Spatial Modeling for Selection of Agricultural Potential Site

Bambang Riadi, Rizka Windiastuti, and Aninda W. Rudiastuti

Geospatial Information Agency of Indonesia (Badan Informasi Geospasial - BIG)
Email: briadi_jasinfo@yahoo.com

Abstract— The agricultural potency of Sigi Regency, Central Sulawesi, mainly consists of two types of commodities, cultivated plants, and non-food products, which are potentially developed to achieve optimal situation. Crops will support food necessity internally, i.e., local area or support inter-regional trading. Development of agriculture plays the role of material either for internal trading or export material. Potential land resources and commodity being the necessary information needed in agricultural planning. This research put forward the concept of agriculturally based on the land system and soil physical information at Sigi Regency, within 527,513 ha of area coverage. Visual interpretation from remote sensing image performed to obtain physical land data. Then, it will be integrated with land-use and land-system information for spatial analysis using Geographic Information System (GIS). Spatial data of agriculture resources potency compiled to obtain the availability of potential location at Sigi Regency including the referral became the purpose of this research. Classification of potential agriculture land reveals the potential of wetland is 45,500 ha, 21,350 ha of dry land, 93,000 ha of plantation land area, and forest area 343,400 ha.

Keywords— Agriculture, commodity, land-use zoning, marginal land, potential.

I. INTRODUCTION

1.1. Background

Spatial modeling activity is intended to determine the potential of each land unit to be analyzed. Mapping the land potential focuses on the aspect of land resource inventory. Mapping of potential land is an early stage as the input of directing the spatial planning. The availability of land maps of each potency will be continued by assessing the capabilities of each land unit [1]. Provision recommendation of Land Potential Maps for agricultural land development includes numbers of information: land coverage, land suitability of paddy farming, annual cropland suitability, also road network and infrastructure availability.

The land suitability for a particular purpose is an activity of land evaluation to illustrate its suitability [2]. Land suitability assessments for certain crops are adapted to environmental conditions and its utilization by the population as high economic value commodities. Evaluation of land suitability is primarily related to evaluation for a particular use, such as for rice field, cornfield and so on [3]. Land suitability might be assessed for present conditions, or after improvement (become potential), moreover, in particular the land suitability due to its physical nature, which consists of climate, soil, topography, hydrology, and or appropriate drainage for a specific productive farming [4].

Concerning the Sigi Regency's land-use, there are rice fields, farm, coconut plantations, cocoa plantations, coffee plantations, settlements, forests and water bodies/lakes. Dominancy of dense forest is located in the central part of the hilly area. While farming, rice fields, and settlements are located along the valleys and streams. Land characteristics used in the Land Suitability Analysis is obtained from existing maps. Numbers of land characteristic data consist of the land title, climatic conditions, landform, land-use, slope, altitude, flood hazard and geological conditions [4]. At this point, the use of land has been chosen based on physically most appropriate and economically profitable [5]. This analysis will also be useful later, to boost the efforts on improving the farming system. Therefore, the land suitability of Sigi Regency is to find the appropriate area for crops and plantations to improve the economy.

1.2. Study Area

This research took place in Sigi Regency, Central Sulawesi, located at 119º38'-120º21' East and 0°52' - 2°03' South (Fig. 1). The extent of Sigi Regency is 5,196 km2. The geomorphology of Sigi Regency is hilly, yet it has a variety of slope region between 0-2%, 2-15% and mostly above 45%. The region elevation is between 32 to 1,350 m above MSL. The average air temperature is 27°C with an annual mean rainfall of 71 mm/month. [6].

Fig. 1: Research location map

1.3. Materials

Topographic map scale 1:25.000 in the year of 2015, Landsat-8 acquired in 2015, DSM SRTM, Development Planning Agency Sigi Regency and statistic data were all materials for carrying agricultural land suitability analysis in Sigi Regency. Image processing and GIS tools were used for image interpretation and spatial analysis. Statistics and secondary data were collected from the Central Bureau of Statistics and Development Planning Agency of Sigi Regency, while spatial data were collected from the Indonesia Geospatial Information Agency. The software used in this study were Microsoft Office, Global Mapper, ER Mapper, Ilwis and ArcGIS.

