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Remote sensing and GIS applications for sustainable food agricultural land mapping and supporting the preparation of regional spatial plans (case study of Badung Regency)

Indayati Lanya, N Netera Subadiyasa, Ketut Sardiana, Gst P Ratna Adi and Made Tri Gunasih

Study Program of Agroecotechnology, Faculty of Agriculture, Udayana University

E-mail: indahnet@yahoo.co.id

Abstract. Local Government (LG) provincial and district /city in Bali until now does not have a Regional Regulation (RR) on determination of Sustainable Food Agricultural Land (SFAL). This is related to the provision of land for non-agricultural development permits. Map of SFAL has been established as a condition for the drafting and revision of the Spatial Plan (SP) [1]. Multi-analytical research methods: super impose analysis of thematic maps, ten thematic maps of physical and environmental conditions (river basin area, land use, irrigation, relief, rainfall, elevation, regional spatial planning, land suitability, productivity, and distance from city center) will be analysed and scored to numerically scoring (numerical classification), toolbox - analysis tools -overlay -intersect. Materials and tools: Quick Bird satellite images 2013 and QGIS software 10.3. Field survey to compile a data base of SFAL at each location. Map and data base SFAL obtained from the analysis of thematic maps of physical and environmental conditions. SFAL 9,642.76 ha was recommended for the revision of SP for 2013-2033; SFAL = 8,824.36 ha is recommended to reflect SP year 2034-2054 ha and 6,510.11 ha for the drafting of SP year more than 2055 location   are in the. SFAL location are in the upstream and center (Petang, Abian Semal, and Mengwi District). Subak rice field that can be converted 829.41 ha – 3,143.66 ha is located in the districts of Kuta and Nort Kuta. Remote sensing and GIS technology can be used for SFAL mapping, through the classification of numerical thematic maps of the physical and environmental conditions of the region.

1. Introduction

Food security is a priority area in the National Research Master Plan. The aim is to minimize the conversion of paddy fields in Indonesia, which reaches 150,000 ha/year to 200,000 ha/year [1]. Indonesia's population growth rate of 1.36%, reaching 262 million people (National Statistics Agency, 2018) [2]. Agricultural land is declining, while the population is increasing, a strategy is needed to reduce the function of productive rice fields, so that there is no food deficit. The Agrarian and Spatial Planning (ASP)/National Land Agency (NLA) Regulation Number 19 of 2016 concerning Determination of Sustainable Food Agriculture Land (SFAL), aims to accommodate SFAL into the SP and Spatial Detail Plans (SDP) [3] The ministry asked for a Ministerial Regulation (MR) to be upgraded to a Presidential Regulation (PR) so that it could be used as a basis in the preparation of the SP, and Regulations on Regional Heads (PR).

The plan for the Presidential Regulation was aimed at stopping the conversion of paddy fields containing the Acceleration of Determining the Land of Sustainable Rice Fields and Controlling the Functioning of Rice Fields. The (PR) will play an important role in preventing the conversion of rice fields, regulating the determination of rice fields, and controlling the integration of rice

fields into the SP. Bali experiences the conversion of paddy fields covering an area of 800-1,000 ha year $^{-1}$ [4]. In this study SFAL in Bali was in the form of rice fields incorporated in the Subak region as a local superiority of Bali [5]. The problem is that until 2018 the Regional Government generally has not implemented: Laws, Government Regulations (GR) and Ministerial Regulations (MR) so that the conversion of rice fields continues to occur without controls and strict punishment, such as: (1) Law No. 41 of 2009 concerning Protection of SFAL[6], (2) GR related to SFAL (GR 1/2011 Establishment of SFAL[7], GR 12/2012 incentive and disincentive [8], GR 25/2012 SFAL Information System [9], PP 30/2012 financing [10], (3) Minister of Agriculture Regulation (7/2012 Technical Guidelines for SFAL Criteria and Requirements) [11]. MR of ASP/NLA No. 19/2016 concerning the Determination of SFAL that has not yet formed a SP [3].

