Analysis of the Mount Tunggangan Wildlife Reserve Area Arrangement, Sragen, Central Java using Geographic Information Systems (GIS) with Ecological Sensitivity and Ecological Pressure Approaches

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Abstract. Conservation forest area has the highest protection function of other forest areas and is a buffer zone of life. However, at present, the condition is that many have experienced damage, a huge reduction, or fought over by various parties who wish to utilize the area for other purposes. One of the strategies and efforts made by the Government is through the spatial distribution approach, which is known as the zoning or block concept. In this regard, this study conducted an analysis of forest planning from the Mount Tunggangan Wildlife Reserve (MTWR) in the Sragen Regency, Central Java Province. Despite its status as a conservation forest area, the MTWR is inseparable from threats and pressures. The purpose of this study is to analyze the factors that influence the classification of ecological sensitivity and ecological pressure on MTWR forest areas for the determination of the area blocks. In this study, using the method of spatial analysis with Geographic Information Systems (GIS) with a tiered quantitative approach. The results of this study indicate that the MTWR forest area is divided into three management blocks, namely protection blocks (72.87%/74.68 Ha), utilization blocks (27.06%/27.73 Ha) and individual blocks (0.07%/0.07 Ha).

1. Introduction
Conservation forest area has the highest protection function of other forest areas and is a buffer zone of life. However, at this time many conditions have been damaged, broadly reduced, or contested by various parties who wish to utilize the area for other purposes. This occurrence is inseparable from the existence of a conservation forest area that borders directly with other use areas, including community-owned areas. Interaction between the forest and the surrounding community is inevitable. Therefore, pressure and threats will continue to occur [1]. Therefore, it is necessary to regulate the management of forest areas related to community interaction around the area in the management of forest areas.
One of the strategies and efforts undertaken by the Government to accommodate the interaction of communities around the forest is to issue a Minister of Environment and Forestry Regulation (Ministry of LHK Regulation) with Number P.76/Menlhk-Setjen/2015 concerning Criteria for the Zone of Management of National Parks and Management Blocks Nature Reserves, Wildlife Reserves, Grand Forest Parks and Nature Tourism Parks. The Ministerial Regulation regulates the process of forest governance in Indonesia, especially in conservation forest areas through a spatial distribution approach, known as the zoning or block concept. The existence of well-designed and scientifically based zoning has become a useful and essential way to allocate proper attention and management efforts, determine the appropriate level of law enforcement, reconcile different user conflicts and establish appropriate monitoring protocols [2].

The problem in Indonesia is that not all forest areas have been laid out zones or area blocks. In addition, some forest areas need to be re-zoned or block-aligned, as changes in physical and ecological conditions occur in the area. This includes the 552 conservation forest areas, only 205 of which have been made forest arrangement (most areas other than the National Park) [3]. Therefore, research related to the arrangement of forest areas in Indonesia is needed at this time. Research by both academics and practitioners related to the arrangement of forest areas will be able to help provide input to the management of the forest area and related parties including the community around the forest area in preparing a forest area management plan.

In connection with this, in this research will conduct an analysis of forest planning in the Mount Tunggangan Wildlife Reserve (MTWR) in Sragen Regency, Central Java Province. The conservation area needs to be arranged in accordance with the Ministry of LHK arrangement with Number P.76/Menlhk-Setjen/2015 because there are changes in ecological conditions in this area and the existing structuring documents still refer to the old regulations. MTWR had experienced deforestation in 1998 in the form of illegal logging, but over time the conditions of the MTWR began to experience natural succession and gradually recovered. MTWR has a functional diversity of flora and fauna. Based on data from the Central Java BKSDA [4] in the MTWR area, there are 22 species of plants that can be found in this conservation area which are included in 11 families. The plant species are dominated by Sonokeling (Dalbergia latifolia) species. The types of fauna that dominate in Mount Tunggangan SM are birds/aves. There are 35 bird species found in the MTWR area. These birds were found, there were five species of birds that were included in the protection status (Regulation of the Republic of Indonesia: Law No. 5 of 1990, PP No. 7 of 1999) and one species included in CITES Appendix II namely Brontok Hawk (Spizaetus cirrhatus). In addition, there are wild animals such as deer (Muntiacus muntjak), hedgehogs (Hystrix brachyura), garangan (Herpestes sp.), long-tailed monkeys (Macaca fascularis), and ferrets (Arctogolidia trivigata).

