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GIS-Based Decision Support System For Determining Priority Zones For Forest Logging Monitoring Using The TOPSIS Method (Case Study: North Sumatra)

Mhd. Fikri Al-Amin[1)], Mahardika Abdi Prawira Tanjung[2)]
[1,2)] Muhammadiyah University of North Sumatra

*Corresponding Author
E-mail: mhdfikrialamin@gmail.com

Abstract
Deforestation and illegal logging in North Sumatra require more effective and spatially integrated monitoring to determine priority areas. This study aims to develop a GIS-based Decision Support System (DSS) to determine priority zones for forest logging monitoring using the TOPSIS method. The study uses a GIS-based DSS approach with the TOPSIS method. The study population includes districts with forest areas and potential for logging, with five districts as alternatives, namely Mandailing Natal, South Tapanuli, Langkat, North Tapanuli, and Dairi. Data were obtained through questionnaires, spatial data, and literature studies. TOPSIS analysis includes the formation of a decision matrix, normalization, weighting, ideal solutions, distance calculations, preference values, and ranking. The results show that the system is able to generate preference values, rankings, and priority zones spatially, while Black Box testing shows that all main functions are successfully implemented. In conclusion, the integration of TOPSIS and GIS can support the determination of forest monitoring priorities in a structured and spatially based manner.

Keywords*: *Decision Support Systems, Forest Monitoring, Geographic Information Systems, Illegal Logging, TOPSIS

INTRODUCTION

North Sumatra Province faces the threat of deforestation and illegal logging, which impact the sustainability of forest ecosystems and the well-being of surrounding communities. Deforestation reached 6,142 hectares between 2024 and September 2025, a 13.98% decrease compared to the previous period. The increase in deforested land since 2019 indicates ecological vulnerability, influenced by road access, population pressure, and fire hotspots. This negatively impacts the sustainability of ecosystems and communities surrounding forests (Koginta Lubis & Dewi Siregar, 2024).

Illegal logging is one of the causes of forest destruction in North Sumatra, exacerbated by a lack of oversight, limited human resources, and suboptimal inter-agency coordination (Sulfiani & Firdaus, 2022). Forest destruction can also trigger flash floods, landslides, and damage to watersheds (Muhaiyaadden et al., 2026). These conditions highlight the importance of determining priority areas for monitoring.

Forest monitoring remains conventional and does not yet utilize multi-criteria analysis to simultaneously consider various vulnerability factors. Some parameters that can be analyzed include land cover changes, proximity to roads, population density around forests, and the presence of hotspots (Komara et al., 2016). Processing these various parameters is necessary to more accurately determine the vulnerability level of an area.

Decision Support Systems (DSS) can be used to assist decision-making in problems involving multiple criteria through data modeling and mathematical methods (Qashlim, 2012). Integrating DSS with Geographic Information Systems (GIS) allows analysis results to be displayed through thematic maps, allowing spatial information to be presented more effectively and supporting transparency in decision-making (Komara et al., 2016).

Another problem encountered in this study is the lack of integration of the TOPSIS method with GIS spatial analysis specifically to determine priority zones for forest logging monitoring. The study used five alternative districts: Mandailing Natal, South Tapanuli, Langkat, North Tapanuli, and Dairi, with criteria including forest cover change, distance from roads, distance from settlements, slope gradient, and forest area status.

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This study aims to design and build a GIS-based Decision Support System to determine priority zones for forest logging monitoring in North Sumatra Province using the TOPSIS method. The urgency of this research lies in the need for more effective, data-driven, and spatially integrated forest monitoring. The novelty of this research lies in the integration of TOPSIS and GIS to determine and visualize priority monitoring zones based on five criteria in five districts in North Sumatra Province.

RESEARCH METHODS

This study uses a GIS-based Decision Support System with the TOPSIS method to determine priority zones for forest logging monitoring in North Sumatra Province. The research alternatives consist of Mandailing Natal, South Tapanuli, Langkat, North Tapanuli, and Dairi Regencies with five criteria: forest cover change, distance from roads, distance from settlements, slope gradient, and forest area status.

The research data consisted of primary and secondary data obtained through questionnaires, spatial data, and literature studies. The questionnaire was used to determine the criteria weights using a Likert scale of 1 to 5, while the spatial data was processed using QGIS. Data analysis was performed using the TOPSIS method through the preparation of a decision matrix, normalization, weighting, determination of the ideal solution, distance calculation, preference value, and ranking.

The study population consisted of regencies in North Sumatra Province with forested areas and potential for deforestation. The sample was determined based on the presence of forest areas and the availability of spatial data, resulting in five regencies as alternative research locations.

The research was conducted by determining alternatives and criteria, collecting and processing spatial data using QGIS, and then using TOPSIS calculations to generate preference and ranking values. These results were then integrated into a GIS to produce a map of priority zones for forest logging monitoring.

