

# UTILIZING REMOTE SENSING AND MACHINE LEARNING FOR ECOSYSTEM SERVICES MAPPING AT GUNUNG MAS TEA PLANTATION

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**Abstract.** Ecosystem services are the benefits humans obtain from various natural resources and processes jointly provided by an ecosystem. In the discussion of ecosystem services, the land cover has an important position to read and reflect the potential of each type of land cover. The main aim in understanding and valuing natural capital and ecosystem services is to make better decisions, resulting in better actions relating to the use of land, water, and other elements of natural capital. Puncak area, Bogor, which is a highland area, has become an area that is synonymous with tea plantations because it has an ecosystem that is suitable for being a tea plantation area. Gunung Mas tea plantation managed by PTPN VIII is one of the largest tea plantations and a contributor to foreign exchange in Indonesia. The tourism potential in the plantation and agricultural business sectors has a high selling value as a tourist object and attraction. The purpose of this study is to find out the distribution of ecosystem services for climate regulation, water flow and flood regulation, and ecotourism and cultural recreation services at Gunung Mas tea plantation which is displayed in the form of an Ecosystem Service Map. The land cover classification was extracted from the Sentinel 2A image, which was then scored based on expert judgment. The scoring results are then processed using the AHP Pairwise Comparison method. The results of the study show that the research area has very high climate regulation ecosystem services, very high water flow and flood regulation, and high cultural recreation and ecotourism ecosystem services.

*Keywords: AHP, ecosystem services, land use and land cover, supervised classification, tea plantation*

## 1 INTRODUCTION

Ecosystem services are the benefits humans obtain from various natural resources and processes jointly provided by an ecosystem (Riqqi et al. 2019). The Millennium Ecosystem Assessment classifies four types of ecosystem benefits, namely provisioning benefits such as food and water production; regulatory benefits such as climate and disease control; supporting benefits such as nutrient cycling and plant pollination; and cultural, spiritual, and recreational benefits (MEA, 2005).

Ecosystem services in the earth's habitat are determined by the presence of endogenous factors and exogenous dynamics as reflected by two components,

namely ecoregion conditions and land cover (land use) as an estimator or proxy (Mustofa 2020). Changes in land use and land cover are one of the main factors affecting ecosystems and the services they provide (Shrestha et al. 2019). In the discussion of ecosystem services, the land cover has an important position to read and reflect the potential of each type of land cover.

Puncak area in Bogor Regency is a highland area that is synonymous with tea plantations. This location has an altitude of 800-1200 meters above sea level with a temperature of around 12-22°C. Gunung Mas tea plantation has become a water catchment area, preventing landslides and protecting biodiversity. Apart from that, the tourism potential in the tea plantation

business sector has a high selling value as a tourist object and attraction, therefore currently the Gunung Mas tea plantation is focused as an Agrotourism business unit of PTPN VIII.

The main aim in understanding and valuing natural capital and ecosystem services is to make better decisions, resulting in better actions relating to the use of land, water, and other elements of natural capital (Daily et al. 2009). Ecosystem services are an important component in developing Gunung Mas tea plantation. The amount of ecosystem services can trigger community involvement in this area to participate in preserving the Gunung Mas Tea Plantation ecosystem as well as provides useful information that can help design the institutions that will guide resource management and policy.

Remote Sensing approach combined with field investigations provides benefits for monitoring land use and cover changes and calculating the economic value of ecosystem services (Shuangao et al., 2021). Therefore, Remote Sensing practice has been widely applied to estimate land use and cover change associated with impacts on ecosystem services in several countries around the world. Sentinel-2 satellites has been successfully used for agricultural, forest and environmental

resolution of Sentinel 2A is also sufficient to produce large-scale data (10 meters high in the red, blue, green and near-infrared bands).

The purpose of this study was to determine the distribution of ecosystem services for climate regulation, water flow regulation and flooding, and cultural recreation and ecotourism in Gunung Mas tea plantations which were displayed in the form of a map. Ecosystem service maps can be used to monitor the impact of changes in the environment, and therefore support sustainable (del Rio-Mena et al. 2020).

The approach used to determine the class of ecosystem services using land cover and ecoregion data. The environmental carrying capacity class presentation is presented spatially with the help of Geographic Information System (GIS) software using Sentinel 2A imagery from the 2021 recording year.

