Impact of spatial plan on the conversion of Subak rice fields and food security, in Badung and Gianyar Regencies, Bali Province

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Abstract. Regional Spatial Plan of Bali Province 2009-2029, allocating rice fields can be converted 10% (± 10,800 ha). Over the next 20 years, the conversion of rice field is permitted 540 ha year⁻¹, the real condition in Bali is 800 ha year⁻¹. Research location in Badung and Gianyar Regencies. Visual satellite image interpretation methods, digitization of on-screen, delineation of subak rice field, field survey, superimpose analysis of Spatial Plan (SP) map with rice field map, trough toolbox-analysis tools–overlay-intersect using QGIS, Harvest Index (HI) of cropping pattern in one year. SP has a negative impact on agricultural land resources and food security. Local Regulation (SP), subak rice fields outside the agricultural area licensed to be converted, and food deficits. Regency of Badung, potential land conversion of 3,324.97 ha (34.44%) from 119 subak with paddy field area of 24,184.85 ha. There are 10 subak 100% and 8 subak > 95% can be converted; projected food deficit -115,343 tons of rice by 2020 for HI 2. In Gianyar Regency, potential land conversion 13,021.41 ha (53.51%) of 66 subak with an area of 24184.85 ha; 8 subak 100% and 8 subak with area < 5 ha can be converted; projected food deficit is about -194438 tons of rice in 2040 for HI 2.

1. Introduction
Subak rice field in Bali experienced conversion of 800 ha year⁻¹ for the last 10 years. Greater than the average land inventory (540 ha year⁻¹) allocated in SP [1]. Chapter 60, paragraph (1) letter a, Local Regulation No. 16 of 2009, on the SP of Bali Province, establishes 76,337 ha or 13.5% of the total area of Bali Province [2], spread over districts/cities. In the Spatial Plan Map, Bali set 11 tourism areas that the existing condition is still a subak rice field. This is contrary to the Subak conservation effort that is designated as world cultural heritage by UNESCO, 2012 [3]. Rice fields in Bali in the form of Subak land. Subak as a traditional institution, preserved and strengthened in Regional Regulation (Perda) No. 9 of 2012 [4]. As a follow-up conservation efforts Subak, the Regional Government of Bali, the Regency has programmed through grants for institutional management and farming activities.

The grant aid is not based on the Subak area, meaning the narrow Subak region (<5 ha) and large (> 100 ha) receive the same grant. Therefore, there are Subak that do expansion which has an impact on the increasing of rice field area [5]; only based on statistical data [6]. The research of Subak land function control strategy, through zoning text and zoning map with remote sensing technology and GIS, produces Subak of the conservation area, buffer and it can be converted [7]. The results of these studies can assist local governments in drafting legislation for Academic Studies, Sustainable Food
Agricultural Land Protection, as mandated in the Act No. 41 of 2009 [8] and Government Regulation No. 1 of 2011 [9].

The regencies of Badung and Gianyar are selected as a research area, as these two districts are experiencing very rapid tourism development compared to the other 6 districts in Bali. Prior research, the highest land conversion function is located around the centers of tourism areas [6].

Based on the above description, research on SP impact on the sustainability of Subak rice field and food balance in Bali needs to be done. Given the subak as a local genius of Bali potentially conflict of interest with the needs of tourism development. The purpose of this study is to analyze the existence of Subak, such as the potential loss of number, name, and area of Subak rice field, the potential conversion of the Subak rice field in a certain year. Furthermore, it is used to calculate the potential of food supply and projection of food balance in Badung and Gianyar regency. Both districts are experiencing with the development of tourism which is very rapid in Bali Province. The hope of Bali SP map can be refined to minimize conversion of Subak rice field and food deficit in both Regencies and as well as in other regencies in Bali.