The new Regional Head, especially in Bali to accommodate the Vision, Mission and Development Program initiated to revise the SP. The (PR) and MR, the Regional Government has a legal basis and is obliged to establish SFAL as a Governor or Regent or Mayor Regulation that must be accommodated in the revised SP and SDP. Research on SFAL through numerical classification for the Province of Bali has been carried out by [12]. The time for the implementation of the research has not yet been issued the MP of ASR/NLA and (PR) so that only technical information is obtained for spatial analysis of SFAL supporting maps, and there is no obligation for SFAL to enter into SP and SDP. Other studies related to SFAL using remote sensing and GIS technology [13] and using spatial analysis in the form of scoring and buffering from various basic spatial data, in the form of land cover data, soil type, slope, irrigation, rainfall, produce very potential land and potentially as SFAL [14].

Based on the description above, the map of SFAL area and SFAL map is very necessary as a basis for compiling and reflecting SP, SDP, and DSP. The purpose of this study is to: (1) obtain physical and environmental factors that influence the stability of food crop agricultural resources, (2) obtain a map of SFAL areas in accordance with the physical and environmental conditions of the research area, and (3) get the method analysis based on remote sensing technology and Geographic Information System (GIS) according to the requirements of the Government Regulations and Ministerial Regulations mentioned above.

2. Material and methods

The research location in Badung Regency was focused on the land area, consisting of five subdistricts, namely: Petang, Abian Semal, Mengwi, North Kuta, and Kuta; Excluding the Jimbaran hill area in South Kuta District (figure 1).
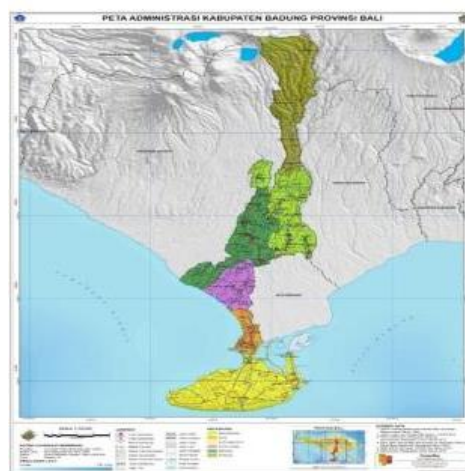
Figure 1. Map of research area location.
(Source: Regional Government of Badung, 2013)

2.1. Materials and tools
This research uses materials and tools such as: QuickBird satellite images 2015 and QGIS 2.10.3 software. Data, maps, and information on the physical and environmental conditions of the research area. Data and information to make 10 thematic maps of the physical and environmental conditions of the research area consist of: (1) river basin area, (2) irrigation, (3) land use, (4) suitability of agricultural land with the Regional Spatial Plan, (5) relief, (6) rainfall, (7) elevation, (8) suitability of agroecosystem land, (9) rice production (tons ha^{-1}), (10) distance from city center) and (11) minimum area.

2.2. Methods
Research was done using a variety of methods (Multi-analytical research) include: (1) preparation of 10 thematic digital maps of the physical and environmental conditions of the research area using technology of remote sensing and GIS. To get SFAL maps with the aim of protecting the potential of agricultural land resources, that is: then thematic maps are weighted (1-10) and in score (1-3) according to their contribution to the sustainability of agricultural land and regional food security. Weighting and scoring refers to the results of previous studies [12]. Preservation of paddy fields is based on the main variables, namely natural and environmental conservation (position of location/watershed, relief, height of place), variable supporting productivity of paddy fields (irrigation, agroecosystem land suitability, rainfall, production, minimum units) and external variables (RTRW and distance from the development center). (2) Numerical classification is done using toolbox - analysis tools -overlay – intersect menu. Population distribution values, averages and standard deviations were calculated. The total value is more than 125 for the SFAL class, Buffer value (100-125), and a value of less than 100 for paddy fields that can be converted.