## 2 MATERIALS AND METHODOLOGY

### 2.1 Location

Gunung Mas tea plantation, located in Cisarua District, built by the Dutch colonial government, is a landmark of the Puncak area. Gunung Mas tea plantation is now state-owned and is managed by PT Perkebunan Nusantara VIII. The research

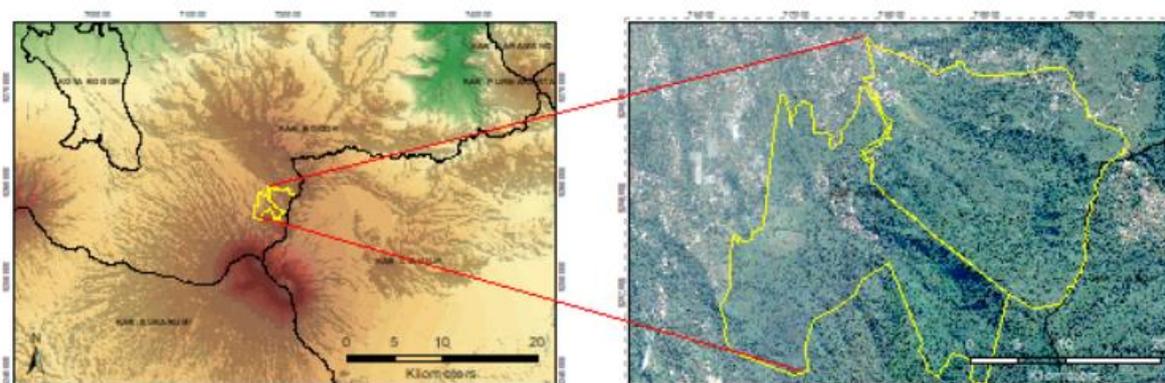


Figure 2-1: Research Area, Gunung Mas, West Java, Indonesia.

monitoring applications (Pandit et al. 2018). The spectral resolution of Sentinel 2-A is capable of producing a multi-spectral band with 13 channels which include visible, near-infrared, and shortwave infrared sensors gives the sensor high potential for mapping various vegetation characteristics. The spatial

area is located in Afdeling 1 and 2 tea plantations of Gunung Mas, with an altitude of 1000-1600 above mean sea level. This area is located in the administrative area of North Tugu Village and South Tugu Village, Cisarua District, Bogor Regency.

The research area is in the volcanic cone Volcanic ecoregion, a large group of landform units that occur due to volcanic activity (P3E Java). Examples of these landforms include craters, volcanic cones, calderas, lava fields, foot slopes, plains, and volcanic fluvial plain.

**2.2 Data**

Sentinel 2-A imagery is used in this research to obtain data and information on land use and land cover. High-Resolution Satellite Imagery data is used as a base map in conducting field surveys and forming training data for classification and accuracy testing.

The ecoregion area is known from the Java ecoregion map produced by the Java ecoregion Development Control Center (KLHK P3E Jawa, 2015). High-resolution satellite images and field survey results are used for the supervised land cover classification process.

Administrative boundary data was obtained from RBI map 1:25.000, produced by BIG The afdeling boundary data was obtained from PTPN VIII. Apart from that, we collect field data as training and testing data for land cover modelling. Field survey data were taken using Avenza Maps apps.

Table 2-1: Data Sources.

Data	Data Source
High-Resolution Satellite Imagery Sentinel 2A	Geospatial Information Agency European Space Agency
Ecoregion Map	Java Ecoregion Development Control Center
Afdeling Border Administration Border	PTPN VIII Geospatial Information Agency
Ground Marking	Field Survey

**2.3 Methods**

Sentinel 2A was classified into 6 class of land cover: Forest, Built Land, Vacant Land, Tea Garden, Mix Garden, and Water Bodies. Ground marking data and high-resolution satellite imagery was conduct as a training and testing data. Land cover scores were carried out by giving questionnaires to

experts which were then processed using the AHP method.

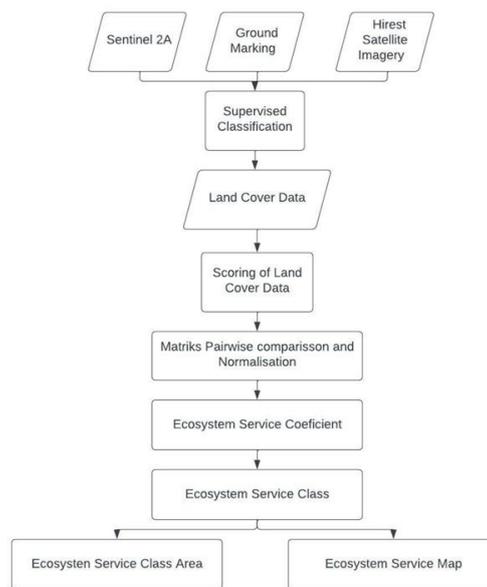


Figure 2-2: Research Flowchart.