Despite its status as a conservation forest area, the MTWR is inseparable from threats and pressures. This relates to the existence of the area which borders directly with community-owned land and plantations. Some threats to the area include illegal logging and forest fires, although this is currently rare. In addition, sometimes, people who are not permitted to enter the forest area are sometimes found to collect grass and tree branches [4]. The MTWR area is also surrounded by tourist areas such as the Bayut Reservoir/Bukit Cinta tour, Bayanan hot spring, Sendang Panguripan hot spring and Grojogan Teleng waterfall, which are the mainstay tourist destinations of Sragen Regency. The existence of tourist destinations around the MTWR area has the potential to put pressure on the area if there is also a tendency of community interest in the existence of natural tourism in this region.

The wildlife reserve area in addition to having the primary function of protecting animals and their habitats is also one of the conservation areas that can be utilized for environmental services. Therefore, in the arrangement of the MTWR area must be balanced between the primary function as a conservation area with the function of its utilization. The arrangement of the area is carried out through the distribution of blocks with a comprehensive analysis, taking into account various factors including ecological, biophysical, economic and social factors, as well as the potential threats and pressures that exist, in order to keep the management objectives as animal and habitat protection maintained.
The management block is arranged based on specific criteria by considering the degree of ecological sensitivity. It is also done by considering other factors which are classified as ecological pressures. Ecological sensitivity is used to determine the protection block while consideration in determining the utilization block is carried out using ecological pressure. Ecological pressure also aims to determine the conditions, potential uses or interactions of the region with the community. In addition, the determination of blocks also takes into account the need for managing the MTWR area.

The purpose of this study is to analyze the factors that influence ecological sensitivity and ecological pressure and to compile the determination of the MTWR forest area block based on the level of ecological sensitivity and ecological pressure. It is expected that the research can provide recommendations for MTWR area managers and all stakeholders in formulating forest management policies so that they can maintain the conservation forest area.

2. Methodology

The location of research on forest planning arrangement analysis was carried out in the Mount Tunggangan Wildlife Reserve (MTWR) area (figure 1). This area is administratively located in Jambeyan Village and Jetis Village, Sambirejo District, Sragen Regency, Central Java Province. This area is one of the conservation forest areas of 37 (thirty-seven) conservation forest areas in Central Java Province and the only one that has the status of a Wildlife Sanctuary. The Gunung Tunggangan SM area is under the management of the Central Java Natural Resources Conservation Office (BKSDA) as the Technical Implementation Unit of the Ministry of Environment and Forestry. This area has an area of about 104 hectares.

![Figure 1. Map of research location in Mount Tunggangan Wildlife Reserve](image)

The method used in this study is a spatial analysis method with a Geographic Information System (GIS) using a tiered quantitative approach. The tiered quantitative method in this study was carried out with an analysis of the values of ecological sensitivity and ecological pressure from the MTWR area to determine the arrangement of the area blocks. Ecological sensitivity values consist of an analysis of vegetation cover, wetness/water source, land cover, slope, the sensitivity of soil types to erosion, rock
(geology) sensitivity to landslides, and protected flora and fauna habitats. The value of ecological pressure consists of analyzing the potential of community activities in the area based on the distance from settlements, roads, gardens and rivers, as well as the location of community accessibility within the area, religious/cultural location, location built, encroachment location, location of fire, and potential of tourist sites limited. Data matrix compiling the ecological sensitivity values of the MTWR region is shown in table 1 and the ecological pressure of the MTWR region in table 2. The operational framework of the study can be seen in figure 2 below.

