

# Using site-selection model to identify suitable sites for seagrass transplantation in the west coast of South Sulawesi

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# Using site-selection model to identify suitable sites for seagrass transplantation in the west coast of South Sulawesi

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**Abstract.** The success of seagrass transplantation is very much depending on the site selection and suitable transplantation methods. The main objective of this study is to develop and use a site-selection model to identify the suitability of sites for seagrass (*Enhalus acoroides*) transplantation. Model development was based on the physical and biological characteristics of the transplantation site. The site-selection process is divided into 3 phases: Phase I identifies potential seagrass habitat using available knowledge, removes unnecessary sites before the transplantation test is performed. Phase II involves field assessment and transplantation test of the best scoring areas identified in Phase I. Phase III is the final calculation of the TSI (Transplant Suitability Index), based on results from Phases I and II. The model was used to identify the suitability of sites for seagrass transplantation in the West coast of South Sulawesi (3 sites at Labakkang Coast, 3 sites at Arerange Bay, and 3 sites at Lale-Lae Island). Of the 9 sites, two sites were predicted by the site-selection model to be the most suitable sites for seagrass transplantation: Site II at Labakkang Coast and Site III at Lale-Lae Island.

## 1. Introduction

Seagrass bed is a valuable marine resource both ecologically and economically in Indonesia. The ecological role of this vegetation in the marine environment has been the subject of many studies. Increased human activities in coastal areas such as dredging or catchment run-off, transportation, cultivation activities, reclamation, overfishing and continuous domestic waste, can damage the seagrass habitat and degrade the conditions of the vegetation [1].

To overcome the destruction of seagrass beds, it is necessary to do restoration efforts one of which is by transplanting the seagrass plants on a substrate or a suitable habitat. Seagrass transplant success varies considerably. Of the possible factors that can directly influence the survival of transplanted seagrass, poor site-selection has been identified as the major limitation. Thus, site selection is an important step in any seagrass transplantation attempt [2-3].

Several methods to select suitable site for seagrass transplantation have been reported on the tropical and subtropical area. In the Thai Coastal water, [4] simply chosen a site where current and wave action are reduced for the seagrass tropical seagrass *Enhalus acoroides* (L.) transplantation experiments. Whereas, [5] selected the optimal site for restoration of the eelgrass *Zostera marina* in the Taehwa River estuary (Korea) based on the density, morphology, and growth rate of the transplanted seagrasses. In the Bangka Island water (Indonesia), [6] used several parameters including similarity environmental condition of donor site to the transplantation site, water depth, bed

morphology, and wave exposure of the transplantation site as determined parameter in selecting suitable site for seagrass transplantation.

In the United States, a site-selection model for seagrass transplantation has been recently developed by [3]. The model synthesizes available historic and literature-based information, reference data and simple field measurements to identify and prioritise locations for large-scale seagrass *Z. marina* restoration. The model has been tested on several seagrass transplantation projects on the Northeastern coast of the United States with a high success rate (survival exceeds 62%). The site selection model introduced by [3] used parameters that commonly require for seagrass growth such as sediment type, wave exposure, depth, and water quality so that the model can be applied widely. To our knowledge, a site-selection model to identify suitable sites for tropical seagrass transplantation has not been attempted in Indonesia. Therefore, the main objective of this study is to develop and use a site-selection model to select suitable sites for tropical seagrass *Enhalus acoroides* transplantation in the West coast of South Sulawesi.

## 2. Material and Methods

### 2.1. Study site

This study was conducted on June - November 2009 at nine sites in the West coast of South Sulawesi (Indonesia), which are three sites in the Lae-Lae Island (Makassar City), Awerange Bay (Barru Regency) and coastal area of Labakkang (Pangkep Regency) (figure 1).



Figure 1. Map showing of the study sites in the West coast of South Sulawesi.

### 2.2. Methods

**2.2.1. Development of Site-selection Model.** The site-selection model was developed from the model introduced by [3] by making several modifications that suitable for Indonesia's tropical waters. The model is developed based on the physical and biological characteristics of transplantation sites such as the history of seagrass existence, seagrass distribution, sediment type, wave exposure, water depth, water quality, light intensity in the waters, and the existence of bioturbating marine organisms. The physical and biological characteristic data of the transplant sites is obtained from the results of field measurements. The physical and biological characteristic data of the transplant site was then compiled to formulate a quantitative site-selection model.

