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SPATIAL PLANNING FOR SUSTAINABLE RICE FARMING DEVELOPMENT AT WATERSHED AREAS TO SUPPORT FOOD SECURITY USING LANDFORM APPROACH (A CASE STUDY OF GUNUNG MAS REGENCY, CENTRAL KALIMANTAN)

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ABSTRACT

The policy of food security has been formulated and established by Indonesian government in order to increase food production one of several programs proposed include land expansion for rice farming through extensification agricultural system. Gunung Mas regency with total areas of 1,084,012 hectares, geographiclly, located at upland areas with elevation range 100 to 500 meters above sea level and it consists primarily of hillocky plain and mountainous including specific river stream system covered this region. The need of land use planning and policy was then urgently required since the region has opportunity to be developed especially for agriculture. The objective of this study was to determine appropriate landuse based on the potential of water resource through delineation areas for rice farming according to it suitability within watershed areas. In the view of the scarcity of data, basic information that was used include landform data devired from DEM. The technology of GIS and remote sensing was spatially used to generate slope classes, river system, and resulting data from land evaluation process. The result of spatial analysis showed that land utilization for rice farming development was allocated in the southern part within watershed areas of Kahayan, Rungan, and Manuhing river with total area of 200.254 Ha or 86.83% of total developed areas for rice farming. While in the north, land allocation with total area of 30.373 Ha (13.17%) where located at watershed of Kayahan river was established for the future use. The water management within

watershed areas can then be formulated based on the availability of water resource to to meet water supply through irrigation system.

Key words: landuse, landform, water resource, planning, Gunung Mas regency

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1. INTRODUCTION

The policy of food security has been formulated and established by Indonesian government in order to increase food production. In Indonesia, it has outpaced population growth over the last ten years. Most of the food crops consumed in Indonesia are produced by smallholder farmers. Most rice production is still focused in Java, in which being the largest producer (https://www.plantagbiosciences.org/people/rob-o-hagan/2017/08/29/the-state-of-food-security-in-indonesia-and-west-java/). In order to support rice production stability, all of regions outside Java island is required to develop agricultural sector especially for rice. It can then be implemented through land expansion for agriculture because of their wide areas potential.

The need of land use planning is then urgently required since the region has opportunity to be developed especially for agriculture. The availability of the lands can be considered as main factor that should be taken into account without ignoring the other biophisical aspects. In the case of Gunung Mas regency, the region with total areas of 1,084,012 hectares consist primarily of hillocky plain and mountainous. In addition, in this uplands areas, there is main river, called Kahayan river, streaming from the northern part to southern part and as the longest river, it passes through this region with the length of 242 kilometers. Based on pre-elementary study, the result of spatial analysis showed that there several river as branch of main river such as Rungan, Manuhing and Miri river.

The local community mainly relies on the existence of these rivers. In general, in Kalimantan, the local community do relies on the existence of these rivers not only for daily activities but also for farming (Darmadi, 2017). In Gunung Mas regency, with total population of 60,559 people by the end of 2019, according to the main employment, the number of workers working in the agriculture, forestry and fisheries sectors was still dominant at 18,423 people (30.44%) (BPS-Statistics of Gunung Mas Regency, 2020).

Mostly, many human settlement are located along the rivers and daily activities of farming is also conducted at surrounding areas which also include within watershed areas. Watershed is not simply the hydrological unit but also socio-economic-ecological entity which plays crucial role in determining agriculture (Wani and Kaushal, 2009). In this case, the appropriate management of watershed areas is then required in order to open the lands for agriculture on sustained basis. Furthermore, strategic spatial planning can then be formulated through proper land use in order to develop the areas while at the same time conserving the environment overall (Oliveira *et al*., 2018). The objective of this study was to develop the concept of land use planning at watershed areas in order to allocate the agricultural lands for rice using landform approach. This study was conducted based on data available in the view of data scarcity at reconnaissance scale in Gunung Mas regency.