Table 1. The data matrix compiling the ecological sensitivity of the MTWR area

| Compiler Data | Class criteria | Information | Score |
|---------------|----------------|-------------|-------|
| Classification of NDVI values | 0.72 – 0.92 | Very Dense Vegetation | 10 |
| | 0.42 – 0.72 | Dense Vegetation | 8 |
| | 0.22 – 0.42 | Medium Vegetation | 6 |
| | 0.12 – 2.2 | Rare Vegetation | 4 |
| | -0.1 – 1.2 | Very Rare Vegetation | 2 |
| Classification of spring protection areas | 0 – 100 meters | Very High protection | 10 |
| | 100 – 200 meters | High protection | 8 |
| | 200 – 500 meters | Medium protection | 6 |
| | > 500 meters | Low protection | 3 |
| Slope classification | > 45 % | Very Steep | 10 |
| | 25 - 45 % | Steep | 8 |
| | 15 - 25 % | Rather Steep | 6 |
| | 8 - 15 % | Sloping | 4 |
| | 0 - 8 % | Flat | 2 |

| Compiler Data | Class criteria | Information | Skor |
|---------------|----------------|-------------|------|
| Classification of soil sensitivity to erosion | Regosol, Litosol, Organosol, Renzina | Very sensitive | 10 |
| | Andosol (Andisol), Laterit (Oxisol), Grumosol (Molisol), Podsol (Spodosol) | Sensitive | 8 |
| | Brown Forest Soil (Inceptisol), Non-Calcic Brown (inceptisol), Mediteran (Alfisol) | Insensitive | 6 |
| | Latosol (Oxisol) | Rather sensitive | 4 |
| | Alluvial, Tanah Glei, Planosol, Hydromorph Gray, Groundwater | Not sensitive | 2 |
| | Laterite | Sedimentary rocks | Low sensitivity | 10 |
### Table 2. The data matrix compiling the ecological pressure of the MTWR region

| Compiler Data | Class criteria     | Information                  | Score |
|---------------|--------------------|------------------------------|-------|
| Classification of rock type sensitivity (geology) | Volcanic rocks | Medium sensitivity | 6     |
|               | Alluvial rocks     | High sensitivity             | 3     |
| Classification of protection areas on fauna locations that are included in protected status | 0 – 500 meters | High protection | 10    |
|               | 500 – 1,000 meters | Medium protection            | 6     |
|               | > 1,000 meters     | Low protection               | 3     |

| Compiler Data | Class criteria     | Information                  | Score |
|---------------|--------------------|------------------------------|-------|
| Classification of potential community activities in the area based on distance from Settlements | 0 – 200 meters | High activity potential | 10    |
|               | 200 – 500 meters   | Medium activity potential    | 6     |
|               | > 500 meters       | Low activity potential       | 3     |
| Classification of potential community activities in the area based on distance from the road | 0 – 200 meters | High activity potential | 10    |
|               | 200 – 500 meters   | Medium activity potential    | 6     |
|               | > 500 meters       | Low activity potential       | 3     |
| Classification of potential community activities in the area based on distance from plantations | 0 – 200 meters | High activity potential | 10    |
|               | 200 – 500 meters   | Medium activity potential    | 6     |
|               | > 500 meters       | Low activity potential       | 3     |
| Classification of potential community activities in the area based on distance from the river | 0 – 200 meters | High activity potential | 10    |
|               | 200 – 500 meters   | Medium activity potential    | 6     |
|               | > 500 meters       | Low activity potential       | 3     |
| Classification of the area of use at the location of public accessibility within the area | 0 – 50 meters  | High activity potential | 10    |
|               | 50 – 100 meters    | Medium activity potential    | 6     |
|               | > 100 meters       | Low activity potential       | 3     |
3. Results

