

# ENVIRONMENTALLY SOUND SPATIAL MANAGEMENT USING CONSERVATION AND LAND EVALUATION APPROACH AT SLOPING LANDS IN HUMID TROPIC (A CASE STUDY OF ANTANG KALANG SUB-DISTRICT, CENTRAL KALIMANTAN, INDONESIA)

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Submitted: 2018-09-14 Accepted: 2019-05-06

## ABSTRACT

The main problem faced by sloping lands in the humid tropic includes land degradation influencing natural ecosystem damage broadly. Land conversion and improper land-use have been widely recognized as the main cause of environmental damage since the demands for agricultural lands become greater than land resource available. The objective of this study was to determine the concept of appropriate land-use planning through environmentally sound spatial management in order to prevent land and environmental degradation. The sub-district of Antang Kalang was chosen as study area representing sloping lands in humid tropic that have a susceptibility to erosion. Conservation approach by the use of USLE erosion risk prediction model and land evaluation through land suitability classification was used in this study. The geographic information system (GIS) and remote sensing (RS) technology were applied to generate spatial basic information and to assist in spatial analysis. Two crops, upland rice, and rubber, representing food crop and estate p have been selected based on the local resource that has been existed since a long time ago. The result of spatial analysis shown that the arable land for agricultural practices covers 9,039 hectares (23.19%) while for non-arable land, it is allocated for forest preservation with total areas 29,934 hectares (76.81%). Land-use planning and land resources management involving conservation aspect and land suitability evaluation should be taken into account for farming practice at sloping lands areas since the value of soil loss potential appears as an indicator of erosion risk. Permanent cultivation system and the intercropping farming system is the option of recommended agricultural practice at sloping lands in the humid tropic that have a susceptibility to erosion.

**Keywords:** Land-use, Planning, Management, Land suitability, Conservation

**How to Cite:** Bhermana, A., and Susilawati. (2019). Environmentally Sound Spatial Management Using Conservation and Land Evaluation Approach at Sloping Lands in Humid Tropic (A Case Study of Antang Kalang Sub-District, Central Kalimantan, Indonesia). Sains Tanah Journal of Soil Science and Agroclimatology, 16(1): 76-89 (doi: 10.20961/stjssa.v16i1.24004)

**Permalink/DOI:** <http://dx.doi.org/10.20961/stjssa.v16i1.24004>

## INTRODUCTION

In Central Kalimantan, Indonesia, mostly, the demands for agricultural lands become greater than land resource available.

This reasonable opinion appears since many land-use allocations ignore appropriate land-use for forestry and wildlife as well. With a population density of 16 people km<sup>-2</sup> (BPS Provinsi Kalimantan Tengah, 2017), in general, a land resource that is still available should then be managed with environmentally sound

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spatial management. In order to ensure land resources can be used for the future generation, on the basis of natural environment condition and capability of land resources, agricultural land-use must not be on increased agricultural productivity solely, but rather on sustainable development that is appropriate to the environment.

Appropriate land-use planning is then required in order to achieve long-term sustained yields involving the successful management of resources for agricultural lands to satisfy changing human needs while maintaining and enhancing the quality of the environment and conserving natural resources (Hoffman, 2017; Altieri, 1992). Planning is underpinned by the assumption that adequate information exists for those exercising public authority to make decisions regarding the best use of land in the future (Flaherty & Smit, 1982) and is concerned with sustainable land-use allocation (Garcia et al., 2017) and it must be based on an understanding both of the natural environment and of the kinds of land-use envisaged (FAO, 1976). The function of land-use planning for agricultural purposes is, therefore, to guide decisions on land-use in such way that the resources of environment are put to the most beneficial use, while at the same time conserving those resources for the future.

The main problem related to land resources and natural environment as well that is still found in Central Kalimantan involve improper land-use doing simultaneously with deforestation. Initially, land-use changes are the impact of the existence of shifting cultivation as traditional agriculture system (Mulyoutami et al., 2010). The present main issues include land-use expansion for the estate. Massively, opening new lands for oil palm plantation has been practiced since 2005 when the local government established that

estate development is one of the leading sectors of regional development.

The land conversion due to opening new lands for agricultural purposes tend to have a negative impact on the natural environment. In central to northern part Central Kalimantan, mainly dominated by acid tropical soils at sloping lands, unfavorable soils development process occurs since the lands were cultivated inappropriately for agriculture, plantation, mining, and transmigration as well (Angi & Wiati, 2017; Gay-des-Combes et al., 2017). Because of its susceptibility of erosion, many agricultural practices lead to land degradation and soil erosion especially at sloping areas (Espinosa et al., 2017; van Uexkull & Bosshart, 1989; Notohadiprawiro, 1989).

The sub-district of Antang Kalang located in Central Kalimantan was selected as a study area because it represents relevant issues concerning land resource availability including its natural environment and local resource that should be preserved. Further land degradation and environmental damage including soil erosion, deforestation, and loss of genetic resource should then be prevented in order to conserve the quality of the environment.

