Remote sensing and GIS applications for planning of sustainable food agriculture land and agricultural commodity development in Denpasar City

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Abstract: Denpasar as the provincial capital of Bali still has 2225 rice fields. Denpasar Regional Spatial Plan (SP) 2011-2031, paddy fields as Green Open Space (GOS) 1563 ha. GOS is intended for the preservation of agrarian culture, the balance of urban ecosystems, and agro-ecotourism. Preservation of resources and economic improvement of the area needs to be developed a data base of sustainable food agriculture land (SFAL) planning. SFAL from the results of spatial analysis of 10 thematic maps defined as GOS, the Subak region's spatial data base from analysis of satellite images, and subak attribute data from the results of agroecosystem land suitability classification. Information on Subak resource potential using QGIS software version 2.18.0 through join attributes. SFAL/GOS paddy fields for SP years 2031-2050 = 1064.14 ha (47.83%), for SP more than 2050 = 695.09 ha (31.25%) from 2015 paddy fields. Paddy fields in North Denpasar and East Denpasar ± 80 % as SFAL/GOS, South Denpasar and West Denpasar 0%. Land suitability for lowland rice is 100% very suitable (S1), production increase is done through efforts to improve the availability of irrigation water and phosphor fertilization. Horticultural crops 80% potentially developed, with improved drainage, water availability and fertilization.

Keywords: *sustainable food agriculture land, Green Open Space, Land suitability*

1. Introduction

Sustainable Food Agricultura Land (SFAL) Protection is accommodated in Article 9 of Law No. 41 of 2009 [1], containing the area, land, and reserves for sustainable food agriculture land. The Sustainable Food Agriculture Zone is outlined in Articles 5, 6,7,8, and 9 in Government Regulation (GR) No. 1 of 2011 [2]. Technical guidelines for criteria and requirements for the area, land, and sustainable food agriculture reserves in the Minister of Agriculture Regulation No. 07 / Permentan / OT.140 / 2/2012 [3]. Regarding the SP, the establishment of SFAL in areas that have not yet been formed by SP is listed in Article 4 and 5 of the Ministerial Regulation (MR) of Agrarian and Spatial Planning (ASP) / Head of National Land Agency (NLA) No. 19 of 2016[4]. Especially for Denpasar City has had SP in 2011-2031 [5]; The city's Green Open Space Area (GOS) is in the form of Subak paddy fields with an area of 1563.52 ha. Rice fields in Denpasar City in the form of GOS in Law No. 26 of 2007 [6] and MP of Home Affairs No 1 of 2011 [7], became SFAL in MR ASP/ NLA 19/2016 [4]. In the Denpasar City SP, GOS has not referred to MR ASP / NLA. Therefore, to revise the SP, it is necessary to map and determine SFAL in accordance with the aforementioned Law, GR, and MR. The research objectives include: (1) determining what parameters can be used to make SFAL maps according to physical and environmental conditions in a specific region, (2) test numerical classification and use of remote sensing and GIS technology to create SFAL and FAL maps, as well as agricultural land that can be used for development needs in urban areas, and (3) building an information system for the potential development of land suitability classes for food crop and horticultural commodities in SFAL and FAL.

The method of spatial analysis of the right potential area determines the extent and location of SFAL. Data and information on physical and environmental potential, hereinafter referred to as the data base in Government Regulation No. 25 of 2012 concerning SFAL Information Systems [8]; Article 8 is stated: physical basic data is sourced from remote sensing data and field surveys; Article 28 includes SFAL Information Products consisting of textual, numerical, and / or geospatial types and presented in electronic and / or print media. Based on the GR, SFAL data and information must be based on remote sensing data, field surveys, and the use of Geographic Information System (GIS) technology. Research on spatial analysis of thematic maps to produce location, area and information system of SFAL has been carried [9] and [10]. Conclude that: the application of remote sensing, GIS, and numerical technology from the thematic data and maps of the physical and environmental potential of the provinces and region/cities in Bali can produce SFAL maps that are in accordance with the requirements related to SFAL at a certain time period. A similar study was conducted in Kediri Subdistrict, Tabana Regency to create a zoning map of sustainable food agriculture areas [11].