RESULTS AND DISCUSSION

TOPSIS Implementation

```php
$x = [];

$q = mysqli_query($conn,"
    SELECT *
    FROM penilaian
");

while($r = mysqli_fetch_assoc($q)){

    $x[$r['id_alternatif']]
      [$r['id_kriteria']]
      = $r['nilai'];

}
```

Figure 1. Formation of Decision Matrix

Figure 1 shows the initial stage of TOPSIS implementation by taking alternative data, criteria, weights, and assessment values as a decision matrix.

```php
$r = [];

foreach($alternatif as $id_alt=>$nama){

    foreach($kriteria as $id_kriteria=>$k){

        $nilai = $x[$id_alt][$id_kriteria] ?? 0;

        $r[$id_alt][$id_kriteria]
            = $nilai / $pembagi[$id_kriteria];
    }
}
```

Figure 2. Normalization of Decision Matrix

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This process is performed to equalize the value scale of each criterion before the weighting process. The program calculates the normalized value using the Euclidean vector length method, which involves dividing the value of each alternative by the square root of the sum of all the values for that criterion. This step produces a normalized matrix that is then used in the weighting process.

```
$y = [];

foreach($alternatif as $id_alt=>$nama){

    foreach($kriteria as $id_kriteria=>$k){

        $y[$id_alt][$id_kriteria]
            = $r[$id_alt][$id_kriteria]
            * $bobot[$id_kriteria];
    }
}
```

Figure 3. Weighted Normalized Matrix

Figure 3 shows the program used to create a weighted normalized matrix. The process involves multiplying each value in the normalized matrix by a predetermined criterion weight. The weights used are the normalized weights derived from the respondents' assessments.

```
$a_plus = [];
$a_min  = [];

foreach($kriteria as $id_kriteria=>$k){

    $kolom = [];

    foreach($alternatif as $id_alt=>$nama){

        $kolom[] = $y[$id_alt][$id_kriteria];
    }

    if($k['atribut']=='benefit'){

        $a_plus[$id_kriteria] = max($kolom);
        $a_min[$id_kriteria]  = min($kolom);

    }else{

        $a_plus[$id_kriteria] = min($kolom);
        $a_min[$id_kriteria]  = max($kolom);

    }
}
```

Figure 4. Positive and Negative Ideal Solutions

Figure 4 shows the implementation of determining the positive ideal solution and the negative ideal solution in the system. This process is carried out based on the values in the weighted normalized matrix, taking into account the attributes of each criterion. For benefit-type criteria, the largest value is used as the positive ideal solution, while for cost-type criteria, the smallest value is used as the positive ideal solution. Conversely, the negative ideal solution is determined based on the opposite condition.

```
$d_plus = [];
$d_min  = [];

foreach($alternatif as $id_alt=>$nama){

    $jumlah_plus = 0;
    $jumlah_min  = 0;

    foreach($kriteria as $id_kriteria=>$k){

        $jumlah_plus += pow(
            $y[$id_alt][$id_kriteria]
            - $a_plus[$id_kriteria]
        ,2);

        $jumlah_min += pow(
            $y[$id_alt][$id_kriteria]
            - $a_min[$id_kriteria]
        ,2);

    }

    $d_plus[$id_alt] = sqrt($jumlah_plus);
    $d_min[$id_alt]  = sqrt($jumlah_min);
}
```

Figure 5. Ideal Solution Distance

Figure 5 shows the implementation of calculating the distance of each alternative to the positive ideal solution and the negative ideal solution. The calculation is performed by measuring the difference between the value of each alternative in the weighted normalized matrix and each ideal solution. The result of this process is the distance to the positive ideal solution (Di+∋) and the distance to the negative ideal solution (Di−∋) for each alternative. These values are then used as the basis for calculating the preference value.

```
$preferensi = [];

foreach($alternatif as $id_alt=>$nama){

    $preferensi[$id_alt]
        = $d_min[$id_alt]
        / ($d_min[$id_alt] + $d_plus[$id_alt]);
}
```

Figure 6. Calculation of Preference Value

Figure 6 shows the implementation of the calculation of the preference value for each alternative. The preference value is obtained based on the comparison of the alternative's distance from the negative ideal solution with the total distance from the positive and negative ideal solutions.

