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Geographical Distribution Analysis of Soil Erosion Risk for Land use Planning and Sustainable Agricultural System (*A case study of Gunung Mas Regency, Central Kalimantan, Indonesia*)

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Abstract **- Soil erosion should be considered as important factor in achieving sustainable agriculture system because it leads to land degradation and damage to natural environment. In Gunung Mas regency, land use planning integrated with land use policy need to be formulated because of the availability of land resource that cover almost 1,007,165 hectares or 93,21% of total administrative area. The lands is mostly dominated by upland typology with various slope classes. Thus, the highly precipitation occur in this tropical region lead to soil erosion if proper land use and conservation management are not implemented. The studies about soil erosion in the tropics is very limited in Indonesia, especially in Gunung Mas regency. The objective of this study was to to provide basic information about soil erosion risk based on level of erosion risk including spatial land classification as part of geographic information system (GIS). Erosion prediction model of USLE was used in this study as basic consideration for agricultural land use planning development. The result of erosion risk prediction was then integrated into agricultural land use policy in order to provide land use allocation and recommendation. The result of evaluation using USLE's soil erosion prediction showed that there are 5 classes (class I to V) of soil erosion risk in Gunung Mas regency. More than a half of this region is classified into class V. It implies that these areas have highest potential to soil erosion risk with assumed soil loss > 480 ton/hectares/year. Spatially, distribution pattern of this class is broad areas occur at middle part spreading to the northen part with total areas 566,837 hectares (52.46%). The critical factors that can generate soil erosion include sloping lands and highly rainfall. The dominant landform in these areas is steep slopes to very steep with slope classes 26-40% and 41-60%. Considering soil risk level and classification, the areas with slopes classes <2%; 2-8%; and 9-15% can then be allocated for agriculture purposes. Agricultural land region that suitable for cultivation comprise 33.16% (358,327 hectares) of total areas.**

Keywords **– Soil, Erosion, Land use, Planning, GIS.**

I. Introduction

The need of landuse planning become apparent since an area has opportunity to be developed because of the availability of land resources. Opening the lands for agriculture, therefore, requires specific programs with appropriate policy in order to achieve sustainable agricultrure system. Gunung Mas regency located at tropical region below equator line has potency to be further developed because of its land resource with total areas of 1,080,500 hectares. Since 2014, the land that have been utilized for agriculture including etstate is only 73,335 hectares or 6,79% of total areas of administrative region [8]. Land use planning integrated with land use policy can then be formulated for the remaining areas than cover almost 1,007,165 hectares (93,21%).

Increasing competition on land in the future should be taken into account in landuse planning and policy. At regional level of province in Central Kalimantan, land become a scarce resource increasingly because it is directly affected by human intervension especially for agriculture and estate. One of several impacts due to opening land for agricultural purposes include soil erosion because it leads to land degradation and damage to natural environment. In addition to land use changes, fertile lands become scarcer due to erosion [39]. Land use policy can then be formulated to allocate agricultural land region including conservation areas and preservation areas to keep them in theirs natural condition.

Soil erosion should be considered as important factor in achieving sustainable agriculture system. The aspect land erosion should be integrated into land management in order to protect agricultural land productivity and bring the soil erosion which affects the structure of soils adversely under control, as well. In the most areas, since the lands are cleared and opened for agricultural expantion, erosion will occur while at the same soil fertility will decrease [32]. Further excessive erosion therefore results in significant topsoil losses, leading to declines in agricultural productivity [17], [25].

In Gunung Mas regency, the lands is mostly dominated by upland typology with various slope classes. Thus, the highly precipitation occur in this tropical region lead to soil erosion if proper land use and conservation management are not implemented. Soil conservation as integral part of land use planning is technological innovation to support sustainable land use by improving land quality and reducing land degradation [28].

Data and information about soil erosion risk is then urgently required in land use planning especially to prevent environmental damaging that can affect sustained land use and productivity. The studies about soil erosion in the tropics have been conducted in the Southeast Asia but it is very limited in Indonesia, especially in Gunung Mas regency, Central Kalimantan [34]. One of the most important data related to erosion that is required for land use planning include land classification based on soil

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erosion risk. It can provide basic information about soil erosion risk classification according to its level of erosion.