2. Material and Methods

Geographical area of Denpasar City. Denpasar city is at 08035'31 "- 08044'49" south latitude and between 115010'23 "- 115016'27" east longitude. Bordering Badung Regency in North and West, Gianyar and Badung Strait to the east, total area 127.78 km. Denpasar city is composed of four sub-districts (North, East, South, and West), and 42 of Subak. Materials and method used include WorldView satellite imagery in 2015. Data and information to make 10 thematic maps or 10 SFAL supporting maps, namely maps: watershed, irrigation, land use, suitability of agricultural land with SP, relief, agroecosystem land suitability, production, and distance from the city center. The 10 maps in weights 1-10 and score 1-3 each support map. Using land surveying and land suitability tools, as well as a set of computers and Arc-GIS 10.2 software.

Research methods include analysis of satellite imagery, field surveys, making 10 thematic digital maps, numerical classifications (weighting, score, value calculation, average and ± 0.5; 1 standard deviation), overly-selective and reselek). Land suitability information system, using land surveys and soil analysis, as well as agroecosystem land suitability classification [12]. Subak rice fields as spatial data, while land suitability class data as attribute data. The land suitability information system is carried out by joint attributes. Display of land suitability class information for various food crops and horticulture commodities is done by clicking the desired spatial data.

3. Result and Discussion

3.1. Sustainable food agricultura land map

The numerical classification results to obtain SFAL maps as in Figure 1 and Figure 2. Figure 1 numerical classification, population values with class intervals an average value of ± 0.5 standard deviation. Whereas Figure 2 results in the classification of interval classes an average value of ± 1 standard deviation. Figure 1 shows a wider GOS / SFAL (1064.14 ha) of GOS / SFAL (695.09 ha) in Figure 2. The reduced SFAL in Figure 2 is allocated to land requirements for non-agricultural development which are assumed to increase with increasing planning time. In contrast to the food crop area (FAL) is relatively the same, both in Figure 1 (906.84 ha), and in Figure 2 (926.59 ha). The location of the FAL will decrease with the length of time planned. Inventory of land for non-agricultural development has been accommodated in a numerical classification, namely the parameter distance from the city center. As a result, FAL locations are decreasing with increasing planning time, especially in areas bordering the strategic tourism areas of Sanur and Kuta. For that reason, these parameters are needed in SFAL mapping for a certain time.

Numerical classification using a class interval value of ± 0.5 standard defiation produces a map of SFAL / GOS and FAL for periodic SP planning for 2021-2051 (Figure 1). To get a map of SFAL / GOS and FAL in planning SP period> 2015 (Figure 2) obtained from interfal class values ± 1 standard definition. SFAL / GOS and FAL maps are the results of spatial analysis of 10 thematic maps of the

physical and environmental conditions of the study area. The selection of class intervals (GOS / SFAL, FAL, and convertible agricultural land) is determined by the distribution of pupulation values,

