Habitat suitability analysis for the olive ridley sea turtle (*Lepidochelys olivacea*) nesting using geospatial approach

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Abstract. The degradation of coastal habitats has the potential to drastically reduce sea turtle populations. The research focuses on the habitat suitability analysis for the olive ridly sea turtle (*Lepidochelys olivacea*) nesting. The suitability level of turtle nesting habitat can be known by analysing some parameters, by utilizing remote sensing technology and geospatial processing. This research aim was to analyze the effect of environmental parameters on the suitability areas for olive ridley sea turtle spawning habitat and to map the suitability location for olive ridley sea turtle spawning ground. The study area was the Kuruma Asih Turtle Conservation Area in Jembrana Regency, Bali, Indonesia. The research was descriptive research with survey, interview and observation approaches. The analysis was done by geospatial analysis with the use of Digital Elevation Model (DEM) data, as well as Landsat 8 satellite image. Based on the analysis of DEM and Landsat 8 images, it was obtained that the condition of the beach slope was included in the class of slightly sloping slope, the ranges of surface temperature was 25–31°C and medium to high density vegetation was identified as the dominant habitat feature. The results obtained on the suitability map of turtle nesting habitat was included in the suitability category with the a level of accuracy of 87%. Based on the three parameters applied, land use followed by the beach slope were the parameters that most affected the suitability of turtle spawning habitat in the study area. The suitability of turtle spawning habitat was included into quite appropriate categories.
Key Words: Digital Elevation Model, hatching rate, satellite images.

Introduction. The degradation of coastal environments directly affects the nesting habitats of sea turtles along the coastal area of Bali Island, Indonesia due to human activities and natural factors. Bad nesting conditions in the coastal area can determine a decrease in sea turtle populations dramatically. The olive ridley sea turtle (*Lepidochelys olivacea*) is stated in the Red Data Book of the International Union for Conservation of Nature and Natural Resources (IUCN 2021) as a vulnerable species, which means that the turtle is threatened with extinction due to several factors and one of which is the damage to species nesting habitat.

Turtles are animals that during their lifetime migrate from one place to another. Turtles can migrate along the Pacific Ocean, Indian Ocean and Southeast Asia. Six of the seven species of sea turtles can be found in Indonesia, namely the green turtle (*Chelonia mydas*), leatherback turtle (*Dermochelys coreaceae*), loggerhead turtle (*Caretta caretta*), hawksbill turtle (*Eretmochelys imbricata*), flat turtle (*Natator depressa*) and olive ridley sea turtle (*Lepidochelys olivacea*) (Mardiana et al 2015). As the second smallest and most abundant of all sea turtles found in the world, the olive ridley sea turtle (*Lepidochelys olivacea*) is a species of turtle included in the family Cheloniidae. This species is also known commonly as the Pacific ridley sea turtle. *Lepidochelys olivacea* lives in warm and tropical seas, particularly in the Pacific and Indian Oceans, but is is also found in the Atlantic Ocean's warm waters (WWF-India 2020).

Sea turtles have an amphibious nature and are dependent on two habitats, namely land and water. Sea turtles can be found from shallow marine waters to deep sea waters; however, female turtles migrate to the coast during their nesting season, to make nests and lay eggs. In general, the nesting areas of olive ridley sea turtle are sandy beaches on islands near deep sea waters. Turtles choose their nesting habitat not arbitrarily. The distance from the shoreline to the mainland will affect the percentage of hatching eggs. The closer the location to the mainland, the higher the percentage of hatching eggs will be (Nurhidayati et al 2013). In addition, the hatching time and hatching rate of eggs are also influenced by the surrounding land cover, the shadier the turtle nesting area is, the safer the turtle nests will be and the better the hatching eggs will be (Sukada 2009). The waters of West Bali island are one of the areas that are often used as nesting grounds by the olive ridley sea turtle (*Lepidochelys olivacea*) (Nuitja 1992). Turtle nesting habitat is one of several important matters regarding their conservation activities. Information on turtle nesting habitat can be used to determine the suitability of the turtle nesting habitat, so that conservationists can take further actions such as improving the surrounding environment and keeping it in good condition, besides information on land suitability for turtle nesting habitat which can help make it easier for conservationists to collect turtle eggs and transfer them to a semi-natural nest. The turtle nesting habitat can be known in advance by analyzing several parameters that can be obtained by utilizing remote sensing technology.