Farming system based on conservation recognised as ‘good agricultural practice’ practices might have beendemonstrated to considerably reduce soil loss in the other part but it is usually only adopted after soil erosion has been identified as a significant problem [16]. In the case of Gunung Mas regency, the existency of natural land resource should be protected through appropriate agricultural land use planning. Moreover, data and information on conservation practices are rarely collected systematically and stored centrally.

This study was then conducted in order to provide basic information about soil erosion risk based on level of erosion risk including spatial land classification as part of geographic information system (GIS). Erosion prediction model of USLE was used in this study as basic consideration for agricultural land use planning development.

II. Methodology

The sudy area was focussed in Gunung Mas regency, Central Kalimantan province, Indonesia (Figure 1). The study area was selected mainly in the view of scarcity of erosion risk data and potential widely land availability. Basic theory used in this study is the use of soil erosion risk prediction model of Universal Soil Loss Equation (USLE). The USLE formula as proposed by Wischmeier and Smith [40] is then implemented to determine soil loss prediction that represent soil erosion risk level.

The equation of USLE is given by the expression:

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

Where:

- E is 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) and are combined in a singleindex
- C is the crop factor/nature of plant cover
- P is the conservation practice factor used to manipulate the LS factor

The application of remote sensing (RS) technology is used to obtain land satelit imageryand interpretation data especially for current land use land cover data. Furthermore, geographic information sistem (GIS) technology is used to integrate the resulting data into spatial format for further analysis. GIS is also used to generate digital elevation model (DEM) for terrain and landform analysis purpose. Based on deskwork study and field verification, both qualitative and quantitative descriptive analysis is then used to decide spatial planning systematically.

The data sets required in this study involving land and climatic data. Basically, they are required to determine factors within USLE model. The RS procedure use imagery data obtained from Landsat 8 with acquisition time November to December 2015. While for DEM analysis, it use SRTM 30 meters data. Other relevant spatial data for GIS procedure include soil maps, rainfal disribution map, agroclimatic zone map, and administrative maps. Overlay technique and on-screen digitation were used within GIS environment. Each specific data represents factors required to implement USLE matematical mode Table 1). Schematically, an overview of general procedure in this metodology is described at Figure 2.

Table 1: Data requirement for USLE matematical model

No	Factor within USLE model	Specific data source
1	Erosivity	Rainfall distribution map; agroclimatic zone map
2	Soil erodibility	Soil maps
3	Slope and length gradient	DEM; slope maps
4	Crop and vegetation	Land cover map
5	Conservation practice	Land cover and present land use map

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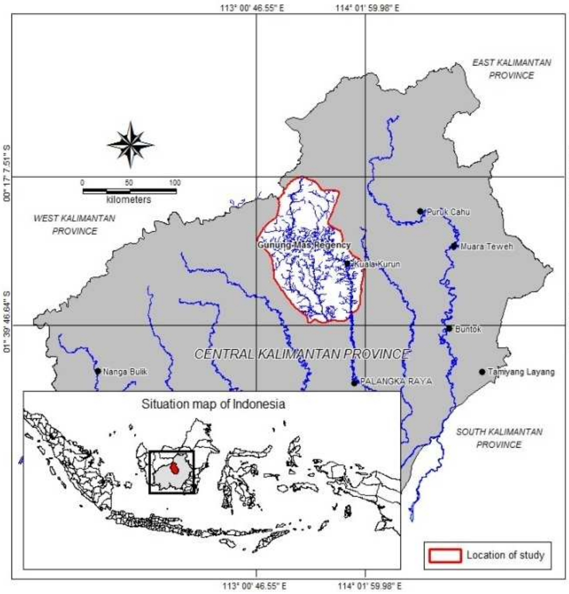