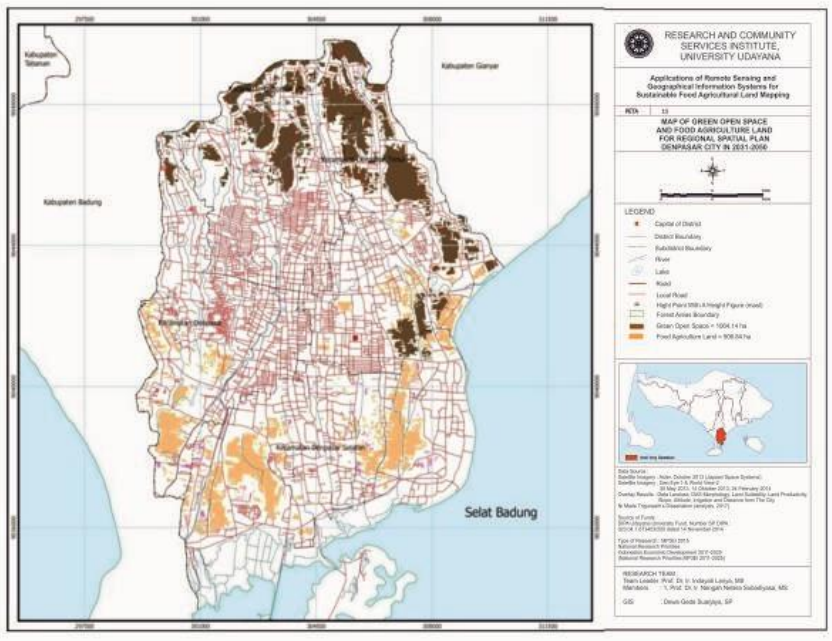

Figure 1. Peta GOS/SFAL food and agricultural land for the revision of SP Denpasar City 2032-2052 (Source: Data Analysis, 2016).

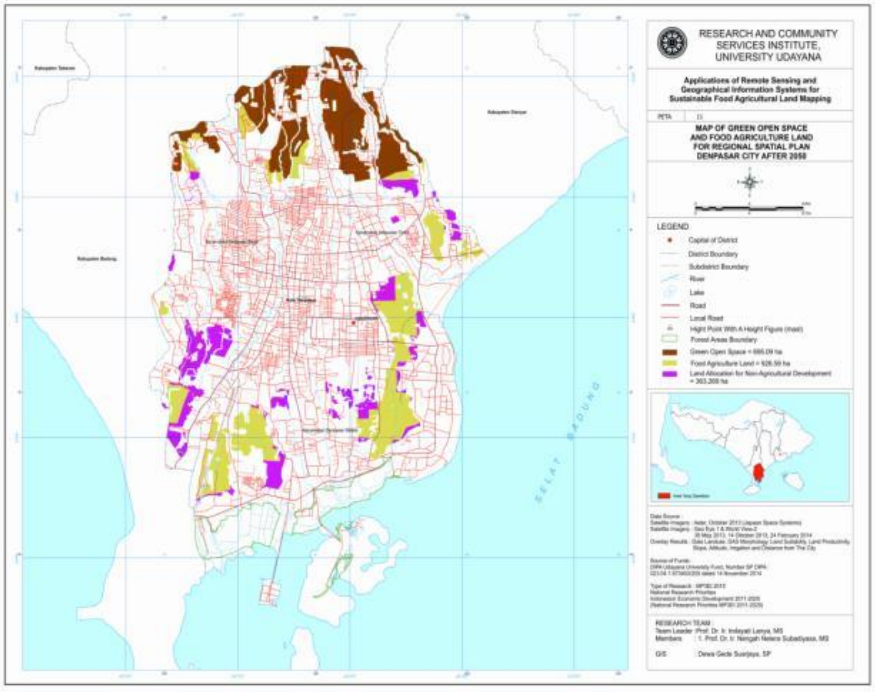

Figure 2. Peta GOS/SFAL food and agricultural land for the revision of SP Denpasar City > 2050 (Source: Data Analysis, 2016).

average values ± the amount of standard deviation values and the suitability of the results of food inventory analysis, as well as the food balance projections in a given region and year.

The food balance for Denpasar City in the 2016 research year has experienced a food deficit. Such characteristics of the physical potential of the region, the distribution of location and area of SFAL is based on the needs of GOS for the balance of urban ecosystems and the preservation of the Agricultural Culture. The agrarian culture needs to be maintained and preserved, because this Subak system agriculture brought the City of Denpasar as a member of the Indonesian Heritage City Network in 2010 and the Indonesian Heritage Conservation Agency (BPPI) in 2011. Denpasar City was also a member of the 2013 Organization of Word Heritage City (OWHC). Farming of paddy fields with irrigation of the subak system that still exists in urban areas is unique, it needs to be revitalized through the integration of agriculture and tourism so that the subak rice fields can be maintained and preserved. Therefore the mapping of SFAL/GOS and FAL is very necessary, both for spatial revision, as well as for the preservation of nature and agrarian culture, as well as agrotourism to maintain its membership in the OWHC, and maintain the balance of urban ecosystems.