2. METHODOLOGY

The general methodology used spatial analysis approach and visual interpretation (Yaolin *et al*., 2008). The geographic information system (GIS) and remote sensing was employed to assist analysis process, in addition to generate data (AbdelRahman et al., 2016). Basic data and information mainly used in this study include landform data taken from digital elevation model (DEM) data derived from Suttle Radar Topography Mission (SRTM) 30 meters. Other relevant data required for this study also include landsat imagery, soil map and land system at reconnaissance with scale of 1:250.000. This level refers to guidelines provided by Indonesian Government Regulation No. 100/2000 about mapping scales for regional spatial land use planning and with this scale, land resource information is hierarchically can be implemented to allocate rational landuse for planning process (Baja, 2012; FAO, 1985; Aubert, 1981; Webster, 1981).

The procedure of land evaluation was also used in order to identify land suitability classification and land allocation for rice farming that has the opportunity to be developed (Panhalkar, 2011; BBSDLP, 2011; Sys et al., 1993). The general flowchart of methodology was provided at Figure 1. While for location of study, it was focused on Gunung Mas regency, Central Kalimantan province with total areas of 1,084,012 hectares. Geographically, it is situated between latitudes 00^{o} 17' 7.51" S and 01^{o} 39' 46.64" S and longitudes 113^{o} 00' 46.55" E and 114^{o} 01' 59.98" E (Figure 2).

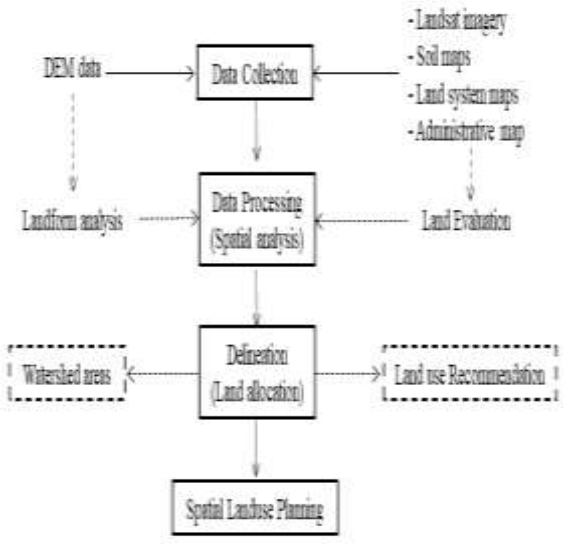

Figure 1. General flowchart of methodology

Figure 2. The situation map of Gunung Mas

Furthermore, this region is charaterized by a rather constant temperature throughout the year, high humidity and high precipitation. Based on Oldeman agro-climate classification, Gunung Mas regency is classified into zone A and B1 (Oldeman et al., 1980). 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 in average, the rainfall in Gunung Mas Regency during 2019 was 257 millimeter. The highest was on December (505 millimeter), while the lowest one was recorded on July (20 millimeter). The highest number of rainy days was on December (17 rainy days) and the lowest one was on July (2 rainy days).

Based on this climate condition, it can be assumed that water availability is quite sufficient for farming activities especially for rice farming. However, it should be supported by utilizing the existence of hidrology of rivers as potential of water resource. The water resource ecosystem can provide basic products for maintaining production activities, in addition functions of natural ecosystem structure, ecological processes, and regional ecological environment, which can support agricultural development (Zhang *et al*., 2018).

The region of Gunung Mas is mainly located at upland areas with elevation range 100 to 500 meters above sea level. Most of the upland areas are highly weathered, acidic, infertile and poorly buffered soils (Adiningsih et al., 1988). 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 (USDA, 2010). In general, with appropriate land management, the suitable lands for agriculture, however, can be cultivated for crop cultivation with ranges from low to high for rice and moderate for dry land food crops (Sawiyo et al., 2000).

3. REGIONAL ZONING OF WATER RESOURCE

The management of water resources in watershed areas can be invited through zonation with considering digital information (Yi-Cheng *et al*., 2012). In order to identify potential of water resources in study areas, land surface interpretation was conducted based on digital elevation model (DEM) and land satellite imagery. The application of GIS and remote sensing was employed in this study in order to generate spatial data of river flow paths as hidrology system and to delineate watershed areas that can be allocated for farming as well. The result of data interpretation showed that the study area was covered with specific river stream pattern, as shown at Figure 3.