The use of remote sensing satellite technology with spatial analysis is one of the techniques in Geographical Information Systems (GIS) which is very good in providing information about several environmental conditions that can be used as a parameter to see the suitability of the turtle nesting habitat (Fathin 2016). This studys aim was to analyze the effect of environmental parameters on the suitability areas for olive ridley sea turtle spawning habitat and to map the suitability area for olive ridley sea turtle spawning ground in the Kuruma Asih Turtle Concervation Area, Jembrana Regency, Bali, Indonesia.

Material and Method

Dataset. This research is a descriptive study based on survey methods, interviews and observations. The aspects discussed in this study were related to the analysis of the land suitability map for *Lepidochelys olivacea* in the Kuruma Asih Turtle Conservation Area. The reseach was conducted form March 2019 to February 2020. Research location is part of Jembrana Regency, Bali, Indonesia (Figure 1).

Primary data used were turtle nest distribution data obtained through field surveys and interviews with conservationists at the Kurma Asih Perancak Turtle Conservation Area, Bali, Indonesia. Secondary data used in this study was Digital Elevation Model (DEM) data from www.tides.big.go.id, and also Landsat 8 satellite image data from www.earthexplorer.usgs.gov. Satellite data processing and analysis was carried out with the help of QGIS software (QGIS Develotment Team 2019). The data was analyzed using spatial analysis to determine the percentage of the beach slope, land surface temperature, and land use in coastal area of Jembrana Regency, Bali. Overall data analysis will produce information about the suitable area for olive ridley sea turtle nesting habitat.

Coastal slope analysis. The DEM data used in this study came from Ifsar, Terrasar-X and Alos Palsar data. Slope value was obtained by processing the elevation data and applying the reclassify 3D analyst tools in the GIS. Three slope classes were identified, which we present in Table 1.

Table 1

Slope classes

Slope (%)	*Score*	*Slope classes*
0 – 3	1	Flat
3 – 8	2	Slight ramps
8 – 16	3	Sloping
>16	1	Steep

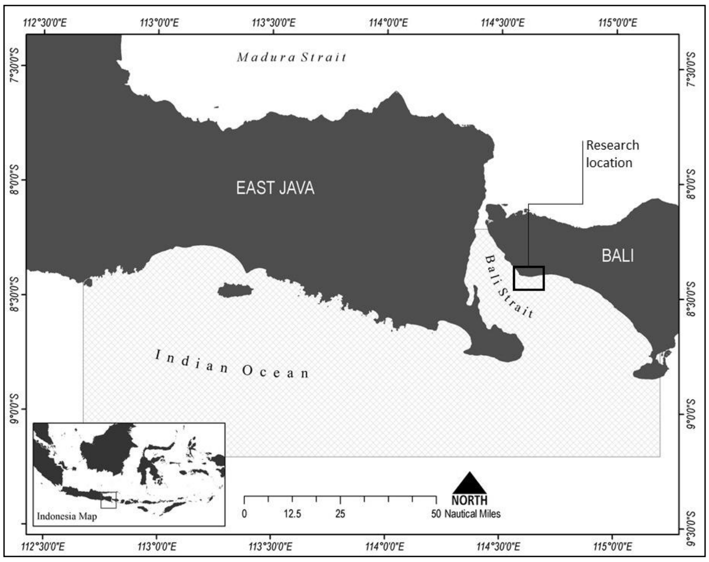

Figure 1. Research location (map generated using QGIS software).

Land surface temperature. The land surface temperature can be identified through processed Landsat OLI 8 (USGS EROS 2019) image data. The Digital Number (DN) of the image was converted to the TOA Spectral Radiance value using band 10 in the Landsat OLI 8 (USGS EROS 2019) satellite imagery. This process applied the following equation (1):

$$L\lambda = MLQcal + AL \quad (1)$$

where Lλ is the Top of Atmosphere spectral radiance, ML is the radiance value of band 10, Qcal is the Digital Number of band 10, and AL is the radiance add of band 10.

