Remote sensing and GIS application for mapping data base of sustainable agriculture land in Denpasar City

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Abstract. The Government of Indonesia has issued legislation in an effort to protect sustainable food agricultural land (SFAL), supplemented by Ministerial Regulation, which the aim is for national food security and sovereignty. The assessment accuracy of rice field data is depending on the spatial resolution and temporal variation. Geospatial based agricultural database inventory supports agricultural development programs. The research objective was to compile the SFAL data base (agricultural resources and ownership map). Research methods include analysis of high-resolution Word View 2018 satellite imagery, field surveys and thematic mapping. QGIS 3.6 software, SAS Planet and Locus GIS. Land resources inventory (paddy area in three subak 59.8 ha, Typic Tropaquepts, rainfall of 1,500 to 2,000 mm year⁻¹, origin slope 3 to 8%, terraced, very suitable for lowland rice, suitable for horticulture). Human resources (82 people as owner, 88 farmers as cultivator), 70.95% of those have primary school education and 78.3% are aged 51 to 70 years old. Artificial resources (4,800 m tertiary irrigation channel, 2,470 m farm roads, 5 tractors), rice-rice-horticulture cropping pattern, produce 6.5 t ha⁻¹ of rice. Map and information system of subak rice fields, land suitability and geospatial-based land tenure information as SFAL database can assist local governments in sustainable agricultural development.

1. Introduction
The Indonesian government already has laws (UU), four Government Regulations (GF), one Presidential Regulation (PR) and three ministerial regulations (MR), relating to SFAL. The protection of SFAL as an agricultural resource is aimed at accelerating the achievement of national food security and sovereignty. The problem is that most of the Regional Governments (Pemda) do not yet have a spatial map for SFAL and information technology-based SFAL databases, according to the rules above, in order to accelerate the implementation and success of agricultural development.

Law 41/200 on Protection of SFAL [1] and legal basis has been issued in 2011, 2012, 2016, 2019 [3], [4], [5] [6], GF No. 1 of 2011 [1], GF No. 12 of 2012 [3], GF No. 25 of 2012 [4], GF No. 30 of 2012 [5], PR No.59 of 2019 [6], MR Agriculture No. 7/2012 [7], MR Agrarian and Spatial Planning/National Land Agency (ASP/NLA) [8]. All of these regulations are aimed at protecting rice fields as an asset in realizing national and regional food security. The main problem up to 2019 out of 514 districts/cities and 34 provinces, there are only 222 districts (43.19%) covering an area of 5.6 million ha that stipulate SFAL in RTRW, 107 districts and 26 provinces have enacted SFAL Regional Regulation [9]; Including the City of Denpasar has not yet stipulated SFAL regulations, even though it already has a SFAL map in the framework of revising the Regional Spatial Plan (RSP) and Detailed Spatial Planning (DSP) and there is no SFAL data base yet. The next problem is that none of the Regional Governments (Pemda) that have Regional Regulations (RR) SFAL have compiled an information system on land resources...
(LR), Human Resources (HR), Artificial Resources (FS) and Agricultural Resources (AR) that the Local Government (LG) must have to protect and conserving subak rice fields and documenting it based on information technology, in accordance with the laws and regulations above.

The conversion of productive rice fields with technical and semi-technical irrigation continues to occur, because there is no protection for agricultural resources. Especially in Bali, the available land for non-agricultural development is only in the form of productive subak rice fields. Traditional agricultural systems that apply soil conservation (bench terraces) and water (subak irrigation system) are capable of maintaining sustainable farming, with an average productivity of 5.5 t ha\(^{-1}\) [10]. The need for tourism facilities and infrastructure continues to increase, resulting in changes to the function of productive rice fields which continue to occur even uncontrollably due to the absence of Regional Regulations (RR) SFAL [11].

RR SFAL in other LGs does not yet have spatial data and the SFAL Information System (SFALIS). SFAL needs to be stipulated in the RSP to ensure food availability. SFAL at least contains: area, location, textual, numeric and spatial data and information. The SFAL Information System, at least contains information on: natural physical, artificial physical, human and socio-economic conditions, land ownership, land area and location and certain types of commodities which are staple food [4]. Mapping of SFAL based on remote sensing and Geography Information System (GIS) at a scale of 1:5,000 has been carried out throughout the city of Denpasar, especially in 41 subaks in 2019, resulting in very accurate data and maps that have been approved by stakeholders, through the analysis of 11 thematic maps and participatory [11]. The results of the SFAL mapping activities for the three subaks (table 1).