3.2 Agroecosystem Land Suitability Information System in Denpasar City

The geospatial information system of agricultural land suitability consists of two main components, namely: spatial data and attribute data. Spatial data is a unit of development land (polygon boundary of subak region). The attribute data for each subak region is compiled from the results of the classification of actual and potential agroecosystem land suitability for food crops and horticulture (Table 1). The incorporation of spatial data and attribute data is done by using software QGIS, through the join attribute menu. Furthermore, to find out the possible land suitability class information that can be developed in SFAL and FAL, it is done using GIS technology, simply by clicking on the desired SFAL or FAL area. The example of displaying land suitability class information for each subak using GIS technology can be seen in Figure 3.

The data in Table 1, informs that rice fields are potentially classified as very suitable classes (S1). The input of fertilizers and the sufficiency of irrigation water are still needed to increase the productivity of paddy fields. paddy fields in the GOS/SFAL area can be developed for other commodities such as corn, spinach, chili and watermelon/melon, in addition to paddy field. The results of land suitability classification for maize and horticulture plants are generally classified as suitable (S2) with limiting factors for soil drainage and temperature (S2rt). Therefore, besides planting rice it is necessary to improve drainage through making mounds and planting during the dry season, after planting paddy fields. NPK fertilization in accordance with the needs of each plant is still needed to increase the production of the commodity being cultivated. Thus: corn, spinach, chili, watermelon and other horticultural plants have the potential to be developed in SFAL and FAL.

Based on Table 1 and Figure 3 it can be specified as follows: land suitability classes for wetland rice are potentially very suitable (S1) in all subak areas if irrigation water is met. Land management and fertilization according to the recommended fertilizer dosage to increase production. Fertilizer needs based on the results of research in Denpasar are: 200 kg urea + 100 to 150 kg SP36 + 50 kg KCl or without KCl. Potential development of chili plants, land suitability including very suitable and suitable (S2), spread throughout Subak. Potential for the development of jackfruit and melon, tomatoes are classified accordingly (S2). Increased production for horticultural plants is carried out by rolling to improve soil drainage in paddy fields. NPK fertilization to meet plant nutrient needs. In addition, planting time is carried out in the dry season to avoid excess water requirements for plants.

Table 1. Example of attribute data, class of suitability of actual and potential agroecosystem land for food crops and horticulture in Denpasar City (Source: Data Analysis, 2016).

Subak / vilage		Area (ha)	Rice field		Corn		Pinate		Chili		Watermelon/melon	
ID	Name		actualy	Potential	actualy	Poten tial	actualy	Potential	actualy	Poten tial	actualy	Poten tial
1	2	3	4	5	6	7	8	9	10	11	12	**13**
5107100310101	Sembung Paguyangan Kaja	100.51	S2r	S2r/S1	80% S3r, 20% S2t	80% S2r, 20% S2t	80%S3r, 20% S2t	80%S2tr, 20% S2t	S3r	S2r	70%S3r, 30%S2w	70% 2wr, 30% S2w
510710200141	Anggabaya Penatih	27.81	S2n	S1	50%S3r, 50% S2t	50% 2tr, 50% S2t	75%S3r, 25% S2t	75%S2tr, 25% S2t	50%S3r, 50% S2r	50%S2 50% S1	S3r	S2wr
510710100021	Kerdung Pedungan	217.48	S2n	S1	S2r	80% S2r, 20% S2t	75%S3r, 25% S2t	75%S2tr, 25% S2t	S3r	S2rn	80% S3r, 20%S2wr	80%S2wr, 20% S1
510710100081	Intaran Barat Sanur Kauh	89.02	S2r	S2r/S1	S2r	80% S3r, 20% S2t	70% S3r, 30% S2t	70% S2tr, 30% S2t	70%S3r, 30% S2r	70%S2r 30% S1	70% S3r, 30%S2w	70%S2wr, 30% S 2w
510710100091	Sanur Sanur Kaja	50.25	S2r	S2r/S1	30%S3r, 70% S2t	30%S2tr, 70% S2t	25%S3r, 75% S2t	25%S2tr, 75% S2t	25%S3r, 75% S2r	25% S2r, 75% S1	50% S3r, 50%S2w	50%S2wr, 50% S 2w