Land surface temperature was calculated from the calculation of temperature brightness by changing the radiance value. The result of the brightness temperature was represented in Kelvin units (Equation (2) and (3)) (USGS EROS 2019).

$$T = K2/(\ln\,(K1/L\lambda 1)) \quad (2)$$

The results of the brightness temperature were represented in Kelvin units, and to be able to carry out the next analysis we had to convert the results in Celsius units. Changing from Kelvin units to Celsius temperature units can be done by using the difference between the Kelvin to Celsius temperature unit, namely 273.15.

$$\mathrm{T} = \mathrm{K2}/((\ln(\mathrm{K1}/\mathrm{L}\lambda + 1)) - 273.15 \quad (3)$$

where, T is temperature brightness in Kelvin, Lλ is Top of Atmosphere spectral radiance, K1 and K2 is band-specific thermal conversion constant from metadata.

Moreover, the Normalized Difference Vegetation Index (NDVI) is a function to determine the level of vegetation density in a certain area. NDVI calculations are necessary to find out the value of the fraction of areas covered by vegetation which help to find out the information on land surface temperature. Band 4 (red) and band 5 (near infrared) on Landsat OLI 8 (USGS EROS 2019) were used to obtain NDVI values with the following algorithm (4) (Avdan 2016):

$$NDVI = (Band5 - Band4)/Band5 + Band4) \quad (4)$$

The Fractional Vegetation Cover (FVC) value can be estimated by utilizing the previously obtained NDVI value and by knowing the NDVIsoil value (soil) and the NDVIveg value (vegetation). FVC has a function as a fraction of the estimated value of an area covered by vegetation with the following algorithm (5):

$$FVC = (NDVI - NDVIsoil)/NDVIveg - DVIsoil))^2 \quad (5)$$

where, NDVIsoil is NDVI value for land surface (0.2), and NDVIveg is NDVI value for vegetation (0.5)

The next step is to calculate the Land Surface Emissivity (LSE). The function of the LSE is to calculate the characteristics on the earth's surface and calculate its ability to convert heat energy into energy, using algorithm (6) (Avdan 2016):

$$LSE = \varepsilon s * (1 - FVC) + \varepsilon V * FVC \quad (6)$$

where εs is land emissivity on band_10 (0.971) and v is vegetation emissivity on band_10 (0.987).

Land Surface Temperature (LST) can be determined using a mathematical algorithm (7) and (8) as follows:

$$LST = TB10/(\{1 + [(\lambda * TB10/\rho) \ln LSE]\}) \quad (7)$$

$$\rho = h * c/\sigma \quad (8)$$

where TB10 is Brightness temperature (K) Band_10, λ = 10.8, h = 6.626 x 10-34 J s, σ = 1.38 x 10-23 J/K, c = 2.998 x 108 m/s, ρ = 1.438 x 10-2 mK = 1.438 x 10-2μmK.

Reclass of the land surface temperature was done using the following criteria (Table 2).

Table 2

Land surface temperature classes

Temperature (°C)	*Score*
<26	1
26 – 29	2
29 – 32	3
>32	1

Land use analysis. Land use data is obtained by classifying land cover. The classification types are divided into five classes including medium density vegetation, high density vegetation, agriculture, vacant land, and settlements. Classification was carried out using the supervised method of Maximum Likelihood (Richards 1994). The classification results will be scored on the class attribute table with each score on medium density vegetation, high density vegetation, agriculture, vacant land, and settlements, namely 3, 2, 1, 2, and 0.01 (Table 3).

Table 3

Land use classes

Land use	*Score*
Medium density of vegetation	3
High density of vegetation	2
Agriculture	1
Bare land	2
Settlement	0.01

Geospatial analysis and accuracy assessment. The results of the scoring for each parameter were performed by spatial analysis with an overlay technique using a raster calculator tool. The total score of the turtle nesting habitat was obtained by adding up the value of the score for each parameter multiplied by the weight of each parameter, using the following algorithm (9):

$$Total\ score = ((slope\ score * 3) + temperature\ scope * 1)) * landuse\ score \quad (9)$$

By calculating the total maximum and minimum score difference divided by class number, the land suitability categories were created. The suitability classes for habitat suitability of olive ridley sea turtle are described in Table 4.