Table 1. Recommended status of Subak Anggabaya, Umadesa and Umalayu for SFAL\(^a\).

| District / Subak name | Rice Field Area | SFAL recommendations (ha) |
|-----------------------|-----------------|---------------------------|
|                        | Rice Field Area | SFAL recommendations (ha) |
| Anggabaya             | 23.32           | 21.65 1.01 0.18 0.49     |
| Umadesa               | 11.30           | 10.49 0.21 0.00 0.60     |
| Umalayu               | 25.01           | 23.62 0.30 0.01 1.09     |
| Total                 | 59.63           | 55.76 1.52 0.19 2.18     |

\(^a\)Source: Research by Lanya et al. (2019) [11]

The plan for SFAL data base compilation activities in Denpasar City to be carried out in 2020, but postponed due to the Covid-19 Pandemic incident. Therefore, the research was carried out in only a few subaks, including Subak Anggabaya, Subak Umadesa and Subak Umadui in which 93.51% of the area is highly recommended as SFAL (table 1). In addition, the three subaks have been designated as City Green Open Space (CGOS) areas in the SP map (LR 27/2011) [12] and the results of academic studies are designated as sustainable subaks [13]. Previous research, obtaining LR, FR data and information that is accurate, current, fast and easily accessible and communicated, uses remote sensing and GIS technology [14].

Based on the above problems, the research objectives can be determined: (1) inventory and description of the SFAL data base, such as data and information on LR, FR, HR, AR and their land suitability and (2) mapping and compiling a land ownership information system using remote sensing technology and GIS. The main benefit of this research is expected to be able to assist the Regional Government of Denpasar City in compiling a geospatial-based LP2B data base. Academic benefits enrich knowledge and skills in the use of remote sensing technology and GIS for inventory, description and mapping of LR, HR, FR, AR and communicating Geospatial based SFAL resources.

This research used remote sensing technology and GIS (QGis), Locus Gis, field survey and digital mapping. Data and maps (soil, climate, agrogeology) and field surveys were used to identify LR, FR,
HR, AR descriptions. Map of land parcels from ASP/NLA is a reference for tentative land ownership boundaries. The data of human resources (farmers) were obtained through structured interviews with Pekaseh (head of the subak group), the head of the subak (tempek) section and PPL (Field Extension Officer).

2. Materials and methods
The research was conducted in three subaks (Anggabaya, Umadesa and Umadui), located in Penatih Sub-District and Penatih Dangin Puri Village, East Denpasar District, Denpasar City, Bali Province. Subak Umalayu is directly adjacent to Gianyar Regency and in the southern part is bordered by Trengguli Street. West Subak Anggabaya is bordered by North Denpasar District, while the northern part of the three aforementioned subaks is bordered by Badung Regency.

Geographical location is located at 8°35′28″ to 8°35′52″ south latitude and 115°13′56″ to 115°13′58″ east longitude. In Denpasar City, the Spatial Planning is designated as Green Open Space (GOS) [12] and the results of the study have the potential to be designated as sustainable subak [13]. The SFAL mapping study, based on spatial analysis of 11 thematic maps (physical, environmental and SDP conditions) is highly recommended as SFAL with an area of 59.80 ha [11]. The research location of three subaks in Denpasar city is marked in color (figure 1).

![Figure 1. Map of research location.](image)

2.1. Materials and tools
The research materials consisted of: Indonesia Earth Map (RBI) Denpasar City at scale of 1:25,000, Denpasar City administration map [12]. High Resolution Worldview Satellite Imagery of Denpasar City 2018, map of land parcels from the SP/NLA portal [9] as a reference for the delineation process of land ownership boundaries, subak map of Denpasar City Year 2019 [11]. Hardcopy of A0 sized worldview satellite images of Subak Anggabaya, Umalayu and Umadesa in 2018, semi-detailed soil maps for Denpasar sheet [15], rainfall map [16], hydrogeological map [17], geological map [18] data and land suitability maps for agroecosystems in Denpasar City [19]. The definitive group needs plan (RDKK) as a control of the area of farmer land ownership for fertilizer applications and an interview questionnaire form for information on farmers and agricultural resources.