3. Result and discussion
3.1. Mapping the regional physical and environmental conditions of the study
The results of mapping physical and environmental conditions (10 thematic maps) using remote sensing and GIS technology show that: the area of Badung Regency stretches from the sea to the mountains, the area of 418.52 km^2 is at an altitude of 0-2075 m asl [15] (NSA, Badung, Regency, 2017). Upstream Watersheds are in the District of Petang, The middle part of the Watershed is in the Abian Semal and Mengwi Districts, and the downstream is in Kuta and North Kuta Districts, and the Mengwi District beach area. Relief is flat to mountainous, orographic rainfall, increasingly towards the mountain is greater (1,644-3,000 mm year^{-1}). Land use in the upstream area is dominated by dry land with horticulture plants, a little forest on the top of the mountain, and coffee in steep slopes. The middle and downstream parts are dominated by rice fields, except Kuta Subdistrict. The middle and downstream part of the research area is dominated by rice fields, except in Kuta District. The results of the analysis of satellite imagery QuickBird in 2015, obtained an area of 9,657.77 ha of paddy fields, dry land area of 7,828.34 ha, and non-agricultural land area of 24,370.23 ha.

All rice fields land in Badung Regency have terraces and semi-technical irrigation (Subak system). The use of paddy fields and the number of subaks in each district are: Petang District 993.86 ha (16 subak), Abian Semal 1,470.41ha (33 subak), Mengwi 4,464 ha (49 subak), Kuta Utara District 1,406.75 ha (19 subak), and Kuta only 31.12 ha (2 subak). The suitability of rice fields with the area of agricultural land in the 2013-2033 SP of Badung Regency is only 9,657.77 ha (60.41%). This means that in the SP, an area of 6,328.80 ha (39.59%) was allocated for non-paddy land use (may be converted). Subak rice fields which are allocated for non-development (100% may be converted), are located in all fields of Kuta and North Kuta Subdistricts, namely in Petitenget Subak, Kerobokan Kelod village and Umalas, Canggu Village, Kuta District [16].

The physical and environmental conditions of Subak Rice Field (LP2B) are technically irrigated, the potential agroecosystem land suitability classes for wet rice are classified as very suitable, N and P fertilizer inputs are needed, rice production generally reaches > 6.5 tons ha^{-1}, except in North Kuta sub-district and Kuta ranged from 5.5 to 6.5 tons ha^{-1}, caused by lack of

irrigation water due to the construction of settlements in paddy fields. Physically, the condition of agricultural land in the form of subak irrigated rice fields, bench terraces, agroecosystem land suitability is very suitable, so the presence of rice fields in the watershed (figure 2) and agroecosystem land suitability (figure 3) very influential on the results of sustainable food agriculture zoning.
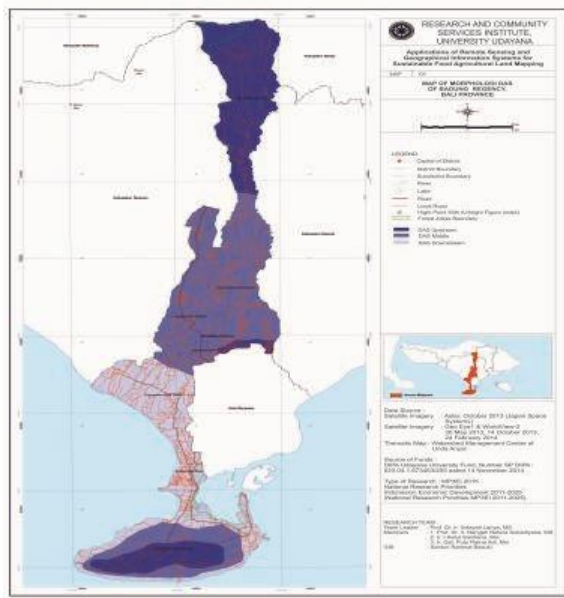
Figure 2. Watershed morphology map.
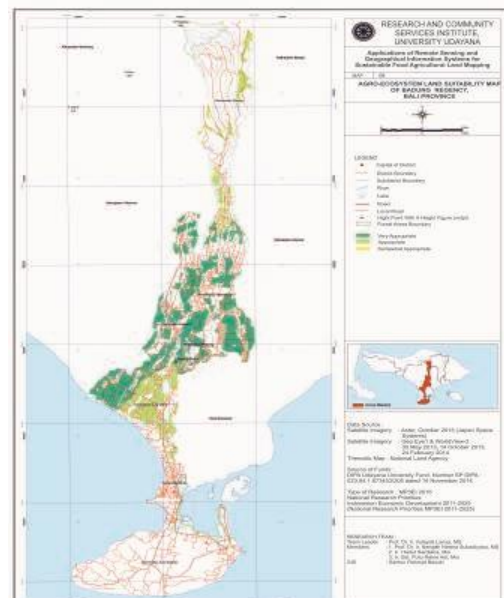
Figure 3. Map of agroecosystem land suitability.