The objectives of this study were to provide basic concepts of environmentally sound spatial management through appropriate land-use planning on the basis of local resource and long-term use and yields. The aspect of conservation and land evaluation approach was used in order to determine the spatial concept as basic plans. The geographic information system (GIS) and remote sensing (RS) technology were applied to generate spatial basic information and to assist spatial analysis.

## **MATERIAL AND METHODS**

### **General Overview of Study Area**

The study area is focussed on Antang Kalang sub-district, Central Kalimantan

province, Indonesia with total areas 38,973 hectares (Figure 1). It is situated between latitudes 01° 11' 41" S and 01° 27' 14" S and longitudes 112° 27' 07" E and 112° 49' 45" E. This site location is classified into a humid tropical region because of its geographical position located below the equatorial line with humid climate system and rainfall distribution throughout the years (Wohl et al., 2012).

Administratively, this area belongs to Antang Kalang sub-district, Kotawatingin Timur regency. Inside the location, there are only 5 groups of settlement, known as village, namely Tumbang Ngahan, Tumbang Ramei, Tumbang Hejan, Tumbang Nusa and Tumbang Gagu. They are located at river stream areas with a total population of 1,569 persons and mostly dominated by Dayak tribe for these five villages. With the density of 4 persons km<sup>-2</sup>, it reflects that in general, the lands are still widely available related to land-use for human living.

The majority of the Dayak community in this site location work as farmers and traditional farming used to agricultural practice is shifting cultivation. Some of them spend time with latex rubber tapping, hunting, and traditional mining. These daily activities have been carried out since a long time ago, derived from their ancestor in the past.

The climatic condition of study areas generally determined by its geographical position on the equator and it is categorized into the humid tropical region, characterized by a rather constant temperature throughout the year, high humidity and high precipitation (Loo et al., 2015). Based on available nearest climate station records located in Katingan around 103 kilometers from the center of the study area, it has annual rainfall around 2947 mm. The rainy season starts from October to May while the dry season runs from June to September. The relative humidity is about 77% with mean temperature 30°C. Additional

information for climate can be obtained from Oldeman Agroclimatic Zone (1980) and it shows that study area falls within climatic zone A according to the Oldeman system. It implies that the number of consecutive wet months is > 9 months and consecutive dry months less than 2 months.

The typology of land in the study area classified into upland with specific acid tropical soils that have low fertility status and susceptible to erosion (Suharta, 2010; Amien, 1990). There are three soil great groups found in the site study location, namely, Paleudults, Hapludults, and Dystrudepts. These tropical soils are the products of rapid weathering and strong leaching, so that, most of these soils would probably be best left under forest (Suharta, 2010; van Uexkull & Bosshart, 1989).

The methodology used in this study was the implementation of soil erosion prediction model and land resource evaluation. Soil erosion prediction model is applied to determine areas susceptible to erosion spatially. The universal soil loss equation (USLE) with mathematical formula by multiplying several factors involving rainfall erosivity, soil erodibility, slope, land cover, and conservation practice to determine the value of average soil loss due to land surface erosion (ton ha<sup>-1</sup> year<sup>-1</sup>) (Wischmeier & Smith, 1978). While for land evaluation, the procedure refers to The "FAO Framework for Land Evaluation" through the matching process between land parameters with crop requirements leads to an assessment of the suitability of land-use for the crop (FAO, 1976; Wahyunto et al., 2016; Sys et al., 1993). The resulting evaluation was, therefore, then integrated into a GIS environment for further spatial analysis using qualitative descriptive analysis procedure.

The GIS technology was applied to generate spatial data as part of geospatial information based on the result of USLE calculation and land evaluation. In addition to

spatial analysis purposes, GIS was also applied to facilitate, improvement, storing, displaying, future utilization, and updating data (Abdel Rahman et al., 2016; Andy et al., 2002; Eswaran et al., 1992; Goodchild et al., 1992; Tomlinson, 1968). Furthermore, the RS technology was also used in this study mainly to identify land cover, present land-use, and digital elevation model (DEM) that represent basic factors for conservation aspects including soil erosion prediction model.

Basic data and information as datasets consist primarily of spatial data and tabular data obtained from field survey and literature study involving soil maps, climatic maps, land characteristics, and land-use requirements. These data were used for both land conservation analysis and land resource evaluation purpose. Two crops, upland rice and rubber, representing food crop, and estate p

have been selected based on a local resource that have been existed since a long time ago.

The other primary data include a) Landsat imagery accessed from Landsat 8 with a resolution of 30 meters on March 2016 considering the minimum cloud-covered for the study area (Sitanggung, 2010) and b) DEM data taken from SRTM 30 meters (Smith & Sandwell, 2003). These data were mainly used to understand the land cover spatial pattern and landform characteristics that have a close relation to soil erosion risk level and land evaluation as well. Further support data was also completed through field survey. PC-based GIS and RS software for data interpretation and spatial analysis used in this study were ErMapper, Global Mapper, and Arc View. An overview of general methodological steps is provided in Figure 2.