Fig 1. The map of location of study

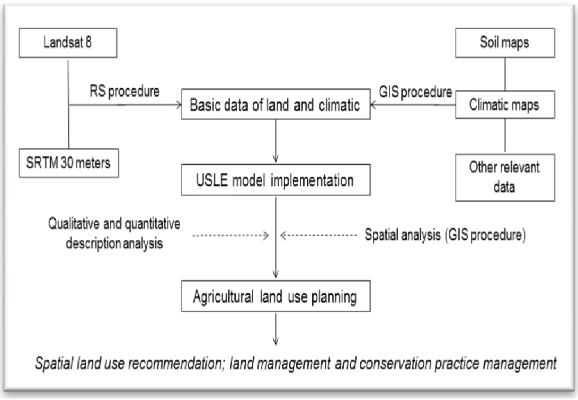

Fig. 2. An overview of procedure

III. Results and Discussions

A. Land and Climate Information

Geographicaly, Gunung Mas regency located below equator line with coordinate position 113^o 00' 46.55" E to 114^o 01' 59.98" E and 00^o 17' 7.51" S to 01^o 39' 46.64" S (Figure 1). The major landform found in this regency consist of hilly to mountainous. They are found at central to northern parts with various slope classes involving 9-15%; 16-25%; 26-40%; 41-60; and >60%. While in the southern parts, flat to undulating plains are found with dominant slope classes < 2 and 2-8%.

Slope, as part of landform, in addition to determine type of agriculture [3], it can also determine level of erosion risk withn an areas because slope, as morphological factor, result in overland flow so it should be considered in land use especially in agriculture planning [12]. Sopher and Baird [31] reported that on slopes of 25 to 40 percent, it is not uncommon to have soils with only A and C horizons. This is because erosion is taking place at a rate fast enough to allow only a shallow A1 horizon to form. Moreover, on slopes and uplands, drainage is usually sufficient to produce well aerate, oxidized soils with bright-colored B horizons and low organic matter contents. The GIS analysis calculate that sloping land with slope class >25% is 407.400 Ha or 37,70% of total area of Gunung Mas regency. This area should then be taken into account in landuse planning because the areas are particularly at risk of erosion.

The dominant soil found in Gunung Mas consist of 3 soil orders involving Ultisols, Inceptisols and Entisols with following great groups: Tropudults, Dystropepts, Tropaquepts, Tropopsamments and Ustipsamments [37]. In relation to erosion, soil type has contribution to the value of soil erodibility that represents both susceptibility of soil to erosion and the amount and rate of runoff [36]. Based on spatial analysis, the major soil great group of Gunung Mas regency is Tropudults covering 705,512 hectares (65.29%). Most of the upland soils of Ultisols are highly weathered, acidic, infertile and poorly buffered [2]. In general, acid humid tropical soils found in this regency dominated by low activity clays which compact especially in the subsurface and are susceptible to erosion especially on sloping lands [21], [24]. The aspect of conservation should be then taken into account in agricultural land use planning.

The climate condition of Gunung Mas regency is generally determined by its geographical position on the equator [23]. It is charaterized by a rather constant temperature throughout the year, high humidity and high precipitation. Based on Oldeman climate classification, this area is classified into zone A and B1 [26]. Zone A that cover in the central to northern part has consecutive wet months >9 months. While in the southern parts, consecutive wet months is 7-9 months. The number of consecutive dry months for the whole areas is <2 months in a year. Local climate station reported that number annual rainfall varies between 2.864 and 3,577 mm. Related rainfall to climate has closely relationship to soil erosion. The stronger rain within an areas, the more and faster water erosion occurs [29], [30], [35].

In general, based on land and climate data, the most important factors influencing soil erosion and land degradation as well in Gunung Mas regency include slope and higly rainfall. Since raindorps falling on the lands break down soil surface structure and detach particles, the sloping lands also controll overland flow and erosion [9]. The evaluation of land and climate was conducted in order to provide factors required for USLE calculation such as rainfall erosivity, soil erodibility, slope length and steepness.