3.1. Vegetation cover
Vegetation cover is a critical indicator in the measurement of ecological sensitivity. In this study, the analysis of vegetation cover in the MTWR area was carried out with a remote sensing approach through the analysis of Normalized Difference Vegetation Index (NDVI). NDVI is the best factor to indicate the status of growth and vegetation cover and is most widely used in remote sensing research in vegetation. NDVI has values ranging from -1 to 1. When there is no vegetation cover on the earth's surface, the value is negative or zero. Conversely, vegetation cover will make the NDVI value positive, meaning more vegetation cover means a higher value. Higher NDVI values indicate that an area has stronger ecological recovery and lower vulnerability [5], [6], [7], [8].

Vegetation cover was obtained through NDVI analysis from Sentinel-2 satellite imagery. Sentinel-2 image results that have been through radiometric and atmospheric correction become material for NDVI calculations. NDVI is calculated on a per-pixel basis as a normalized difference between the red and near-infrared bands of an image with the formula:

\[ \text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \]  

NIR is a near-infrared band value for a pixel and RED is a red band value for a pixel. In Sentinel-2 imagery using band four as RED and band eight as NIR [5], [6], [8].

After the NDVI value is generated, classification is then made into several vegetation cover classes. Vegetation cover in MTWR consists of 4 types of density, namely very high, high, medium and low vegetation density. Almost all MTWR areas have high vegetation density with an area of 93.72 Ha or 91.46%. The very high vegetated area covers 2.05% of the area, then the moderate vegetation area closes around 6.48% of the area and the low vegetation area covers only 0.01% of the area. The analysis results can be seen in figure 3 (a).
3.2. Protected fauna habitat
Based on the Central Java BKSDA inventory data (2013), essential animals found at MTWR are the Brontok eagle (*Spizaetus cirrhatus*). Habitat Brontok eagles tend to be in steep cliff areas, areas that are somewhat open and adjacent to bird nests. At the location of the protected fauna habitat, a buffer analysis was performed to protect the habitat from the Brontok Hawk with a distance of 500 m, 1000 m and > 1000 m. The results of the analysis can be seen in figure 3 (b).

3.3. Slope
Most of the MTWR areas have steep slopes with a percentage of 45.42% or an area of 46.56 Ha. The area with steep slopes is in a rough condition, located almost evenly throughout the region except in the North and Southwest. Around 33.74% of the MTWR area has a very steep topography with an area of around 33.43 Ha. This area has several hilltops located in the south of the region with ridges stretching from North to South and Northwest to South. 14.18 Ha from the area has a rather steep topography or
3.4. Spring
Based on inventory data from Central Java [4], the MTWR area has two seasonal spring locations. At the location of the springs, a buffer analysis is performed to protect springs with distances of 500 m, 1000 m and > 1000 m. The results of the analysis can be seen in figure 4 (b).

![Figure 4](image-url)

3.5. Geology
The geological conditions of the MTWR area based on geological maps consist of the formation of Mount Lawu larvae which are volcanic rocks and Jabolarangan breccia rocks which are sedimentary rocks. Sedimentary rocks are rocks that have a high sensitivity to landslides. Volcanic rocks are rocks that have moderate sensitivity to landslides [9]. The geological map of the MTWR area can be seen in Figure 5 (a).

![Figure 5](image-url)

3.6. Type of soil
Based on the map of soil types in Sragen Regency, the MTWR area has soil types included in the black grumusol and litosol complex types. This type of soil has a sensitivity to erosion based on Minister of Agriculture Decree Number 837/Kpts/Um/11/1980 Regarding Criteria and Procedures for Determining Protected Forests [9]. Volcanic rocks are rocks that have moderate sensitivity to landslides. A map of the soil types of the MTWR region can be seen in Figure 5 (b).

