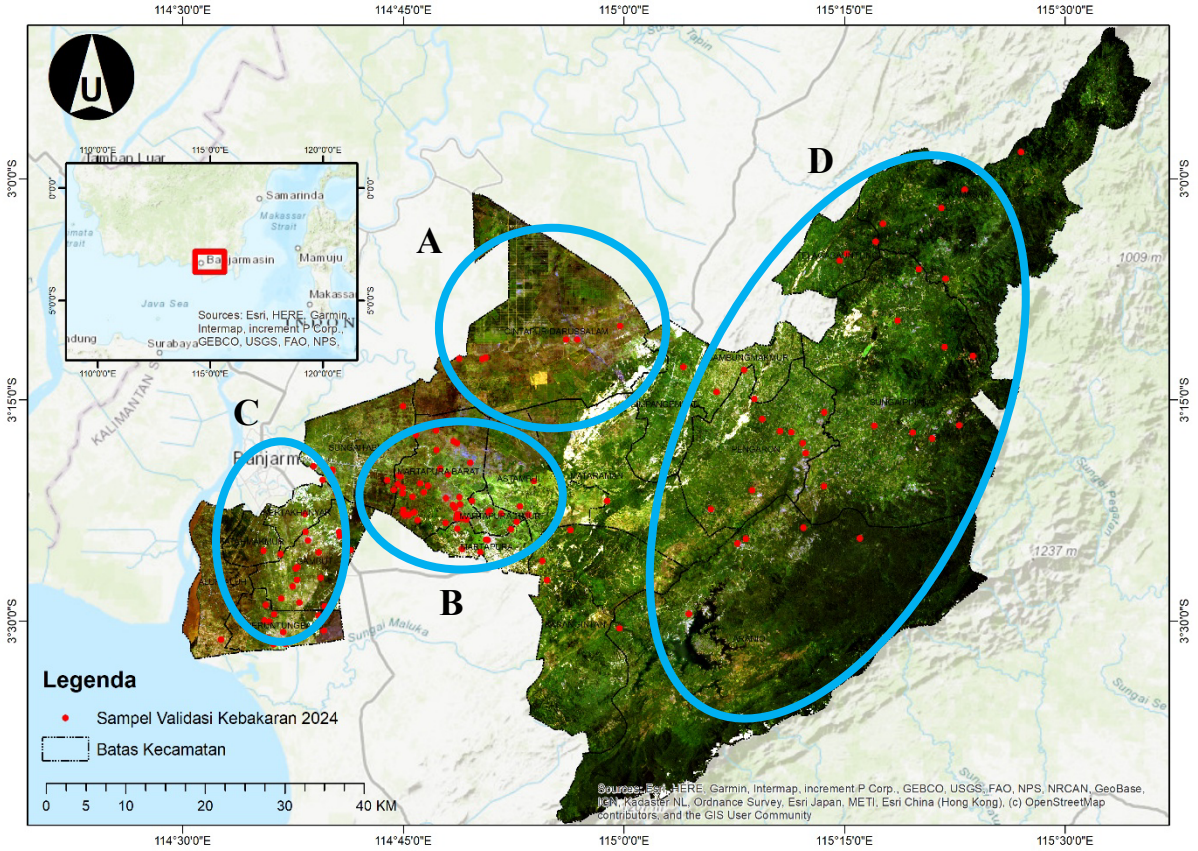


Figure 5. Validation Sample Map with Original Color Composite Landsat 8 Image Background

Based on Figure 5, it can be seen that the spatial pattern of the distribution of forest and land fires in zone B and zone C is the zone with the most fires in zone D also has the same spatial distribution pattern as in the results, although in the research results it was found that zone A became the highest zone of fire vulnerability but from the results and validation had the same fire pattern even though the level of vulnerability with the number of points was different, This is because the data used to build the model is fire data in 2023 while for validation using fire data in 2024 there is a difference in conditions because the forest and land fires that occurred in 2023 had burned vegetation in zone A so that in 2024 the vegetation in that zone has not yet experienced complete vegetation growth so that the zone has only a few fires.

Table 3. Overall Accuracy and Kappa results.

Accuracy Test		
	Overall Accuracy	***Kappa Coefficient***
Training Data (2023)	98,47%	96,82%
Test Data (2024)	71,64%	40,82%

The accuracy test used in this research is a confusion matrix that gets accuracy and kappa results. Based on the results of this study, the accuracy result is 71.64% while the kappa index value is 40.82%. Previous research conducted by Karurung et al. (2025) obtained a similar accuracy of 78.67% for accuracy in the same season. Better results were seen in the rainy season which resulted in an accuracy of 83.15%, indicating that the accuracy results of this study were quite good. Then for the accuracy of kappa in this study is also quite good according to Table 1. The effect of this percentage of accuracy is due to composite median image data, so it does not produce pure spectral values, then the influence of clouds covering the image is also one of the causes of the lack of accuracy produced. In addition, when compared to previous studies that used several more input data such as distance to settlements, roads, to the use of physical data such as elevation from the Digital Elevation Model (DEM), the accuracy value was greater. The use of a longer time span from 2015 to 2021 also has a positive impact compared to this study which only used data in 2023. However, the difference in accuracy of about 7% is not significant enough so that the results of this study provide more effective results with a shorter time span using less input data, namely only using spectral channels and several index transformations.

