Land use land cover change in Badung Regency, Bali

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Abstract. Demand for land use can cause an undesirable impact. Bali Island has been exploited as the midpoint of tourism activities and altering land use over the last two decades. Badung regency is the hinterland area of Denpasar City, the capital city of Bali Province. Land conversion in Badung was caused by the construction infrastructures related to tourism development. Conversion occurred from agricultural lands to built-up lands. This research analyzed remote sensing data, taking the advantage of abundant, serial data acquisition. This study used Landsat 7 ETM and Sentinel 2 satellite images obtained from 2010 to 2020. Land cover types were identified by visual interpretation and LULC changes were analyzed by overlaying land use maps. Identified land-use types included eight categories, i.e. paddy fields, forests, mangroves, built-up areas, mixed gardens/plantations, upland fields, shrubs, and water bodies. Land use has changed significantly in the past 10 years especially in built-up areas, upland fields, and paddy fields. The trend showed that built-up areas persistently increased from 2010 to 2020. Paddy fields, shrubs, mixed gardens/plantations, and mangroves fluctuated in terms of the acreage; rose from 2010 to 2015, but were reduced in the rest of the period. Water bodies did not change throughout.

1. Introduction
The land is a physical environment comprising soil, climate, relief, hydrology, and vegetation that affect its potential use [1]. Land use is a form of human intervention in meeting their needs by utilizing existing land availability [1]. Increasing demand for land use endures with the necessities of human life [2], in which, uncontrolled land use and land cover (LULC) change deliver a negative influence.

LULC change is most likely to occur in urban areas and their hinterland, where urban expansion influences land utilization in hinterland areas [3]. Urban expansion is linked to the urbanization process which tends to increase every year, especially in developing countries. In Southeast Asia, urban expansion was about 2.8% higher than the ones that happen in the rest of the world [4,5]. In Indonesia, a similar pattern has been observed, with a higher concentration of change was seen in Java. The exceptional LULC change phenomenon in Indonesia has been in the Greater Jakarta Metropolitan Area. It generally converts agricultural lands into built-up areas like residential and industrial estates. The conversion related to residential areas was evenly distributed throughout the Greater Jakarta area, while alteration into industrial areas was concentrated in Bekasi and Tangerang regencies and municipalities [6,7]. LULC changes has also been observed in Surabaya City, dominated by conversion from ponds and mangrove forests into settlements of Sub Central Business District of Surabaya City [3].
Bali Island has been exploited as the center of tourism activities in Indonesia since the 20th century [8]; hence, it has also been a subject to land-use conversion. From previous research, 54% of land use has changed over 16 year period in Bali [9]. The alteration was concentrated in Sarbagita, the metropolitan area of Bali Island [8]. As a hinterland of Denpasar City, and also a part of the Sarbagita area, Badung Regency has experienced land-use changes caused by the construction of accommodation and other infrastructures for tourism development [10]. This is a direct consequence of developing tourism sectors and increasing population in Badung Regency. As a result, the demand for land-use change is high [11] and often consumes prime agriculture lands to accommodate requests in built-up lands, both for settlements and buildings [8]. As land alteration usually occupies large areas and could be scattered, monitoring such important issues requires a specific monitoring scheme, with special mention of analyzing data from Earth-observing satellites.

Spaceborne remote sensing data have been demonstrated to be useful for monitoring land use and land cover change because of abundant data available to the public [11]. Remote sensing data can be integrated with Geographic Information System (GIS) to investigate a LULC change and they were shown to be an efficient tool [8]. This study analyzed land use land cover change from 2010 – 2020 covering the whole Badung Regency, the hinterland area of Capital City of Bali Province [8]. A preliminary research reported in this article will continue to analyze land use and land cover prediction in 2030 based on spatial planning of Badung Regency.

2. Methodology

2.1. Study Area
This research is located in Badung Regency, Bali (Figure 1). It has 6 districts, i.e. North Kuta, Kuta, South Kuta, Mengwi, Abiansemal, and Petang Districts. Geographically, Badung Regency cover 8°14′01″ South - 8°50″52″ South and 115°05′03″ East - 115°25′51″ East, or about 418.52 km2, occupying 7.43% of the entire island of Bali. Total inhabitant in 2019 was 670,200; rose significantly from 543,332 in 2010 and 615,146 in 2015.

Figure 1. Administration of Badung Regency (The Study Area)
2.2. Data Sets and Research Framework
This research exploited Landsat 7 ETM image of 2010 and Sentinel 2 images in 2015 and 2020. All imageries were employed to derive land cover data with the following categories: paddy fields, forests, mangroves, built-up areas, mixed gardens/plantations, upland fields, shrubs, and water bodies, covering the whole regency. Satellite images were analyzed by visual interpretation, yielding a series of the map with a scale of 1:50,000 to comply BIG National Standards for District Level.