The accuracy assessment was conducted to determine and show that the method used was in accordance with the data on the distribution of turtle nests in the field. The accuracy assessment is a percentual value obtained using the following formula (10):

$$\%Accuracy\ assessment = (number\ of\ correct\ sample * 100\%)/(total\ number\ of\ sample) \quad (10)$$

The accuracy value is high if it has a percentage value of more than 85% accuracy and the accuracy value is bad if it has a final value less than 85%. The accuracy value of less than 85% is not good for further research (Short 1982).

Table 4

Habitat suitability classes for the olive ridley sea turtle

Suitability Classes	*Categories*	*Score*
I	Suitable	24.02 – 36
II	Quite suitable	12.03 – 24.01
III	Not suitable	0.04 – 12.02

Results

Coastal slope. The coastal slope map in the research area can be categorized into a slightly sloping class (31.8 Ha or 40%). Meanwhile, coastal area with a slope of 0-3% (flat) and more than 16% (steep) have a combined area of 37% or 29.7 ha. Furthermore, the 8-16% slope class (ramps) has a percentage area of 23% or 18.8 Ha.

The nesting habitat of olive ridley sea turtles which is located in an area with a low slope, compared to the turtle nests located on a high slope, will be more susceptible to risks such as waves of sea water (Setyawatiningsih et al 2011). The area can be a potential nesting habitat if the beach is easily accessible from sea level. Coastal sloping conditions will make it easier for the turtles to climb up and make nests to lay eggs.

Land surface temperature. Based on the analysis of Landsat 8 (USGS EROS 2019) satellite imagery in March 2019 - February 2020, the dynamic values of the annual land surface temperature in the study area range from 25 to 31°C, where the lowest temperature was recorded in February (25°C) and the highest was recorded in November (31°C).

This condition was related to the seasonal conditions in Indonesia where in December-February there is a rainy season which causes the land surface temperature to decrease, and in June-August there is a dry season which causes an increase in land surface temperature. The climatology station of Jembrana Regency, Bali reported that the decrease in the average rainfall occurred in June with an average rainfall of 7.2 mm (light rainfall), causing an increase in land surface temperature. Meanwhile, in December there was an increase in the average rainfall, with an average of 20.18 mm (moderate rainfall), causing a decrease in land surface temperature. The land surface temperature factor is the basis on which turtles choose their nesting location. The temperature of the land surface can affect the success rate of hatching eggs, thus encouraging the turtles to choose a nesting site with a stable temperature. Turtle embryos are very susceptible to temperature fluctuations (Howard 2014).

Land use. Image classification of Landsat 8 satellite (USGS EROS 2019) on February 15, 2020 showed that the largest land use area in Jembrana area, Bali Province of 32% was identified as high density of vegetation, 30% was of medium density of vegetation, 11% was bare land, and 8% were settlements, and agriculture land was 19%.

Land use is one of the factors in choosing where the turtle lays its eggs. The relationship is with the conditions around the turtle nesting habitat. High density of vegetation in some areas, can increase the interest of the adult turtle to lay eggs. The growth of this vegetation can affect the period time of hatching and the hatching rate of turtle eggs, where if the more shade the habitat for the turtle nesting will provide a better hatching process will occur. Although other parameters such as beach slope and land surface temperature are suitable for the olive ridley sea turtle nesting habitat, the existence of coastal structures and water conditions around the coast can become a barrier for the turtle to lay eggs (Sukada 2009). The condition of vegetation in the turtle nesting habitat has a close relationship, especially with the density of vegetation cover related to the intensity of light entering the bottom surface, so that it will provide a sense of security and calm when the turtle lays its eggs in the nest. Vegetation can also affect the temperature stability of the nest. In addition, vegetation acts as a shelter for turtles when laying eggs so that they can avoid predators (Putra et al 2014).

