

An Assessment of the Environmental Sensitivity of the Coastal Zone of Negombo, Sri Lanka

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Abstract

The coastal area of Sri Lanka provides various ecosystem services amidst various challenges. For instance, coastal erosion is an ongoing problem caused by human activities. Sensitivity assessment one of the measures which helps planning coastal areas to ensure better urban development and environmental protection. This study developed a framework for the assessment of the environmental sensitivity of coastal zones. The framework primarily considered sensitive biological factors and external disturbances, demonstrated in the Negombo coastal zone. 16 indicators were selected, considering the area with AHP technique, and the weighted summation method was used to assess the sensitivity. The assessment enables the study region of an area of around 38km² to be divided into zones of very high, high, moderate, low, and very low sensitivity. The maps generated out of this assessment can be used to identify areas that require prioritized management. The very highly sensitive areas need priority in management as the sensitive biological aspects and external disturbances were both high in them. In the other areas, either the external disturbance or the sensitive biological aspects are high. Having identified the level of sensitivity, appropriate actions could be taken to either maintain the status of the biological aspect or to regulate the external disturbance in that area. Some areas were identified as very low to low sensitivity indicating their potential for development. This study provides a model framework to assess the sensitivity of coastal zones as a measure towards planning for sustainable developments in them.

Keywords: Coastal Zone; Environmental Sensitivity Assessment; Framework; Sustainable Development

1. Introduction

Like all different ecosystems, the coastal ecosystem provides a variety of services and goods that support the needs of the people. However, some ecosystems are sensitive to human activities and environmental changes, for which they face a variety of challenges (Hu et al., 2019). This is typical for the coastal area of Sri Lanka. The coastline of Sri Lanka is approximately 1,620km, rich with natural resources that support the livelihoods of millions (IUCN-Sri Lanka, n.d.). Over the last few decades, the coastal zone has undergone rapid urbanization due to the economic and social benefits it could provide along with the advantages of

plentiful natural capital (IUCN-Sri Lanka, n.d.). Hence, coastal ecosystems and the critical habitats in them are exposed to threats from various sources (Ministry of Environment & United Nations Development Programme, 2021).

This study focuses on the coastal area of Negombo that consists of sandy beaches, coral reefs, mangroves etc., and provides a home to several species of fish, crustaceans, etc. (Urban Development Authority, 2019). It is also one of the major contributors to the fishing and tourism industries (Urban Development Authority, 2019). Due to the scenic beauty in the area,

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many people are often attracted to visit Negombo and hence, many tourism-related activities such as boat riding, tourist resorts, etc., are abundant in the area.

While there are many advantages of having ecosystem services that help to sustain the livelihood of the communities and the economy of the country, several negative impacts have arisen out of human activities in the area. For instance, discharge of oil from fishing vessels haphazard building of anchoring sites for fishing boats, especially in the lagoon area, pollutants from tourism related activities are clearly observable in this area.



Figure 1: Sensitivity analysis for Negombo
Source: Urban Development Authority, 2019

Hence, there is a need for innovative methods to face these challenges, strengthening ecological systems, and make proper use of their natural capital, ensuring sustainable development (United Nations Global Compact, 2022).

Comprehensive sensitivity analysis is a method that helps ensure better urban development and environmental protection (Gan et al., 2018). It helps with making decisions towards more sustainable spatial planning. According to the UNEP World Conservation Monitoring Centre, sensitivity comprises the importance of an

area or asset based on the ecological or socio-economic values it contains, combined with its susceptibility which relates to how severely those values may be affected by any given pressure (NEA & UNEP-WCMC, 2020).

Sensitivity mapping is a spatial tool that displays the relative sensitivity of these assets to specific pressure within a land or seascape. These maps can then be used by decisionmakers for planning and managing development to minimize environmental and social risks in sensitive areas (NEA & UNEP-WCMC, 2020). So, by carrying out sensitivity analysis, extremely sensitive areas to conserve and manage could be identified and at the same time, low-sensitive areas could be identified as a potential area for future development (Hu et al., 2019).

However, when considering the situation in Sri Lanka, sensitivity assessment, which could help with management practices, have not been carried out to a comprehensive stage. Under the Development Plan of Negombo (Urban Development Authority, 2019), a sensitivity analysis was carried out as shown in Figure 1.