3.7. Accessibility in the area
Based on BKSDA Central Java inventory data (2013), within the MTWR area, there are footpaths which are the access of the surrounding community to other locations and are patrol roads. There is also an asphalt road that has been built and is a link between villages that are a little into the MTWR area. At the accessibility location within the area, a buffer analysis is carried out for the area's vulnerability with distances of 50 m, 100 m, and > 100 m. The results of the analysis can be seen in Figure 6.
Figure 6. Results of GIS analysis of accessibility within the area MTWR

3.8. The distance of Mount Tunggangan SM area from settlements, plantations, roads and rivers

The MTWR area is surrounded by private land owned by the community and plantation land owned by PTPN. This has the potential to cause community activities to enter the MTWR area. Potential community activities in the area can be mapped with the approach of calculating the distance of the location of community activity centers such as settlements, roads, plantations and rivers to the MTWR area. The distance calculation is done by buffer analysis for potential activities to the MTWR area with distances of 200 m, 500 m and > 500 m. The analysis results can be seen in figure 7 (a) and (b) and figure 8 (a) and (b).

Figure 7. Results of GIS analysis on the calculation of the distance of community activity centres in the form of settlements (a) and roads (b),
3.9. Ecological sensitivity and ecological pressure of MTWR

The determination of the ecological sensitivity and ecological pressure values of the MTWR area is done by overlaying SHP from spatial data that has been previously processed. The analysis process is the sum of the scores from each of the constituent spatial data. Ecological sensitivity values obtained from the overlay of vegetation cover classification data, protection of springs, slope, the sensitivity of soil types to erosion, geological sensitivity to landslides, protection of protected fauna habitats. Ecological pressure values are obtained from overlaying data on the classification of potential community activities in the area based on the distance from settlements, roads, plantations and rivers to the MTWR area and the location of community accessibility within the area. The sum results are then classified into 3 (three) classes, that is high, medium and low as in tables 3 and 4. The results of the value analysis ecological sensitivity and ecological pressure can be seen in figure 9 (a) and (b).

**Table 3. Classification of MTWR ecological sensitivity values**

| Class | Total score | Information   |
|-------|-------------|---------------|
| 1     | < 20        | Low sensitivity |
| 2     | 20 – 40     | Medium sensitivity |
| 3     | 40 – 60     | Medium sensitivity |

**Table 4. Classification of MTWR ecological pressure values**

| Class | Total score | Information   |
|-------|-------------|---------------|
| 1     | < 20        | Low pressure  |
| 2     | 20 – 35     | Medium pressure |
| 3     | 35 – 50     | Pressure high  |
3.10. Determination of block designation in the MTWR area

The determination of block designation within the MTWR area is adjusted to the nomenclature of the Minister of Environment and Forestry Regulation Number P.76/Menhk-Setjen/2015 concerning Criteria for Management Zone of National Parks and Management Blocks of Nature Reserves, Wildlife Reserves, Grand Forest Parks and Nature Tourism Parks. In the regulation in clause 8, it is stated that the management block in the Wildlife Reserve area consists of protection blocks, utilization blocks and other blocks. What is intended by other blocks is rehabilitation blocks, religious, cultural and historical blocks, and/or individual blocks. Other blocks as referred to are stipulated if there has been damage to the area, cultural/religious/ historical sites or there have been activities outside the forestry sector before the establishment of the Wildlife Sanctuary.

The determination of the MTWR area block is done by overlaying the shp results of the classification of ecological sensitivity with ecological pressure, then the determination of the block area of Mount Tunggangan SM as per the ecological criteria of Kusumandari and Sabarudin [10] which has been modified in table 5. The results of the analysis of the determination of the block MTWR area can be seen in figure 10.

| Ecological Pressure | Ecological Sensitivity |
|---------------------|------------------------|
| High                | High                   |
| Other Blocks        | Utilization Block/other|
| Medium              | Block Protection       |
| Block Protection    | Block Protection       |
| Low                 | Block Protection       |
4. Discussion

Vegetation cover is a critical indicator in the measurement of ecological sensitivity. The results of the
NDIV analysis in Figure 3 (a) show that almost all MTWR areas have high vegetation density with an
area of 93.72 Ha or 91.46%. The highly vegetated area covers 2.05% of the area, then the moderate
vegetation area closes around 6.48% of the area and the low vegetation area covers only 0.01% of the
area. The results of the analysis of the vegetation density show that the MTWR
area is composed of
trees that are densely crowned and healthy, and only a few are rarely. It also shows that the MTWR area
is included in the tropical rainforest ecosystem [8]. The condition of the close and healthy vegetation
cover is a suitable place for the habitat of various fauna as a shelter and foraging.