Habitat suitability for olive ridley sea turtles. The results of the habitat suitability analysis of the olive ridley sea turtle can be categorized as quite suitable (48%), while the not suitable category reaches 32%, and as for the suitable category there was 20% of the total of the study area. This result was based on geospatial analysis of environmental parameters as shown on Figure 2 as the slope map, Figure 3 as the land surface temperature map, and Figure 4 as the land use map.

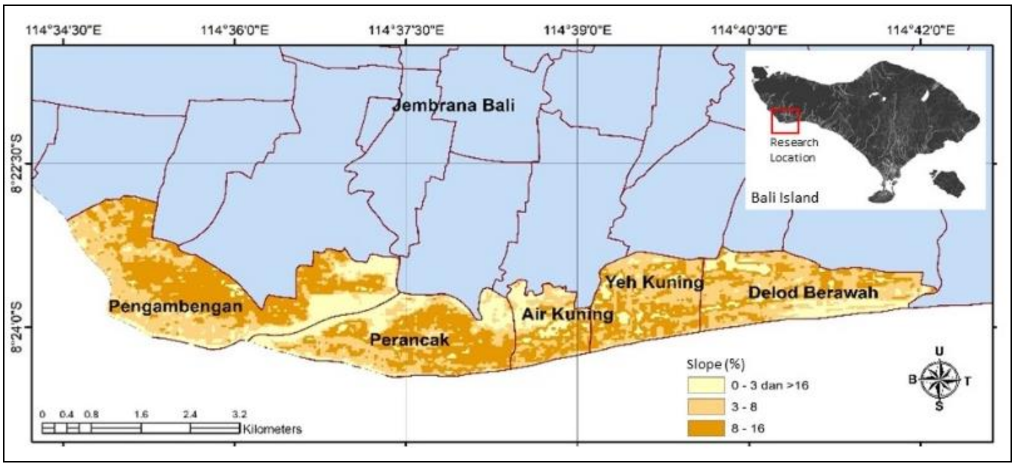

Figure 2. Slope map (generated using QGIS software).

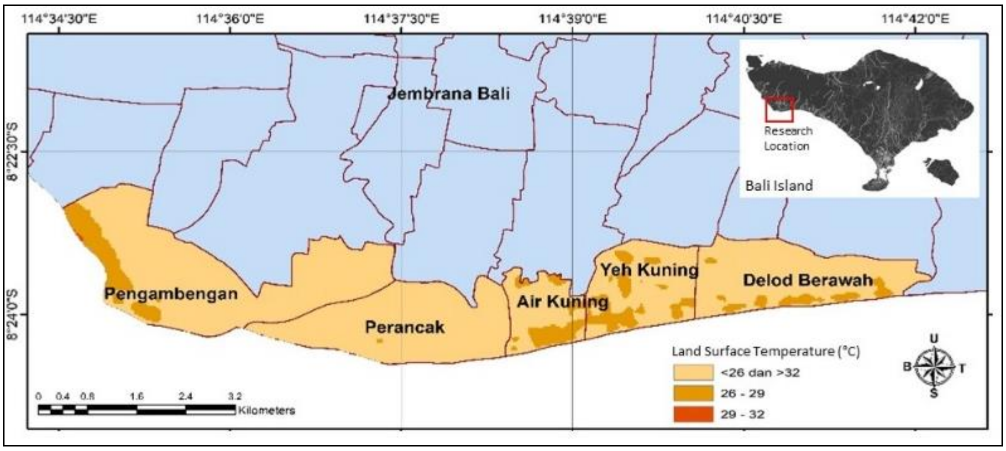

Figure 3. Land surface temperature map (generated using QGIS software).