3.2. Spatial analysis of SFAL supporting maps

The food crop agricultural land studied is subak rice fields. The results of the spatial analysis of physical and regional conditions (10 thematic maps supporting SFAL) through weighting and scores, as well as numerical classification, population distribution values, average values and standard deviations, and the determination of three classes of subak rice fields (sustainable, buffer, and conversion). Furthermore, through the overlay and intersect menus, the distribution of sustainable rice fields, buffer rice fields and rice fields can be converted to stock of non-agricultural land allocations is presented in figure 4. Sustainable rice field is sustainable food agriculture until infinite years, while buffer rice fields are rice fields that are used as sustainable food crops with a certain area according to the planning year.

The longer the planning year, the buffer rice field area will decrease, because of the need for non-agricultural development. Rice fields that can be converted are rice field that are outside the agricultural land area in the SP for the current year. The results of the first phase of the research, spatial analysis of 10 thematic maps and numeric classifications obtained subak zonation maps, sustainable, buffer and convertible. The zone of subak rice fields is sustainable and buffer, then it is called SFAL. Food balance data: projections of land use change and population projections up to 2050 are used to select class intervals that correspond to the area of rice fields needed. The results of spatial analysis and numerical classification for SFAL mapping are recommended for SP revisions (2033-2050) which are included in figure 4.

The map shows the pattern of the spread of SFAL which is brown and green. Green will decrease with the longer planning time. The results of the spatial analysis of 10 thematic maps using GIS technology found an extensive SFAL + buffer area of 8,824.36 ha and convertible rice fields 829.41 ha. SFAL is found in all area of Petang, Abian Semal and Mengwi Districts.

Whereas the subak rice fields that can be converted are found in all Kuta and parts of North Kuta Districts. The main cause is the location of paddy fields outside the agricultural land area in the SP, according to the agroecosystem is classified as appropriate and the production of paddy rice is 5.5-6.5 tons ha^{-1}.
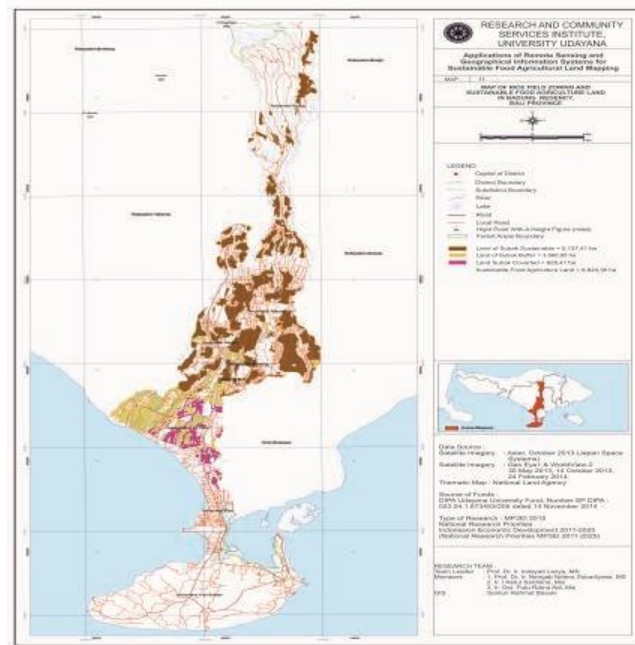
**Figure 4.** Map of sustainable food agriculture for SP 2033-2050.