There are several main river found in this study areas. The Kahayan river was considered as the biggest river flow from the northern part to the south. It has many tributary rivers along the flow path as potential water resource that can be utilized for irrigation at large scale farming (https://www.eolss.net/Sample-Chapters/C07/E2-24D-03-01.pdf). In order to determine the zonation of watershed areas, the pattern of river stream was then further analized using buffering technique within GIS environment. As a result, the buffering zone based on provide the regions that represent watershed areas around the rivers and their tributary. In addition to water resource, this regional zoning of watershed areas can support farming activities through conserving rainfall and water supply especially during the dry season (Sivanappan and Panchanathan, 1985). On the other side, during rainy season, extensive constructed systems provide rapid drainage of precipitation from watersheds, so that soils can warm and dry rapidly in the spring, allowing specific crops to grow. (https://editions.lib.umn.edu/openrivers/article/agriculture-and-the-river-the-universitys-role-in-societal-learning-innovation-and-action). The result of spatial analysis showed that there are several main watershed with sub-watershed areas in location of study as shown at Figure 4.

Further spatial analysis showed that the pattern of watershed areas based main river of Kahayan occupy the region from northern part ke southern part with total area of 317,113 Ha. While in the south there are two sub-watershed areas referring to Rungan and Manuhing river with total area of 147,804 Ha. Therefore, these areas were used as basis for determining farmland areas as integral part of watershed management in the term of land use planning for rice development in Gunung Mas regency.

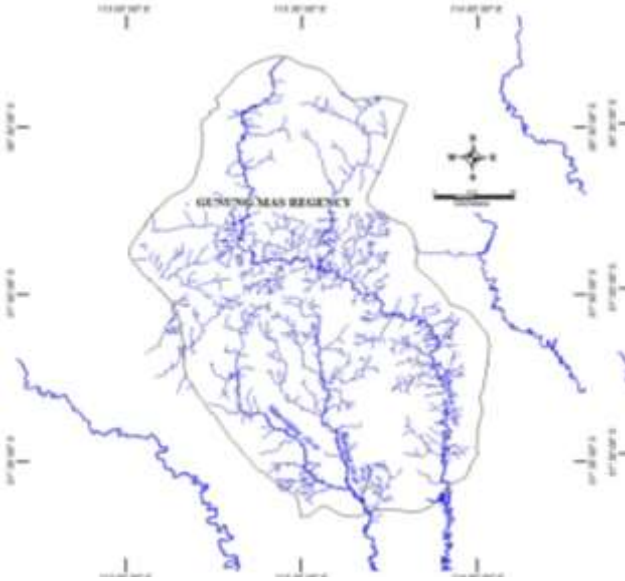

Figure 3. The pattern of river system in Gunung Mas regency

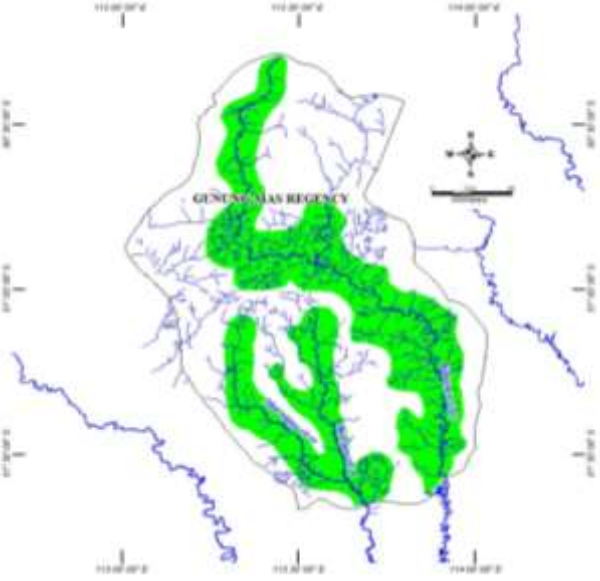

Figure 4. The pattern of watershed areas in Gunung Mas regency

4. LAND ALLOCATION FOR AGRICULTURAL DEVELOPMENT

Further delineation areas for watershed that represent the availability of potential water resource should be then follow up by determining agricultural land regions. Based on soil resource information, 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 (Adiningsih et al., 1988). In general, acid humid tropical soils found in this regency dominated by low activity clays which compact especially in the sub-surface and are susceptible to erosion especially on sloping lands (Leiwakabessy, 1989; Notohadiprawiro, 1989). In addition, based on landform data, land surface of this study areas is vary from flat to hilly dan mountainous. In order to obtained detailed information about general landform condition, terrain condition was represented at Figure 5 and derived terrain data in the form of contour digital map was represented at Figure 6.