II.   METHODS

Geographic Information System was used for the analysis of the land suitability (both wetland and dry land). Generally, the implementation stage of the activity was divided into preparation stage, analysis phase and map preparation (Figure 2). During the preparation stage, primary data (topographic maps and satellite imageries) and secondary data (thematic maps and tabular data of study area) were collected. Generalization method was used to put on the research results in particular sheets. DEM (Digital Elevation Model) was produced by harnessing contour map and spot heights, then we used

ArcGIS to derivate thematic maps, elevation, and slope, from the DEM. Study literature was carried on to get references about national regulation and regional policies connected with the term of land resources and forest. The land cover map was produced by the extraction of the topographic map [7]. Overlay method was utilized to carry on the spatial analysis, therefore the maps must have the same reference system on map projection, grid system, and horizontal datum. Physical analysis of agricultural resources with geomorphological approach and landform unit was used as the basis of spatial analysis. This approach could be utilized for physical conditions analysis in term of natural resource potency evaluation (i.e., agricultural land, forests).
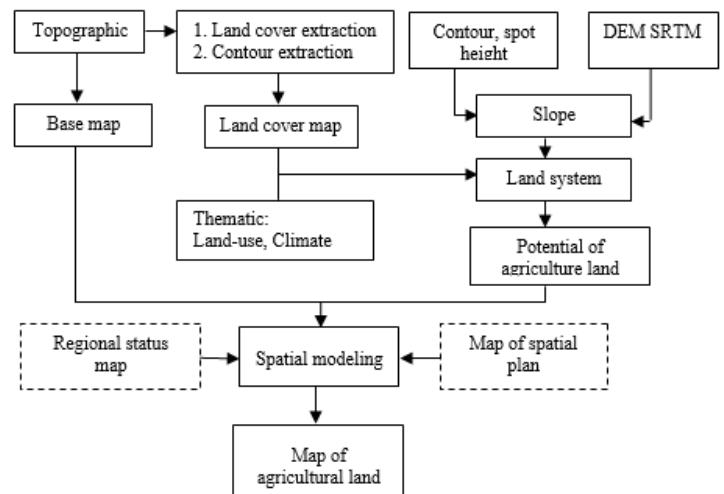

Fig. 2: Flowchart of agricultural potential site selection

The core of this research was spatial modeling, by gradually adoption of several methods with different stage conditions. The first step, spatial modeling on GIS tool was used to generate potential agricultural land data from the existing classification. The Geographical Information System tool with the overlay method was used for spatial operations [8], the scoring base was performed on the spatial analysis. Secondly, we matched potential land data with the area status to analyze and earn land availability data. At the last step, the land availability map was matched with the existing land map in order to yield the agricultural zone development [9].

Land resource elements became the main concern during process of land suitability analysis of Sigi Regency. Some elements that were used for analysis included slope, vegetation cover, landscape diversity, soil stability, and rainfall. Slope and landscape slope factors were obtained from the Digital Elevation Model (DEM), whereas vegetation cover was obtained from topographic maps and image interpretation (i.e., Landsat) [10].

Concept of sustainable development required minimum space needs and was centralized in villages to

control the growth factor. The land suitability results provided referrals for forest zoning and buffer areas, also productive agricultural areas [11]. The analytical process produced thematic maps that could be presented in the form of a printed map such as Land-cover Map, Map of Farming Areas or Land-uses map.

Agricultural land changes over time due to technology development and cultural adaptation. Technology will affect the productivity of land, while culture will determine the needs of every individual's life [12]. Agricultural potential is associated with weather and land conditions with the types of agricultural and plantation business. Agricultural development is one of the development systems that aims to cultivate agricultural enterprises in rural areas which can trigger economic activity and provide jobs to improve the community welfare. The approaches taken for this research were expected to find the most actual potency of the study area.

III. RESULTS AND DISCUSSION

Topographically, around 2/3 of Sigi Regency was hilly and mountainous, while the rest was lowland (Figure 2a). Soil and rock types found in Sigi were the combination of limestone rock and old volcanic rock causing the lowlands fertile. Land clearing or deforestation resulted in decreasing of vegetation area. Such conditions require management efforts which take account of the principles of conservation, optimization and intensification, and synergy between agriculture and plantation. Along with human needs as well as regional needs, essential commodities by local resources are served by agriculture and plantations. Community welfare can be achieved when production of various commodities is well managed, balanced and optimal. Land cover analysis showed that 75% of Sigi Regency is forest area (Fig. 3b). Table 1 shows three types of forest area based on their function and their extent. Data from Center of Statistics Bureau, 2016 for Sigi Regency stated that agricultural commodities in Sigi were defined as food and non-food commodities [6]. After this, the statistics data would then be integrated with spatial data on land use analysis results (Table 2).
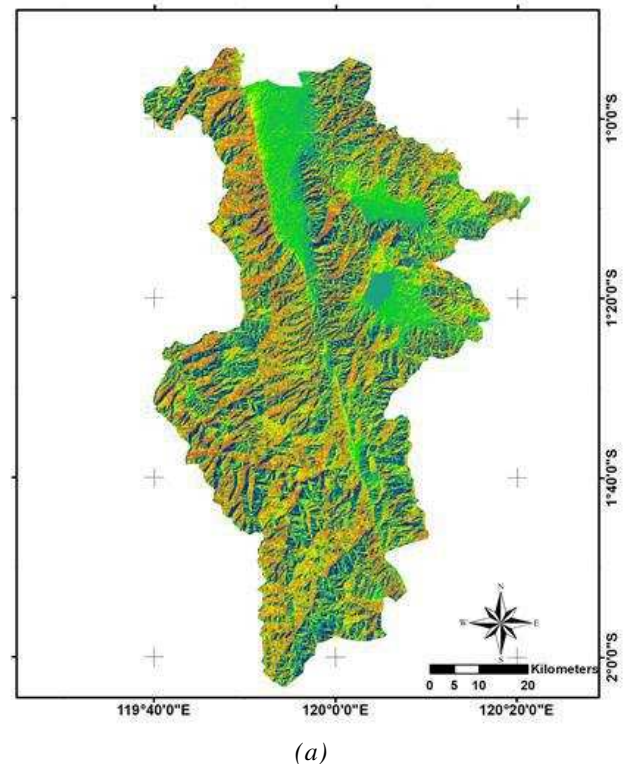
Table.1. Land cover classification