**2.3.1 Classification and Regression Tree**

Land cover classification is processed using Machine Learning on the Google Earth Engine (GEE) platform, the algorithm used in the classification process is the Classification and Regression Tree (CART) algorithm. Earth Engine hosts satellite imagery and stores them in a public data archive that includes historical earth images that are over forty years old, Earth Engine also provides API and other tools to enable an analysis of large data sets.

Classification and Regression Trees (CART) feature selection was successfully used for vegetation and crop classification in moderate to high spatial resolution imageries (Abdullah et al. 2019). CART is a binary decision regression tree developed by Breiman et al. (2017) and used for simple decision-making in logical if-then scenarios (Aldiansyah and Saputra 2022). CART is a non-parametric statistical method that can describe the relationship between the response variable (dependent variable) and one or more predictor variables (independent variable) If the response variable is continuous, the method used is the regression tree method, whereas if the response variable has a categorical scale, the method used is the classification tree method (Hartati et al.

2012). The "classifier.smileCart" technique in the GEE library is used in this study to perform CART classification.

**2.3.2 Analytical Hierarchy Process (AHP)**

Analytical Hierarchy Process (AHP) solves a complex unstructured situation into several components in a hierarchical arrangement, by assigning a subjective value to the relative importance of each variable, and determining which variable has the highest priority (Rosardi et al. 2022). Scoring of land cover data is carried out through a questionnaire instrument on the role of land cover on ecosystem services. The assessment and weighting of ecosystem services are carried out through AHP with a pairwise comparison calculation method. The use of a pairwise comparison matrix which is a matrix from the AHP method is intended to produce relative weights between criteria and alternatives (Andryannur et al. 2022). Land cover will be compared with other land cover in terms of how important it is to the achievement ecosystem services.

**2.3.3 Ecosystem Service Coefficient (ESC)**

The Ecosystem Service Coefficient (ESC) is a value that indicates the size of the value of ecosystem services obtained from the calculation of the pairwise matrix multiplication of land cover and is used to map the types of ecosystem services (Febriarta and Oktama 2020).

**2.3.4 ESC Range Classification**

The classification range of the ecosystem services coefficient is normalized using a scaling approach with a range of values etween 0-1. The value is closer to 1, meaning the ESC of an area is getting higher and vice versa. Each value of ecosystem services produced has a different range of values or classes, which are obtained from different maximum and minimum values. Based on the guidelines for the preparation of carrying capacity, the ESC value can be classified into 5 levels, with the following geometric approach (Kementerian Lingkungan Hidup dan Kehutanan (KLHK) 2019):

$$X_n = B/A \dots\dots\dots(1)$$

B = Maximum Value, A = Minimum Value, n = Number of Class

After obtaining the coefficient of ecosystem services, the final stage of mapping ecosystem services is making a layout, which is the process of organizing the data used as output, and how the data will be displayed. Geographic Information System (GIS) can display various kinds of information as the final result of an operation. Ecosystem service maps are displayed in five ordinal classification forms, starting from very low, low, moderate, high, and very high.

**3 RESULTS AND DISCUSSION**

**3.1 Land Cover Classification**

The land cover in the research area is classified into six classes, namely: Forest,

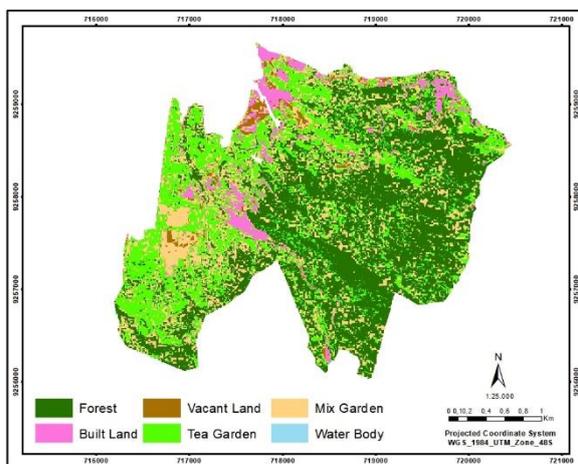


Figure 3-1: Land cover classification map.