B. Existing Landuse

Existing landuse represents land cover information that can influence soil erosion risk. During the rains, as precipitation falls, the first defense that vegetation provides against erosion is raindrop interception [17]. Remote sensing technology integrated with GIS was used to produce land cover data based on information provided by Landsat 7 ETM+. As a results, it is shown that the region of Gunung Mas regency is mainly covered by forest. Both tertier tropical forests and shrubs cover almost 1,059,877 hectares or 98,09% of the region. While the remaining areas have been used for agricultural lands, estate and settlement with total areas 20,623 hectares

(1.91%). Both agricultural lands and estate are located surrounding the settlement areas which is scattered spatially. Shifting cultivation as traditional farming is still applied by mostly local community.

In this study, the evaluation of existing land use that reflect vegetation’s cover percentage with specified cover and management is then associated with support conservation pratice [15], [33]. Land cover map and field verification is then used basic information. The result of evaluation contribute the factor of cover management and conservation practice within USLE calculation. However, based on field observation, assuming no support conservation practice in the study area, it was then not used in calculations.

C. The Level of Soil Erosion Risk

The predominant aspects of environmental biophysic that predispose soil erosion in Gunung Mas regency include sloping lands and highly rainfall condition. The lands are mainly covered by forest so that cultivated lands may be neglected. It can then be assumed that this region is still in safe condition naturally. However, the information of soil erosion prediction for land use planning should be provided in order to develop this region while at the same time preserve its natural condition.

The result of evaluation using USLE’s soil erosion prediction show that there are 5 classes of soil erosion risk in Gunung Mas regency. Classification of soil erosion risk including criteria and coverage areas spatially as part of GIS is shown at Table 2 and Figure 3.

Table 2: Land classification of soil erosion risk in Gunung Mas regency

Soil erosion risk class	Criteria of soil loss (*) (ton/hectares/year)	Areas (hectares)	Areas (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	566.837	52,46
		1,080,500	100,00

(*)Source: Komaruddin [20], Departemen Kehutanan [13], Direktorat Jenderal Reboisasi dan Rehabilitasi Lahan [14].

At natural condition, based on prediction value of USLE, more than a half of this region is classified into class V. It implies that these areas have highest potential to soil erosion risk with assumed soil loss > 480 ton/hectares/year. Spatially, distribution pattern of this class is broad areas occur at middle part spreading to the northen part with total areas 566,837 hectares (52.46%). The critical factors that can generate soil erosion include sloping lands and highly rainfall. The dominat landform in theses areas are steep slope to very steep with slope classes 26-40% and 41-60%.

On the other side, the lowest percentage of soil erosion is fall into class III. It ocuppies only 31,992 hectares (2.96%) with assumed soil loss 60-180 ton/hectares/year. Spatially, this areas are located along the main rivers at slope class < 2% where human settlement and agricultural practice exist. Although the lands have been opened for agriculture without conservation practice, they are cultivated using minimum tillage with traditional farming system called sifthing cultivation.In this region, agricultural activities is practiced for subsisten purposes only. Because human population density is only about 10 people/km^2, this traditional farming is an ideal solution for agriculture in the humid tropics [10]. Normally, fallow periods after opening the lands are long enough to restore both soil fertility and vegetation so that natural environment can still be preserved.

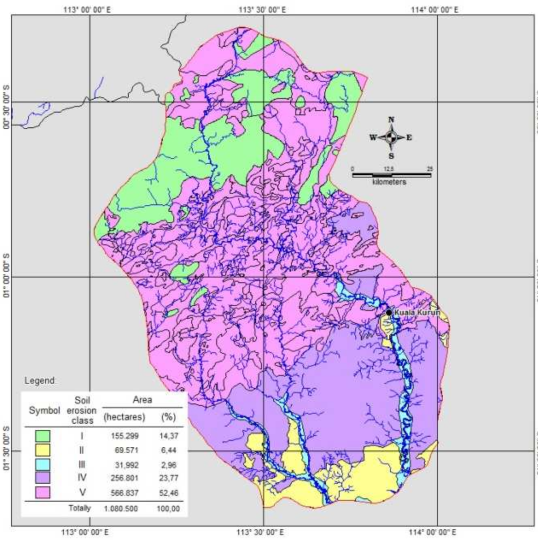

Fig. 3. The map of soil risk erosion in Gunung Mas regency

D. Agricultural Land Use Planning

Appropriate land use planning is required since the region has opportunity to be developed. Because it can destroy or conserve ecosystem services, proper land allocation should be determined based on potential ecosystem service to balance of their protection [39]. In this study, using GIS technology, agricultural land allocation was determined through overlaying the map of soil erosion prediction to the map of slope classification that have been dveloped.

