Spatial landuse planning for developing sustainable food crop areas using land evaluation approach and GIS application (a case study of Pulang Pisau Regency, Central Kalimantan)

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Abstract. The need of landuse planning become apparent since the lands have the opportunity to be developed. Appropriate landuse planning based on spatial land resource data management is then required, in order to achieve sustainable landuse. The objective of this study was to design and allocate appropriate agricultural land regions for land use policy through extensification and intensification programs in order to support sustainable food crops development areas. The procedure of land resource evaluation consisting of land capability evaluation (LCE) and land suitability evaluation (LSE) was applied to determine land allocation of arable lands for rice farming development. The use of geographic information system (GIS) technology was also employed not only for spatial data management but it can also be applied to support decision making within establishing landuse planning. In the case of Pulang Pisau District, land allocation for extensification and intensification regions are mainly found in southern part and mostly located at watershed areas with each total area of 380,261 ha (36.81%) and 29,941 ha (2.90%), respectively. In order to support these potential areas, specific programs can then be formulated to increase the yield and productivity for these regions.

1. Introduction

The Indonesian government has set a target of food self-sufficiency and this policy has been implemented by local government at regional level including Central Kalimantan Province. According to BPS-Statistics of Central Kalimantan Province (2020), at regional scale, by the end of 2019, total area of rice cultivation is 393,919 ha or only 2.55% of the total areas of Central Kalimantan Province and this indicate that land potency based on areas is still available [1].

In Central Kalimantan, one of several regency that has been established as food basket area include Pulang Pisau Regency. Comparing to the other regencies, by the end of 2019, this regions can produce 59,061 tons [1]. Some efforts that have been conducted in order to increase rice productivity include intensification and extensification program. In addition to intensification, land expansion as part of extensification program should then be taken into account because of the availability of the potential lands, while at the same time, the aspect of sustainability should be still considered. The need of landuse planning is then urgently required in order to achieve sustainable agriculture.

Proper landuse should be implemented because not all of the lands can be optimally utilized depending on their land potential and suitability [2]. Land use planning is then required in order to achieve proper land use because if the land is utilized improperly, the productivity will rapidly decreases
and the ecosystems become jeopardized [3]. As part of land use planning, land evaluation approach can be used to identify and recognize lands for specified purposes [4-6]. The need for land resources evaluation become apparent when the region has an opportunity to be developed and decisions on land use have always been part of the evolution of human society. By assessing land resources for alternative uses relative to the land-related requirements or goals of society, it should be possible to identify certain areas which are strategically important for particular activities [7].

The information as a result of land evaluation can then be integrated into geographic information system (GIS) for further (spatial) analysis and automated data management [8,9]. In order to develop appropriate land use planning, the GIS application with its capacity in data integration, analysis and visualization, it becomes the main tool to support decision making. Spatial concepts for land use planning involving land allocation for agricultural land regions can then be planned and performed accurately [7]. It can then support regional development policy and common agricultural policy [10]. The objective of this study was to design and allocate appropriate agricultural land regions for land use policy through extensification and intensification programs in order to support sustainable food crops development areas.

2. Materials and methods
The study was focused at Pulang Pisau Regency with total area of 1,033,122 ha (figure 1). This area was selected in accordance with local government policy that this region has been established as food basket area in Central Kalimantan.