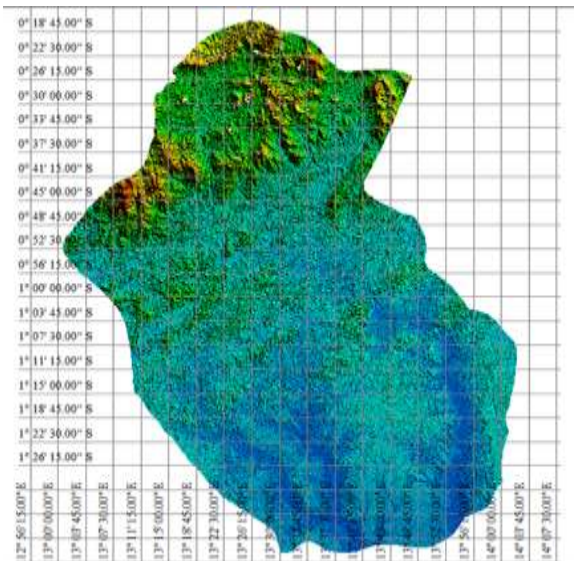

Figure 5. Landform condition based on the DEM data in Gunung Mas regency

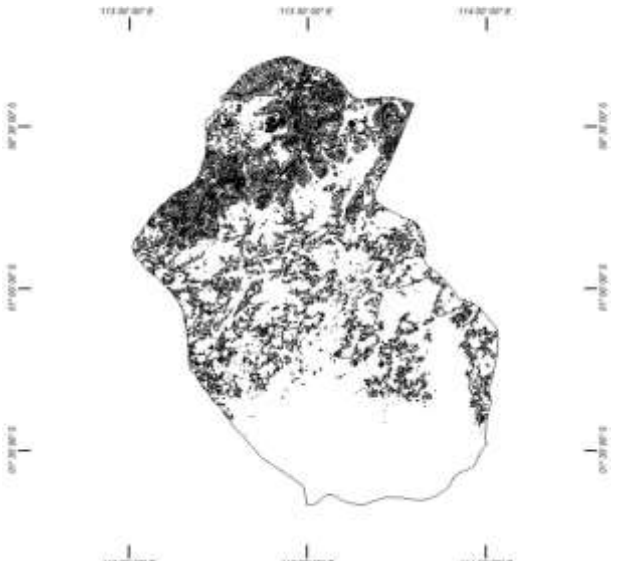

Figure 6. Digital countour map with interval of 100 meter in Gunung Mas regency

The result of visual interpretation to the digital elevation model (DEM) represented at Figure 5 and Figure 6 showed significantly that in the southern part, the regions are mainly dominated by flat areas. While in the north, the regions are mainly dominated by sloping lands with landform hilly to mountainous. This regions was then directed to forest because many studies have concluded that potential for loss of natural environment through landslides is increasing in many hilly and mountainous areas (Forbes and Brodhead, 2013).

Landform with topographic complexity of hilly terrains is limiting factor especially for sloping lands (Kandari *et* al., 2014; Wezel *et al*., 2002). In addition, the aspect of conservation should be then taken into account in agricultural land use planning. Problems of erosion, sedimentation, drought, and floods continue to occur as a result of damaged watersheds (Pambudi, 2019). The DEM data can then be used as basic reference to determine slope classes. The interpretation of landform based on DEM data generated several slope classes as shown at Figure 7.

Landform information for slope classes can then be further analysis using land evaluation approach in order to determine proper land use for rice faming. Slope is critical factor that should be considered for agricultural practices. Slope can be used to determine agricultural types and it also can be used to identify level of erosion risk especially at sloping lands sloping land with slope class >25% so that these areas are more directed to forestry (Amelia *et al*., 2016; Khan *et al*., 2007).

According to crop requirement as proposed by BBSDLP (2011), based on slope parameter, the land suitability class for rice is slope class 2-15%. The result of spatial analysis showed that totally, there are 7 slope classes in Gunung Mas regency as provided at Table 1. However, for optimum growth, the other land parameter such as water availability, soil fertility and the others should be taken into account. Because this study only focus on landform, the slope parameter was then used as basic of land allocation for farming. Using the overlay technique within GIS environment, the map of spatial distribution of slope was then integrated into the map of watershed areas in order to generate agricultural land regions for rice farming.