No.	Name	Area (Ha)
1.	Protected areas	249,500
2.	Plantation in forest areas	141,450
3.	Non-forest estate uses	128,650

Table.2. Land-cover at Sigi Regency

No.	Types	Area (Ha)	%
1.	Settlement	32,454	6.25
2.	Non-forest estate	43,156	8.31
3.	Paddy fields	22,242	4.28
4.	Forest	343.403	66.09
5.	River/water body	22.137	4.26
6.	Dry fields	56,210	10.81
	Total	519,602	

(a)

(b)

Fig. 3: DEM of Sigi Regency (a) and Land-use map (b)

Table 2 shows the results of land-use identification and the potential for agricultural site, and these results could be used to recommend direction of land availability (land potential). Distribution of potential land in a region is crucial information to do spatial management based on the alignment of the needs with the optimization of land use and environmental sustainability. Fig. 4 shows the potential of agricultural land in Sigi Regency.
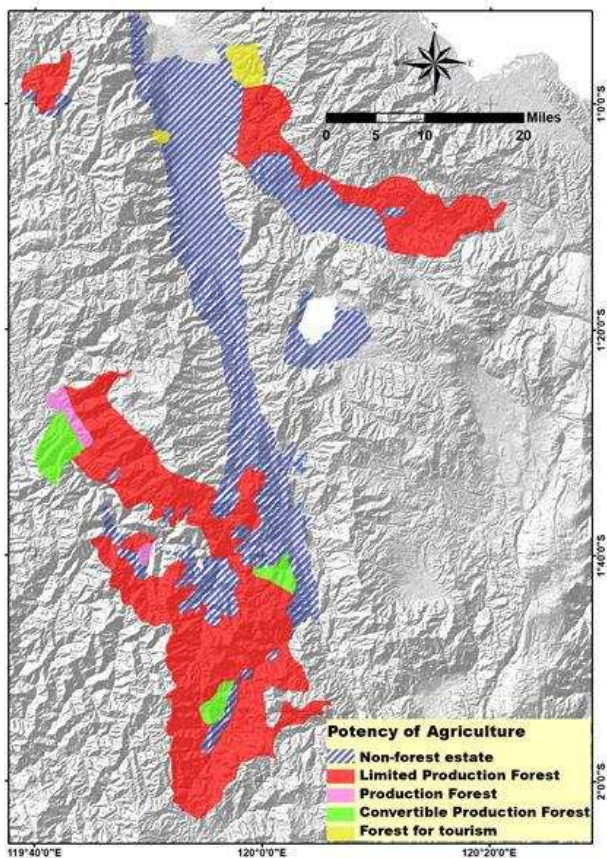

Fig. 4: Potency of agriculture

Superior commodities cultivation needs to follow topographic characteristics of the region. Since the topography of Sigi Regency is varied in slope, thus the region with a slope of 0-2% could be very potential for wetland farming and residential activities. Areas with slope of 2-15% could be potential for types of businesses, but the soil and water conservation should by wisely considered. Areas with slope range of 15 - 40% would not be feasible for plants cultivation, therefore planting in the area should be functioning as conservation. Lastly, areas with a slope of > 40% are highly threatened by erosion, so it is only suitable for being part of the protected forest.

