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Mangrove diversity and suitability assessments for ecotourism in Cimalaya Wetan Coast, Karawang District, Indonesia

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Abstract. *Pin TG, Supriatna J, Takarina ND, Tambunan RP. 2021. Mangrove diversity and suitability assessments for ecotourism in Cimalaya Wetan Coast, Karawang District, Indonesia. Biodiversitas 22: 803-810.* Mangrove forest has been a popular ecotourism destination recently. One of the methods to assess the mangrove potential for ecotourism is by using Tourism Suitability Index (TSI). This study was aimed to assess the ecotourism potentials of mangrove forest sizing of 56.43 hectares in Cilamaya Wetan Sub-district, Karawang District, West Java Province, Indonesia using the TSI method. To assess the mangrove variables, 10 sampling stations have been selected across the coast. In each station, 10 sample plots sizing of 10 m x 10 m have been established. The TSI was measured based on mangrove variables including species diversity, density, and thickness. We recorded six mangrove plant species belonging to three plant families. *Avicennia alba*, *Bruguiera gymnorrhiza* and *Rhizophora stylosa*, were common species found along the coast. Shannon-Wiener index (H') showed that the west and east parts of Cimalaya Wetan had high mangrove diversity compared to the central part. The TSI analysis showed that the most suitable areas of mangrove forests for ecotourism were 32.18 hectares (57.11% of the total area), mainly located in the east part of the coast. Moreover, the moderate and least suitable areas were 19.12 hectares (33.94%) and 5.03 hectares (8.93%), respectively, and located in the central part of the coast.

Keywords: Biodiversity, coast, ecotourism, mangrove, suitability

INTRODUCTION

A coastal ecosystem is a community unit consisted of vegetation, animals, and other organisms that interact with their environment. The coastal ecosystem, i.e., mangrove forests, has potential in natural resources and environmental services. Mangrove is a type of woody species, grows in coastal areas between the land and the sea which only exists in tropical and partly subtropical areas. As a typical ecosystem in coastal areas, the mangrove forests have many functions, and benefits to supporting the sustainability of other nearby ecosystems along the coasts. The ecosystem of mangrove forests can be function physically, ecologically (biophysically), and economically. One of the economic functions of mangrove forests is the potential for tourism, aquaculture, and conservation areas. Species richness and versatility of the mangrove ecosystem attract people to use it as a coastal ecotourism destination (Bahar 2004; Purnomo et al. 2013; Agussalim and Hartoni 2014).

Coastal ecotourism can be one of the most potential tourist destinations that can be created in Indonesia, considering the enormous coastal biodiversity and ecosystem that can be found along Indonesia Coasts (Putra et al. 2015). Mangrove ecosystem is a part of a coastal ecosystem that can be developed into coastal tourism. In addition to ecotourism, mangrove forest has a very important role in maintaining ecosystems and nutrient cycles in coastal areas, i.e., erosion control, catching sediment, and coast protection from floods or Tsunami (Yulianda et al. 2018). The potential of mangrove forests for ecotourism is determined based on the suitability assessment. The assessment is focused on the characteristics of the ecosystem, including ecological aspects and socio-economic-cultural dimensions. Yulianda (2007) found that the suitability of mangrove forest for ecotourism has to consider certain variables based on the levels of importance. The variables are classified into four suitability assessment levels, i.e., S1 (very/most suitable), S2 (suitable), S3 (conditionally/least suitable), and N (not suitable). The mangrove suitability assessment is made by considering mangrove thickness, mangrove density, and mangrove species composition (Yulianda 2019).

Karawang Coast of West Java, Indonesia, has the most extensive mangrove forest species in West Java, i.e., 36 species, with an area of 10,005.46 hectares which covers approximately 28.76% of the total mangrove forests in West Java (Dinas Kehutanan Jawa Barat 2018). One of the mangrove forest ecosystems which is used as an area of ecotourism in Karawang is located in the Sub-district of Cilamaya Wetan. According to the Long-Term Development Plan (2005-2025) of the local government of

Karawang District, Cilamaya Wetan is a priority for mangrove forest development. Since the inauguration of the Tangkolak Maritime Center (TMC) in Sukakerta Village on 26th December 2018, there have been activities of tourist visits that increased almost 100%. Therefore, there is a need to study the suitability of ecotourism potentials of mangrove ecosystems in Cilamaya Wetan of Karawang, West Java, Indonesia.