![Figure 1. General situation map of study location in Pulang Pisau Regency.](image)

The methodology used in this study was land evaluation approach. In order to achieve sustainability principle, the procedure of land assessment used land capability evaluation (LCE) and land suitability evaluation (LSE). The LCE approach was used in order to determine arable land considered as developed areas and non-arable land based on land capability classification. The methods of LCE approach refer to land capability classification proposed by USDA in which class I to IV, lands can still be utilized for agricultural purposes, while for class V to VIII, the lands are unsuited to cultivation [11, 12]. Soil information provided by land mapping units involving slope classes, erosion, drainage, soil effective depth, texture, rock outcrop, and flooding were then evaluated referring to criteria for land
capability classification. The principle of limiting condition was used for LCE to define land class [13]. This classification can help ascertaining agricultural production potential of land on a sustain basis [14]. Therefore, it lead to determining land allocation for non-arable land and arable land as developed areas for agricultural development and basic consideration for land use planning as well. Land suitability evaluation (LSE) approach was also used in this study through evaluating land mapping units suitable for cultivation or developed area for agriculture as a result of LCE. The methods of LSE used procedure of matching between land quality/characteristics and crop requirement. The minimum rule was used to determine limiting factors as land suitability class based on land use requirements and crop requirements [15,16]. Rice commodity was selected as part of prime food crop and crop growth requirement for rice was used in LSE to classify its suitability [15].

The GIS technology were applied as computer-based tool for mapping and analyzing feature events on earth. In this study, remote sensing (RS) technology was also employed to survey and monitor biophysical aspects [17]. It was then used to provide land cover information especially for standing crop of rice [18]. While for the GIS, it was applied to integrate the RS’s data and the result s of land evaluation as part of mapping process for further spatial analysis. Several usefull tools used in this study include ER Mapper 7.0 and Arc Gis 10.1 software. These tools was employed to organize dan manage spatial data while at the same time, they can also used to assist spatial analysis. The results of LCE and LSE were integrated into GIS environment for further spatial analysis including visual interpretation [19]. Spatial analysis refers to geolocated data involving areal data, point data and continous data [20]. The application of GIS ensure data precision that is considerably higher than that of manual methods when organizing a land use planning project [21].

Materials required in this study include several base maps consiting of soil maps, land system maps, agroclimatic maps, topographical maps and administrative maps. This study was conducted on the basis of information at reconnaissance level with scale of 250,000. This level refers to guidelines provided by Indonesian Government Regulation No. 100/2000 about mapping scales for spatial land use planning. Primary data of land cover as RS’s data was accessed from Landsat 8. For field verification, the GPS device was used to identify land cover and to compare between the resulting maps that have been produced and real condition in the field.

3. Results and discussion

3.1. General biophysical aspect of study areas

As study areas, Pulang Pisau Regency is situated between 00°24’44” and 03°28’47” South Latitude and 113°34’17” and 114°20’32” East Longitude (figure 1). The climate of this region was determined by its geographical position on the equator. Geographically, it is considered as wet equatorial climates that occur mainly within 5° north and south of the equator. It is dominated during most of the year by deep, moist, equatorial air masses and frequent heavy convectional rainfall [22]. The wet monsoon usually starts from October to March, while dry monsoon occurs on April to September [23]. By the end of 2019, based on the last ten years record, annual precipitation of this region is 2,449 mm to 3,229 mm. Period of consecutive wet months ranged between 10 to 12 months while dry months occur between 0-2 months. The high precipitation is influenced by temperature resulting in high evaporation intensity, causing water-saturated air conditions and potentially active rain cloud. For soil temperature and moisture regime, they have fairly homogeneous conditions for each climatic regime. Since the elevation of the whole areas of these district is less than 700 m above sea level, the temperature regime is isohyperthermic, while moisture regime is udic in which the number of consecutive dry months is less than 3 months per year.

This region is mainly divided into 2 land typology i.e. wetlands and drylands. Wetlands areas is mainly found in the southern part and covered by tidal swamplands and peatlands dominantly. This region is characterized by high soil acidity and low soil fertility [24]. Drylands occupy the northern part and also have low soil fertility due to high leaching and low organic matter content [25]. The base maps of soil and land system informed that this study areas consist primarily of mineral and organic soils.
Several major soil types in study areas include Inceptisols, Entisols, Spodosols and Histosols. The organic soils is mainly found in the southern part of Pulang Pisau Regency where many rice farming activities has been existed. Based on field observation, mineral soils was mainly found in the northern parts, while in the south, they are located at watersheds areas as alluvial soils and in the other regions as sandy soils.