The tools used are laptops, QGIS 3.6 software (64 bit), Microsoft Excel 2010 and Microsoft Word 2010 software, SAS Planet software and Locus GIS software to facilitate delineation of subak
boundaries and land ownership in the field. The Global Positioning System (GPS) of cell phone cameras is used as a means of determining location and shooting in the field, writing equipment and questionnaire books.

2.2. Methods
Mixed qualitative and quantitative research methods, including visual interpretation of word view satellite imagery of Denpasar City 2018, continued digitizing paddy field polygons and land ownership referring to the ASP/NLA plot map, manual analysis of thematic maps (semi-detailed soil maps, rainfall maps, hydrogeological maps), tentative mapping of land ownership, surveys and field observations. Interview and reinterpretation of LR (soil type, rainfall, slope, groundwater, agro-ecosystem land suitability) and HR (farmers’ name, address, age, education and area; owners’ name and address; ownership status and production sharing system) were used as attributes; while the spatial data is in the form of paddy field ownership polygon. FR (irrigation canal, jogging tract/farm road, subak hall), AR (type of commodity, crop rotation pattern, type of fertilizer, production, tractor) and land ownership (farmer as owner and cultivator and area).

Research implementation includes: (1) literature study, (2) analysis of satellite imagery for mapping subak rice fields and a map of rice field ownership and a map of rice field ownership (3) tentative mapping of land ownership, (4) field survey of paddy field ownership and HR data, (5) compiling HR database (preparation of HR information system). The interpretation of paddy fields from satellite images is characterized by the appearance of checkered plates, small in size, regular patterns and the green color indicates the growth phase of lowland rice plants, surrounded by greenish white lines that indicate rice fields. Primary data are farm roads or jogging tracks and irrigation canals are digitized from satellite imagery and field observations. Tentative mapping of land ownership is carried out by digitizing paddy fields and referring to the ASP/NLA plot of land. The obtained land tenure polygon is printed at A0 paper size as a concept map (material for field observation and checking).

The field survey was carried out using a structured method, through interviews with Pekaseh (head of the Subak organization), Agricultural Extension Center (AEC), Field Extension Officers (FEO) and cultivators and/or owners (20 respondents). LR secondary data from analysis of land resource maps; HR and AR data were obtained from interviews with stakeholders (AEC, FEO, Pekaseh and farmers). Likewise, to determine the certainty and improvement of the boundaries of rice fields ownership on the concept map is communicated and discussed with stakeholders. Revision of the boundaries (polygons) of land ownership used the Locus GIS application that has been installed on the Android mobile phone (HP). The compilation of information systems for LR, FR, AR and land ownership was carried out using the QGIS 3.6 application. The spatial data for LR and AR are in the form of subak polygons; Whereas land ownership is in the form of polygon plots of land. Attribute data is in the form LR, FR, HR, AR and subak tables.

3. Results and discussion

3.1. Agricultural land resource database
LR, FR and AR data and information are the results of joint spatial data attribute (subak polygons) and attribute data (subak resources) resulting in information as in figure 2. The figure informs that: rice fields are formed from volcanic plains, with the main material of mountain volcanic tuff of Batur, Buyan and Bratan Purba [18], 2% to 5% original slope, bench terrace micro slope, tertiary subak irrigation, soil types in the three subaks classified into soil family, fine Tropoquepts, non-acid mixtures, isohypertermic [15]. Rainfall ranges from 1,500 to 2,000 mm year⁻¹ [16], groundwater is shallow [17]. The source of irrigation water comes from Tukad Ayung, Kedewatan Dam, Gianyar. Availability of irrigation water throughout the year is in good status, with a subak irrigation system equipped with a jogging track as a farming road and agro-tourism facilities. Because the three subaks are as Agroecotourism Area [12].