MATERIALS AND METHODS

Study area

The study was conducted in the mangrove forests, located in the sub-district of Cilamaya Wetan, Karawang District, West Java Province, Indonesia. The mangrove areas were divided into 10 sampling stations (Figure 1). The selection of the sampling stations was based on the physical existence (appearance) of the mangrove forests, which was considered suitable for ecotourism. The sampling stations covered coastal areas from $6^0$10'50'' S, $107^0$33'20" E to $6^0$12'30'' S, $107^0$38'20" E. The coast has 84 km in length, stretches from the east to the west coasts.

Data collection

The fieldwork was conducted from September to October 2019. The mangrove forests were assessed based on direct observation in designated sampling stations. The observations were conducted using transect methods following Hutabarat (2009) and Sofian et al. (2012). In each station, a 100 m transect was located and positioned perpendicular from the beach to the mainland. In every 10 m distance along the transect, a 10 x 10 m^2 sampling plot was established. In total, 100 sampling plots were representing 10 stations. Inside the plots, mangrove species and numbers of mangrove trees with a trunk diameter of ≥ 10 cm and a height of ≥1.5 m were recorded.

Data analysis

Tourism Suitability Index (TSI)

The TSI was calculated to determine the suitability of an area for the development of ecotourism. The index was used to determine area capacity in supporting various activities that would be undertaken in the designated area. The variables used for calculating TSI following Yulianda (2007), and the equation followed Nelly et al. (2020), as follows:

$TSI = \Sigma(N_i/N_{max})$ x 100%, with:

TSI : Tourism Suitability Index
N_i : the-i variable value (weight x score)
N_{max} : the maximum value of a variable

The suitability class or level of TSI for mangrove ecotourism was classified as follows:
S1 : very/ most suitable, TSI ranges of 67-100%;
S2 : suitable, by TSI ranges of 34-66%;
S3 : conditionally/ least suitable, TSI ranges of 0-33%

Figure 1. Locations of 10 sampling stations in the coastal area of Cilamaya Wetan Sub-district, Karawang District, West Java Province, Indonesia covering coastal mangrove areas from $6^0$10'50'' S, $107^0$33'20" E in the west coast to $6^0$12'30'' S, $107^0$38'20" E in the east coast. Note: 1-2. Sukakerta Village, 3-4-5. Rawagempol Kulon Village, 6-7. Muarabaru Village, 8. Cilamaya Wetan Village, 9-10. Kali Bawah Village

The level of suitability can be classified into three levels consisting of very (most) suitable (TSI 67-100%), moderately suitable (TSI 34-66%), and least suitable (TSI 0-33%). The determination of the level of suitability was based on the multiplication between the score and weight of each variable. The suitability of mangrove ecotourism was determined by three variables, i.e., mangrove thickness, mangrove density, and mangrove species composition. All variables at each sampling station were classified and calculated in Microsoft Excel 2013 according to the data obtained. The values obtained from each station were divided by the total value and multiplied by 100%, and then the values of suitability level of mangrove forests for each sampling station can be obtained.

Mapping, biodiversity, and statistical analysis

All TSI values were tabulated in Geographic Information System (GIS) database and mapped using ArcGIS. Mangrove species composition was calculated using the Shannon-Wiener (H') index of diversity and denoted as: $H' = \Sigma[P_i \ln (P_i)]$ where P_i is the proportion of the mangrove species i in total individuals. The range of H' is from 0 (low diversity) to 1 (high diversity). Statistical analysis was performed using Bray-Curtis correlation to cluster sampling stations to develop the dendrogram.

RESULTS AND DISCUSSION

Mangrove diversity

The total mangrove areas in Cilamaya Wetan, Karawang were estimated at approximately 56.43 hectares with spanning from 1.66 to 14.47 hectares. The small areas of mangroves were common in the central and eastern parts of the coast, while the western part has wider mangrove areas (Figure 2). Six mangrove species were belonging to three families have been recorded (Table 1). Rhizophoraceae was the common family in Cimalaya Wetan Coast since this family has more species compared to other families. *Avicennia alba, Bruguiera gymnorrhiza* and *Rhizophora stylosa* were the top-three common species since those species can be observed in every station. Stations 7 and 8 had lower species diversity compared to other stations.