2.2.2. *Application of Site-selection Model.* The site selection model consists of three phases: Phase I identifies potential seagrass habitat using available knowledge, removes unnecessary sites before the transplantation test is performed. Phase II includes field assessment or transplantation tests at potential sites identified in Phase I. Phase III is the last stage in which a TSI (Transplant Suitability Index) score was calculated based on the results of Phase I and Phase II. Details of the activities of each stage of the site-selection model are presented as follows:

*Phase I: Identify potential habitat for seagrass and PTSI Value Calculation.* Phase I involves a review of available information to select and prioritize potential transplant sites. In this phase, information on characteristics of vegetated areas and areas without vegetation, sediment type, wave exposure, depth, and water quality are compiled to identify possible sites for seagrass transplantation, especially potential seagrass habitats. These characteristics contribute to the Preliminary Transplant Suitability Index (PTSI) calculation, which is used as initial screening in site selection (table 1) [3]. Due to information for the PTSI were not available for the study sites in published and unpublished literature, basic field measurements of the various PTSI parameters were performed.

**Table 1.** Data used during Phase I in the preliminary transplant suitability index (PTSI) for identification of potential seagrass habitat.

Parameter	PTSI rating	Reference
Historical seagrass distribution	1 for previously unvegetated 2 for previously vegetated	[7]
Current seagrass distribution	0 for currently vegetated 1 for currently unvegetated	
Proximity to natural seagrass bed	0 for < 100 m 1 for ≥ 100 m	[8]
Sediment	0 for rock or cobble 1 for > 70% silt/clay 2 for cobble free with <70% silt/clay	[9]
Wave exposure	0 for > mean + 2 SD of measurement result relative exposure index at each location 1 for ≤ mean + 2 SD of measurement result relative exposure index at each location	[10]
Water depth	0 for > 2 m during low tide 1 for < 0,5m or 1,5 – 2m during low tide 2 for 0,5 m – 1,5 m during low tide	Modified from [11]
Water quality (total suspended solid/TSS concentration)	1 for > 20 mg l <sup>-1</sup> 2 for < 20 mg l <sup>-1</sup>	[12]

Each of the parameters presented in table 1 receives a rating. The PTSI score is calculated by multiplying the ratings of each parameter in Table 1. PTSI scores that may appear are 0, 1, 2, 4, 8, and 16. Site that has any parameter with 0 (zero) rating will cause the score PTSI becomes 0, and the site will be excluded and no longer considered in the next site selection stage. Whereas a site with a higher

PTSI score has greater likelihood as a successful area for seagrass planting and the site is ranked for further evaluation to obtain a TSI (Transplant Suitability Index) score.

*Phase II: field assessments and test-transplanting.* Phase II is a continuation of Phase I where at this stage a field assessment and transplantation test at a site with a high PTSI score identified at Phase I. At this stage, site-specific light intensity data was collected, assessment of bioturbation activity and monitoring the rate of survival of transplanted seagrasses were conducted.

The light conditions at each site were measured with a lux meter to determine the intensity of light arriving at the bottom of the water. The existence of fauna that potentially disrupts seagrasses (bioturbators) such as crabs, shrimp diggers, worms, stingrays, green urchin, and swans was observed through an underwater visual survey with the help of video or divers. At each selected site (with a high PTSI score), seagrass (*E. acoroides*) transplantation tests were conducted using Sprig method [13, 16]. 50 planting units were planted in each 1 x 2 m plot with intervals of 0.2 m. Planting unit survival was monitored every month for two months.

*Phase III: calculating the TSI (Transplant Suitability Index) score.* In Phase III, the TSI Score was calculated for each test-transplanting site (table 2). TSI was determined by combining the results of PTSI in Phase I and measurement results of light intensity, bioturbator activity and transplantation test (seagrass survival rate) obtained in Phase II.