Maps of tertiary irrigation channels and jogging tracks (Agroecotourism Areas) used for farming roads are listed in figure 3. The length of irrigation channels in the three subaks is 4,800 m, Subak
Anggabaya (1,700 m), Subak Umadesa (1,100 m), Subak Umalayu (2,000 m) and the quality of irrigation channels is good. Likewise, the jogging track is classified as good, 1.5 m wide and the length of the jogging track in the three subaks is 1,885, consisting of Subak Anggabaya (1,190 m), Subak Umadesa (630 m) and Subak Umalayu (650 m) and the need of tractors is 5, while a minimum of 6 tractors required (1 tractor 10 ha⁻¹).

The jogging tracks in the three subaks have been used for sport activities, besides the farm road. While the farm road that connects the three subaks has not been built, it is estimated to be 500 m long. The construction of a connecting farm road to the three subaks has been proposed by pekaseh to the Denpasar City Government in 2019 (information from pekaseh). Irrigation canals in Denpasar City not only serve as a provider of agricultural water, but also as drainage channels. The canals experience leakage in some places. The main factor of leakage of irrigation channels is the presence of rice crabs. In contrast to the farming road in the form of paping, the potential damage is caused by poor construction, so the paving block can easily come off.

Research locations in three subaks covering an area of 59.63 ha, are in the upstream area of Denpasar City, bordering two districts (Badung in the north and Ginyar in the east). The terraced rice fields are a rainwater catchment area, water catchment area, which can be used for flood control and balancing the urban ecosystem [19]. Physical and environmental conditions, as well as the availability of data base LR, FR, HR, AR based on geosocial, agreement between pekasef and farmers are supported by legal aspects in SP, as well as world agrarian cultural heritage [20], sustainable subak academic studies [13]. The three subaks in this study that already have the data and information in accordance with what is preserved in the law and regulations are very much in compliance with the requirement to be designated as an SFAL area.

Land characteristics and land quality in three subaks are the same. This is due to the same land use pattern over the centuries, namely paddy-paddy-palawija/horticulture). The use of fertilizers with the same type and dosage since the implementation of the Bimas program in the 1970s. Water availability is sufficient, rotated in every 15 days for each Tempek/Munduk (part of the subak) according to the plant growth phase. Soil fertility levels are medium, which expressed by high CEC, BS and K, low N and P₂O₅, low to moderate C-organic, as a result of burning straw and crop residues/horticulture on the grounds to facilitate and accelerate soil cultivation, as part of farming capital. Slightly inhibited drainage and fine texture, due to the siltation process in the rice field system, medium soil solum (≤75 cm). The average rice productivity is 6.5 t ha⁻¹ and rice production is 9.5 t ha⁻¹ in Subak Margaya, West Denpasar.
sub-district [21]. Paddy rice productivity can reach 11.5 t ha\(^{-1}\) by adding dolomite in rice field, in addition to N and P. This is supported by sufficient irrigation water, raw material for volcanic rock, fine soil texture, so that without fertilizer input, rice production in Denpasar and Tabanan ranges from 4 to 5 t ha\(^{-1}\) [22].

The land suitability in the three subaks is very suitable for lowland rice. This is due to the characteristics of LR and soil management in general using the government package fertilizer for more than 40 years, suitable for horticultural crops (corn, soybean, tomato, chili, mustard greens, spinach, eggplant, watermelon). Increasing productivity is carried out by fertilizing nitrogen (N) and phosphorus (P) for lowland rice, the element of potassium is not needed, because the K in the soil is high, which comes from irrigation water from volcanic landform. Cultivating soil and making drainage channels are required for palawija and horticultural crop farming. Apart from NP fertilization, crop rotation patterns are generally rice-paddy-palawija or horticulture. The land suitability class is very suitable for all subak rice fields in Denpasar City [23, 24]. The integration is between spatial data (subak polygon) and attribute data (agroecosystem land suitability class) (figure 4). This can be operated via QGIS to determine the geospatial-based land suitability class for a particular subak and can be informed interactively.