The spatial distribution of mangrove diversity in the terms of Shannon-Wiener indices (H') is presented in Figure 3. The west and east parts of Cimalaya Wetan Coast had a high mangrove diversity, while the central part had a lower diversity. These results are related to the absence of several species in station 7. The characteristics of surrounding areas are also contributed to the lower diversity. Based on the TSI (Figure 4), only 13.84 hectares (24.57%) of Cimalaya Wetan Coast was very suitable for ecotourism considering the mangrove species diversity (Figure 9). The areas were located in the eastern parts and some patches were located in the western parts.

Mangrove density and thickness

Mangrove areas in Cimalaya Wetan Coast had a high density, and very suitable for ecotourism based on the TSI density, i.e. 49.64 hectares (88.11%) (Figure 9). This means that the mangrove areas were very dense as can be seen in the west and east parts of the coast (Figure 5). Considering the TSI thickness, the mangrove areas were only 19.95 hectares (35.41%) suitable for ecotourism. The thickness of mangrove forests with several rows of trees can be observed in the eastern part, followed by the western and central parts (Figure 6). The central part of the coast, including stations 4, 5, 6, and 7, had the lowest mangrove thickness spanning from 26.52 m (95% CI:25.69-27.35 m) to 62.24 m (95% CI:59.48-64.99 m), while the highest mangrove thickness ranging from 75.51 m (95%CI:72.99-78.01 m) to 104.83 m (95% CI:102.15-107.52 m) was observed in the eastern part (Figure 8).

Mangrove areas for ecotourism

The most suitable mangrove areas for ecotourism were determined based on the accumulation of the TSI values, including TSI species, TSI density, and TSI thickness. The value is denoted as the TSI total, and the spatial distribution of the TSI total can be seen in Figure 7. Based on the TSI total, there were 57.11% or equal to 32.18 hectares of mangrove forests in Cilamaya Wetan suitable for ecotourism (Figure 9). Those areas were mainly located in the eastern part of the coast (Figure 7). The central part was considered as conditionally suitable areas. The dendrogram analysis based on clustering of sampling stations using the TSI values is presented in Figure 10. The cluster analysis showed a similar pattern. Stations 5, 8, 9, and 10 were clustered together and separated from the cluster of stations 1, 2, 3, and the cluster of stations 4, 6, 7. Those clusters indicated different TSI values. Stations 5, 8, 9, and 10 which are mostly located in the eastern part, represented areas of coasts that are very suitable for ecotourism, while stations 1, 2, 3, 4, 6, and 7 represented areas with the TSI values ranging from moderate to least suitable that are mostly located in the western and central parts of the coast.

Table 1. Mangrove diversity of Cilamaya Wetan Coast, Karawang District, West Java Province, Indonesia

Family	Species	Stations									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Acanthaceae	*Avicennia alba*	+	+	+	+	+	+	+	+	+	+
Rhizophoraceae	*Bruguiera gymnorrhiza*	+	+	+	+	+	+	+	+	+	+
	Rhizophora apiculata	+	+	+	+	+	+	-	-	+	+
	Rhizophora muncronata	+	+	+	+	+	+	-	-	+	+
	Rhizophora stylosa	+	+	+	+	+	+	+	+	+	+
Sonneratiaceae	*Sonneratia alba*	+	+	+	-	-	+	+	+	+	+

Note: +: present

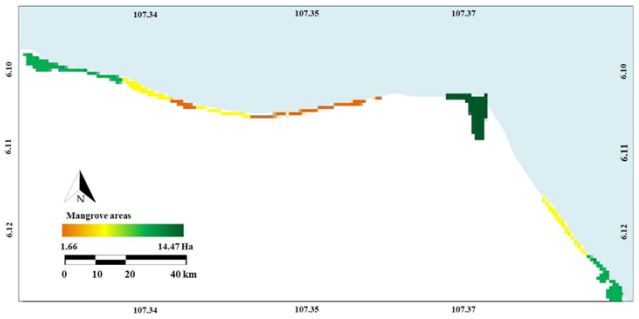

Figure 2. Mangrove areas (hectare) in 10 sampling stations in Cilamaya Wetan Coast, Karawang, Indonesia

