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# Land Identification for Establishing Conservation Areas in Sloping Land Contexts Using a Geographic Information System: A Case Study of Gunung Mas Regency, Central Kalimantan Province, Indonesia

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**Abstract:** The critical factor that should be considered for land utilization on sloping lands is the slope parameter. The misuse of lands leads to land degradation and damage to the natural environment. The study area of Gunung Mas Regency is mostly dominated by upland typology with various slope classes. Thus, the high precipitation that occurs in this tropical region will lead to soil erosion if proper land use and conservation management are not implemented. Thus, this study was conducted to provide basic information on potential land resources that should be allocated for conservation purposes. The results can be used as a basic consideration for the land use planning process. A geographic information system (GIS) was applied to analyze the results of the erosion prediction model that was interpreted within the spatial environment. The result of evaluation using soil erosion prediction from the Universal Soil Loss Equation (USLE) showed that there are five classes (class I to V) of soil erosion risk in Gunung Mas Regency. More than half of this region is classified into class V. This implies that these areas have the highest potential for soil erosion risk, with assumed soil loss > 480 tons/hectare/year. Spatially, the distribution pattern of this class is that broad areas occur in the middle part and spread to the north, with a total area of 566,835 hectares (52.46%). These areas can then be allocated and established as conservation areas. The critical factors that can generate soil erosion include sloping lands and high rainfall. The dominant landform in these areas is steep to very steep slopes, with slope classes of 26%–40% and 41%–60%, respectively.

**Keywords:** sloping lands, land use, conservation, geographic information system.

# 使用地理信息系统在坡地环境中建立保护区的土地识别：印度尼西亚中加里曼丹省古农马斯摄政的案例研究

**摘要**：坡地利用土地应考虑的关键因素是坡度参数。滥用土地导致土地退化和自然环境破坏。古农马斯摄政的研究区域主要以具有各种坡度等级的高地类型为主。因此，如果不实施适当的土地利用和保护管理，该热带地区发生的高降水将导致水土流失。因此，本研究旨在提供有关应分配用于保护目的的潜在土地资源的基本信息。结果可作为土地利用规划过程的基本考虑因素。应用地理信息系统 (地理信息系统) 分析在空间环境中解释的侵蚀预测模型的结果。使用通用土壤流失方程 (USLE) 的土壤侵蚀预测进行评估的结果表明，古农马斯摄政的土壤侵蚀风险有五个等级（I 级至五级）。该地区一半以上的地区属于 V 类。这意味着这些地区具有最高的土壤侵蚀风险，假设土壤流失 > 480 吨/公顷/年。从空间上看，该类分布格局为中部广域、北扩，总面积 566835 公顷，占 52.46%。然后可以分配和建立这些区域作为保护区。造成土壤侵蚀的关键因素包括坡地和高降雨量。这些地区的主要地貌是陡峭到非常陡峭的斜坡，坡度等级分别为 26%~40%和 41%~60%。

**关键词**： 坡地、土地利用、保护、地理信息系统。

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# 1. Introduction

In Indonesia, the main problem related to the existence of forests that should be overcome involves tree cover loss. Statistical data have shown that from 2002 to 2019, Indonesia lost 9.48 million hectares of humid primary forest [16]. Several main causes of forest area loss involve land expansion for agriculture, especially for real estate; natural disasters, such as forest and land fire; and the development of infrastructure, such as roads and settlements.

As an important part of tree cover, forests provide several benefits, such as generating oxygen and storing carbon to maintain air quality [1]. In addition, they can maintain wild life and biodiversity to provide functioning ecosystems that supply oxygen, clean air and water, plant pollination, pest control, wastewater treatment, and many ecosystem services [17]. Ultimately, these functions can provide for and ensure sustainable land use for future generations.

In the case of Gunung Mas Regency, most of the lands are dominated by an upland typology, which has various slope classes with high precipitation because of the characteristics of the tropical region. Deforestation, including tree cover loss, indicates that erosion will occur. Proper land use and conservation management should be implemented to prevent tree cover loss, while at the same time, the lands can still be utilized in accordance with their capability and suitability. Establishing conservation areas should be considered in land use planning [2]. Technically, such practices can be used to support sustainable land use by improving land quality and reducing land degradation [3].