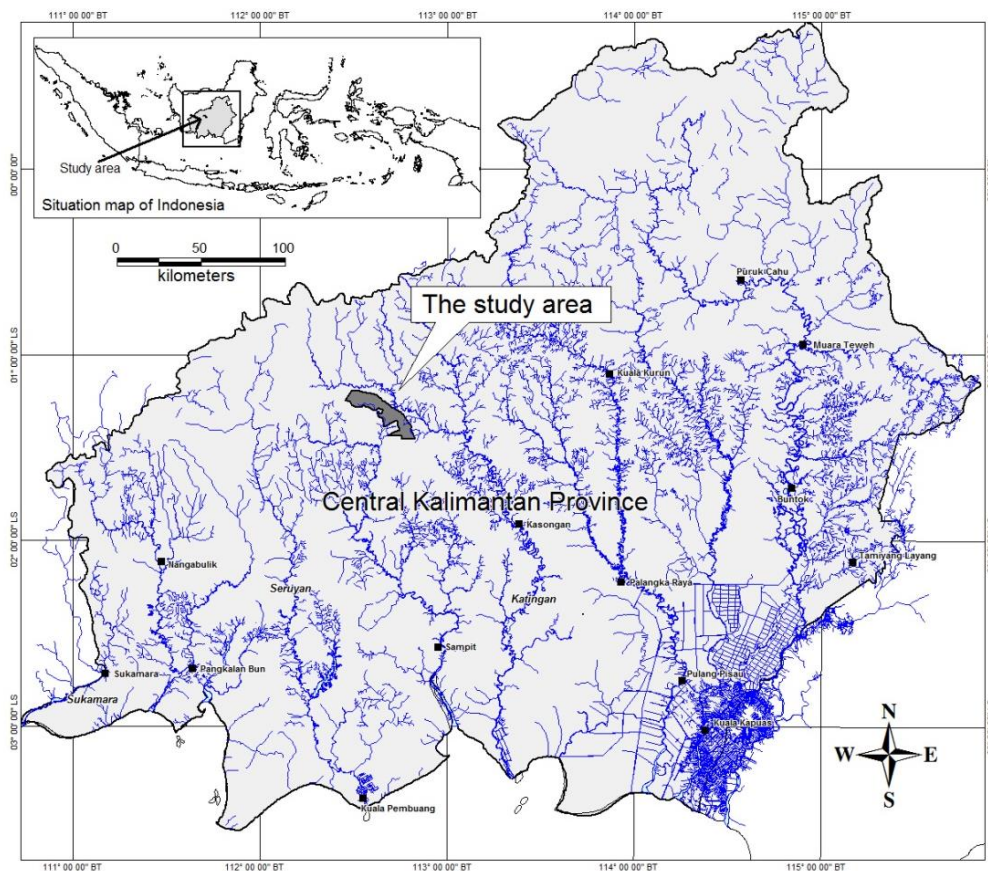
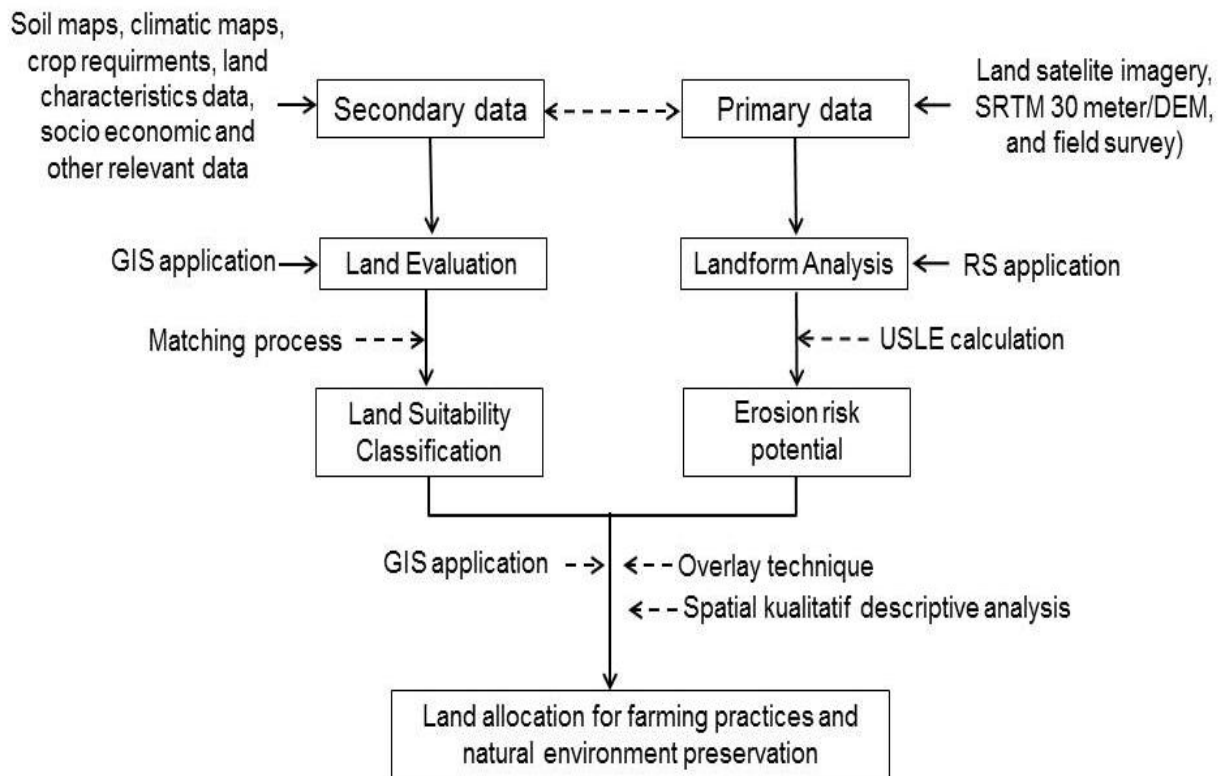