The condition of vegetation cover, which is mostly meeting is also useful to reduce the potential for
erosion and landslides in the MTWR area. This is related to this area which is dominated by steep slopes
with a percentage of 45.42% and very steep with a percentage of 33.74%, and only a small portion of
the topography is rather steep (13.83%), sloping (4.89%) and flat (2.09%). It also relates to the type of
soil in the form of black grumosol and latosol complexes that are sensitive to erosion, as well as its
constituent rock types in the form of sedimentary rocks and volcanic rocks that are sensitive to
landslides.

Based on the results of the analysis of the constituent data of pressure on the area, it can be seen that
the accessibility within the area and the distance of the area to the plantations provide the potential for
community activities within the area to be higher than other compiler data. This should be anticipated
by the area manager so that illegal activities in the area can be reduced and the threat of forest fires can
be reduced.

The results of the ecological sensitivity analysis show that most of the MTWR areas are areas with
high sensitivity (72.89%/74.69 Ha), moderate sensitivity at 26.97% (27.64 Ha) and only a few with low
sensitivity at 0.14% (0.14 Ha). High sensitivity is located in areas with steep and very steep slopes, with
dense vegetation, landslide-sensitive soil types, rock types that are susceptible to landslides and close to
water sources and protected fauna habitats. Low sensitivity is located in areas with flat slopes, with
moderate vegetation, and far away from springs and protected fauna habitats.

The results of the ecological pressure analysis show that high ecological pressures are found in the
Northeast, South and West Regions. Areas with high ecological pressure is an area close to settlements,
rivers and plantations. Some of the MTWR areas are areas with moderate ecological pressure that
are not close to settlements, roads, rivers and plantations. Areas with low ecological pressure are located
in the middle of the area far from settlements, roads, rivers and plantations, and are on very steep slopes.
The results of the analysis of the determination of blocks originating from overlaying of ecological sensitivity and ecological pressure show that the MTWR area is dominated by protection blocks of 72.87% (74,68 Ha), then there are utilization blocks of 27.06% (27,73 Ha), and individual blocks of 0.07% (0.07 Ha). The existence of a particular block is to accommodate the existence of asphalt road between villages that have been built, and its position is slightly entered into the area. The individual block is in the southwest of the MTWR area. Protection blocks are in areas that have high ecological sensitivity with low, medium and high ecological pressure. This protection block is an area with steep to very steep slopes, is a protected fauna habitat, is the protection of springs and low levels of human threats. The utilization block is in an area that has low and moderate ecological sensitivity with moderate to high ecological pressure. The utilization block can be used for limited natural tourism and carbon storage and sequestration, water mass, water energy, heat energy and wind energy based on the Minister of Environment and Forestry Regulation Number P.76/Menlhk-Setjen/2015.

5. Conclusion
The MTWR area is organized into three blocks, namely protection blocks at 72.87% (74,68 Ha), utilization blocks at 27.06% (27,73 Ha), and individual blocks at 0.07% (0.07 Ha). This protection block is an area with steep to very steep slopes, protected fauna habitat, springs protection and low levels of human threats. The utilization block can be used for limited natural tourism and carbon storage and/or sequestration, water mass, water energy, heat energy and wind energy based on the Minister of Environment and Forestry Regulation Number P.76/Menlhk-Setjen/2015. The unique block in this area is asphalt road between villages that have been built, and its position is slightly entered into the area.

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