The main factor in converting rice fields is designated as a tourism support area. SFAL distribution includes sustainable rice fields and buffers. There are upstream and middle sections of the watershed, the suitability of agroecosystem land is very suitable, and rice production > 6.5 tons / ha. In the spatial revision it is necessary to consider the suitability of paddy fields with the area of agricultural land contained in the SP.

Phase two research uses 11 thematic map parameters of physical and environmental conditions including minimum units. The numeric classification model uses the mean values with differences in the standard deviation interval (± 0.5; ± 1; and ± 1.5) obtained in the map of subak regions in figures 5, 6 and 7. The picture shows the pattern of SFAL distribution decreases with the longer years of planning, indicating that the longer the planning time, the smaller the area of SFAL. The physical and environmental conditions of rice fields in Badung Regency are relatively uniform, such as micro relief in the form of terracing, semi-technical irrigated rice fields (Subak system), productivity of paddy rice, suitability of agroecosystem land. Therefore the main factor of the SFAL parameter is the position on the watershed morphology, rainfall and height of the place.
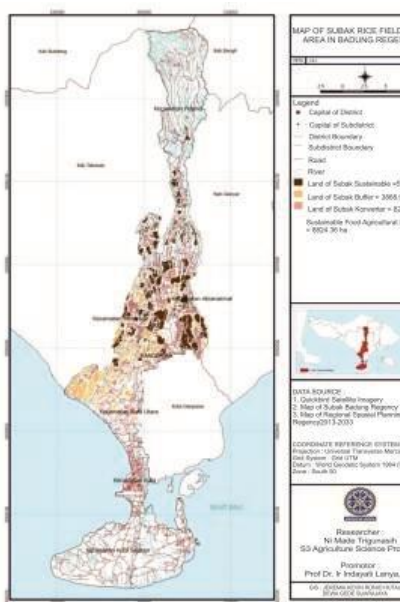
The area of SFAL 9,642.76 ha was recommended for the revision of SP for 2013-2033; SFAL = 8,824.36 ha is recommended to reflect SP year 2033-2053 and SFAL = 6,510.11 ha is recommended for revision SP 2050 - to infinity. Based on the results of the first study using 10 variables and the second study using 11 variables, the same results were obtained, namely SFAL = 6,510.11 ha – 8,824.36 ha which needed to be accommodated for SP 2033-2053 and the following, and used for Regional Head Regulations (Governor, Regent / Mayor) about SFAL. In other words, the SFAL for 2050 is 8,824.36 ha (55.20%) and in 2050 or more is 6,510.11 ha (40.72%) of the total rice fields in 2015 (15,986.57 ha). The location of SFAL deployment such as figure 6 and figure 7, namely: in the Districts of Petang, Abian Semal and Mengwi which are in the upstream and middle parts of the Watershed, altitudes > 100 m asl, rainfall > 2,000 mm year^{-1}, and land suitability of agroecosystems are very corresponding. The SFAL maps listed in figure 5, 6, and 7 can be chosen to revise the SP and be included in the SDP accommodated in