Regarding level of soil erosion risk in Gunung Mas regency, the main factor that influence agricultural practice and soil erosion prevention is slope. It should be considered when drawing up plans for any agricultural practices. Futhermore, slope should be considered to minimize risk from soil erosion including its impacts such as decreasing soil fertility.

The suitable slope classes for farming activities is respectively <2%; 2-8%; 9-15%; and 16-30% [22], [18], [5]. In the case of Gunung Mas regency, the slope class 16-30% is categorized into class V in soil erosion risk level which is highest degree of soil erosion risk. In addition, steeper slope is also not suitable for operating machinery during agricultural practice and conservation as well.

Considering widely enough land availability in Gunung regency, the areas with slopes classes <2%; 2-8%; and 9-15% can then be allocated for agriculture purposes. Agricultural land region that suitable for cultivation comprise 33.16% (358,327 hectares) of total areas. Geographically, these lands are mainly located in southern part with spatial distribution pattern in the form of a region (Figure 4). The lands with slope classes <2% and 2-8% are located at river stream areas both main rivers and branch rivers. While for slope class 9-15%, they occupy highlands areas with gently topography (Figure 5 and Figure 6).

Specific land use policies therefore can, be formulated in order to utilize these lands. Basic extensification programs can be priority for land use planning rather than intensification program because of the availability of lands. However, because there are 3 groups of slope classess i.e. <2%; 2-8%; and 9-15% , further recommendation is then required in order to achive sustainable agriculture system. The land with slope classes <2% and 2-8% can be considered suitable for agricultural land use because of very slight to negligible limitation. Flooding is sometimes a problem on this land because it is often adjacent to major rivers and streams [19]. Other land management that is required include improving soil fertility; improving soil structure especially for land developed from sandy soil and other inputs depending on each crop growth requirements. At regional level, refering to agroecological zone system and land use recommendation in Central Kalimantan the lands with their slope classes can be allocated for annual crop including food crops. While for slope class 9-15%, the lands are suitable for perrenial crop and estate crop [6], [7], [4].

The aspects of erosion control, however, should be taken into account during agricultural practice. Opening the lands allow erosion occur since the absence of protective surface residue cover, especially during the start of the rainy season, before canopy development [1]. Erosion become more intensive on sloping land and when the runoff occur, the risk of erosion become potential [27], [11]. Appropriate land management and erosion control should be then determined specific to location. The setting of planting periods can refer to season in order to anticipate splash erosion during heavy rainfall. In addition, drainage network can also be developed to overcome runoff during prolounge rainfall season. On the floodplains mostly located surrounding river streams with slope class <2%, food crop of wet paddy rice can be cultivated during wet season and harvested in dry season.

On steeper slopes, perennial tree crops with cover crops beneath have the potential to reduce erosion [30]. The estate crops can then be planted together with annual crop through alley cropping system, the planting of estate crops in two or more sets of single or multiple rows with food crops cultivated in the alleys between the rows of estate crops [38]. Several crops specific to location and prime commodities that can be introduced involve rubber, oil palm, and coffee (perennial/estate crops) while for annual crops, mostly they include wet paddy rice, upland rice, maize, soybean, and cassava. In the future, several soil erosion management programs that may be introduced include contouring, terracing, strip cultivation, and subsurface drainage [16].