The result as shown in Figure 5, informs the ideal potential of hilly and mountainous terrain which preserved its vegetation and could be developed as conservation-based production forests and plantation. The scale of land expansion that was feasible for the optimization of plantation potency in the forest and non-

forest estate is shown in Table 3. The expansion became an alternative for agricultural development to meet the community's need for land.
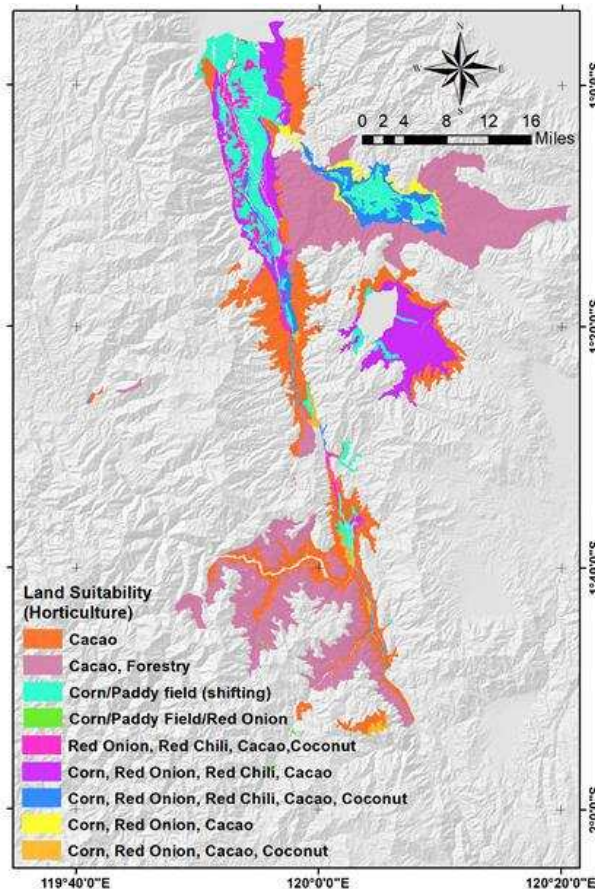

Fig. 5: Land suitability

Table.3. Potency development in non-forest estate of Sigi Regency

No.	Usage	Existing (Ha)	Expansion Plan (Ha)
1.	Plantation	37,304	55,700
2.	Paddy fields	21,805	23,700
3.	Dry fields	1,451	19,945
4.	Settlement	32,454	110,778
	Total	93,014	210,123

Sources: Spatial analysis, data from BAPPEDA Sigi 2016 [13]

In average, the suitable area for plantation crops is very cramped due to domination by forests which the utilizations are restricted by law and governmental regulation. The level of land suitability is also determined by existing thematic data. With the availability of land suitability data, annual cropland development can be directed to commodities that have high economic value. Given the climatological conditions of this region, it is likely that the development of the annual crop sector can be crystallized. Physical limiting factors for annual crop

development in Sigi Regency are in fact insignificant, but more into cost and technology factors, because the agricultural business sector generally lasts for 10-25 years. The results of the study showed that non-forest estate could be used for annual crops and the suitability of cropland can be seen in Table 4 and Table 5.

Table 4. Plantation area at the non-forest estate

No.	Annual Cropland	Area (Ha)
1.	Cashew	9,376
2.	Cacao	24,381
3.	Coconut	5,953
4.	Coffee	2,567
5.	Other plantations	879
	Total	43,156

Source: BPS 2016 [6]

Table 5. Land suitability for cropland

No.	Commodities	Area (Ha)
1.	Paddy fields	29,884
2.	Corn	12,370
3.	Other	1,391
	Total	43,645

A rapid growth of settlements and offices has occurred in Sigi Regency. In 2011, the residential area was 32,454 ha in extent, but in 2014 it bloomed into 110,778 ha [13]. The expansion of settlements also occupied wetlands area, causing paddy fields were degraded by 3,257 ha between 2009 from 2014. This condition has been appalling since Sigi Regency was one of the food support areas in Palu City and its surrounding areas. Foremost, agriculture was the leading economic activity in Sigi Regency.

IV. CONCLUSION

The existence and quality of initial data as input in mapping method became the primary factor for the quality of the information produced. The existence of physical data related to the parameters composing land suitability evaluation in Sigi Regency were lacks and mostly were outdated. The spatial modeling classification resulted in the land suitability evaluation was still in the review scale. Thus, for implementation, ideal analysis would require more compatible spatial data.

Results of this study could be used as initial inputs for land-use planning, spatial planning directions, and policy development for the agricultural sector. Approximately, 29,800 ha area of rice farming commodities was very potential to be maintained, along with the infrastructure. The largest plantation commodities were cocoa (24,300 ha), cashew (9,300 ha), and coconut (5,900 ha). Cocoa

was the most dominant plantation product in Sigi Regency.

The best result for land suitability optimization can be achieved with ideal data. It can provide an excellent picture for decision makers in the local government as well as investment in providing spatial information data that can be used for broader needs.

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