The coastal area depicted in Figure 1 is currently categorized as having low sensitivity. However, this classification does not offer a complete understanding of the area. It is challenging to determine which parts require better management, which are in good condition, but need upkeep, and where there might be potential for development. Surface level sensitivity assessment is not sufficient for sustainable development. Detailed information and a more thorough analysis are required to make well-informed decisions and effectively address environmental and developmental concerns. With Negombo holding significant potential and simultaneously being impacted by adverse factors, it becomes imperative to identify and manage these aspects for the sustainable protection of this ecosystem. Given the lack of clarity in the sensitivity

analysis of Negombo's coastal region, this study aims to establish a more comprehensive framework.

1.1. Research Objectives

The main objective of this research is a comprehensive assessment and mapping of the environmental sensitivity of the coastal zones of Negombo.

This main objective needed to be supported by a general framework, developed through literature review, for the assessment of the environmental sensitivity of any coastal zone, and that could be flexibly adopted to the situation in Negombo.

2. Literature review

Through literature reviews, this chapter focuses on what environmental sensitivity is, the factors that need to be understood to conceptualize environmental sensitivity and an appropriate methodology to carry out the assessment.

2.1. Environmental sensitivity

With the current rate of increasing population and rapid urbanization, consideration of environmental sensitivity of the coastal area gains importance. This is because the interactions between ecosystems and society is crucial for natural resource management (González Del Campo, 2017). Even though the term “Environmental Sensitivity” is commonly and widely used, there is no universal definition for this term and there is no common consent on its use in practice (González Del Campo, 2017).

Based on several definitions identified through literature review, the definition of environmental sensitivity can be depicted as appropriate for the purpose of study. Environmental Sensitivity is about the importance of an area in terms of the ecological aspects including the socio-economic assets received from the natural capital (González Del Campo, 2017; NEA & UNEP-WCMC, 2020), combined with

how these values would respond due to environmental changes caused by internal and external influences (Ersayin & Tagil, 2017; Gan et al., 2018; González Del Campo, 2017; Hu et al., 2019; NEA & UNEP-WCMC, 2020; Silhadi et al., 2020).

2.2. Conceptualization of environmental sensitivity

As mentioned before, there is no universally defined term for environmental sensitivity, and there is no standardized method to assess sensitivity. As this study focuses on the environmental sensitivity of coastal areas, this part of the literature review will discuss how sensitivity is conceptualized while focusing on coastal related attributes.

In certain cases, studies focus on assessing the sensitivity of a particular type of species, or a group of species (for instance fishes) to certain specific factors, such as climate change, recreational activities, eutrophication, heavy metal pollution, fishing, etc. (Hu et al., 2019). Similarly, some studies consider both ecological factors and human activities to understand the relationship between nature and humans, in turn helping with identifying issues that need to be explored to ensure sustainability (Hu et al., 2019).

At the same time, there are a few frameworks for coastal areas that have integrated all three, biological, ecological and utilization factors to assess the sensitivity comprehensively. Described in Table 1 is a small description of some studies that have considered all three factors in the framework.

Table 1. Review of frameworks

Source	Considered factors
Shi et al., 2018	<ul style="list-style-type: none"> • The biological sensitivity factor was represented by considering the different types of species and their diversity. • As for the ecological process sensitivity, the characteristics of the ecosystem and change in the area was considered. Indicators like water quality, erosion and deposition etc. were considered. • To identify the development and utilization factors, indicators that represent the influence of human activities on the ecosystem were considered.
Hu et al., 2019	<ul style="list-style-type: none"> • To identify biological sensitivity, inherent characteristics such ecosystem structure, typical habitats and important species were considered. • The biological sensitivity was categorized under endogenous sensitivity as it considers the sensitive characteristics within the ecosystem. • To identify ecological factors, external characteristics like hazards and risks as well as environmental changes were considered. • As for utilization factors, sea use activities were considered. • Both ecological factors and utilization factors were categorized under exogenous sensitivity in reference to the external disturbance to the ecosystem.
Silhadi et al., 2020	<ul style="list-style-type: none"> • For the biological sensitivity, biodiversity indicator that is integrated into sustainable development were considered. For instance, in this study considered seabed quality and ichthyological stands. • Under biological sensitivity, the habitats present in the coastal zone were considered as well. • As for the ecological sensitivity factor, hydrodynamic characteristics such as swell height and pollution intensity was considered for this study. • For the utilization factors indicators that exert a pressure on the coastal area were considered, for instance human activities, pollution vectors, infrastructure etc.