This study was conducted to provide basic information on potential land resources that should be allocated for conservation purposes. The location of the study was selected to focus on sloping land areas, which have more potential for soil erosion risk compared with flat areas.

# 2. General Biophysical Description of Study Areas

The study areas covered almost 1,080,498 hectares, situated geographically between 113° 00’ 46.55” E to 114° 01’ 59.98” E and 00° 17’ 7.51” S to 01° 39’ 46.64” S (Fig. 1).

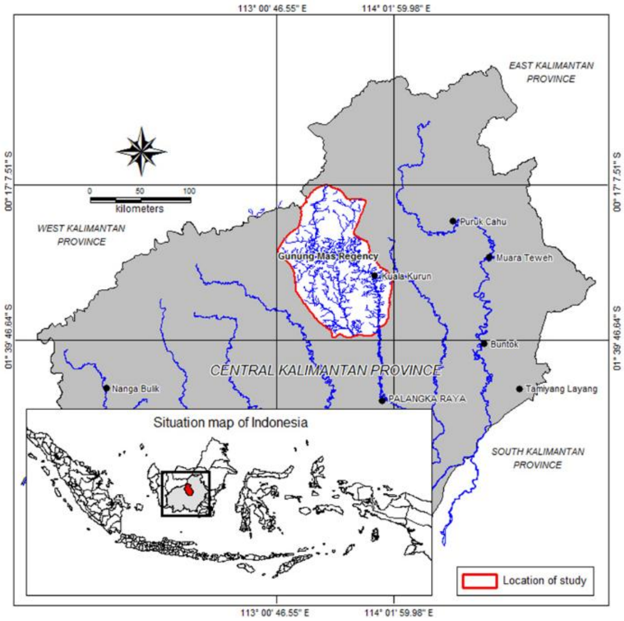

Fig. 1 Geographical position of study areas

## 2.1. Landform Information

A digital elevation model (DEM) can be used for basic analysis and interpretation related to multi-scale landform delineation and the classification of landscapes [4]. The result of interpretation using DEM taken from 30-Meter SRTM illustrated that major landforms found in this regency as the study area consist of hilly to mountainous areas, located in the central part of the region and spreading to the north. Further analysis showed that there are several slope classes—namely, slope classes of 9%–15%, 16%–25%, 26%–40%, 41%–60%, and >60%, with a total area of 892,697 hectares (82.62%).

The landform category of flat and undulating plains is found in the southern and central parts, scattered with dominant slope classes of <2% and 2%–8%, representing a total area of 187,801 hectares (17.38%). The distribution pattern of slope that spatially reflects the general landform is shown in Fig. 2.