2. Material and Methods
Research location is in two Regencies, namely Badung and Gianyar Regency, Bali Province. The 2013 Quick Bird satellite image for research location and image map creation in 2015 was used. The research material consists of Quick Bird satellite images 2013, SP map for Badung and Gianyar Regency, a map of SP, and Quantum GIS (QGIS) software version 10.3. Research methods are multi-analytics, ie: (1) literature study through secondary data collection: Subak data from the Central Bureau of Statistics, map of SP, administration map, (2) visual interpretation of Quick Bird satellite images: delimitation and delineation land use, (3) the field survey to obtain information boundaries of Subak, area, production yield, and cropping pattern, (4) analysis of thematic maps using QGIS: (a) digitization of on-screen delineation of subak rice field, (b) super impose analysis of thematic map between the paddy rice field map and SP map, (c) toolbox - analysis tools – overlay - intersect, (d) identify the result of overlapping of Subak rice filed inside and outside the agricultural land in the SP map, (5) food balance analysis: projected population and food needs, projected area of rice field and food supply. Harvest index (HI) is calculated from rice cropping pattern in one year, HI 1 = rice production only one harvest in one year and HI 2 = rice production in one year twice harvest.

3. Result and Discussion
3.1. Map of the rice fields of Badung and Gianyar regencies
The visual interpretation results of the 2013 Quick Bird satellite imagery and the 2015 field survey, the digitization of on-screen border of subak rice fields, and the layout of rice field use maps for Badung and Gianyar regencies are shown in figure 1 and figure 2. Figure 1 and figure 2 shows that the rice fields spread throughout the region. Especially for Badung regency, the upstream (north) in Petang District and in the southern part (South Kuta District) is dominated by dryland farming. In contrast to Gianyar, where dry land only in the upstream (Tegallalang District).

Dryland is not discussed further because in this study the objective is to obtain subak rice data used for the analysis of land conversion and food balance in a certain year. These data include the names and extent of subak in each village used. District map of subak is used for overlay process with Plan map of Space of each district. Based on the Subak rice field map, it was obtained 119 Subak for Badung Regency and while for Gianyar Regency there are 66 Subak.
Figure 1. Land use map of Subak rice field in Badung Regency (analysis, 2016).

Figure 2. Land use map of Subak rice field in Gianyar Regency (analysis, 2016).
3.2. Map of Land Use of Subak Rice Field with Area of Food Crop Farming in Map of Spatial Plan of Badung and Gianyar Regency

The result of the overlap between Subak rice field map and the area of crop farming land in the spatial planning map of Badung and Gianyar regencies is shown in figure 3 and figure 4. Figure 3 and 4 show that Subak rice fields inside (green color) and outside (brown color) areas of cropland farming in Badung Regency of 3,324.97 ha (34.44%) and in Gianyar Regency 13,021.41 ha (53.51%). The brown color is Subak rice field located in the tourism area, in which outside the agricultural area is generally allocated for tourism accommodation facilities. The potential for conversion of Subak rice fields land is around Kuta paradise area, Ubud, western Gianyar area which is bordered by Denpasar City and Badung Regency, and Ida Bagus Mantra road access. This means that legally aspect of the rice field is allowed to be converted, because it is allocated for tourism accommodation, such as hotels, restaurants and supporting facilities. Examples of Subak rice data in each Subak and village for each district are presented in table 1 and table 2.

Data of the result of identification and analysis of all paddy fields (119) Subak in Badung regency got a total area of 9,653.77 ha. Spread throughout the District, except South Kuta District is dominated by dry land. The number of Subak in each district is Petang 16 subak with the area as follow of 993.84 ha, Mengwi 48 Subak with wide of 3,303.34 ha, Abiansemal 34 Subak with wide 2,918.12 ha, North Kuta 19 Subak with wide of 1,406.75 ha, and Kuta 2 Subak with wide 31.12 ha. Rice field area inside agricultural land area 6,328.80 ha (65.56%) and rice field area outside agricultural land area 3,324.97 ha (34.44%).