Figure 1. The map of situation showing location of study



**Figure 2.** An overview of general methodological steps

The discussion about landform and natural feature of the earth's surface in this study is mainly based on DEM data interpretation taken from SRTM 30 meters. The result of interpretation using remote sensing (RS) technology application and field ground check showed that the study area is categorized into sloping land with altitude ranging from 52.03 meters to 445.79 meters above sea level. As hilly areas, there are three major landform of undulating plains, moderately steep hills, and hillocky plains that cover this site location.

## RESULTS

Based on DEM data interpretation, the study areas were mainly categorized into sloping land. It has been proven by the display of slope shader based on DEM (Figure 3). This

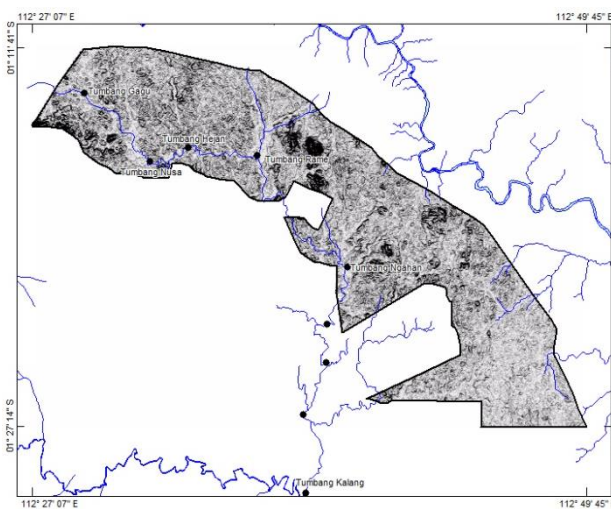
data was then interpreted to provide spatial data of contour including elevation and slope gradient (Figure 4). The result of further interpretation and spatial analysis, therefore, showed that this area is geographically divided into 3 slope classes i.e 4-8%; 16-25 and 26-40 (Figure 5) including each total areas (Table 1).

Table 1 shows that the study area is mainly dominated by the slope class of 16-25% with total area 28,988 hectares (74.37%). Although the land could be suitable for agricultural practice, landform description should be taken into account especially for conservation aspects because the slopes greater than 8% is being prone to erosion (Angima et al., 2003). However, the remaining lands with slope 4-8% that constitute about 23.19% of total study area have the potential to be developed.