Tea Garden, Mixed Garden, Water Bodies, Built Land, and Vacant Land. The results of land cover classification have an overall accuracy of 86.67% and a Kappa coefficient of 79.37%.

The largest land cover is forest land cover which is a protected forest area, with a land cover area of 405.451 Ha. The tea garden is the second largest land cover with an area of 245.790 Ha. The mixed garden has the third largest area with an area of 196.088 Ha. Built-up land and vacant land were ranked 4th and 5th with an area of 48,958 Ha and 7,273 Ha

respectively. The water body has the smallest area of 0.0267 Ha.

### 3.2 Climate Regulation Map

Vegetation is a natural component that is able to control climate through controlling fluctuations or changes in the surrounding climate elements (Saroh and Krisdianto 2020). More than half of the research area is a vegetated area, therefore the research area is an area with very high climate regulation ecosystem services.

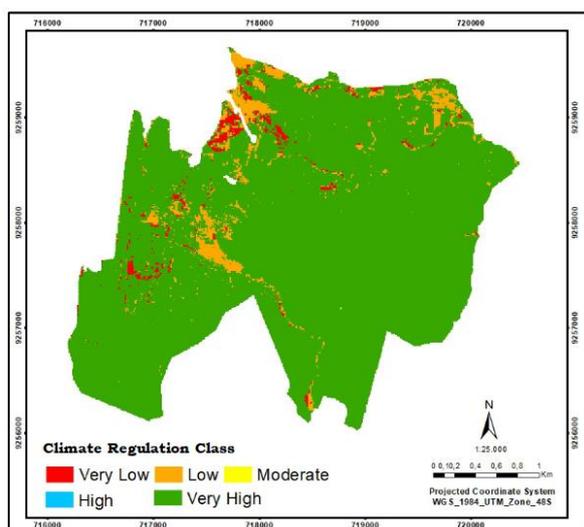


Figure 3-2: Ecosystem Service of Climate Regulation Map.

Table 3-1: Broad of Classification of Climate Regulatory Ecosystem Services.

Climate Regulation Class	Land Cover	Area (Ha)	%
Very High	Forest	847,33	92,75%
High	Tea Garden Mix Garden		
Moderate	Water Body	0,0269	0,00%
Low	Built Land	48,958	5,36%
Very Low	Vacant Area	17,273	1,89%
Total Area		913,59	100%

Ecosystem services for climate regulation in Gunung Mas are influenced by forest land cover, tea gardens, and mixed gardens with ESC being 0.31, 0.263,

and 0.211 respectively. These three land covers have a very high value in the climate regulation ecosystem services class. Waterbody has an ESC value of 0.12 and has a medium ecosystem service class. Built-up land cover has an ESC value of 0.06 and is in the low ecosystem service class. Vacant land has an ESC value of 0.036 and is included in the very low class of ecosystem service.

### 3.3. Water Flow and Flood Management Map

Forest and vegetation land cover functions to prevent erosion, flooding and regulate water management (Kementerian Lingkungan Hidup & Kehutanan 2018). ESC results show that forest and plantation land cover provide good results for water flow and water management ecosystem services.

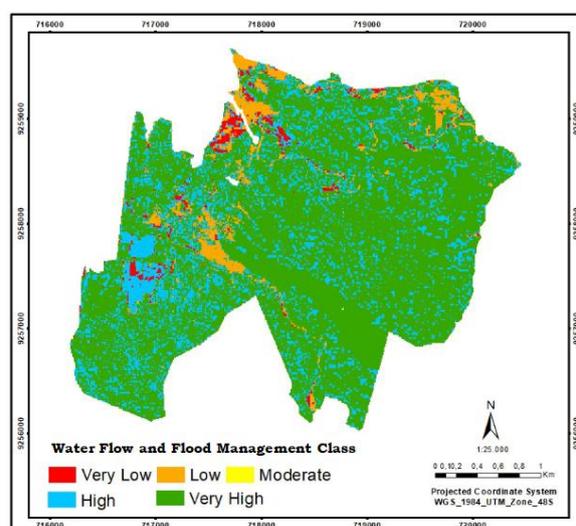


Figure 3-3: Ecosystem Service for Water Flow and Flood Management Map.