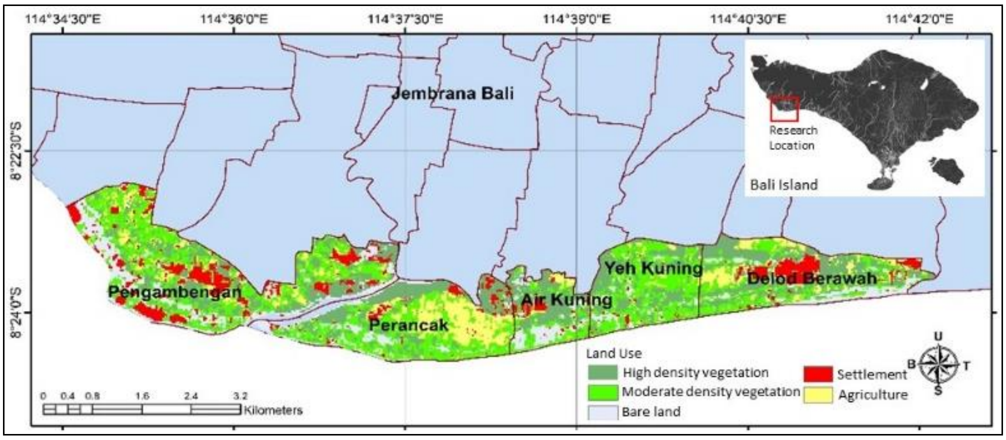

Figure 4. Land use map (generated using QGIS software).

Areas with a quite suitable category were almost evenly distributed on the coast of Jembrana Bali with the eastern coordinate point of 8.3945°–8.4073° South and 114.5818°-114.5839° East, and the western coordinate point was 8.3953°-8,3975° South and 114.6958°–114.6982° East.

Based on the total number of olive ridley sea turtle nests found (350 nests along the coastal area of research study), the average percentage of successful hatching eggs in the five areas of study was 93%. However, based on the results of spatial analysis, it shows that on the coast of Jembrana Bali, precisely in the five villages, the land suitability of the olive ridley sea turtle nesting was quite suitable (Figure 5). This was due to the activities of turtle conservation in this area that will increase the success rate of hatchlings and reduce the failure rate of eggs to hatch caused by internal factors or external factors. Less than 25% of nests found were semi-natural nests (87 nests). The results of the percentage of successful hatching of eggs have different yields, turtle eggs that are placed in semi-natural nests have the percentage value of successful hatching of eggs higher than that of turtle eggs laid in natural nests. Turtle eggs that are in natural nests have a lower percentage value due to uncertain temperature changes, while in semi-natural nests the temperature can be controlled by closing the place to get a stable temperature (Banoet et al 2019).

Moreover, the accuracy assessment was carried out to determine and show that the method applied was in accordance with the turtle nest distribution data in the field. The number of samples obtained in the study was of 32 geographical coordinate points. The sample described that out of 32 points only 4 points did not match. Equation (10) applied for the accuracy assessment, and shows the results of the accuracy value was 85%.

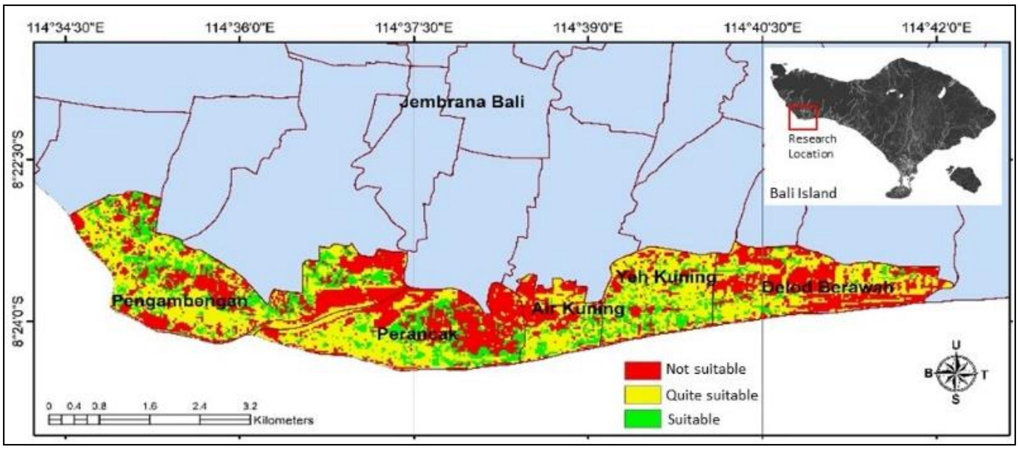

Figure 5. Habitat suitability map for olive ridley sea turtle nests (generated using QGIS software).