Digital Map Implementation

```
<script src="https://unpkg.com/leaflet@1.9.4/dist/leaflet.js"></script>

<script>

var map = L.map('map').setView([2.1154,99.5451],7);

L.tileLayer(
'https://{s}.tile.openstreetmap.org/{z}/{x}/{y}.png',
{
    attribution:'© OpenStreetMap'
}
).addTo(map);

var topsisData = <?= json_encode($gisData); ?>;

fetch('../assets/geojson/kab_kota.geojson')
.then(response => response.json())
.then(data => {

    L.geoJSON(data,{

        filter: function(feature){

            return topsisData.hasOwnProperty(
                feature.properties.name
            );

        },
```

Figure 7. Implementation of Digital Map

The digital map implementation in the system was carried out using the Leaflet.js library with OpenStreetMap as the base map and regional data in GeoJSON format. The GeoJSON data used comes from kab_kota.geojson and serves to display the boundaries of the districts that are alternative research areas. The results of the TOPSIS method calculations are then integrated with spatial data based on the region name, so that each region can be given a priority category and visualized on the map according to the ranking results.

Interface View

Figure 8. System Login Page

Figure 8 shows the login page used as the user's initial access before entering the system. The login page provides an authentication mechanism to ensure that users with access can use the features available on the system.

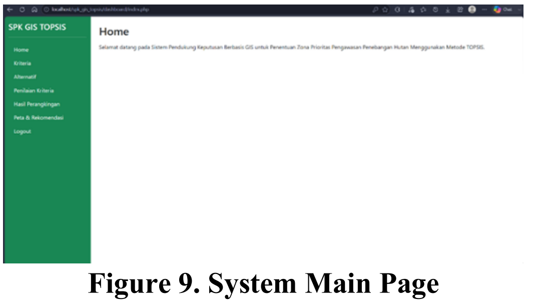

Figure 9. System Main Page

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Figure 9 displays the dashboard page, the system's main page after a user successfully logs in. The dashboard provides navigation to criteria management, alternatives, assessments, ranking results, maps, recommendations, and logout features, allowing users to access each process in the system in a structured manner.

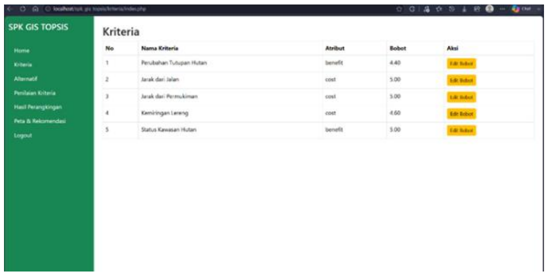

Figure 10. System Criteria Page

Figure 10 displays the criteria page used to present information about the criteria used in the decision-making process, including the criteria name, attributes, and weights. This data forms the basis for the TOPSIS calculation process applied to the system.

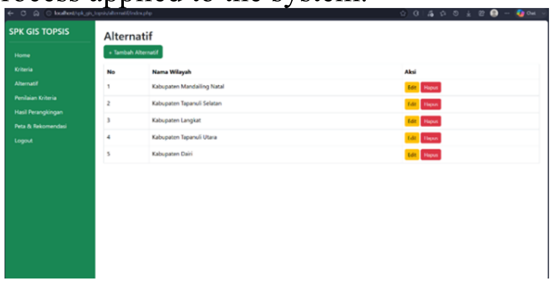

Figure 11. System Alternative Page

Figure 11 displays an alternative page used to manage regional data used as an alternative in the decision-making process. The alternatives used in this study include the regencies of Mandailing Natal, South Tapanuli, Langkat, North Tapanuli, and Dairi.

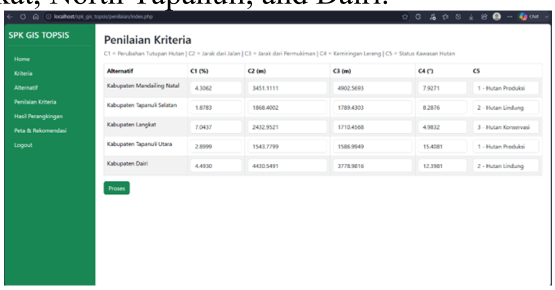

Figure 12. System Criteria Assessment Page

Figure 12 displays the assessment page used to enter the value of each alternative based on predetermined criteria. The entered assessment data is then used as a decision matrix in the TOPSIS calculation process.

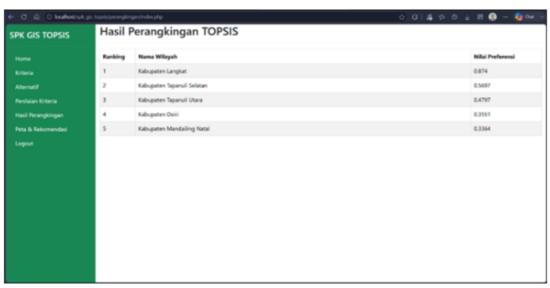

Figure 13. System Ranking Results Page

Figure 13 displays the ranking results page, which displays the preference values and priority order of each alternative based on the TOPSIS calculation results. The results displayed in the system are compared with the results of previous calculations to ensure that the implementation process produces appropriate values and ranking order.