2.3. Evaluation methods

To assess environmental sensitivity, various evaluation methods have been carried out (Hu et al., 2019). When considering how indicators were chosen for assessing the sensitivity, many case studies have chosen indicators based on the characteristics of the selected case study area, as well as data availability (Hu et al., 2019; Shi et al., 2018; Silhadi et al., 2020). The data are collected from various sources such as reports from which secondary data can be obtained (Hu et al., 2019; Shi et al., 2018; Silhadi et al., 2020), field surveys (Hu et al., 2019; Silhadi et al., 2020) and

some data were acquired through remote sensing (Hu et al., 2019).

As the selected indicators were expressed in many different ways, measurements, and units, they needed classification. For example, several indicators were devised based on the sensitivity (Hu et al., 2019; Silhadi et al., 2020), whereas some were marked based on the distribution status (Butt et al., 2019; Hu et al., 2019) where the value of 1 indicated the presence, while 0 indicated the absence (Hu et al., 2019). The layers of the indicators were then presented using Geographic Information Systems (GIS) (Gan et al., 2018; Hu et al., 2019; Ni et al., 2022; Silhadi et al., 2020). Spatial

interpolation was performed for specific indicators where values for points were present only in certain areas (Hu et al., 2019; Silhadi et al., 2020).

Different indicators have different meanings when it comes to measuring environmental sensitivity in different contexts (Hu et al., 2019). Therefore, each indicator requires weighting. This was done using the Analytical Hierarchic Process (AHP) method, where experts scored each indicator based on the contribution (Gan et al., 2018; Hu et al., 2019; Ni et al., 2022; Shi et al., 2018). Then by carrying out spatial overlay, the comprehensive assessment result can be obtained (Butt et al., 2019; Gan et al., 2018; Hu et al., 2019; Ni et al., 2022; Silhadi et al., 2020).

As for the analysis of the map, based on the sensitivity level, the areas were analyzed accordingly as shown in the accompanying Figure 2.

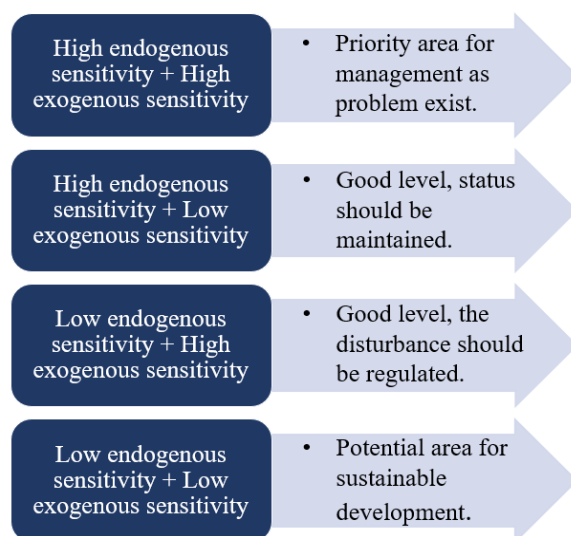


Figure 2: Analysis of Maps (Hu et al., 2019)

Environmental sensitivity in coastal areas is concerned with the significance of biological resources in providing ecosystem services and their ability to withstand external disturbances. In summary, to comprehensively assess sensitivity, three key factors—biological sensitivity, ecological sensitivity, and utilization factors were considered. The methodology involves using GIS for data mapping and AHP for determining indicator weights, as demonstrated in

existing literature. The resulting map can be analysed to understand both internal and external ecosystem sensitivity.

3. Methodology

3.1. Framework for environmental sensitivity assessment of the coastal zone

As the literatures reviewed had widely considered three factors namely, biological sensitivity, ecological process sensitivity and utilization factors (Hu et al., 2019; Shi et al., 2018; Silhadi et al., 2020) these were considered in this study for the assessment of the sensitivity of coastal areas, as shown in Figure 3.