Each site is assigned a rating for each parameter in Table 2. First, the PTSI rating is assigned: 0 if the PTSI score is  $\leq 1$ ; 1 if the PTSI is 2 or 4; 2 if the PTSI is  $\geq 8$ . TSI ratings for light are assigned as follows: 0 for light  $< 20\%$  surface irradiance; 1 for light  $\geq 20\%$  surface irradiance; 2 for light greater than light measured in the reference seagrass beds. The TSI rating for bioturbation is based on the number of bioturbating organisms observed at a site; 0 if abundant bioturbators were observed, 1 for the observed presence of bioturbators; 2 if no bioturbating organisms were found. After assessment of the test transplants, 0 is assigned for  $< 20\%$  survival, 1 for 20 to 40% survival, and 2 for  $> 40\%$  survival of the transplanted seagrass. The TSI score is finally calculated as follows:  $TSI = PTSI \times \text{light conditions} \times \text{bioturbator activity} \times \text{seagrass survival rate}$  [3]. Site that has a zero TSI score will not be considered for transplantation. Similarly, sites that have a TSI score  $< 8$  were also rejected for transplantation. Sites with the highest TSI score at the end of Phase III will be selected as the most suitable site for seagrass transplantation.

**Table 2.** Data from Phase II for calculation of the transplant suitability index (TSI) to select the most suitable seagrass transplant sites.

Parameter	TSI Rating	Reference
PTSI	0 for PTSI = 0 - 1 1 for PTSI = 2 - 4 2 for PTSI = 8 - 16	
Light (field data)	0 for $< 20\%$ surface irradiance 1 for $\geq 20\%$ surface irradiance 2 for irradiance $>$ reference seagrass	[11, 12]
Bioturbation (field data)	0 for abundant 1 for present 2 for not present	[13]
Seagrass survival (test-transplants)	0 for $< 20\%$ 1 for 20 - 40 % 2 for $> 40\%$	[3]

### 3. Results and Discussion

#### 3.1. Phase I: identify potential habitat for seagrass and PTSI Value calculation

The seagrass history distribution parameters are recommended by [7]) as one of the important considerations in choosing a transplant location. The seagrass existence history at the study sites obtained from interviews with local communities showed that all site was previously occupied/vegetated by seagrass except at the Site I of Awerange Bay and Site II in the Lae-Lae Island. Previously vegetated sites receive a PTSI rating of 2 and previously unvegetated sites receive a rating of 1 (table 1).

Current seagrass distribution is important knowledge relative to transplanting activities because restoration should not be done at sites where seagrass already exists. The sites were assigned a PTSI rating of 0 if the sites currently vegetated with seagrass and a rating of 1 when the sites are currently unvegetated. The results of field measurements and based on the available seagrass distribution map indicate that all current sites were not overgrown with seagrass and hence all sites receive a PTSI rating of 1 for this parameter.

The distance of a possible transplant site from natural seagrass was included to ensure that transplanting is taking place outside an area that could be naturally revegetated by seed. If a site is less than 100 m from a natural seagrass bed, it is considered within the range of natural revegetation, based on [8], and the sites receive a PTSI rating of 0. If a site is over 100 m from a natural seagrass bed, it is rated 1. The results of field measurements and based on the available seagrass distribution map showed that the distance of all sites from natural seagrass beds was more than 100m and therefore all sites achieving a rating of 1.

The sediment particle size is an important parameter that has a major influence on the growth and spread of seagrass [9]. The results of sediment grain size analysis at each study site indicated that the sediment on the site was all sandy (free of pebbles) with mud content <70% except at Site I of Awerange Bay and Site II of Lae-Lae Island where seabed sediment of the two sites was rocky (corals). Sites that composed of sandy sediment with mud content <70% received a PTSI rating of 2 whereas sites with rocky (coral) substrate received a PTSI rating of 0 (not suitable for seagrass growth).

The wave exposure was incorporated as one of the parameters in PTSI because it has been shown by previous studies that wave energy can damage the leaves and remove plants that can obviously interfere with transplanted seagrasses [7]. The exposure of the transplant sites to the waves was determined by calculating the relative exposure index following the method introduced by [10] based on wind speed and wind direction data and effective fetch length. The relative exposure index calculation results showed that the relative exposure index value at each location was less than mean + 2 SD at each measurement location, and therefore all locations achieving a PTSI rating of 2.