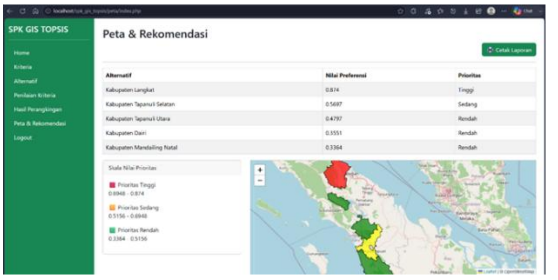

Figure 14. System Map and Recommendation Page

Figure 14 displays a map page that displays the ranking results in a spatial visualization. Each region is displayed based on its monitoring priority category, allowing users to understand the geographic distribution of priority zones. This visualization is used to support understanding the ranking results and determining priority monitoring areas.

Figure 15. Download Report

Figure 15 displays the PDF download feature for ranking reports. This feature allows you to save the ranking results for priority logging monitoring areas as a file or document that can be used for documentation.

System Testing

Table 1. System Testing Results Using Black Box Testing

No	Tested Functions	Testing Scenario	Expected results	Test Results
1	Login	Enter the correct username and password	System Displays Dashboard	Succeed
2	Criteria	Opening the criteria page	Criteria data is displayed	Succeed
3	Alternative	Open alternative page	Alternative data is displayed	Succeed
4	Evaluation	Entering criteria values	Saved Assessment Data	Succeed
5	TOPSIS Calculation	Running the calculation process	The preference value is generated	Succeed
6	Ranking	Opening ranking results	Values and ranking order are displayed	Succeed
7	Digital Map	Open the map page	Priority areas and zones are displayed	Succeed
8	Logout	Click logout	The system returns to the login page	Succeed

CONCLUSION

This research produces a GIS-based Decision Support System to determine priority zones for forest logging monitoring in North Sumatra Province using the TOPSIS method. The system processes five criteria, namely changes in forest cover, distance from roads, distance from settlements, slope gradient, and forest area status in five alternative areas. The implementation results show that TOPSIS can produce preference values and regional rankings, while integration with GIS is able to present these results in the form of priority zone maps. Testing using the black box testing method shows that all main functions of the system, from login, data management, TOPSIS calculations, ranking, digital maps, to downloading reports, are successfully carried out according to their functions. Practically, the system can help provide more structured and spatially based information to support the determination of priority areas for monitoring.

This study is limited by its coverage area, which only uses five districts as alternatives and relies on the availability of spatial data used in the analysis. The system also focuses on determining priority zones and does not yet include forest damage prediction or law enforcement aspects. Future research is recommended to expand the coverage area, add more diverse criteria and spatial data sources, and compare TOPSIS with other decision-making methods to obtain more comprehensive results. System development can also be directed at regular data updates so that priority zone information is more in line with field conditions and further supports forest monitoring and management processes.

REFERENCES

Koginta Lubis, M., & Dewi Siregar, F. Y. (2024). Analisis pertanggungjawaban pidana terhadap perusakan hutan di Kecamatan Batang Lubu Sutam Kabupaten Padang Lawas. *Jurnal Ilmiah Penegakan Hukum, 5*(2), 94–100.

Komara, A. D., Djamal, E. C., & Renaldi, F. (2016). Sistem pendukung keputusan penentuan prioritas pemadaman hotspot kebakaran hutan dan lahan menggunakan metode analytic hierarchy process dan weighted product. *Jurnal Teknik Informatika dan Sistem Informasi, 2*(3), 382–392. https://doi.org/10.28932/jutisi.v2i3.524

Muhaiyaadden, F. A., Gunawan, F., Jasmine Aulia, N., Imam Syahid, M., & Munsif Ahmad, A. (2026). Analisis hukum terhadap pembiaran penebangan hutan dan alih fungsi lahan menjadi perkebunan sawit yang memicu banjir bandang di Sumatera. *Adagium: Jurnal Ilmiah Hukum, 4*(1), 66–88. https://doi.org/10.70308/adagium.v4i1.267

Qashlim, A. (2012). Penerapan metode analytic hierarchy process (AHP) untuk pengambilan keputusan. *KLIK: Kajian Ilmiah ..., 1*, 8–14. http://www.djournals.com/klik/article/view/935

Sulfiani, A. N., & Firdaus, R. (2022). Pengawasan pemerintah dalam praktek illegal logging di Kelurahan Battang Kecamatan Wara Barat Kota Palopo: Government supervision in illegal logging practice in Kelurahan Battang Kecamatan Wara Barat Palopo City. *Jurnal Administrasi Publik, XVIII*(2), 263–282. https://makassar.lan.go.id/jap/index.php/jap/article/view/110/75