Discussion. Land suitability map was determined by spatial overlay of the parameters (slope, land surface temperature and land use). The parameters were classified into several classes and score (as described in Table 1, Table 2, Table 3). The suitability area for the olive ridley sea turtle (*Lepidochelys olivacea*) in the study area has shown that 34% of the area was identified as not suitable area (40.9 Ha), the quite suitable area was 43% (52.3 Ha), and suitable area was 23% (27.7 Ha). Areas with the category of quite suitable were distributed along the coast of Jembrana, Bali where the eastern coordinate point was 8.3945°–8.4073° South and 114.5818°–114.5839° East, and the western coordinate point was at 8.3953°–8.3975° South and 114.6958°–114.6982° East.

Based on observation from January to April, no *Lepidochelys olivacea* nests were found at the research location. In May, 29 nests were found and the numbers increased in the following month, namely to 39 nests. In June, the number of nests found decreased to 19 nests and continued to decline in the following month, namely August to 2 nests. Furthermore, from September to December, no turtle nests were found at the research location. All types of turtles lay eggs more than once in a period of one season. The nesting season for turtles in the tropics comes earlier, namely between December and July and may be carried out by turtles up to several times (Marcovaldi 2001). The percentage of successful hatching of turtle eggs found at the research location was 94% and can be categorized as a good level. Hatching success is categorized as high enough if the average value for all hatched eggs is above 50% (Maulana et al 2017).

The accuracy assessment of the suitability map in this study was also carried out by calculating the accuracy by comparing the results of the spatial overlay with the sampling points in the field. Based on 32 sampling points, 4 points were obtained that did not match the results of the suitability map model or the results of the accuracy test reached 87%. The accuracy value is high if it has a percentage value of >85% accuracy and the accuracy value is bad if it has a final value <85%. The accuracy value of <85% is not good for further research (Short 1982). Based on the description of sampling points, it was described that the coastal slope was identified as flat and slightly sloping (0–3 % and 3–8 %) (see Table 5).

Table 5

Categories description based on accuracy assessment

No	*Categories*	*Slope (%)*	*Land surface temperature (°C)*	*Land use*
1	Suitable	8-16 (sloping)	<26	Vegetation coverage with medium density
2	Quite Suitable	8-16 (sloping)	<26	Bare land
3	Not Suitable	0-3 (flat)	<26	Bare land

The land surface temperature was <26°C, and the land uses were identified as residential areas and bare land. This condition was not suitable for turtle nesting habitat due to the existence of settlements. Temperature mainly distributed in the built-up areas and low temperature areas, mainly in water and vegetation areas (Chen et al 2021). Based on observations of land surface temperature during February at the research site there was a decrease in temparature caused by seasonal change. Turtles have a tendency to choose nesting habitats with characteristics including dry sandy beaches, where there is vegetation cover such as pandanus (*Pandanus tectorius*), and they do not like to lay eggs in areas with settlements around the coast, sloping or rather steep beaches and tend to avoid coastal areas with bumpy beach surface (Afandy 2016).

Conclusions. This study tries to map the habitat suitability for the olive ridley sea turtle (*Lepidochelys olivacea*) nesting through a geographic information system approach. All geographic data used in data analysis is processed through a spatial overlay approach. The use of spatial data such as slope, land surface temperature, and land use performed good result in habitat suitability mapping of olive ridley sea turtle nests. Based on the three parameters applied, land use followed by beach slope was the most influential parameter on the suitability of the olive ridley sea turtle habitat study area. The slightly sloping of the coastal area helps olive ridley sea turtle to lay their eggs. Moreover, habitat suitability of olive ridley sea turtle was in the quite suitable category. Based on the results of the analysis, it can be explained that the suitable habitats for the olive ridley sea turtle (*Lepidochelys olivacea*) nesting, classified into the moderate to high category, were areas with an average temperature of 32°C and where the slope tends to be steep.

In addition, this area was also identified as the settlement area.

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Conflict of Interest. The authors declare no conflict of interest.

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