In the site selection model developed by [3], very shallow waters (<0.5 m at low tide) or deeper water (> 2 m at low tide) are given a PTSI value of 0 because they are not suitable for *Z. marina* (eelgrass) growth. Seagrass *E. acoroides* that we tested in this study can still grow well at depths of less than 0.5 m or even in the intertidal zone exposed for several hours at the lowest tide [17] Therefore, the parameters of depth parameters in the model that developed in this study were given PTSI 1 for the location where the depth is less than 0.5 m and 0 for the depth > 2 m because the light arriving at the bottom of the waters is limited to depth > 2m. While the optimal depth for transplantation is 0.5 – 1.5 m at low tide and given a PTSI value of 2. The result of depth measurement at each study site indicated that almost all site had a depth between 0.5 m and 1.5 m except at Site I of Labakkang coastal area and sites II and III of Awerange Bay where water depth was less than 0.5 m.

Similar to water depth, water quality is a location-specific parameter, various types of data suitable to rate water quality for the PTSI, depending on what is available [3]. In this study, the total suspended solids (TSS) were used as water quality parameter. According to [12], seagrass plants can grow well if water TSS concentration less than 20 mg l<sup>-1</sup>. Therefore sites where the TSS concentration < 20 mg l<sup>-1</sup> are rated 2 while sites with the TSS concentration > 20 mg l<sup>-1</sup> are rated 1 (see table 1). The

measurement of TSS concentrations at each study site showed that all sites had a concentration of TSS  $> 20 \text{ mg l}^{-1}$ , and therefore all sites received a PTISI rating of 1.

PTISI rating of each physical and biological parameter explained above is summarized in table 3. Ratings for each parameter in the table 3 are multiplied to determine PTISI score for each site. Results of the PTISI Score calculation are also presented in table 3. As explained earlier, a site with a higher PTISI score has greater likelihood as a successful area for seagrass planting and the site is ranked for further evaluation to obtain a TSI score. Based on the PTISI scores presented in table 3, sites II and III of Labakkang Coast, Sites II and III of Awerange Bay, and Sites I and III of Lae-Lae Island were sites that have a greater likelihood of being successful areas for seagrass planting so that these sites were evaluated further to get a TSI score. The three other sites were no longer considered in the next site selection stage because of their small PTISI score.

**Table 3.** Parameter ratings of the PTISI and the final PTISI score for the 9 transplant sites.

Ratings for each parameter are multiplied to determine PTISI score for each site.

Site name	Historical seagrass	Seagrass distribution	Proximity	Water depth	Water quality (TSS)	Sediment	Wave exposure	PTISI Score
Site I (Labakkang)	2	1	1	1	1	2	1	4
Site II (Labakkang)	2	1	1	2	1	2	1	8
Site III (Labakkang)	2	1	1	2	1	2	1	8
Site I (Awerange)	1	1	1	2	1	0	1	0
Site II (Awerange)	2	1	1	1	1	2	1	4
Site III (Awerange)	2	1	1	1	1	2	1	4
Site I (Lae-lae)	2	1	1	2	1	2	1	8
Site II (Lae-lae)	1	1	1	2	1	0	1	0
Site III (Lae-lae)	2	1	1	2	1	2	1	8

### 3.2. Phase II: field assessments and transplantation test

At this phase, site-specific light intensity data was collected, assessment of bioturbation activity and monitoring survival rate of the transplanted seagrasses were conducted. The result of measurement of light intensity and macrofauna condition at each study site and the survival rate of seagrass transplants are presented in table 4.

**Table 4.** The light intensity, macrofauna condition (bioturbator), and survival rate of seagrass transplants.

Site name	Light intensity (%)	Bioturbation activity	Survival rate of transplanted seagrass (%)
Site II (Labakkang Coast)	75	not present	86
Site III (Labakkang Coast)	69	not present	72
Site II (Awerange Bay)	68	present	62
Site III (Awerange Bay)	58	present	40
Site I (Lae-Lae Island)	73	not present	84
Site III (Lae-Lae Island)	69	not present	90

Light is a critical factor of the survival and growth of seagrass [14]. Reduced light conditions that get to the bottom have been implicated in limiting seagrass metabolic activity which can eventually cause seagrass death [15]. The results of the measurement of light intensity on the surface and the bottom of the waters at each study site by using lux meters showed that the intensity of light reaching the bottom was greater than 20% in all sites, and therefore all sites received a TSI rating of 1.