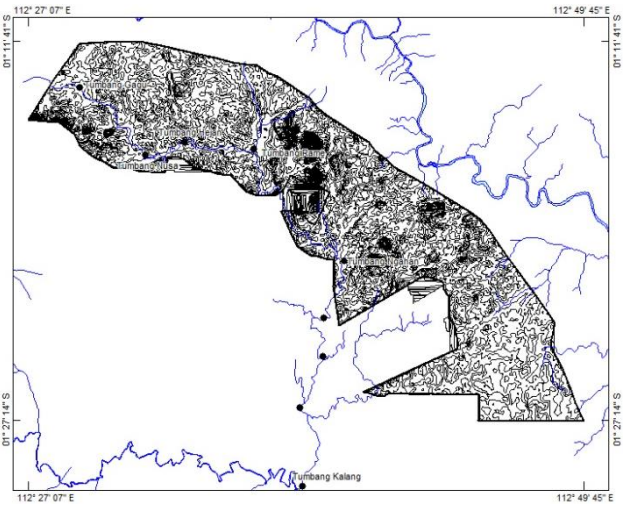


**Table 1.** The classification of slope and landform description for the study area

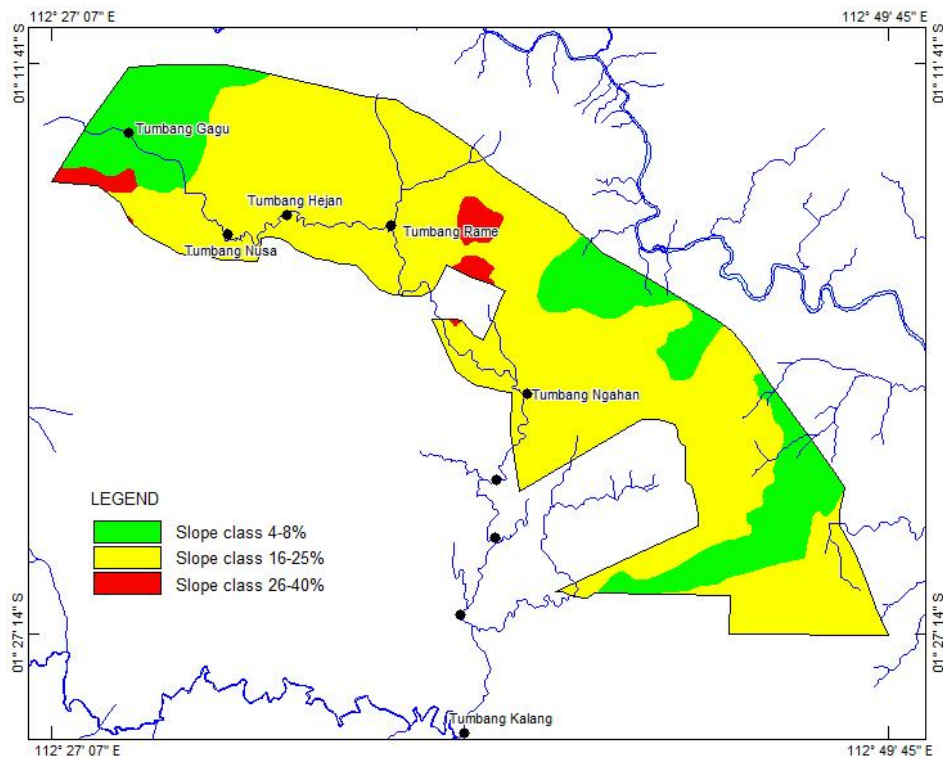
No	Slope class (%)	Landform	Areas (Hectares)	(%)
1	4-8	Undulating plain	9,039	23.19
2	16-25	Moderately steep hills, hills with a moderately steep dip and steep scar	28,988	74.37
3	26-40	Steep narrow ridges	946	2.43
Total			38,973	100.00



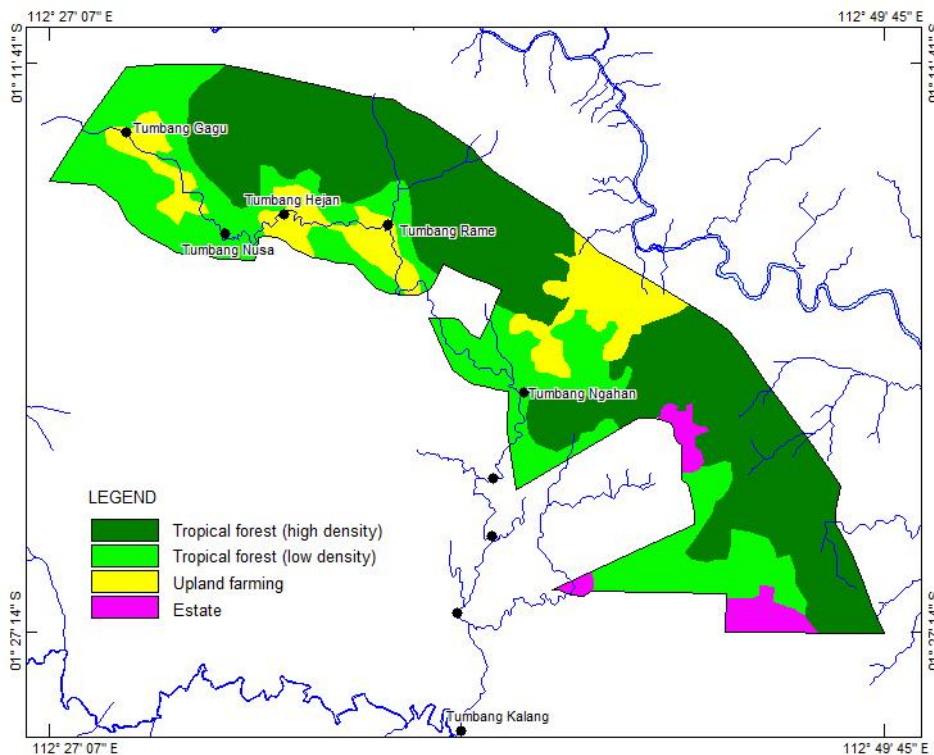
**Figure 3.** The view of slope shader based on DEM



**Figure 4.** The map of contour with interval of 20 m



**Figure 5.** The map of slope class distribution in the study area



**Figure 6.** The map of land cover showing present land-use in the study area

### Land Cover and Vegetation

Spatial identification of land cover including the specific location of vegetation used mainly RS technology based on land satellite imagery of Landsat 8 on March and April 2015 considering the minimum cloud cover percentage in order to obtain best GeoTiff format images. The result of Landsat imagery interpretation was then integrated into GIS environment as shown in Figure 6 that represent land cover and present land-use of the study area. At present, the land is still mainly covered by forest including high-density bush with total areas 29,056 hectares or 74.55% of whole areas of a site study. It indicates that the lands are still available for general land-use.

However, in the south, it has been identified that there are several parts of areas that have been cultivated for the estate. Based on the ground survey, several cultivated lands are a land expansion of oil palm plantation that has been existed in the southern part for

several years ago. Land conversion impact to the existing natural environment is, therefore, should be taken into account for future land-use because these sloping land areas are still covered by natural vegetation.