Table 1 Slope classification in Gunung Mas regency

Slope class (%)	Critera	Area (Hectares)	% of total area of Gunung Mas regency
<2	Flat	31,481	2.90
2-8	Very gentle	151,421	13.97
9-15	Gentle	231,917	21.39
16-25	Moderately steep	194,327	17.93
26-40	Steep	40,321	3.72
41-60	Very steep	281,712	25.99
>60	Extremely steep	152,833	14.10
Total areas		1,084,012	100,00

5. SPATIAL LANDUSE PLANNING FOR RICE FAMING

Based on visual interpretation, referring to slope class distribution (Figure 7), there are 3 slope classes mainly found in the southern part of study location i.e. class 9-15% (*gentle*); 2-8% (*very gentle*); and <2% (*flat*). Spatially, the formation of these slope classes is an integrated region and some spatial part of slope class of 2-8% are scattered in the central with total area of 414,819 Ha (38.27%). While the other classes with slope class > 15% were distributed in the northern part and allocated for forest.

In accordance with land suitability evaluation, the three slope classes in the south are suitable for rice farming. Further spatial analysis was then conducted to delineate proper land use for rice farming within watershed zone. The result of overlay technique represented the areas that suitable form farming along the river within watershed areas in Gunung Mas regency with total area of 230,627 Ha (21.28%) (Figure 8). The allocation of agricultural land regions in watershed areas was designed in order to accommodate the need of water supply in the landscape for farmlands (Barron and Stacey, 2008). For agricultural development, these watershed areas can provide potential utilizable water resource especially irrigation for paddy field farming (WWF, 2003).

6. LANDUSE POLICY FOR RICE FARMING DEVELOPMENT

The need of landuse planning and landuse policy established in some jurisdictions legislation is required in order to protect sustainable agriculture including agricultural reserves (Bousbaine et al., 2017). The policies of landuse should involve recommendation within agricultural domain that apply specifically several sector such as proper land allocation within watershed environment and water resource management through water supply enhancement (FAO, 2017).