Water and Flood Management Ecosystem Services are influenced by forest land cover and tea gardens with ESC respectively 0.582, 0.203. Both of these land covers have a very high value of ecosystem service class regulating water flow and flooding. The mixed garden land cover has an ESC value of 0.148 and has a high ecosystem service class. The water body land cover has an ESC value of 0.053 and is included in the medium ecosystem service class. Built-up land cover has an ESC value of 0.01 and is included in the

low ecosystem service class. Vacant land has an ESC value of 0.002 and is included in the very low class of ecosystem services.

Table 3-2 : Broad of Classification of Ecosystem Services Regulation of Water Flow and Flooding.

Water Management Class	Land Cover	Area (Ha)	%
Very High	Forest	651,24	71,28%
	Tea	196,09	21,46%
	Garden Mix		
Moderate	Garden		
	Water Body	0,03	0,00%
Low	Built Land	48,96	5,36%
	Vacant Area	17,27	1,89%
Total Area		913,587	100%

### 3.4 Cultural and Recreational Ecosystem Service Map

Agrotourism is one of the core businesses managed by PTPN VIII at Gunung Mas Tea Plantation. The benefits of Agrotourism include improving social empowerment system, strengthening social ties and developing social skills and relationships, increasing the income of local people, diversifying products and intensifying economic activities, providing job opportunities, and alleviating poverty (Rosardi et al. 2021).

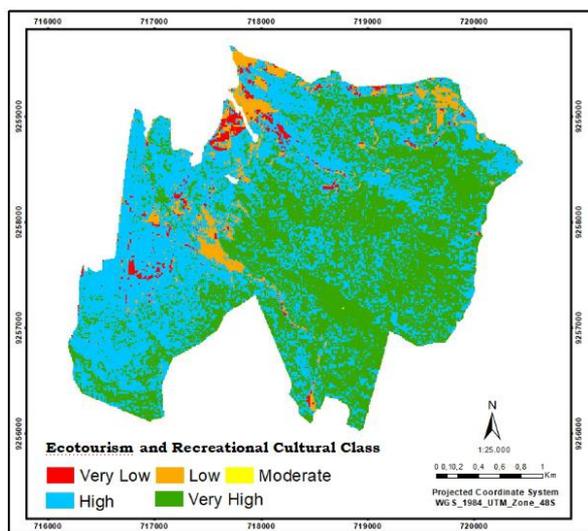


Figure 3-4 : Ecotourism and Recreational Cultural Ecosystem Service Map.

Cultural, Recreational, and Ecotourism Ecosystem Services (ES) are significantly influenced by forest land cover, which holds an Ecosystem Service Class (ESC) value of 0.330. This high value places forest land cover in the very high category for Cultural, Recreational, and Ecotourism ES. Tea gardens and mixed gardens, with ESC values of 0.225 and 0.189 respectively, are categorized as having a high Ecosystem Service Class. Water bodies, having an ESC of 0.140, fall into the medium class. Built-up areas, with an ESC of 0.078, are in the low ecosystem service class, while vacant land, having an ESC of 0.040, is classified in the very low category. It is notable that the high Ecosystem Service Class is primarily generated by forest land cover and tea plantations.

Table 3-3: Broad of Classification of Recreational Culture and Ecotourism Ecosystem Services.

Recreation and Ecotourism Class	Land Cover	Area (Ha)	%
Very High	Forest	405,45	44,38%
	Tea		
High	Garden Mix	441,88	48,37%
	Garden		
	Water Body	0,027	0,00%
Moderate	Built Land	48,958	5,36%
	Vacant Area	17,273	1,89%
Total Area		913,59	100%

## 4 CONCLUSION

We validated the benefits of using Land Use and Land Cover (LULC) data from fused satellite imagery to assess the impact of land use on ecosystem services in the Gunung Mas Tea Plantation. Our findings indicate:

A. The research area, with a total of 847,329 hectares, is classified as having a very high climate regulation ecosystem service class. This is primarily due to the forest land cover, tea gardens, and mixed gardens.

B. The area has a Very High Ecosystem Service Class for Water Flow and Flood Management, covering 651,241 hectares. This high class is mainly attributed to forest land cover and tea plantations.

C. With a total area of 441.87 hectares, the research area is rated highly for Ecotourism and Recreation Culture Ecotourism Service Class. This is due to the land cover of tea gardens and mixed gardens. Additionally, the forest land cover, spanning 405.451 hectares, is classified as a Very High ecosystem service class.

Understanding the role of ecosystem services in decision-making and valuing these services provides crucial information. This can assist in designing effective resource management institutions and policies. Moreover, quantifying the amount of ecosystem services can encourage community involvement in preserving the Gunung Mas Tea Plantation ecosystem.

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