Figure 6 also shows that upland farming has been practiced through opening new land for shifting cultivation. It covers only 8,760 hectares (22.47%). Although the land has been opened for agricultural practice, the local farmer still uses traditional technique through their indigenous knowledge. For instance, based on the ground survey, they opened the land at undulating plains with slope class less than 8%. In this case, the aspect of conservation has been fulfilled during farming practice.

### DISCUSSION

#### Land and Environment Degradation

Land is an important aspect in the natural environment. In addition to soil, slope, as part of landform, is one of several factors

that determine the type of agriculture (Altieri, 1987) so that it should be considered in agricultural land-use planning (de Lima, 1988). In this study, slope information was used not only as one of several factors in the USLE prediction model but it also was used to determine land suitability classification in land evaluation.

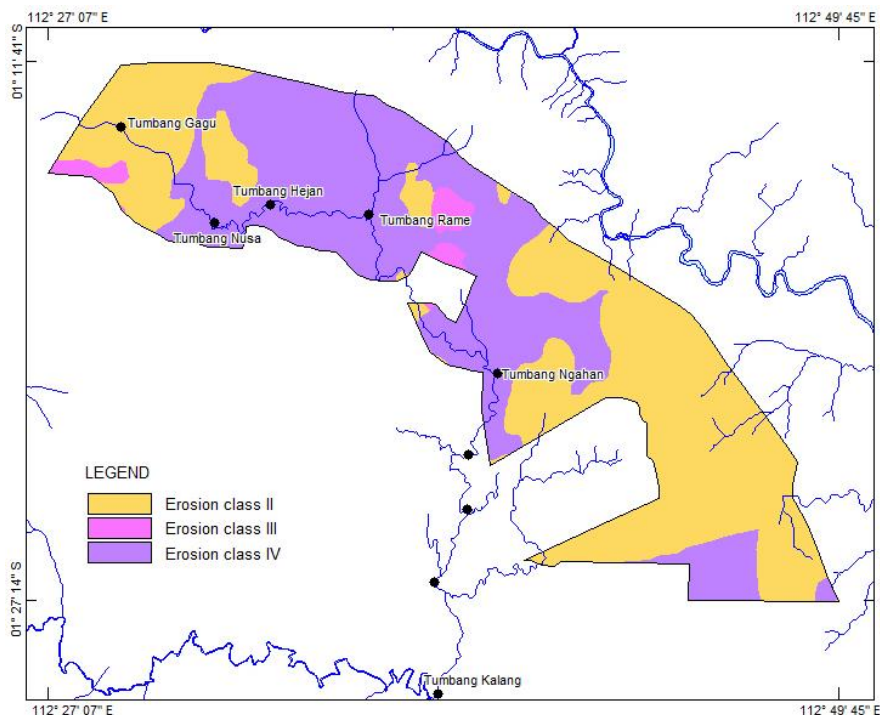
The potency of soil erosion is then should be early known through erosion risk level classification. The result of calculating data input according to the USLE erosion prediction model shown that there are 3 classes of erosion risk level in the study area. Each class reflects the level of erosion risk through soil loss potential (ton hectare<sup>-1</sup> year<sup>-1</sup>),

total areas (Table 2) and spatial distribution (Figure 7).

Table 2 and Figure 7 explain that the lowest potential of erosion risk in site study is class II with average soil loss potential 32.79 ton hectare<sup>-1</sup> year<sup>-1</sup>. This class occupies 51.63% (20,123 hectares) of the total study area located geographically in the southern spreading to the central part. On the other side, it is also found in the northern part. This region can then be allocated for agricultural practice. However, because the value of soil loss potential appears, both soil and environment conservation intervention measures should be implemented.

**Table 2.** The classification of the erosion risk potential in the study area

No	Class	Soil loss potential (ton/hectare/year)	The average of USLE model calculation results (ton hectare <sup>-1</sup> year <sup>-1</sup> )	Total area	
				(Hectares)	(%)
1	II	15-60	32.79	20,123	51.63
2	III	60-180	72.91	938	2.41
3	IV	180-480	459.28	17,913	45.96



**Figure 7.** The map of erosion risk potential classification in the study area



Originally, located in humid tropical regions, the whole areas of Antang Kalang in which the study area take place is endowed by a large area of tropical forest (Rahu et al., 2013). In Kalimantan, on a larger scale of typical lowland rainforest, there are almost 180 tree species hectare<sup>-1</sup> (Kartawinata et al., 1981). During the field survey, in addition to giant species of *Shorea* spp, the other plants that have been found are local rubber (*Hevea brasiliensis*). Along the river stream, some local orchid species were also found beside other species of ornamental plants. The existing of land cover involving crop growth data as well as cropping patterns and land-use contributes to USLE erosion prediction model through the value of vegetation practice (Angima et al., 2003; Wischmeier & Smith, 1978).

#### **Land Suitability for Farming Practice and Genetic Resource Preservation**

The availability of arable land is the potency of land resource that can be used for human living. However not all the lands can be used optimally because of their limiting factors. Land evaluation approach was then used in this study to determine land suitability classification for several existing crops in certain areas. The importance of land resources evaluation for better agricultural land-use and sustainable agriculture become more clear since it has taken environmental control into account and an efficient land-use that does not degrade the land resources can be achieved (Sharu et al., 2013; Kumar et al., 2017).