Governor Regulations, Regents or Mayors in a given year, in accordance with applicable national and regional regulations and policies.
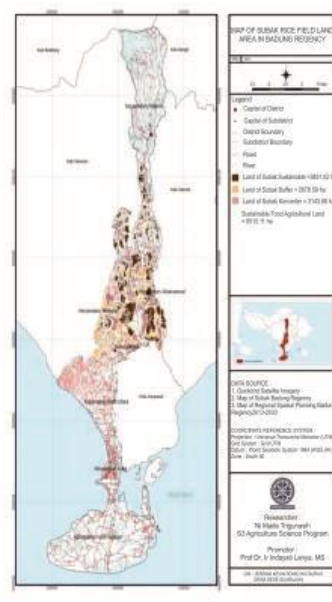
Based on the results of the first and second stages of SFAL mapping in Badung Regency at an altitude of 0- 20,275 m asl, with 10-11 parameters, it has similarities to semi-permanent irrigation systems, micro terracing reliefs, production > 6.5 tons of grain ha^{-1} every harvest; then the main parameters for determining SFAL are: (1) location in the watershed, (2) place height, (3) rainfall, and (4) agroecosystem land suitability. But if the 11 parameters are different, then the 11 parameters are determinants of the SFAL area. For this reason, the location of the SFAL distribution pattern is determined by differences in the number and type of parameters. In other words numeric classification requires deep knowledge of SFAL and its parameters, as well as expertise in spatial data analysis. SFAL maps with various models can be done through spatial analysis in accordance with physical and environmental conditions related to the potential for conservation and development of SFAL.
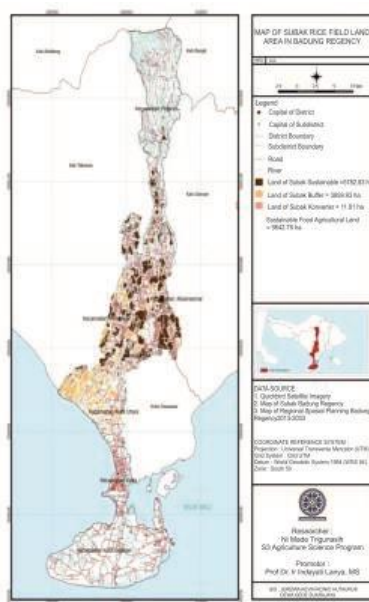
Figure 5. Mode I SFAL for SP: 2013-2033.   **Figure 6.** Model II SFAL for SP: 2034-2054.   **Figure 7.** Model III SFAL for SP: 2055-2075.

The number and type of parameters for spatial analysis are determined by the physical and environmental conditions of the study area. Projected data on agricultural land area and population projections in a given year are used as a comparison in the selection of numerical classification models. Remote sensing and GIS technologies are used to create thematic maps as supporting maps and numerical classifications. Different number and types of parameters to obtain SFAL maps in different districts/cities [17] and [18]. In other words, the input of thematic maps of physical and environmental conditions as SFAL maps, determination of weights, and score of each parameter, as well as the selection of class intervals, greatly determine the results of regional classification and SFAL maps.

4. Conclusion and recommendation
4.1. Conclusion
The physical and environmental parameters of the study area consist of thematic maps supporting SFAL are: (1) Position of location in the Watershed or upstream area, (2) irrigation, (3) land use, (4) suitability of agricultural land with the Regional Spatial Plan, (5) relief, (6) rainfall, (7) high place, (8) agroecosystem land suitability, (9) rice production (tons ha^{-1}), (10) distance from city center, and (11) minimum area.

Map of the area of sustainable food agriculture is obtained from the results of spatial analysis of physical and environmental conditions and numerical classification. The area of SFAL 9,642.76 ha was recommended for the revision of SP for 2013-2033; SFAL = 8,824.36 ha is recommended to reflect SP year 2033-2053 and SFAL = 6,510.11 ha is recommended for revision SP 2050- to infinity. Based on the results of the first study using 10 variables and the second study using 11 variables, the same results were obtained, namely SFAL = 6,510.11 ha – 8,824.36 ha which needed to be accommodated for SP 2033-2053 and the following, and used for Regional Head Regulations (Governor, Regent or Mayor) about SFAL.

Remote sensing and GIS technology can be used for creating maps Sustainable Food Agricultural Land, through the creation of thematic maps, spatial analysis, and numeric classification. The type and number of thematic maps according to the physical and environmental conditions of the research area are related to the sustainability of agricultural resources.

4.2. Recommendation

Remote sensing and GIS technology is recommended for spatial analysis of physical and environmental potential for monitoring and revision of the SP, as well as Regional Head Regulations (Governors, Regents/Mayors) about SFAL. Spatial data analysis of the physical and environmental conditions of the research area can be used to map SFAL and SFAL areas, as well as convertible agricultural land.

Acknowledgments

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