Bioturbation has been noted as one of the important factors affecting natural seagrasses and transplanted seagrasses. The visual observations of epifauna combined with infauna observations in the sediments showed that almost all transplantation sites were free of fauna that potentially interferes seagrass transplants except in two sites at the Awerange Bay. At the two sites, several gastropods of *Cerithium sp* were observed inside the transplantation plots and hence these the two sites of Awerange Bay received a TSI rating of 1. While sites in the Labakkang coast and Lae-Lae Island were rated 2 because bioturbators that potentially disrupt the transplants were not found at these locations.

A final and critical step in assessing a site for seagrass transplantation is to conduct a test-transplant, in which the transplants respond to the prevailing environmental conditions and integrate the combination of site-specific factors which might limit their survival and growth [3]. The result of seagrass transplantation tests showed that the transplants survival rates varied from 40% to 90%. Site III in the Awerange Bay received a TSI rating of 1 because the seagrass survival rate of the site was only 40%, and other sites were rated 2 because the survival rates of the seagrass were > 40%. Low survival rates observed in the sites of Awerange Bay were most likely due to the presence of epibenthic bioturbating organism, i.e. gastropods *Cerithium sp* that damage seagrass transplants. In addition, observed lower light intensity in the sites of Awerange Bay compared to those in the Labakkang coast and Lae-Lae Island may be responsible for lower seagrass survival rate in Awerange Bay. As explained earlier that reduced light conditions that get to the bottom has been implicated in limiting seagrass metabolic activity which can eventually cause seagrass death.

### 3.3. Phase III: calculating the TSI (Transplant Suitability Index) score

In Phase III, the TSI Score was calculated for each test-transplanting site. TSI was determined by combining the results of PTSI in Phase I and measurement results of light intensity, bioturbator activity and transplantation test (seagrass survival rate) obtained in Phase II. Each site is assigned a rating for PTSI, light conditions, bioturbator activity, and seagrass survival rate (table 5). Ratings for each parameter in the table 5 were multiplied to determine TSI score for each site. Site that has a zero TSI score will not be considered for transplantation. Similarly, sites that have a TSI value < 8 were rejected for transplantation. Sites with the highest TSI score at the end of Phase III will be selected as the most suitable site for seagrass transplantation.

**Table 5.** Parameter ratings of the TSI and TSI Score for 6 seagrass transplantation testing sites. Ratings for each parameter are multiplied to determine TSI score for each site.

Site name	PTSI	Light intensity	Bioturbator activity	Survival rate of transplanted seagrass	TSI Score
Site II (Labakkang Coast)	2	1	2	2	8
Site III (Labakkang Coast)	2	1	2	2	8
Site II (Awerange Bay)	1	1	1	2	2
Site III (Awerange Bay)	1	1	1	1	1
Site I (Lae-Lae Island)	2	1	2	2	8
Site III (Lae-Lae Island)	2	1	2	2	8

Based on the TSI score presented in table 5, the most suitable sites for the seagrass transplantation were Site II at Labakkang coast and Site III at Lae-Lae Island because in addition to having a high TSI score, the transplantation test results also indicated high seagrass survival rates at these two sites. The sites in the Awerange Bay were rejected to be a suitable seagrass transplant site because they had a small TSI score (< 8). The site selection model was developed and tested in the West coast of South Sulawesi. For future applications beyond this region, the model requires additional testing and evaluation sites to proof that our site selection is working in the other tropical waters.

## 4. Conclusion

Application of site-selection model on nine sites in the West coast of South Sulawesi indicated that the most suitable sites for seagrass *E. acoroides* transplantation were Site II in the Labakkang Coast and

Site III in the Lae-Lae Island. These two sites were selected as the most suitable sites for seagrass transplantation because in addition to having high TSI (Transplant Suitability Index) scores, the test-transplanting showed high seagrass survival rates at the two sites.

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