Two selected crops based on local existing commodities consists of upland rice and rubber have used for evaluation. In fact, upland rice farming has been practicing by local farmers to meet the basic need of food in these areas. While, for rubber, it has been cultivated since they leave the land to open the other areas. The benefit of extra income taken from

rubber tapping has also been widely understood by the local community in this study area.

The result of land resource evaluation provides information that both upland rice and rubber were classified into marginally suitable-S3 due to limiting factors of nutrient retention such as pH and base saturation (Figure 8). However, this condition can be solved through proper improvement. Further evaluation to determine potential land suitability after improvement describe that both rubber and upland rice can reach the higher suitability class become highly suitable-S1. Land allocation for each crop was then justified according to the priority of the needs. Therefore, mainly on the basis of land suitability, landform and existing cultivated land, the most suitable lands for rubber and upland rice is located on undulating plains with slope class 4-8% meanwhile at slope 16-25%, the lands are not recommended to be cultivated because of marginally suitable-S3 for both of crops. The map of land suitability as a result of the land evaluation is shown in Figure 8.

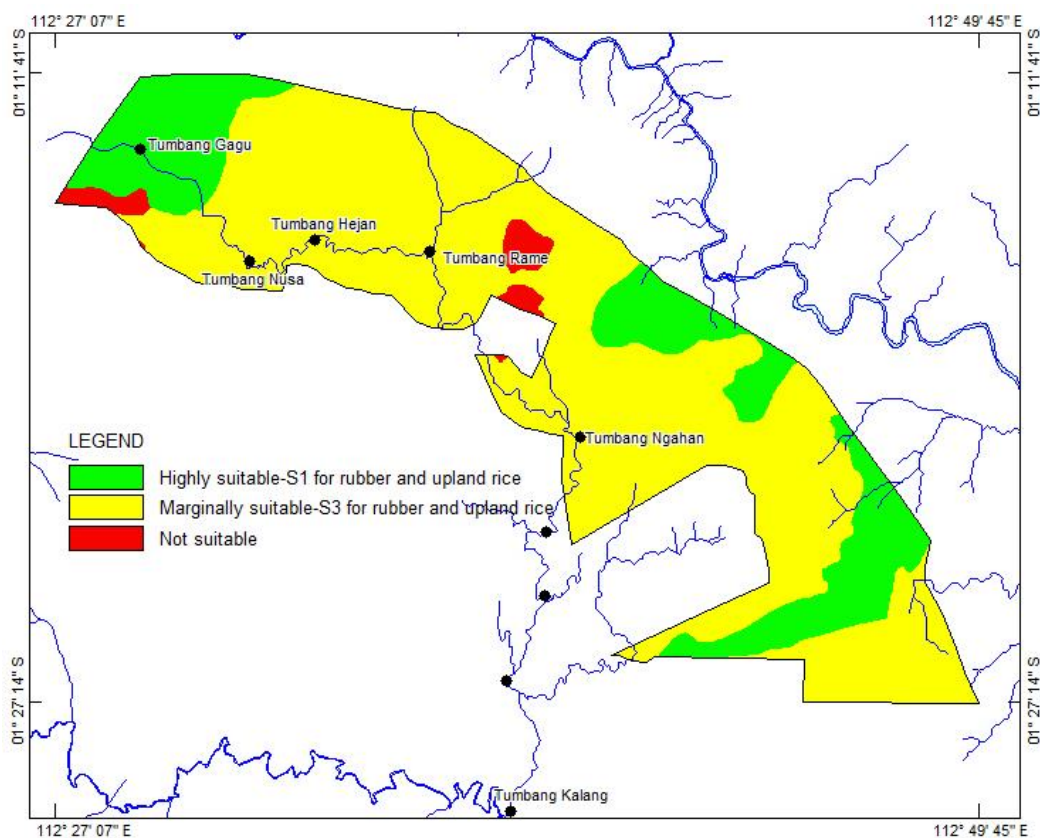
In order to ensure optimum yield on a sustained basis and conserve the natural environment, the result of the land evaluation was then further integrated into erosion risk potential data. The GIS application through an overlay technique was used to provide new layer information (O'Sullivan & Unwin, 2003). In this study, land suitability map was then overlaid to erosion risk potential map to produce spatial information about the appropriate land allocation for farming practices and natural environment preservation. The result of spatial analysis shown that most suitability of the land for selected crops occupy the region with the lowest of erosion risk potential (Figure 7 and 9). As a result, spatial information of land-use allocation was then developed as shown in Figure 9. It describes that recommended

agricultural land-use planning can be implemented in the southern, central and northern part of the study area with total area 9,039 hectares (23.19%). However, because the potential of erosion risk has already occurred, indicated with risk potential class of II (soil loss potential 15-60 ton hectare<sup>-1</sup> year<sup>-1</sup>), the aspect of conservation should be integrated during agricultural practices. Among the villages located in the study area, Tumbang and Tumbang Ngahan can be a priority for initial agricultural development program because they are geographically located in the agricultural land region. For Tumbang Ngahan, although it lies near arable land for agriculture, it strategically considered as main gate access to enter site location.