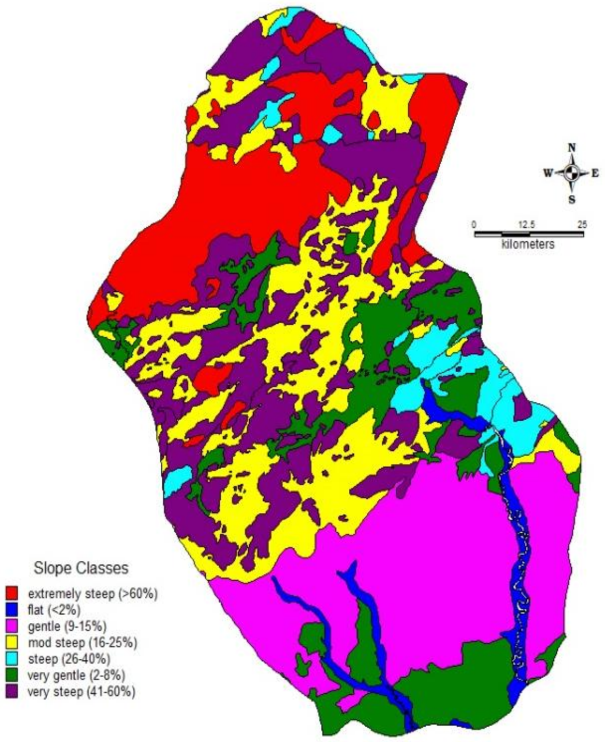


Fig. 2 Spatial distribution pattern of slope classes in study areas

**2.2. Climate Conditions**

In terms of climate, the study area is mainly determined based on its geographical position, which is located around the equator and characterized by high humidity and precipitation, with a rather constant temperature throughout the year [5]. Based on the local climate station, the amount of annual rainfall varies between 2,864 and 3,577 mm. The climate conditions in these areas are closely related to soil erosion. In the case of Gunung Mas Regency, rainfall can be considered a factor affecting erosion because this region has consecutive wet months spanning more than 9 months [6].

Rainfall erosivity is a major driver of sediment and nutrient losses [7]. The stronger the rain within an area, the more and faster water erosion occurs [8, 9, 10].

## 3. The Universal Soil Loss Equation (USLE) Model Approach

The model of soil erosion risk prediction known as the Universal Soil Loss Equation (USLE) has been widely used to determine soil erosion risk levels [2, 11]. The assessment of soil erosion refers to biological aspects, such as climate, landform/topography, and land resources. The USLE mathematical formula proposed by Wischmeier and Smith was used in this study to determine soil loss predictions that represent soil erosion risk levels [12]. The USLE equation is provided by the following expression:

$$E = R.K.L.S.C.P.$$

where:

• $E$ is the mean annual soil loss;
• $R$ is the rainfall erosivity index;
• $K$ is the soil erodibility index;
• $LS$ are the factors of slope length $(L)$ and slope steepness $(S)$, combined in a single index;
• $C$ is the crop factor/nature of plant cover;
• $P$ is the conservation practice factor used to manipulate the LS factor.

The application of GIS technology was used to generate spatial data as part of geospatial information and for spatial analysis based on basic data such as DEM and the result of soil erosion assessment [13, 14].

## 4. Soil Erosion Risk Classification

Based primarily on land areas evaluated using the mathematical formulas of the universal soil loss equation (USLE), this case study of the Gunung Mas Regency, Indonesia, includes/uses five classes of soil erosion risk, as shown in Table 1. The distribution pattern of each class is shown in Fig. 3 using a spatial format.

The results of the evaluation using the USLE approach showed that more than half of this region comes under the classification of class V, implying a soil loss level of >480 tons/hectare per year. In some areas of the region studied, there existed fields of exposed land due to the effects of logging and the illicit timber industry. In others, there were large areas of exposed land due to forest fires.

Geographically, class V shows a distribution pattern that extends across broad areas located in the center and towards the north of the region, covering a total of 566,835 hectares (52.46%). The existence of this class indicates that these areas were assigned to conservation zone I. Class IV can be assigned to conservation zone II, which covers a total area of 256,801 hectares (23.77%) (Fig. 4).

The other erosion classes (classes I, II, and III) can be considered non-conservation zones because of the low percentage of soil erosion in classes II and III, and a soil loss contribution of only <15 tons/hectare/year in class I. However, conservation concerns still have to be considered due to the degradation of the land.

Based on the results of overlaying the soil erosion risk map and the slope map, especially in classes V and IV (part of conservation zones I and II), it can be seen that these regions belong to the slope classes of steep, very steep, and extremely steep. Therefore, these zones should be considered for the implementation of specific conservation programs.

Conservation management can be prioritized to zone I and then extended to zone II. The management of conservation projects such as reforestation programs can then be formulated.

Taking into consideration the landforms presented through the overlaying of the soil erosion risk map (Fig. 2) and the slope class map (Fig. 3), specialized programs should be focused on erosion zone I since the zones found in the northern area are mainly dominated by sloping land areas.

The inclination and length of the slope are important factors in calculating runoff and soil erosion in areas with the same rainfall conditions. Slope structure also plays a role in the erosion process [15].