Information :

Land suitability class: S1 = very suitable S2 = suitable S3 = marginal suitable

Limiting factor: r = medium texture t = temperature 27o2 28 oC w = water availability (rainfall 1300-400 mm / month
n = nutrient available (Nitrogen = low, and phosphorus = moderate)

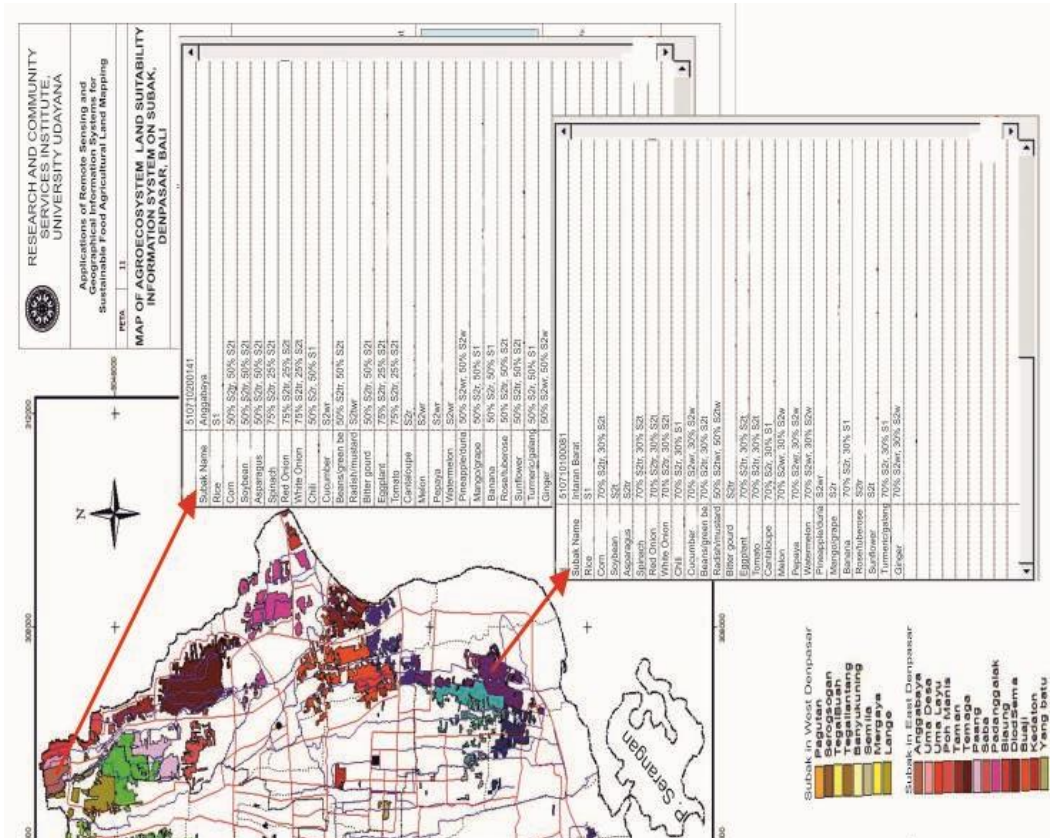

Figure 3. Example of agroecosystem land suitability class information map for food crops and hoticulture in Denpasar City (Source: GIS Analysis, 2017).

4. Conclusion

Parameters that can be used to analyze spatial data on physical and environmental conditions to make SFAL maps include thematic maps: (1) location position on the river basin / area, (2) existing land use, (3) irrigation water availability, (4) conformity location of agricultural land with area of space allocation in SP, (5) rainfall, (6) place height, (7) relief, (8) agro-ecosystem land suitability, (9) rice paddy production, and (10) distance from city center.

Remote sensing and GIS technology can be used for spatial analysis of physical and environmental conditions in the form of thematic maps and numerical classifications to produce SFAL, FAL classes and inventory of agricultural land for urban development.

The suitability of agro-ecosystem land for food crops and horticulture is classified as very suitable and appropriate, potentially can be developed in SFAL and FAL. The land suitability information system is built through GIS technology.

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