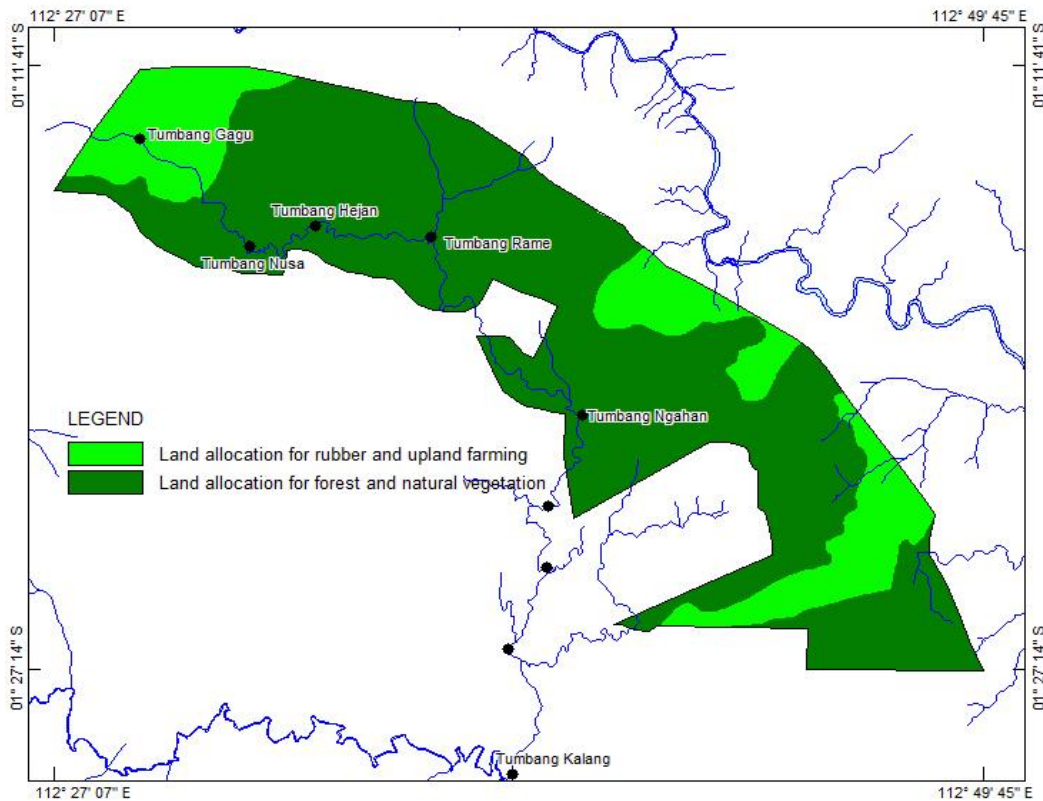
In the case of Antang Kalang, related to conservation aspects, an initial step toward sustained land-use and environment

preservation changes the concept of shifting cultivation to permanent cultivation. Basically, the negative environmental impact of shifting cultivation includes any changes in soil physical and chemical properties and changes in soil nutrient status leading to land and forest degradation and environmental damage (Stadtmueller, 1990; Salinas-Melgoza et al., 2017). Furthermore, deforestation, as part of opening the lands in this traditional system or even modern agriculture and other activities such as illegal logging leads to a direct loss of biodiversity (Jeus et al., 2012).

On the other side, the non-arable lands covering almost 29,934 hectares (76.81%) can be recommended for forest preservation. The existence of tropical biodiversity that plays an important part in environmental balance is then should be a priority especially at sloping lands that have high susceptibility of land degradation.



**Figure 8.** The map of land suitability for rubber and upland rice in the study area



**Figure 9.** The map of land allocation for farming practices and forest in the study area

In the study area and its surrounding, local plants, wildlife, plants, and animals were still found. Natural resource that could be direct or indirect used involve goods and service such as species for food, medicine and buildings material as well.

As a final result, spatial information about land allocation based on land resource and its natural resources can then be used as basic consideration for land-use planning at sloping lands that have permanent limiting factors for agricultural practice and other relevant activities related to land conversion in the future. The aspect of conservation should be integrated into sloping lands management. Intercropping of rubber and upland rice could be an option that can be implemented for farming practice (Simpson, 2010).

## CONCLUSION

The concept of land suitability derived from land evaluation and USLE erosion prediction model can be used for

environmental spatial management to determine the land-use allocation of the agricultural land region and natural environment areas precisely. In order to provide relevant information within spatial data, the use of geographic information system (GIS) and remote sensing (RS) technology is required in displaying data, interpretation and spatial analysis.

## ACKNOWLEDGMENTS

The authors wish to thank Prof. Dr. Zulkifli Zaini as a team leader who contributes both thought and funds. In addition, also thank PT. Poyry Indonesia for any relevant data required in this study. Any remaining errors or omissions will be responsibility accepted by the authors.

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