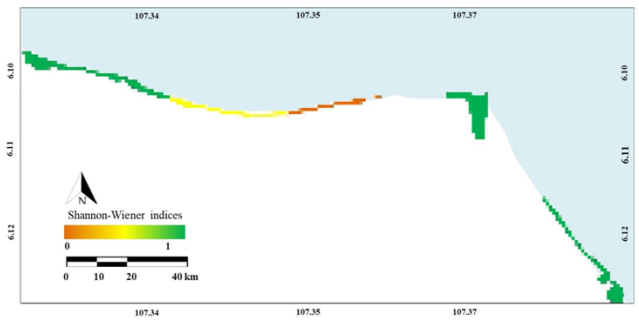

Figure 3. Mangrove Shannon-Wiener (H') index of diversity in 10 sampling stations in Cilamaya Wetan Coast, Karawang, Indonesia

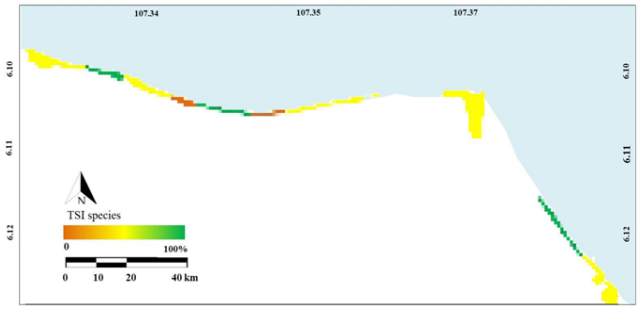

Figure 4. TSI based on mangrove species composition in 10 sampling stations in Cilamaya Wetan Coast Coast, Karawang, Indonesia

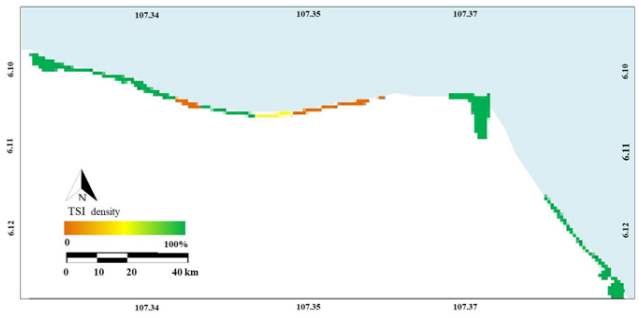

Figure 5. TSI based on mangrove density in 10 sampling stations in Cilamaya Wetan Coast, Karawang, Indonesia

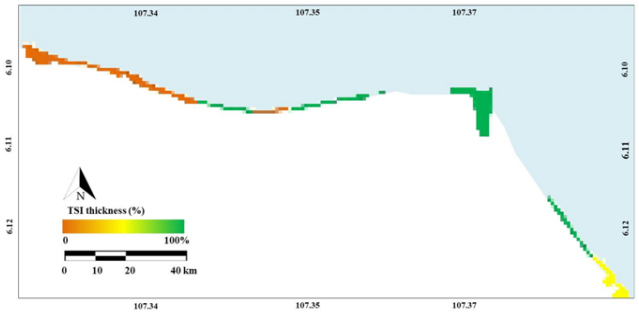

Figure 6. TSI based on mangrove thickness in 10 sampling stations in Cilamaya Wetan Coast, Karawang, Indonesia

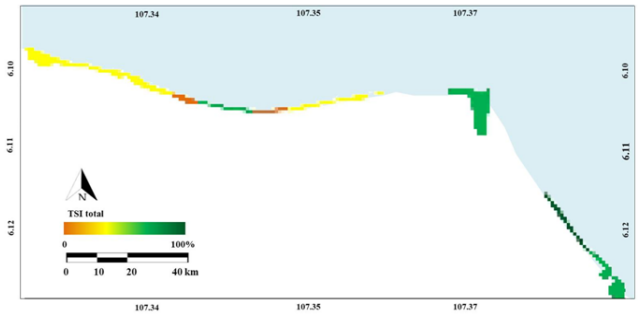

Figure 7. The total TSI in 10 sampling stations in Cilamaya Wetan Coast, Karawang, Indonesia