Subak that will be lost 100% as many as 10 subak with an area of 237.7 ha and potentially lost (area <5 ha) as much as 8 Subak with an area of 286.96 ha.

The total area of Subak (66) in Gianyar Regency is 24,184.85 ha, located in seven districts. Blahbatu District 9 Subak area of 1,859 ha, Gianyar District 19 Subak area 2,102 ha, District Payangan 7 Subak area 1,411 ha, Sukawati District 12 area 2,721 ha, sub-district Tampaksiring 9 Subak area 1,160 ha, Tegallalang District 7 Subak area 1,238 ha, Ubud District 7 Subak area 1,553 ha. Rice field area inside agricultural land area is about 11,163.46 ha (46.49%) and rice field area outside/converted the agricultural land area 13,021.41 ha (53.51%). 100% of the Subak rice field will be lost, converted to non-farm use by 8 subak, with a total area of 1,630.69 ha. The potentially lost (area < 5 ha) amounted to 8 Subak with an area of 1,849.18 ha.

Example of rice field allocation in agricultural area in SP of Badung Regency for central tourism area in Kuta District 0.07 ha from 31.12 ha, it means that it can be converted 99.77% area, for North Kuta area of rice field 282.34 ha from 625.06 ha or 54.83% can be converted, while for Mengwi District rice field area of 99.47 ha from 133.88 ha, may be converted 25.70%. Similarly, the allocation of rice fields in the area of agricultural land in SP Gianyar regency for central tourism area of Ubud only 34.48 ha from 1,555 ha, or 97% of rice fields may be converted, while for District Tampaksiring rice field 850.19 ha from 1161 ha or 26.77%.

Whereas the potentially lost with an area <5 ha is located in the city centers. Especially for Gianyar Regency, the potential loss of paddy field Subak is located in the border area with Badung Regency and Denpasar City by the beach, and around the main access road tourism Ida Bagus Mantra road. The main cause is the supply of land for non-agricultural development in the two districts is only a Subak rice field. Legally aspect, the transfer of rice field is allowed to be converted to non-agriculture, due to the Regional Regulation and Spatial Plan Map of the territory. In other words, the development of tourism in both districts has a negative impact on agricultural land resources in the form of rice field Subak, especially in the food supply.
Figure 3. The result of the overlap between paddy field map and agricultural land area on the spatial map in every Subak and village area in map of SP Badung Regency 2012-2032 [10].

Figure 4. The result of the overlap between paddy field map and agricultural land area on the spatial map in every Subak and village area in Map of SP Gianyar Regency 2012-2032 [11].
Table 1. The Sample of Subak rice field in each village in District of Badung Regency.