Land use interpretation was carried out through delineation of objects guided by elements of interpretation, including color, shape, size, pattern, shadow, texture, site, and association [13]. To better recognize the objects, band combination was displayed in Red Green Blue (RGB) format. This research employed a true color band combination that is 321 for both Landsat 7 and Sentinel 2. Remote sensing data were processed using ENVI 5.1 for image processing and ArcMap 10.7.1 for visual interpretation. After interpretation was completed, LULC change analysis was carried out.

Change analysis was done by investigating interpretation results based on 2010, 2015, and 2020 datasets. The change was calculated from the following pair of data: 2010 and 2015 images, 2015 according to the 2020 map, and the entire period of observation (2010 to 2020) (Figure 2). Boolean overlay was done in GIS software. By calculating the difference of acreage, LULC change was assessed and evaluated.

3. Results and Discussion
3.1 Land Use Land Cover Changes during 2010 - 2015
The most significant change in the 2010 - 2015 period was in paddy fields, while the smallest one was in mangroves. During the period—, paddy field coverage increased by 6,089.08 ha, while, forested areas were reduced by 6,033.6 ha. Regions covering mangroves, built-up, mixed gardens, and shrubs were increased by 2.5 ha, 2,648.1 ha, 2,648.1 ha, and 3,533.6 ha, respectively. Uplands were found depleted significantly (8,309.8 ha); while water bodies did not change (Table 1) as they were fully represented by the sea. Changes was predominantly forest to garden/plantation conversion in the northern part of Badung Regency, suggesting eminent deforestation and/or forest degradation. In the middle slope of the test site, land alteration was due to rice intensification that was developing more rice irrigated fields from existing uplands. The southern part of the region is generally urbanized areas, making sense of
upland conversion to urban-related land-use types such as shrubs and built-up (Figure 3). In this region, shrubs were considered as abandoned lands prior to further development as built up.

Table 1. LULC Change of Badung Regency in 2010-2015

| Land Use            | Area (ha) | 2010   | 2015   | LULC Change Calculation (ha) |
|---------------------|-----------|--------|--------|-----------------------------|
| Paddy Field         | 5,762.4   | 11,851.4 |       | 6,089.0                     |
| Forest              | 6,046.7   | 13.1   |        | -6,033.6                    |
| Mangrove            | 580.5     | 583.0  |        | 2.5                         |
| Build Up Area       | 6,972.9   | 9,621.1 |       | 2,648.1                     |
| Garden/Plantation   | 3,825.6   | 5,544.4 |       | 1,718.8                     |
| Upland Fields       | 14,838.9  | 6,529.1 |       | -8,309.8                    |
| Shrub               | 772.7     | 4,306.3 |       | 3,533.6                     |
| Water bodies        | 42.3      | 42.3   |        | 0                           |

3.2 Land Use Land Cover Changes in 2015 - 2020

Within the 2015 - 2020 time span, built-up areas were the most important change, which was understood as the outcome of urbanization. During the period, the smallest change was in the forest. While this was seen as an improvement compared to the prior period, insignificant changes in conservation areas should be further examined. In the 2015 - 2020 period, notable land-use types being decreased included paddy fields, forests, mangroves, mixed gardens/plantations, upland fields, and shrubs. As Table 2 suggests, the largest depletion occurred in shrubs covering 1,526.2 ha; followed by uplands of 246.2 ha, mixed gardens/plantations of 114.1 ha; paddy fields of 97.5 ha; and mangroves of 0.7 ha. Water bodies did not change throughout. Land-use changes were largely conversion of mixed gardens/plantations into agricultural fields, either upland or paddy fields in the northern part of Badung Regency. Conversion in the middle and southern part of Badung Regency was due to built-up expansion which consumed upland fields (Figure 3).

Table 2. LULC Change of Badung Regency in 2015-2020

| Land Use            | Area (ha) | 2015   | 2020   | LULC Change |
|---------------------|-----------|--------|--------|-------------|
| Paddy Field         | 11,851.4  | 11,753.9 |       | -97.5       |
| Forest              | 13.1      | 12.5   |        | -0.6        |
| Mangrove            | 583.0     | 582.3  |        | -0.7        |
| Build Up Area       | 9,621.1   | 11,915.9 |     | 2,294.7     |
| Garden/Plantation   | 5,544.4   | 5,430.2 |       | -114.1      |
| Upland Fields       | 6,529.1   | 6,282.9 |       | -246.2      |
| Shrub               | 4,306.3   | 2,780.1 |       | -1,526.2    |
| Water bodies        | 42.3      | 42.3   |        | 0           |

3.3 Land Use Land Cover Changes in 2010 – 2020

The most significant LULC change in the 2010 - 2020 period was related to paddy fields, while the smallest one was in mangroves. Around 5,991.5 ha of new rice fields were yielded, indicating efforts in securing foods in the outskirt of Denpasar. As a consequence of bordering megacity, land-use conversion into built-up areas was similarly high, i.e. 4,942.9 ha. Although less significant, conversion in shrublands, mixed gardens/plantations, or mangroves was notably important in future investigation. The largest depleting land-use class was upland fields, followed by forest. These statistics suggested that land-use change in the test site was generally related to the conversion of upland fields, which may not
entirely be productive. Location-wise, dominant changes were from forests situated in the northern part of the regency. In the middle and southern parts, change was predominantly from upland fields to built-up areas (Figure 3).