### 3.2. Land capability evaluation (LCE)

In the term of sustainability, the use of land is primarily determined by land capability through land allocation for arable land and non-arable land so that LCE approach is suitable for farmland [26,11,13]. The LCE approach in this study was initial step toward in landuse planning through spatial information that can be used as basic consideration for land use planning. The spatial orientation of planning as part GIS may ensures optimum land use and optimum distribution of investment as well as avoids (land use) conflicts [27,28]. In addition, the LCE approach can also be implemented in soil conservation and crop management practices [29].

The methods of LCE refer to land capability classification proposed by USDA in which class I to IV, lands can still be utilized for agricultural purposes, while for class V to VIII, the lands are unsuited to cultivation [11]. Based on land resources information assessed using LCE procedure, the region of Pulang Pisau Regency was primarily classified into 3 land capability classes i.e., class II (410,202 ha), class VI (300,727 ha), and class VIII (322,193 ha). For class I, the excellent class for arable use was not found because of no land parameter suitable with land criteria. This condition was also found for class III, IV, V, and class VII. Some criteria, not suitable with general condition of land resources in study areas involve slope (2-8%), peat depth (>1.5 m), and sandy soils. For each land class, it was described in table 1. While for spatial distribution of capability classification, it was represented at figure 2.

#### Table 1. Land capability classification in Pulang Pisau Regency (study areas).

| Land capability class | Limiting factors                      | Area (ha) | % of total area of region |
|-----------------------|---------------------------------------|-----------|--------------------------|
| II                    | Slope (>3-8%)                          | 410,202   | 39.70                    |
| VI                    | Peat depth (>1.5 meters); Texture class: sandy soils (coarse) | 300,727   | 29.11                    |
| VIII                  |                                        | 322,193   | 31.19                    |
|                       | Total areas                            | 1,033,122 | 100.00                   |

### 3.3. Land allocation for agricultural land regions

Further evaluation through spatial analysis was then conducted in order to define land allocation for arable land and non-arable land. Based on relative degree of limitation, the classes fall into two groups. Classes’ I-IV can be used for cultivation, whilst classes V-VIII are not suitable [13,14]. In this case study for Pulang Pisau Regency, the region with land classes II was defined as arable land considered as developed area available for agriculture, while for region with land classes VI and VIII falls into non-arable land and not recommended for agriculture because of very severe permanent limitations. The spatial distribution pattern of agricultural land regions in the study area was mainly found in the southern part of Pulang Pisau Regency. Geographically, they occupy along the river dominated by wetlands consisting of peatlands and swamplands. While in the north, in relative small area, they were only found in the river sides dominated with alluvial soils that are still influenced by tidal phenomenon. In relation to sustainable agricultural development, appropriate land management should then be implemented in a range of farming systems and scales of production units, as a contribution to food security and environmental protection, facilitated by supportive government policies and programs [30]. Spatially, land allocation for agricultural land regions with total area of 410,202 ha (39.70%) was presented at figure 3.
3.4. Land suitability for rice farming

Land suitability evaluation (LSE) is essential not only planning a sustainable agricultural system, but also for increasing production [31]. The LSE approach was addressed to agricultural developed areas based on the result of LCE. The combination of LSE and LCE approach for assessing land resource is expected to ensure the resources can be used for future generation because the land is utilized on sustainable development that is appropriate to the environment.

The result of land evaluation using matching procedure between crop requirement and land characteristics lead to the conclusion that arable lands for rice farming have land suitability class S3 (marginally suitable) at reconnaissance level with scale of 250,000. Several limiting factors that have been identified based on land assessment including slope, nutrient retention, oxygen availability, soil acidity, and peat depth. These indicate that the lands should be managed appropriately in order to produce optimum yields.