| No | Subak Name          | Name of Village | Area of Rice Field Subak (ha) | Area of Subak Rice Field in Agricultural Area (ha) | Area of Subak Rice Field in Agricultural Area (%) |
|----|---------------------|-----------------|-------------------------------|---------------------------------------------------|---------------------------------------------------|
|    |                     |                 |                               |                                                   |                                                   |
|    | Mengwi District:    |                 |                               |                                                   |                                                   |
| 1  | Babakan Sobangan    | Sobangan        | 42.34                         | 37.46                                             | 88.47                                             |
| 2  | Babangan           | Kwum            | 44.94                         | 34.10                                             | 75.88                                             |
| 3  | Batan Asem         | Mengwi Tani     | 3.74                          | 1.73                                              | 46.26                                             |
| 4  | Batan Badung       | Gulingan        | 30.00                         | 25.59                                             | 85.30                                             |
| 5  | Batan Wani         | Sading          | 12.86                         | 0.59                                              | 4.59                                              |
|    | Total              |                 | 133.88                        | 99.47                                             | 74.30                                             |
|    | North Kuta District: 10 samples from 19 Subak | | | | |
| 1  | Banjar Sari        | Tibubeneng      | 47.08                         | 3.46                                              | 7.35                                              |
| 2  | Bantan             | Tibubeneng      | 50.75                         | 37.70                                             | 74.29                                             |
| 3  | Daksina            | Tibubeneng      | 57.56                         | 37.35                                             | 64.89                                             |
| 4  | Dawas              | Tibubeneng      | 16.89                         | 1.18                                              | 6.99                                              |
| 5  | Gaji               | Dalung          | 60.94                         | 28.21                                             | 46.29                                             |
| 6  | Petitenget         | Kerobokan Klod | 59.82                         | 0.00                                              | 0.00                                              |
| 7  | Sahi               | Dalung          | 140.10                        | 34.95                                             | 24.95                                             |
| 8  | Tegal              | Kerobokan Kaja  | 88.34                         | 68.58                                             | 77.63                                             |
| 9  | Umaalas            | Canggu          | 16.72                         | 0.00                                              | 0.00                                              |
| 10 | Umadesa            | Canggu          | 86.86                         | 70.91                                             | 81.64                                             |
|    | Total              |                 | 625.06                        | 282.34                                            | 45.17                                             |
|    | Kuta District : 2 Subak |             |                               |                                                   |                                                   |
| 1  | Abianbase          | Kuta            | 19.09                         | 0.07                                              | 0.37                                              |
| 2  | Seminyak           | Seminyak        | 12.03                         | 0.00                                              | 0.00                                              |
|    | Total              |                 | 31.12                         | 0.07                                              | 2.25                                              |

Table 2. The Sample of Subak rice field in each village in District in Gianyar Regency.

| No | Name of Village | Area of Subak Rice Field (ha) | Area of Subak Rice Field in Agricultural Area Ha | Area of Subak Rice Field outside Agricultural Area Ha |
|----|-----------------|-------------------------------|-----------------------------------------------|-----------------------------------------------------|
|    |                 |                               | Area of Subak Rice Field Field in Agricultural Area % | Area of Subak Rice Field in Agricultural Area % |
|    |                 |                               |                                               |                                                   |
|    | Tampaksiring District: 9 Subak | | | | |
| 1  | Manukaya        | 111                           | 30.63                                        | 27.59                                               | 58.16                                               | 52.40                                             |
| 2  | Pejeng          | 99                            | 65.45                                        | 66.2                                                | 33.41                                               | 33.80                                             |
| 3  | Pejeng Kaja     | 146                           | 113.64                                       | 77.59                                               | 32.82                                               | 22.41                                             |
| 4  | Pejeng Klod     | 64                            | 41.99                                        | 65.87                                               | 21.76                                               | 34.13                                             |
| 5  | Pejeng          | 193                           | 153.01                                       | 79.38                                               | 39.75                                               | 20.62                                             |
| 6  | Pejeng Kangin   | 163                           | 152.79                                       | 93.85                                               | 10.00                                               | 6.14                                              |
| 7  | Pejeng Kawan    | 22                            | 7.00                                         | 32.36                                               | 14.63                                               | 67.64                                             |
| 8  | Sanding         | 80                            | 52.32                                        | 65.2                                                | 27.92                                               | 34.80                                             |
| 9  | Tampaksiring    | 283                           | 233.36                                       | 82.48                                               | 49.58                                               | 17.52                                             |
|    | Total           | 1161                          | 850.19                                       | 73.23                                               | 310.81                                              | 26.77                                             |
|    | Ubud District: 8 Subak |             |                               |                                                   |                                                   |
| 1  | Lohtunduh       | 268                           | 3.01                                         | 1.12                                                | 264.52                                              | 98.87                                             |
| 2  | K edewatan      | 72                            | 0.00                                         | 0.00                                                | 71.64                                               | 100                                               |
| 3  | Mas             | 279                           | 3.45                                         | 1.23                                                | 270.41                                              | 96.92                                             |
| 4  | Peliatan        | 121                           | 3.66                                         | 3.02                                                | 117.37                                              | 96.98                                             |
| 5  | Petulu          | 121                           | 0.36                                         | 0.3                                                 | 120.19                                              | 99.70                                             |
| 6  | Sayan           | 154                           | 0.00                                         | 0.00                                                | 153.60                                              | 100                                               |
| 7  | Singakerta      | 359                           | 8.00                                         | 2.23                                                | 350.57                                              | 97.77                                             |
| 8  | Ubud            | 181                           | 16.00                                        | 8.86                                                | 164.58                                              | 91.20                                             |
|    | Total           | 1161                          | 850.19                                       | 73.23                                               | 310.81                                              | 26.77                                             |
3.3 Food Balances