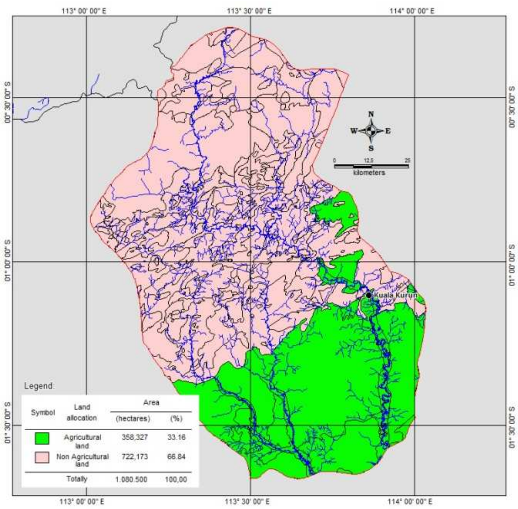

Fig. 4. The map of agricultural land allocation in Gunung Mas regency

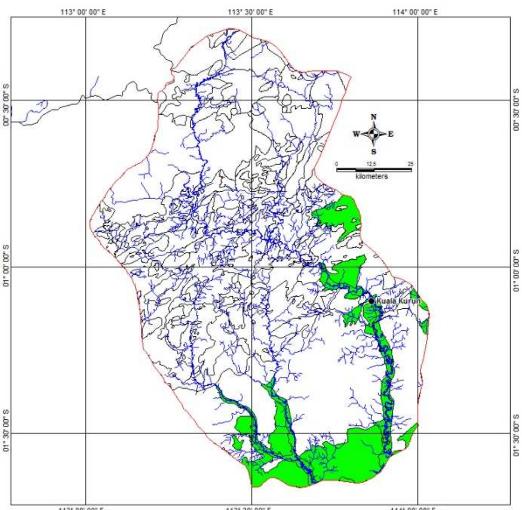

Fig. 5. Spatial distribution of slope class <8% and 2-8%

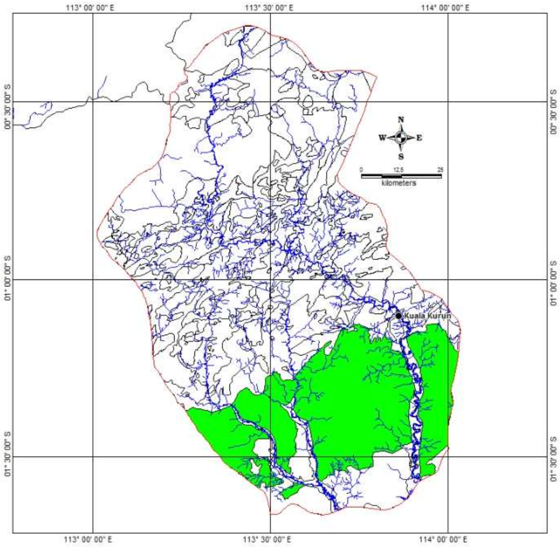

Fig. 6. Spatial distribution of slope class 9-15%

IV. CONCLUSIONS

- Gunung Mas regency consist primarily of 5 (five) class of soil erosion risk. based on prediction value of USLE, more than a half of this region is classified into class V with assumption soil loss > 480 ton/hectares/year. Spatially, distribution pattern of this class is broad areas occur at middle part spreading to the northen part with total areas 566,837 hectares (52.46%). While the lowest percentage of soil erosion is fall into class III. It ocuppies only 31,992 hectares (2.96%) mostly located along the main rivers at slope class < 2% with assumed soil loss 60-180 ton/hectares/year.
- Regarding level of soil erosion risk in Gunung Mas regency, the main factor that influence agricultural practice and soil erosion prevention is slope. It should be thebn considered when drawing up plans for any agricultural practices.
- The land with slope classes <2% and 2-8% can be considered suitable for agricultural land use especially for food crops While for slope class 9-15%, the lands are suitable for perrenial crop and estate crop
- On steeper slopes, perennial tree crops with cover crops beneath have the potential to reduce erosion. The estate crops can then be planted together with annual crop through alley cropping system, the planting of estate crops in two or more sets of single or multiple rows with food crops cultivated in the alleys between the rows of estate crops.

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