### 3.2. Ownership of subak rice fields

Based on the ASP/NLA plot map and the revision of land ownership boundaries from the results of checking and field observations, as well as interviews with stake holders, data on the number of ownership polygons, area, number of farmers (owners and cultivator), as well as the average ownership in the three subaks were obtained and listed in table 2. The number of farmers is smaller than the number of polygons because one farmer can work with more than one owner, one reason is that the average land ownership is only 0.2254 ha. The characteristic of farmer as owner and cultivator is that they are as part-time farmers; this is the impact of the many job opportunities outside the agricultural sector that are more certain and promising, such as working in the government, private, tourism and supporting sectors. The rice field ownership map is shown in figure 5.

The average ages of farmers are 55 years old, cultivators are 57 years old. 34 to 40 years old of 2 people (0.77%), 41 people (15, 895) 41 to 50 years old, 150 people (58.14%) 5 to 60 years old, 52 people (20.16%) 61 to 70 years old and 13 people (5.04%) > 70 years old. Data and age graphs of farmers (figure 6). Most of the cultivator farmers (70.95%) have elementary school education (ESE), 11.49% of junior high school (JHS), 17.57% high school (HS). Owner’s farmer education is 62.9% ESE, 12.84% JHS, 22.94% HS and 1.83% of Diploma 3 graduates. Figure 7 shows the data and graph of the relationship between the education of the owner and tenant farmers in each subak. The number of sharecroppers with 2 (cultivator farmers): 1 (owner farmer), part-time farmers and the age of the farmers are generally between 51 to 65 years old and they have elementary school education, not professional farmers, so government programs generally pass like that of course, even if the farming is profitable.

### Table 2. Number of polygons, area of subak, owner and farmer and average ownership of rice fields in Subak Anggabaya, Umadesa and Umalayu.

| No | Subak Name | Total Polygon | Total area Subak (ha) | Total farmers (people) | Owners (people) | Cultivator (people) | Land ownership average (ha) |
|----|------------|---------------|-----------------------|------------------------|-----------------|---------------------|---------------------------|
| 1  | Anggabaya  | 96            | 23.32                 | 63                     | 28              | 12.22               | 0.2471                    |
| 2  | Umadesa    | 62            | 11.30                 | 42                     | 22              | 7.40                | 0.1779                    |
| 3  | Umalayu    | 100           | 25.01                 | 65                     | 32              | 13.25               | 0.2505                    |
|    | Total      | 258           | 59.63                 | 170                    | 82              | 32.57               | 0.2252                    |

Source: field survey (analysis of data from BPP, PPL, Pekaseh and Farmers, 2019).
The younger generation (aged ≤45 years) 13 people (7.65%) out of 170 people. In addition, SP 2011-2031 subak rice fields outside the agricultural area are 998 ha, meaning that due to SP, legally permitted rice fields can be converted into non-agricultural land [25]. Therefore the strategy of the Denpasar City Government to develop sustainable subaks through nature and cultural preservation programs is a priority program in the 2016 to 2021 Denpasar City Medium-Term Development Plan (MTDP) [26]. The land conversion control strategy in Denpasar City has been researched, the result is the draft SFAL Protection Academic Study [19]. For this reason, it is very important to determine the SFAL along with the SFAL data base to be compiled and mapped to protect Subak rice fields as a local advantage of Bali.

Tables 2, figures, 5, 6 and 7 show that farmers in the study area are dominated by smallholders, aged 51 to 60 years, primary school education and part-time farming, not professionals. Such farmer characteristics are a limiting factor in the implementation of agricultural development programs. The impact on subak rice fields functions more as a counterweight to the urban ecosystem (GOS) and the preservation of subak as a cultural heritage. This is in accordance with the mandate of Law No. 41 of
2009, Article 8, namely: in the case of a city area where there is food agriculture land, the land can be designated as SFAL to be protected [1].

The result of the joint attribute process between the land ownership map and the farmer's statistical attribute data can be done by clicking on the polygon of rice field ownership and the attribute data for the information of farmer human resources will appear. Mapping of paddy field ownership plots spatially refers to the ASP/NLA map, most of which are in accordance with field conditions. The geospatial-based data base (figure 8) can be used to comply with the SFAL Information system requirements in GR 25 of 2012 concerning SFAL Information Systems as stated in Article 28: Information products consist of textual, numeric and/or geospatial types. Likewise figures 2, 3, 4 and 5 are intended to fulfill Articles 6, 8, 10, 12, 14, 16, 18, 24 and 28 [4]. The existence of a GIS locus program makes it very easy for field survey activities to identify and refine boundaries when ownership changes occur in the field.