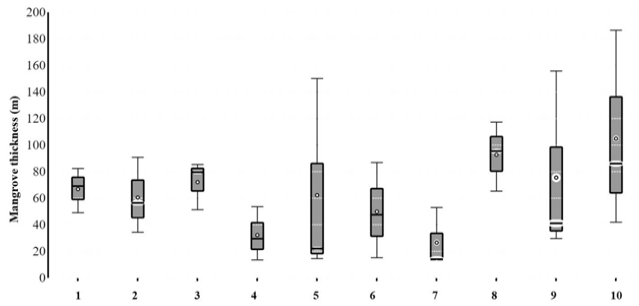

Figure 8. Mangrove thickness (m) in 10 sampling stations in Cilamaya Wetan Coast, Karawang, Indonesia

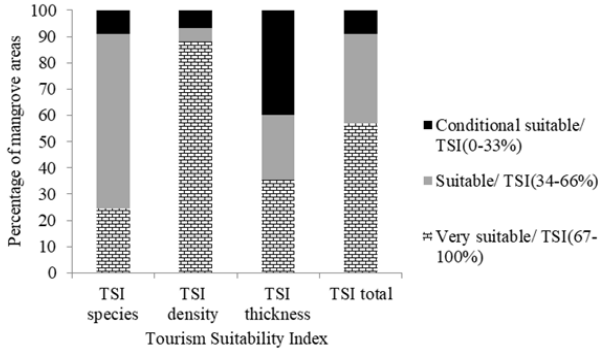

Figure 9. Percentage of mangrove areas (%) with the total area of 56.43 hectares based on TSI values and the levels of suitability in Cilamaya Wetan Coast, Karawang, Indonesia

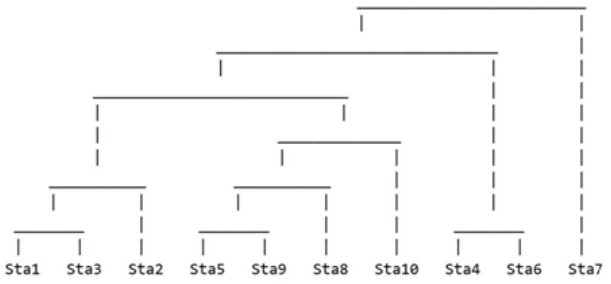

Figure 10. The cluster of sampling stations based on TSI values in Cilamaya Wetan Coast, Karawang, Indonesia

Discussion

Several mangrove species observed in Cimalaya Wetan, Karawang were comparable in numbers of species to other coastal areas that also have a potential for ecotourism. Latupapua et al. (2019) have observed 10 mangrove tree species belonging to six families in Siahoni coastal village, Buru District. Nelly et al. (2020) found three mangrove tree species belonging to two families in Iboih village, Sabang, while Lasabuda et al. (2019) have documented 15 mangrove tree species in Labuan Uki Bay, Bolaang Mongondow District. Variations in the number of family and species were related to the characteristics of the environment in each location. A high number of mangrove family and species was resulted from the presence of mangrove forest management, while in Cimalaya Wetan Coast, particularly station 7, the mangrove forests were surrounded by aquaculture ponds. The establishment and expansion of aquaculture have caused deforestation and threatened the mangrove forests (Maulana 2011, Muharam 2014). This situation has affected the mangrove forests, which previously had a high number of mangrove species and are considered suitable for ecotourism. As the result, mangrove forests in Cimalaya Wetan Coast have a lower diversity compared to other mangrove forests which have been designated as ecotourism.

Another characteristic of mangrove forest in Cimalaya Wetan Coast is a high density and low thickness. This indicates that the mangrove forests in the Cimalaya Wetan Coast are only available in the beach or fringing zone, and were created only from mangrove reforestation program through planting activities. The mangrove species mostly found in Cimalaya Wetan Coast were the species that can adapt to the intermediate and fringing zones. The species that can adapt to the landward zones contributed to the mangrove thickness, for example, *Rhizophora apiculata* and *Nypa fruticans* were absent in station 7. The mangrove thickness in Cimalaya Wetan Coast with the maximum value of 104.83 m is lower compared to the other coasts. The landward of mangrove thickness can reach 204 m (Fitriana et al. 2016), 212 m (Sadik et al. 2017), and even 726 m (Susi et al. 2018). The land-use conversion in landward zones has reduced the thickness of mangroves on the Kerawang coast. The previous thick mangrove forests from the beach to the landward zones have been logged and left only several layers of mangrove tree-rows on the beach.

