Agroecological management at sloping land areas using land resources evaluation approach to achieve sustainable agricultural development (a case study of Gunung Mas Regency, Central Kalimantan Province, Indonesia)

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Abstract. The appropriate concept of land use planning is required since the lands have the opportunity to be developed for agricultural purposes. Gunung Mas regency with total areas of 1,084,012 hectares is mainly covered by forest with various slope classes. The objective of study was to allocate the lands to be utilized based on its capabilities and suitability for food and plantation crops. Land evaluation approach was implemented to provide appropriate land use planning especially for food crop farming and plantation. Hierarchically, procedure of land capability evaluation (LCE) was used to classify lands based on their capability to produce common cultivated crops without deteriorating over a long period of time. Therefore, the proper land use for cultivation was further analysis using land suitability evaluation (LSE) procedure to determine fitness of a given type of land for a specific crop. The application of GIS and remote sensing technology were then used to generate additional spatial data as basic planning analysis. The results showed that agricultural system was located and implemented appropriately at arable lands. The use of LCE and LSE procedure can then be implemented to promote proper land use on sustained basis as important part of agroecological management.

1. Introduction

Agroecology approach is considered as environmentally sound management for sustainable development because with its core principle, it can protect natural resources with appropriate sustainable management [1,2]. The concept of management and sustainability for natural resources refers to ecological concepts and methodological design so that they can then be implemented for long-term enhancement and management of land resource and agricultural productivity [2-4].

The availability of land resource information is therefore required in order to design land use pattern as part of land use planning for agricultural purposes [5]. Gunung Mas regency with total area of 1,084,012 hectares based on pre elimination study for land use, by the of 2018, it mainly consists of forest and shrubs with coverage areas of 1,062,484 hectares or 98.01 % of total areas of regency. This condition indicates that the availability of land resource information is still lack. Mostly, in the tropic, the lands have not been utilized intensively. However, the lands have opportunity to be opened and developed for agriculture in order to facilitate land expansion especially for food crop farming in achieving food security, including plantation for increasing foreign exchange as well. The basic information that can be
obtained not only from deskwork study but also from literature study consisting of land system information, digital elevation model (DEM) and landsat imagery as well as. The aims of this study was to allocate landuse properly based on land resource at reconnaissance level as part of landuse planning. The procedure of land evaluation used in this study involve land capability evaluation (LCE) and land suitability evaluation (LSE). These procedures was used to identify proper land use for agriculture in accordance with their capability and suitability.

2. Materials and methods
Basic data and information as datasets consist primarily of spatial data and tabular data obtained from literature study and deskwork study involving soil maps, climatic maps, land characteristics and land use requirements. Additional data was also completed through spatial analysis based on digital elevation model (DEM), landsat imagery, and field verification.

The methodology of land evaluation involving LCE and LSE [6-9]. There are two selected crops represent agricultural system for food and estate crops. Selected food crops in this study include rice, while for estate crop (plantation) is rubber. The principle of minimum rule for limiting factors within land evaluation was used in this procedure in order to determine the lowest individual rating as limiting to the overall suitability [7,8,10].

The technology remote sensing and geographic information system was employed to generate spatial data as part of geospatial information and also for spatial analysis based on basic data such as DEM and the result of land evaluation as well [11-15]. An overview of general methodological steps is described at Figure 1. The location of study was focussed on Gunung Mas regency, Central Kalimantan province with total areas of 1,084,012 hectares (Figure 2).

![Figure 1. Overview of general methodological steps of study](image)

3. Results and discussion

3.1. General overview of environmental biophysic aspect
Geographically, Gunung Mas regency that located in northern part of Central Kalimantan and located below the equatorial line is classified into humid tropical region, with humid climate system and rainfall throughout the years [6,16]. Climate condition in this region is recognized through constant temperature with relatively high humidity and rainfall. The agro-climate classification of Oldeman has classified this region as zone A and B1 [17-21]. Climatic zone A in the central to northern part has consecutive wet months >9 months. While for climatic zone B1, in the southern parts, has consecutive wet months 7-9 months. These climatic zone also have number of consecutive dry months less than 2 months per year. On average, number annual rainfall between 2,864 and 3,577 mm.

The land cover found in this areas consist natural vegetation including secondary and tertiary forest and shrubs as well as. The result of interpretation of satellite imagery accessed from Landsat 8 showed that in the northern part, in the end of 2018, the areas is still covered by forest. While in the center to
southern parts, they covered by both forest and shrubs. Total areas of both of them is 1,009,732 hectares or 0.93 % of total areas of Gunung Mas regency (Figure 3). This condition indicates that the lands have not been intensively utilized. Therefore, the agroecological principles should be considered in planning especially for land allocation with appropriate land management [17].

3.2. Land resource information

Basic data that has been available include land system maps and soil maps with scale of 1:250,000. Hierarchically, at this scale, information of land resource can be implemented to allocate rational landuse in landuse planning [18-22]. This information can then be used to provide land characteristic for land resource evaluation including LCE and LSE.

Additional data is also obtained through interpretation of digital elevation model (DEM) based on Shuttle Radar Topography Mission (SRTM) 30 meters. The other data especially for correction was obtained based field verification. The result of interpretation using remote sensing technology produced contour map with interval 100 meters. It was derived from SRTM that display DEM data. The result of spatial analysis showed that physiography of undulating and hillocky areas is mainly found in the center spread to the north. With the aids of GIS, this physiography data can then be integrated into land system in order to develop slope classification (Figure 4).