![Figure 8. Information on land ownership in Subak Anggabaya rice fields analysis results, 2020.](image)

The preparation of the SFAL Information System was carried out in detail at a scale of 1:5,000. Word view images downloaded via the SAS palnet, complemented by land parcel maps from ASP/NLA, are very helpful in making geospatial-based land ownership maps. Based on the description above, the enactment of the Denpasar Mayor's Regulation on SFAL Protection, the preparation of the SFAL data base and the RR containing SFAL Areas need to be guarded, because it is very urgent to protect Subak rice fields as a local excellence of Bali and the existence of agriculture in the future.

4. Conclusions

The SFAL data base consists of LR, FR, HR, AP (attribute data) and spatial data in the form of subak polygons. Attribute data are: study area of 59.63 ha, soil type of Typic Tropaquiepts, rainfall ranged of 1,500 to 2,000 mm year\(^{-1}\); semi-technical irrigated rice fields, bench terraces, good condition, 4,800 m irrigation channels, 2,470 m jogging track/farm road and 5 tractors. Rice productivity of 6.5 t ha\(^{-1}\) in moderate soil fertility is very suitable for lowland rice, suitable for secondary crops and horticulture. Fertilization of N and P, Ca and Mg increase lowland rice productivity; improving drainage and fertilization for horticultural crops.

The land ownership map refers to the ASP/NLA plot map, analysis of high-resolution satellite imagery word view and field survey at a scale of 1:5,000 and there are 258 ownership polygons, an average of 0.2257 ha per owner, the cultivated area of each farmers is 0.55 ha, a total of 170 farmers (88 cultivators and 82 owners). The average age of farmers is 55 years dominated (58.14%) of 51 to 60 years old. Most of the tenant farmers (70.95%) have elementary school education (ESE), 1.49% of junior high school (JHS), 17.57% of high school (HS). Owner's farmer education is 62.9% ESE, 12.84% JHS, 22.94% HS and 1.83% Diploma 3.

Remote sensing and GIS applications as well as ASP/NLA plot maps are very helpful in the investment and description of geospatial-based SFAL data and information. Remote sensing technology,
QGIS, Locus GIS and Android cellphones are needed to accelerate the compilation of SFAL data bases and information systems, as well as Regional Regulations on SFAL. This method is recommended for compiling the SFAL Information System research on the geospatial-based SFAL database and it is needed to complement the local government's SFAL information system, using high-resolution satellite imagery, QGs and Locus GIS, as well as ASP/NLA plot maps than can make, accelerate and improve the quality of results. This method is recommended for compiling the SFAL Information System.