A high density of mangroves and a low thickness in Cimalaya Wetan Coast is similar to the mangrove ecotourism site in Iboih Village, where *Rhizophora mucronata* was very dense and dominant as a tree and pole, while the sapling and seedling were dominated by *Rhizophora apiculata*. The high density of certain mangrove species in Iboih village was not driven by natural regeneration but intentionally replanted after the Tsunami. The mangrove species distribution in the Iboih ecotourism site was mainly influenced by the human factor through the mangrove rehabilitation program. The program was carried out by the local government in 2005-2011. A high density of mangroves in Kerawang Coast was also related to the rehabilitation program (Amrial et al. 2015). The program aimed to support the development of mangrove forests in Karawang as an ecotourism destination. The mangrove replanting activity was involving both the local community and local government (Turisno et al. 2018). Even though the mangrove density resulted from the replanting activity, but it did not affect the faunal diversity that inhabits the mangrove forest. Rahmila and Halim (2018) have observed a high bird abundance in the mangrove forest of Mangunharjo ecotourism village that was previously rehabilitated and replanted.

Indonesia is a country with a long coastline and vast marine biodiversity. These characteristics have led to the development of the coastal ecosystem as marine ecotourism destinations. To ensure sustainability, several methods have been developed and applied to assess the ecotourism potential, and one of those methods is the TSI. Recently, the TSI has received growing attention to assess the potential of marine ecotourism. Noviama et al. (2018), Setyaningrum et al. (2019), Wijaya et al. (2018) have assessed the TSI for coral reef ecotourism, while Harahab and Setiawan (2017), Rahmila and Halim (2018), and Simanjuntak et al. (2018) have assessed the potential of mangrove ecotourism. The differences of ecotourism assessment performed in Karawang compared to previous studies were this present study has provided a spatial distribution of the TSI in the form of TSI thematic maps. By using the maps, it can be seen the potential of ecotourism with the surrounding ecosystems, and how the nearby land-use can influence the sustainability of ecotourism.

The most suitable mangrove forests for ecotourism, determined by the TSI value, were located in the eastern part of the coast, in particular the areas of Station 8, 9, and 10. In such areas, the mangrove forests were still in a good condition with high mangrove density, and the thickness reached more than 100 m. With a thickness that reaches more than 100 m from the coastline, it caused the formation of mangrove species to become quite varies, which can be found in more than five different mangrove species in the areas of Station 8, 9, and 10. Another factor influencing high TSI in such areas was related to human activities. The mangrove forests in these areas were then located a bit far from human activities so that this can minimize the conversions of mangrove forests to human settlements and aquaculture ponds. The correlation between high TSI and surrounding land-use can be

observed in other mangrove ecotourism sites. A high TSI of mangrove forest in Ngantep Beach, Malang was correlated by the intact surrounding ecosystems with limited human activities. The percentage of conditionally and least suitable mangrove forests, i.e. 8.93%, was still lower than the ecotourism site in Karangsong, Indramayu which equals to 13.77%. In terms of total areas (in hectare), Cimalaya Wetan, Karawang has more conditionally suitable areas (5.03 hectares) compared to Karangsong which is only 1.27 hectares (Silalahi 2018). The least suitable areas in Karawang need immediate rehabilitation. In line with the development of ecotourism activities, the rehabilitation program can be implemented in the form of mangrove planting. The program should involve the ecotourism stakeholders and local communities to ensure the sustainability of mangrove rehabilitation activities (Setiawan et al. 2017; Situmorang 2018).

Mangrove forests in Karawang District have a promising potential for ecotourism. This study has assessed the ecotourism potential in coastal area of Cimalaya Wetan Sub-district using the TSI approach and concluded that the eastern part of Cimalaya Wetan Coast, especially in Cilamaya Wetan Village (Station 8) and Kali Bawah Village (Station 9 and 10) with areas of 32.18 hectares were very suitable for developing ecotourism. The least suitable areas sizing of 5.03 hectares were observed in the central part of the coast, while the western part with areas of 19.12 hectares was considered as moderately suitable.

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