In general, the classification of slope naturally control agriculture pattern in developing regions [9]. In relation to agroecology, slope class can be considered as factor that can determine the pattern of cultivation system [17]. The result of spatial analysis showed that in this study areas, there are 7 slope classes. Four slope classes categorized into extremely steep (>60); very steep (41-60%); steep (26-40%) and moderately steep (16-15%) are mainly found in the southern parts spread to central parts. While the others such as gentle (9-15%); very gentle (2-8%) and flat (<8%) occupy in the southern parts. In this study, slope classes parameter can then be used in land evaluation to determine land capability classification as basic consideration to allocate rational land use for agriculture (arable lands) and non agriculture.
3.3. Agricultural land regions

On sustained basis, land allocation of arable lands is important part in achieving sustainable agricultural system [5,10,23]. The procedure of LCE was then used in this study in order to allocate arable lands and non-arable lands. Based on land resources information and land capability classification method proposed by USDA, Gunung Mas regency was primarily divided become 6 land capability classes i.e., class II, III, IV, VI, VII and VIII. In addition to assist ascertaining agricultural development potential, this capability classification can be used as basic for zonation of arable lands and non-arable land. Class I as the best class for arable land and class V were not found because of no land parameter suitable with criteria of the lands. Several limiting factors found as a result of land capability evaluation include slope, drainage, and texture. The result of land capability classification is shown at Table 1.

| Land capability class | Limiting factors | Total areas (Hectares) | % of total area of Central Kalimantan province |
|-----------------------|------------------|------------------------|---------------------------------------------|
| II                    | Slope (>3-8%)    | 113,301                | 10.45                                       |
| III                   | Slope (>3-8%); drainage (poor) | 231,927 | 21.40 |
| IV                    | Slope (>15-30%)  | 192,311                | 17.74                                       |
| VI                    | Slope (>30-45%); texture class (coarse) | 116,952 | 10.79 |
| VII                   | Slope (>45-60%)  | 276,684                | 25.52                                       |
| VII                   | Slope (>60%)     | 152,837                | 14.10                                       |
| Total areas           |                  | 100,00                 |                                             |

Further land assessment was then conducted to allocate arable lands and non-arable lands. Therefore, relative degree of limitation was used for analysis. Class I-IV can be recommended for agriculture, while class V-VIII are directed to natural vegetation [10]. The regions that have land classes II, III, and IV can then be established as arable lands that have potential for agricultural development. On the other side, several areas with land classes VI, VII and VIII were recognized as non-arable land that not suitable for agriculture because of the existence of permanent limitations.

Spatially, the arable lands as agricultural developed areas have total area of 546,473 hectares or 50.41% of entire Gunung Mas regency and geographically they are found in the south spread to the central parts. The remaining non-arable land covers 537,539 hectares (49.59%). (Figure 5).

**Figure 4.** The map of contour with interval of 100 meter (left) derived from DEM data (right) and slope classification for study areas.
In the central parts, the lands suitable for cultivation still require proper land management because of the existence of minor limitations such as slope. While in the south, slope and drainage parameter should be taken into account for land management. Land evaluation approach using LCE can generate spatial information as essential data for discussion in planning. The implementation of geospatial as part GIS may ensures optimum land use and distribution of investment as well as avoids conflicts such as land ownership status [24,25]. For other implementation, LCE approach can also be formulated for land conservation and crop management practices [26].

3.4. Land allocation for agricultural system

Based on availability of land for agriculture as shown at Figure 6, land parameters for arable land were then further assessed using LSE procedure in order to define land suitability for selected crops. Each crop represent group of crops as agricultural system for food crop and estate crops. In this study, crop growth requirement for rice (food crop) and rubber (estate crop) were used to determine each land suitability. The result of land evaluation was then processed and integrated into geospatial system. The results showed that suitability class for both rice and rubber is S2 and S3 with several limiting factors i.e slope, soil acidity, and nutrient retention. Distribution of agricultural system is then spatially determined by slope classification as presented at Figure 6.

![Figure 5](image1.png)
![Figure 6](image2.png)

**Figure 5.** The map of land availability for agriculture in Gunung Mas regency

**Figure 6.** The map of distribution of agricultural system for food and estate crops

The result of spatial analysis showed that zonation of food crops are mainly found along the rivers with total areas of 113,841 hectares or 20.83% of total areas of arable lands. These areas can then be recommended for paddy field. While the areas that are located far from river stream relatively, the lands can be cultivated with up land food crop and secondary crops. Meanwhile, for estate crops, they occupy 79.17% of total arable lands or 432,632 hectares. The specific program including land management can then be formulated to develop the areas on sustained basis.

4. Conclusions

The procedure of land evaluation using principle of capability (LCE) and suitability (LSE) by integrating remote sensing and GIS can be implemented in order to develop agricultural land regions on sustained basis as important part of agroecological management. In the case study of Gunung Mas regency, slope classification can be used as basic consideration for determining agricultural system zonation. Spatially,
food crops areas are mainly located along the rivers with total areas of 113,841 hectares or 20.83% of total areas of arable lands. Meanwhile, for estate crops, they occupy 79.17% of total arable lands or 432,632 hectares.

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