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References
[1] Presiden Republik Indonesia 2009 Undang Undang Nomor 41 tahun 2009 tentang Perlindungan Lahan Pertanian Pangan Berkelanjutan. Menteri Hukum dan Hak Asasi Manusia Republik Indonesia Tahun 2009 Nomor 149 Lembaran Negara No. 5283 Nomor 19. Tambahan Lembaran Negara republik Indonesia Nomor 5279/ Jakarta. Tersedia file: http://www.dpr.go.id/dokjdh/document/uu/UU_2009_41.pdf [diakses tanggal 7 Maret 2014].
[2] Presiden Republik Indonesia 2011 Peraturan Pemerintah Nomor 1 Tahun 2011 Penetapan dan Alih Fungsi Lahan Pertanian Pangan Berkelanjutan. Menteri Hukum dan Hak Asasi Manusia Republik Indonesia Tahun 2011 Nomor 2. Tambahan Lembaran Negara Nomor 5185. Jakarta Tersedia: http://www.hukumonline.com/pusatdata/ [diakses tanggal 7 Maret 2014].
[3] Presiden Republik Indonesia 2012 Insentif perlindungan Lahan Pertanian Pangan Berkelanjutan Menteri Hukum dan Hak Asasi Manusia Republik Indonesia Tahun 2012 Nomor 19. Lembaran Negara Tahun 2012 Nomor 19. Tambahan Lembaran Negara republik Indonesia Nomor 5279. Jakarta. Tersedia: http://www.hukumonline.com/pusatdata/ [diakses tanggal 7 Maret 2014].
[4] Presiden Republik Indonesia 2012 Peraturan Pemerintah Nomor 25 Tahun 2012 Tentang Sistem Informasi Lahan Pertanian Pangan Berkelanjutan. Menteri Hukum dan Hak Asasi Manusia Republik Indonesia Lembaran Negara No. 5283 Nomor 19. Tambahan Lembaran Negara Republik Indonesia Nomor 5279. Jakarta. Tersedia:file: http://www.hukumonline.com/pusatdata/ [diakses tanggal 7 Maret 2014].
[5] Presiden Republik Indonesia 2012 Peraturan Pemerintah Nomor 30 Tahun 2012 Tentang Pembiayaan Lahan Pertanian Pangan Berkelanjutan. Menteri Hukum dan Hak Asasi Manusia Republik Indonesia. Lembaran Negara Tahun 2012 Nomor 55. Tambahan Lembaran Negara Republik Indonesia Nomor 5282. Jakarta. Tersedia: file http://www.hukumonline.com/pusatdata/ [diakses tanggal 7 Maret 2014].
[6] Presiden Republik Indonesia 2019 Peraturan presiden Noimor 59 Tahun 2019 tentang Pengendalian Alih Fungsi Lahan Sawah. Menteri Hukum dan Hak Asasi Manusia Republik Indonesia. Lembaran Negara Tahun 2019 Nomor 163. SK no 008573A www.hukumonline.com /pusatdata/ [diakses tanggal 03 April 2020].
[7] Menteri Pertanian Republik Indonesia 2012 Peraturan Menteri Pertanian No. 07/MAR/OT.140 /2/2012 Pedoman Teknis Kriteria dan Persyaratan Kawasan, Lahan, dan Lahan Cadangan Pertanian Pangan Berkelanjutan. Menteri Hukum dan Hak Asasi Manusia Republik Indonesia. Tersedia file:http:// www.hukumonline.com/ pusatdata/ [diakses tanggal 7 Maret 2014].
[8] Menteri Agraria dan Tata Ruang /Kepala Badan Pertanahan Nasional 2016 Peraturan Menteri Agraria dan Tata Ruang /Kepala Badan Pertanahan Nasional Nomor 19 Tahun 2016 Tentang Penetapan Lahan Pertanian Pangan Berkelanjutan yang Belum terdapat Rencana tata Ruang Wilayah. Direktur Jenderal peraturan Perundang Undangan. . Kemenenteri Hukum dan Hak Asasi Manusia Republik Indonesia. Berita Negara Republik Indonesia Tahun 2016 Nomor Number 727. [diakses tanggal 4 Oktober 2018].
[9] Sarwo Edhy 2020 Pencegahan alih fungsi Lanlahan. Kementrian Pertanian pada Acara Koordinasi dengan pemerintah daerah. Tersedia: https://money.kompas.com/read/2020/06/29/194251926/cegah-alah-fungsi-lahan-kementrian-siap-koordinasi-dengan-pemda?page=all [diakses tanggal 29 Juni 2020].

[10] Badan Pusat Statistik Kota Denpasar 2020 Denpasar Dalam Angka: https://denpasarkota.bps.go.id/publication/download.html/nrbvfeve. [diakses tanggal 5 Agustus, 2020].

[11] Lanya I, M Trigunashih, K Sardianal, D Atthagama and G P Ratna Adi 2019 Laporan Akhir Digisasi dan pemetaan lahan sawah subak di Kota Denpasar. Kerjasama antara Dinas Pertanian Kota Denpasar dengan Fakultas Pertanian Universitas Udayana. Kota Denpasar.

[12] Pemerintah Kota Denpasar 2011 Rencana tata Ruang Kota Denpasar 2011-n2031, 27/2011. Denpasar City Government http://perpustakaan.bappenas.go.id Downloaded on [diakses tanggal 8 July 2014].