Therefore, the result of land evaluation was integrated into GIS environment in order to provide spatial pattern of arable land that represent land suitability for rice. It can then be used as basic consideration of land use recommendation for rice development. Based on spatial analysis, it showed that rice farming development was located at arable lands that have been established as agricultural land regions based on LCE previously. For future use and sustainability, the LCE can be implemented as
initial stage for planning referring to agroecology and land suitability. It is addressed to specific kind of use and primary production with sustained productivity subject to environmental constraints [32].

The result of spatial analysis showed that total area of land suitable for rice farming development is 410,202 ha or 39.71 % of total areas of Pulang Pisau District (figure 4). Geographically, these areas are located along the river streams and mostly found in the southern parts dominated by wetlands with total areas 385,075 ha. While the remaining other suitable lands for rice development was located in the north with total areas 25,127 ha.

3.5. Present landuse of rice farming
The other required information includes existing landuse for rice farming. It can then be used as part basic consideration to determine land allocation for intensification areas. The information of present land use was conducted through identification of standing crop. The application of RS was then used based on its capability to determine the global and physical processes affecting the earth [33]. The RS’ technology was employed to interpret land cover information based on satellite imagery accessed from Landsat 8. The data of standing crop for rice based on coverage areas was spatially integrated into GIS environment in order to provide further information about present landuse for rice specifically (figure 5).

The result of spatial analysis indicate that standing crop of rice was mainly found in the south, in wetlands. They occupied watershed areas where they have been cultivated at alluvial and peatland areas with total areas of 29,941 ha or 2.90% of total areas of Pulang Pisau Regency. Especially for peatlands, these areas can be considered as the subject to land use pressures including agriculture [34]. For management, they can be allocated for intensification areas because of the existence of rice farming that has been carried out since along time ago not only by local people but also managed by immigrants. This information can then be used as part of basic consideration to design landuse planning proportionally.

3.6. Landuse policy and planning for rice farming development
Ecological aspects and sustainable land management including balancing ecological, economic, and social issues should be taken into account in strategic spatial planning [35]. This study still focuced on environmental and biophysical aspects. However, further study about socio-economic aspects should be then completed. The previous spatial that have been generated are biophysical aspects were then further analyzed using overlay technique within GIS environment. This technique is capable to create composite maps by combining diverse data sets [36]. For mapping process, this technique play a central role in many GIS applications because of its simplicity for the implementation in vector and raster GIS [37]. In this study, for analytical operation, it required data layers to be joined physically including the map of present landuse for rice, arable land for rice and administration. The resulting map produced provides new map with new delineated homogeneous polygons that represent delineation of the areas for extensification and intensification.

As a results, based on spatial analysis, the agricultural land regions for rice farming can then be divided into 2 regions i.e. extensification and intensification. Extensification regions are arable lands where suitable for rice but they have not been cultivated and considered as potential lands for future development with total areas of 380,261 ha or 36.81% of total areas of Pulang Pisau Regency. While for intensification regions, they located at arable where the lands have been cultivated for rice farming with total areas of 29,941 ha or 2.90% (figure 6). Specific programs as part of landuse policy such as technologies specific to location can then be formulated in order to increase the yield and productivity for these regions.
Figure 4. Land suitability for rice development in Pulang Pisau Regency.

Figure 5. Present landuse for existing rice farming in Pulang Pisau Regency.
4. Conclusions
Procedure of land evaluation approach through using land capability evaluation (LCE) and land suitability evaluation (LSE) can be used to allocate agricultural land region on sustained basis as basic consideration for landuse planning and policy. In the case of Pulang Pisau District, land allocation for extensification and intensification regions are mainly found in southern part and mostly located at watershed areas with each total areas of 380,261 ha (36.81%) and 29,941 ha (2.90%), respectively. In order to support these potential areas, specific programs can then be formulated to increase the yield and productivity.

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