Regional Regulation (Perda) No 16 of 2009 on Spatial Plans Bali, impact on the decrease of wetland area. Similarly, for the SP of Badung Regency in 2012–2032 and SP of Gianyar Regency in 2013–2033. Potential decreased food security, with a deficit food balance of -115,343 and -679,984 tons of rice in 2030 and 2050 in Badung regency. For Gianyar Regency, food balance also deficit = -225,516.5 for harvest index (HI) 1 or -695227 tons of rice for HI 2 by 2030. Food deficit increased by 2050 as much as -728799 tons of rice for HI 1 or -1016319 tons of rice for HI 2. Analysis population projection, food demand and food supply for Badung and Gianyar Regencies are shown in figure 5 and 6. Based on figure 5 and 6, the projected food demand is inversely proportional to the food supply in these two regions. Food demand increases in line with population growth over time, while food supply declines as the impact of uncontrolled conversion of rice field.

The permissible allocation of land in both districts is very high, affecting food security is weakening, it is necessary to revise the local regulation of SP. The revision of the SP is very urgent to be conducted in order to reduce rice field allowed to be converted. This is related to the preservation of Subak rice field as a source of sustainable food. In line with the process of control over the function of rice field into the non-agricultural land, a strategy is required by law, the Provincial Regulation on the Protection of Agricultural Land for Sustainable Food, so that the fields are not converting Subak continuously.

Another strategy to reduce food deficit is the development agricultural program of increasing paddy rice production of more than 6.5 tons ha\(^{-1}\) each harvest [4], and an increase of HI more than 2, through the five farming. The rapid increase of production can be through the addition of fertilizer in accordance with the needs of the plant, it is expected that the production will increase by 50-100% from the national average production of 4.5 tons ha\(^{-1}\). However, besides the development, maintenance and conservation of irrigation water are very necessary to increase the HI from 1 to 2.5.

**Figure 5.** The Balance of food for Badung Regency in 2015-2050.

**Figure 6.** The Balance of food for Gianyar regency in 2015-2050.
4. Conclusion and Recommendation

4.1. Conclusion
Regional Spatial Plans have negative impacts on agricultural land resources and increasing food deficit, especially in the center of the area satisfied tourist destinations, such as District of Kuta and Ubud.

Legally aspect (Perda SP), Subak paddy field that can be converted function to tourism area and its supporting in Badung Regency is 99.77% in Kuta District, decreasing 54.83% in South Kuta District and 25.70% in Mengwi Sub-district. For Gianyar Regency, Subak rice field which is designated as the highest tourism area is 97.78% in Ubud sub-district and 26.77% in Tampaksiring District.

Food deficit in Badung and Gianyar Regencies continues to increase, in line with population growth, the uncontrolled rate of rice field conversion, low rice production, and the establishment of Subak rice fields as non-agricultural areas in SP.

4.2. Suggestion
Revision of Spatial Plans is needed to protect the Subak rice fields as cultural heritage, nature conservation, and local food security. Especially in the area of Ubud tourism center, accessibility around the road Ida Bagus Manera, Gianyar border with Denpasar, and North Kuta district.

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