### Table 3. LULC Change of Badung Regency in 2010-2020

| Land Use            | Area (ha) | LULC Change |
|---------------------|-----------|-------------|
|                     | 2010      | 2020        |             |
| Paddy Field         | 5,762.4   | 11,753.9    | 5,991.5     |
| Forest              | 6,046.7   | 12.5        | -6,034.2    |
| Mangrove            | 580.5     | 582.3       | 1.7         |
| Build Up Area       | 6,972.9   | 11,195.9    | 4,942.9     |
| Garden/Plantation   | 3,825.6   | 5,430.2     | 1,604.6     |
| Moor                | 14,838.9  | 6,282.9     | -8,556.0    |
| Shrub               | 772.7     | 2,780.1     | 2,007.4     |
| Water bodies        | 42.3      | 42.3        | 0           |

3.4. Trend of Land Use Land Cover Changes

From the aforementioned periods, the LULC trend in Badung Regency during the 2010-2020 observation is obtained (Figure 4). This trend shows that forests and upland fields continued to experience a decrease. The built-up area consistently increased; nonetheless, forest and upland areas depleted. The remaining land uses classes, i.e. rice fields, mangroves, gardens/plantations, and shrubs fluctuated during the time span.
Figure 3. Land Use Land Cover of Badung Regency in (a) 2010, (b) 2015, and (c) 2020.

In the northern part of the site, LULC changes occurred as a result of deforestation. The outcome of the process was predominantly plantations, settlements, and rice fields. This area is generally hilly, with the majority of the population relied on activities related to the agricultural sector [14]. In central and southern parts of Badung Regency, expanding built-up areas continued throughout the observation period through converting dry fields. Denpasar City appeared to put pressure on urban expansion, hence,
promoting more conversion of less productive agricultural fields. Livelihoods of the population in the middle and southern region have mostly engaged in tourism, trade, and service sectors [14].

Table 4. LULC change at Badung Regency

| Land Use        | 2010       | 2015       | 2020       |
|-----------------|------------|------------|------------|
|                 | Area (ha)  | %          | Area (ha)  | %          | Area (ha)  | %          |
| Paddy Field     | 5,762.4    | 14.8       | 11,851.4   | 30.7       | 11,753.9   | 30.2       |
| Forest          | 6,046.7    | 15.5       | 13.1       | 0.03       | 12.5       | 0.03       |
| Mangrove        | 580.5      | 1.4        | 583.0      | 1.5        | 582.3      | 1.5        |
| Build Up Area   | 6,972.9    | 17.9       | 9,621.1    | 25         | 11,915.9   | 30.7       |
| Garden/Plantation| 3,825.6    | 9.8        | 5,544.4    | 14         | 5,430.2    | 14         |
| Moor            | 14,838.9   | 38.2       | 6,529.1    | 16.9       | 6,282.9    | 16.1       |
| Shrub           | 772.7      | 1.9        | 4,306.3    | 11.1       | 2,780.1    | 7.1        |
| Water bodies    | 42.3       | 0.1        | 42.3       | 0.1        | 42.3       | 0.1        |

Figure 4. Percentage of LULC Changes Trend in Badung Regency 2010 – 2020.

4. Conclusion

Land use types in Badung Regency fell into eight categories; i.e paddy fields, forests, mangroves, built-up areas, mixed gardens/plantations, upland fields, shrubs, and water bodies. Land use in the area of interest has changed significantly in the past 10 years especially in built-up areas, upland, and paddy fields. In 2010 built-up areas covered 6,972.9 ha (17.9%) and substantially increased to 11,915.9 ha (30.7%) in ten years. Upland areas were recorded about 14,838.9 ha (38.2%) in 2010 and were halved to 6,282.9 ha (16.1%) in 2020. Satellite image interpretation revealed a substantial increase in paddy fields acreage. i.e. about 5,762.4 ha (14.8%) in 2010 and almost doubled in 2020 (11,753.9 ha; 30.2%).

Badung Regency experienced a continuing increase in built-up areas during the period of interest, as a result of growing Denpasar city. Forested lands and agriculture uplands depleted significantly, alarming deforestation and/or forest degradation that could be detrimental to the neighboring environment. It appears that in the effort of supporting the needs of Denpasar, intensification happened and therefore altering upland fields into a more productive land-use type. Nonetheless, the research
showed a fluctuating pattern observed in paddy fields, shrubs, mixed gardens/plantations, and mangroves, which expanded during the 2010 to 2015 time span but reduced in the rest of the period of observation. This research found that water bodies did not change over the duration.

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