Table 1 Soil erosion risk classification in Gunung Mas Regency

| **Soil erosion risk class** | **Criteria of soil loss (*) (ton/hectares/year)** | **Areas** | |
|---|---|---|---|
| | | **Hectares** | **Percentage** |
| I | <15 | 155.299 | 14,37 |
| II | 15-60 | 69.571 | 6,44 |
| III | 60-180 | 31.992 | 2,96 |
| IV | 180-480 | 256.801 | 23,77 |
| V | >480 | 566.835 | 52,46 |
| | | 1,080,498 | 100,00 |

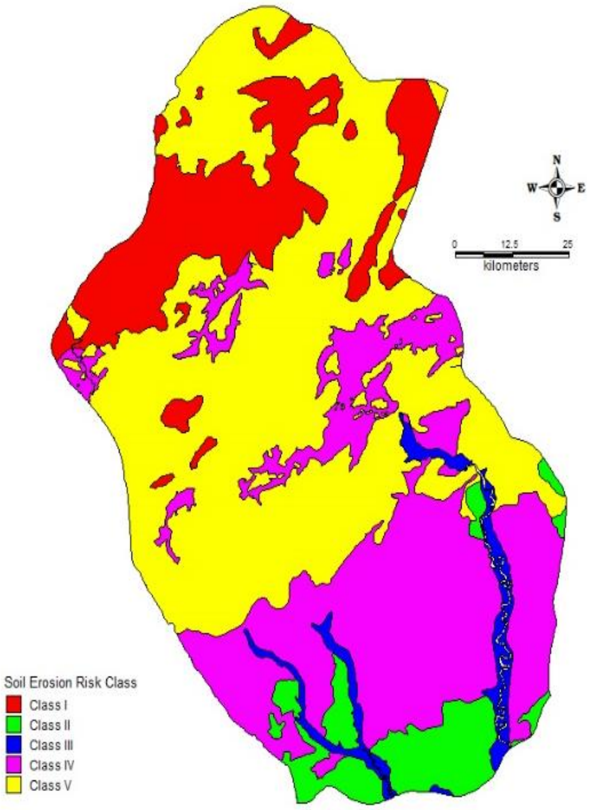


Fig. 3 Spatial distribution pattern of soil erosion risk classes in study areas

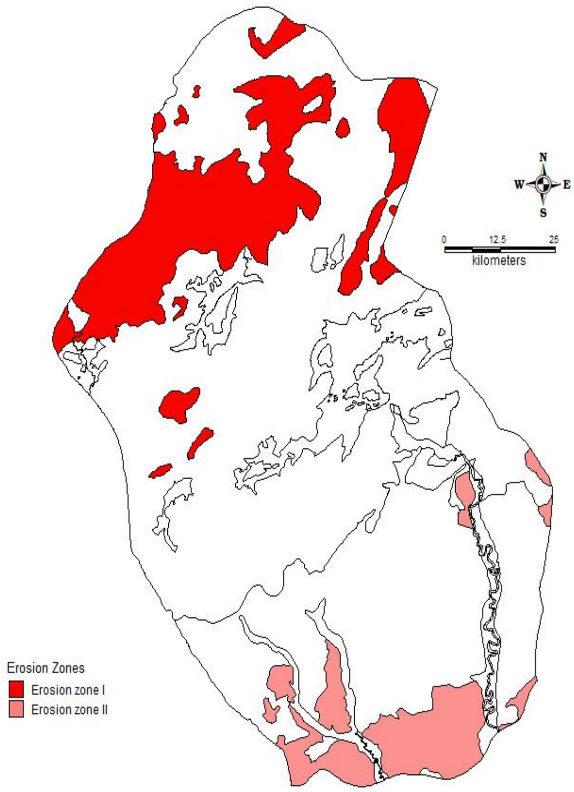


Fig. 4 Spatial distribution pattern of erosion zones in study areas

## 5. Conclusion

The USLE mathematical formula approach, together with the aid of geographic information system (GIS) technology, can be used to identify areas that should be allocated as conservation zones. In view of the scarcity of available data, this approach can be implemented in order to provide basic data for the land-use planning process. In the areas covered by this case study, the critical factors that generate soil erosion include inclination of the land and high rainfall, with the dominant landform being steep to very steep slopes within the slope classes of 26–40% and 41–60%. Considering this landform condition, priority should be given to programs in erosion zone I since this zone is found in the northern region, which is mainly dominated by sloping land areas.

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