[13] Windia W, Sumiyati, K Suamba, W Tika, A D Diasana Putra and Mundra M 2016 Laporan hasil kajian subak lestari Made Ayu Intan di Subak Angganaya, Subak Umalaya Subak Umadui, Subak Intaran Timur dan Subak Timur Intaran Barat Kota Denpasar. Kerjasama antara Dinas Pertanian Kota Denpasar dengan Pusat Kajian Subak Univeritas Udayana. Denpasar. https://simdos.unud.ac.id/uploads/file_pen Research_1. [diakses tanggal 21 Juli 2020].

[14] Lanya I and N N Subadiyasa 2016 Role of remote sensing and geophyc information system mapping for protected areas land rice field subak, buffer zones, and area conversion (case studies in Gianyar Regency) IOP Conf. Series: Earth and Environmental Science 47 (2016) 012037. doi:10.1088/1755-1315/47/1/012037 p 1-8

[15] Pusat Penelitian Tanah and Agroklimat 1994 Peta tanah semi detail Nusadua-Padang Bay Provisnsl Bali. Sheet Denpasar skala 1: 50.000. Pusat Penelitian Tanah and Agroklimat Bogor, Departemen Pertanian. Bogor.

[16] Badan Meteorologi, Klimatology and Geofisika Wilayah III Denpasar 2017 Peta Isohiet Provinsi Bali. Curah hujan tahunan Annual periode 1981 sampai dengan 2010. Badan Meteorologi dan Geofisika untuk informasi. Denpasar. http://balai3.denpasar.bmkg.go.id/normal-ch-tahunan. [diakses tanggal 20 Juli 2020].

[17] Sudadi P, Setiadi H, Sarief B R, Ruchi chat and Hadi S 1986 Peta Hidrogeologi Indonesia lembar P Bali. Direktorat Geologi dan Tata Lingkungan and Pertambangan. Bandung.

[18] Purbo Hadiwidjoyo M M, Samodra H and Amin T C 1998 Peta Geologi Bali- Nusatenggara lebar 1707 skala 1:250.000 Pusat Penelitian Geologi and Pengembangan. Bandung.

[19] Lanya I, Subadiyasa N N, Sardiana K and Ratna Adi G P 2017 Transfer function control strategy of Subak rice field land and agricultural development in Denpasar city IOP Conf. series: Earth and Environmental Science 54 2017 012004 doi:10.1088/1755-1315/54/1/012004 p 1-10

[20] UNESCO 2012 Subak System as Manifestation of the Tri Hita Karana Philosophy (St Petersburg: UNESCO)

[21] Dinas Pertanian Kota Denpasar 2018 Laporan database 2018. Dinas Pertanian Kota Denpasar Denpasar. Tidak dipublikasikan

[22] Lanya I and N N Subadiyasa 2017 Mineral Fertilizer as an Alternative Fertilizer in Increasing Rice Yield in Tabanan Regency. International Journal Of Biosciences and Biotechnology. Asia Oceania Biosciences and Biotechnology Consortium. IV(2) 99-109

[23] Lanya I, N Subadiyasa , K Sardiana and G P Ratna Adi 2019 Remote sensing and GIS applications for planning of sustainable food agriculture land and agricultural commodity development in Denpasar City. IOP Conf. Series: Earth and Environmental Science 313 (2019) 012046 IOP Publishing doi:10.1088/1755-1315/313/1/012046 p1-8

[24] Rehmamana R, Lanya I and Dibia I N. 2020 Aplikasi remote sensing dan sistim informasi geografi untuk perencanana penggunaan lahan berbasis kesesuaian lahan agroekosistem di Kota Denpasar. E-Jurnal Tropika Agroekoteknologi. 9(1) 32-42
[25] Lanya I, N N Subadiyasa and G P Ratna Adi 2018 Impact of spatial plan on the conversion of Subak rice fields and food security, in Badung and Gianyar Regencies, Bali Province *IOP Conf. Series: Earth and Environmental Science* 149 (2018) 012003 doi :10.1088/1755-1315/149/1/012003 p1-9

[26] Pemerintah Kota Denpasar 2016 *Rencana pembangunan Jangka Menengah (RPJM) Kota Denpasar 2016-2021*. Pemerintah Kota Denpasar. Denpasar