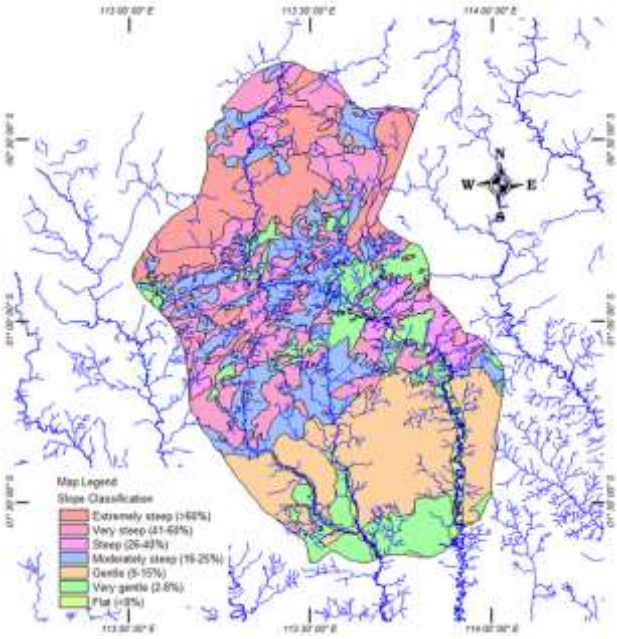

Figure 7. The spatial distribution of slope classes in Gunung Mas regency

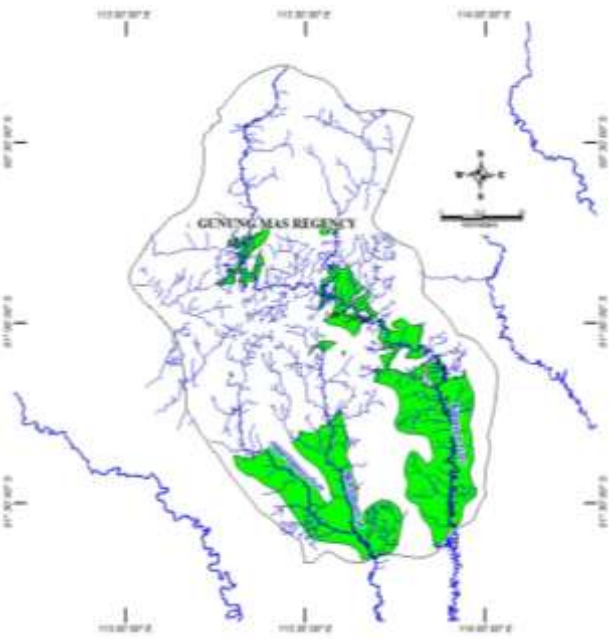

Figure 8. Landuse allocation for rice farming development in Gunung Mas regency

Especially for landuse policy, spatial design for rice farming development in Gunung Mas regency can be allocated within watershed areas in accordance with its land suitability. Rice farming areas development can be allocated in southern part along the river of Kahayan, Manuhing and Rungan. Specific program of intensification can be implemented at the areas where rice farming has been existed. The result of landsat imagery indicated that total areas of existing rice farming is only 1 557,68 Ha or 0.38% of total landuse recommendation for rice within watershed areas. Based on field survey, these areas were mainly found near settlement areas located along the rivers.

Therefore, appropriate spatial landuse allocation policy for rice farming can be formulated according to biophysics aspects and socio-economic aspects as well. Based on data available

and other relevant data, land allocation for rice farming development can be established in watershed areas in the southern part of Gunung Mas regency with total areas of 200.254 Ha or 86.83% of total developed areas for rice farming. While for the other areas was directed in the northern part to accommodate the need of farming lands in the future. This allocation with total area of 30.373 Ha (13.17%) and located at watershed of Kayahan river was established considering the availability of human resource and infrastructure such as transportation, human settlement and related institution support (Figure 9). Specific program that can be implemented include intensification at new arable land for rice and intensification farming at existing rice farming. The introduced water management technology specific to location can also be arranged according to the availability potential water resource within site location.

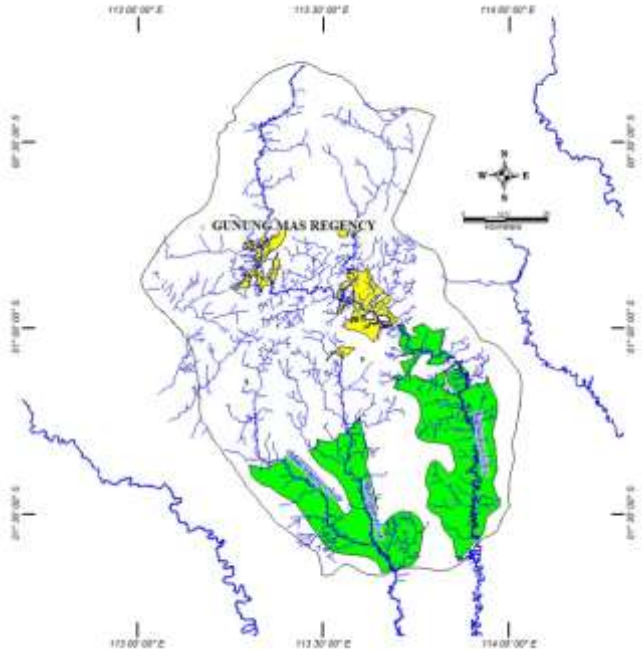

Figure 9. Landuse recommendation for rice farming development in Gunung Mas regency

In the view of scarcity of land resource data, developing sloping lands for rice farming can be carried out through landform approach. The result of spatial analysis with the aid of GIS technology showed that based on slope classes and land suitability evaluation, appropriate landuse recommendation and policy can be allocated spatially, for rice farming development with considering the existence of watershed as potential water resource.

In the case of Gunung Mas regency, land utilization for rice farming development was allocated in the southern part of this region at watershed areas of Kahayan, Rungan, and Manuhing river with total area of 200.254 Ha or 86.83% of total developed areas for rice farming. While in the north, land allocation with total area of 30.373 Ha (13.17%) was established for the future use. The water management within watershed areas can then be formulated based on the availability of water resource to meet water supply through irrigation system.

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