CONCLUSION

Forest and land fires are one of the most important environmental issues because they cause significant damage in the form of forest degradation and habitat destruction for the wildlife living within them. The importance of preventing forest and land fires includes modeling fire risk to identify priority areas for fire management. Based on this study, it was concluded that the northern and central zones of Banjar Regency are the zones with the highest fire risk levels, indicating that these areas require greater attention in forest and land fire management and as a basis for determining forest and land fire mitigation strategies. Based on its quality, the vulnerability model built by Random Forest has good accuracy with an accuracy value of 71.64% and a kappa value of 40.81%.

From this study it can be seen that the quality of data in the form of Landsat 8 images contributes to producing good spectral values so that it can affect the accuracy results, as well as the parameters used, the more parameters related to fire events will produce high accuracy, so it would be better if future research could consider adding several other parameters related to forest and land fires such as rainfall and land cover/use.

REFERENCES

Badri, M., Lubis, D. P., Susanto, D., & Suharjito, D. 2018. The Viewpoint of Stakeholders on the Causes of Forest and Land Fires in Riau Province, Indonesia. *Russian Journal of Agricultural and Socio-Economic Sciences*, 74(2), 4–10. https://doi.org/10.18551/rjoas.2018-02.01.

Chakrabarty, A., Mannan, S., & Cagin, T. 2016. Multiscale Modeling for Process Safety Applications. *Multiscale Modeling for Process Safety Applications,* 1–3. https://doi.org/10.1016/B978-0-12-396975-0.00001-2.

Diskominfo Provinsi Kalimantan Selatan. 2024. *Satu Data Banua*. https://data.kalselprov.go.id/dataset/data/1635.

Fang, Q. 2024. The advantages of using remote sensing technology to monitor forest fires. *Applied and Computational Engineering*, 60(1), 42–48. https://doi.org/10.54254/2755-2721/60/20240830.

Fleiss, J., Levin, B., Paik, M. 2003. *Statistical Methods for Rates and Proportions*. New York: Wiley & Sons.

Husen, D.-, Sandi, D.-, Bumbungan, S.-, -, K.-, & -, K.-. 2022. Analisis Prediksi Kebakaran Hutan dengan Menggunakan Algoritma *Random Forest* Classifier. *Nuansa Informatika*, 16(1), 150–155. https://doi.org/10.25134/nuansa.v16i1.5392.

Karurung, W. S., Lee, K., & Lee, W. 2025. Assessment of forest fire vulnerability prediction in Indonesia: Seasonal variability analysis using machine learning techniques. *International Journal of Applied Earth Observation and Geoinformation*, *138*, 104435. https://doi.org/10.1016/j.jag.2025.104435.

KLHK. 2024. *Kinerja Pengendalian Kebakaran Hutan dan Lahan Tahun 2023*. Diambil 2 Februari 2025, dari https://ppid.menlhk.go.id/berita/siaran-pers/7579/kinerja-pengendalian-kebakaran-hutan-dan-lahan-tahun-2023.

Mareta, L., Hidayat, R., Hidayati, R., & Latifah, A. L. 2020. Pengaruh Faktor Alami dan Antropogenik Terhadap Luas Kebakaran Hutan dan Lahan di Kalimantan. *Jurnal Tanah dan Iklim*, 43(2), 147. https://doi.org/10.21082/jti.v43n2.2019.147-155

Rahimi, E., & Jung, C. 2024. Evaluating the applicability of landsat 8 data for global time series analysis. *Frontiers in Remote Sensing*, 5, 1492534. https://doi.org/10.3389/frsen.2024.1492534.

Rotjanakusol, T., & Laosuwan, T. 2023. Monitoring of forest fire areas using remote sensing technology and multitemporal difference of spectral indices. *ARPN Journal of Engineering and Applied Sciences*, 2066–2074. https://doi.org/10.59018/0923253.

Sivrikaya, F., Günlü, A., Küçük, Ö., & Ürker, O. 2024. Forest fire risk mapping with Landsat 8 OLI images: Evaluation of the potential use of vegetation indices. *Ecological Informatics*, 79, 102461. https://doi.org/10.1016/j.ecoinf.2024.102461.

Thanh Noi, P., & Kappas, M. 2017. Comparison of *Random Forest*, k-Nearest Neighbor, and Support Vector Machine Classifiers for Land Cover Classification Using Sentinel-2 Imagery. *Sensors*, 18(1), 18. https://doi.org/10.3390/s18010018.