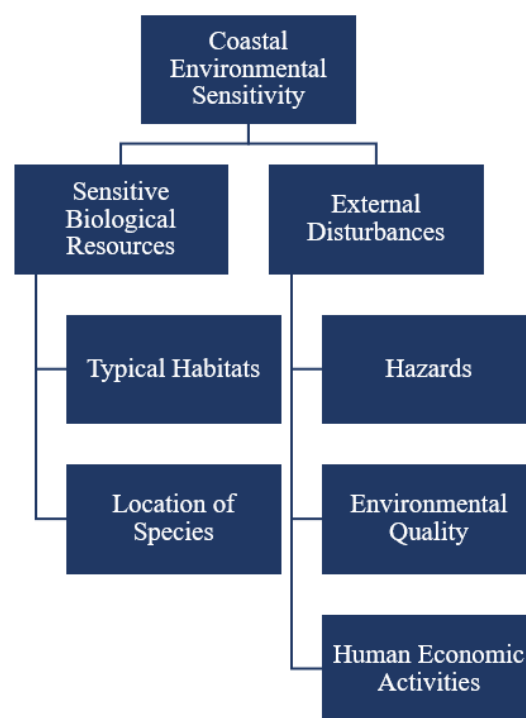


Figure 3: Framework for assessing the environmental sensitivity of coastal zones.

The framework for the assessment of Coastal Environmental Sensitivity is divided into two elements. The first element is sensitive biological resources that will enable to identify the inherent sensitive characteristics of the ecosystem (Hu et al., 2019; Shi et al., 2018). This is assessed based on typical habitat, and location of species. (Hu et al., 2019; Shi et al., 2018; Silhadi et al., 2020). The second element is external disturbances, which includes both the ecological process and utilization factor (Hu et al., 2019; Shi et al.,

2018). This is assessed based on the observable hazards, environmental quality, and the human economic activities (Hu et al., 2019; Shi et al., 2018). By considering these elements in a comprehensive environmental sensitivity assessment, we can identify areas that are more vulnerable to external disturbance. This information can guide priority management actions to protect sensitive areas while also identifying low sensitive areas with potential for sustainable development.

3.2. Boundary delineation of study area

The area selected to assess the framework developed for the environmental sensitivity assessment is the Negombo Coastal zone in Sri Lanka. Along with the positive and negative impacts mentioned before, the availability of data was one of the factors considered in order to define the boundary for this study.

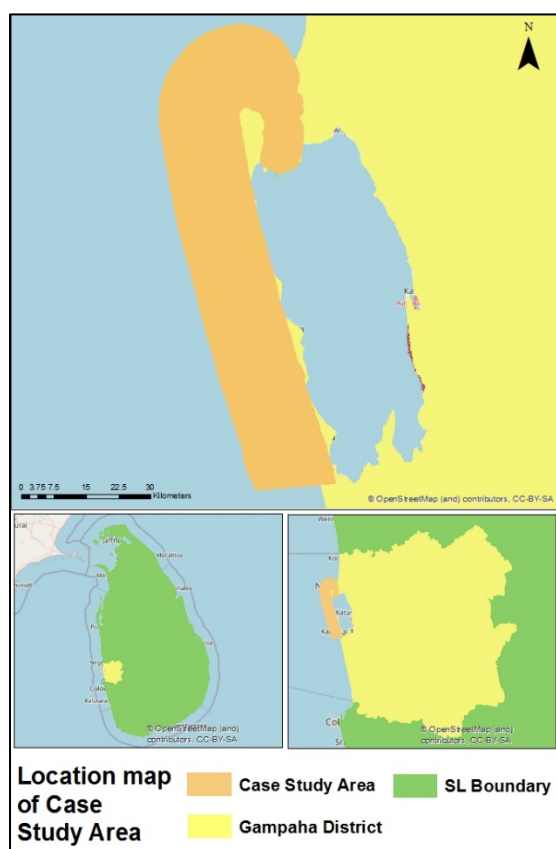


Figure 4. Case study area map.

In addition to that, the definition of coastal zone has been declared as per the “Coast Conservation and Coastal Resource Management Act, No. 57 of 1981 and

amended by the Act, No. 49 of 2011”. Due to this, the coastal zone from Munnakare to Kepungoda (roughly 15km) with an area of around 38 km² was considered for the boundary as shown in the figure 4.

3.3. Selection of indicators

Figure 5 represents the framework with the goal, criterion, factors, and indicators considered for this assessment. These indicators were selected based on the area and data availability. The assessment of coastal environmental sensitivity considers various factors and indicators. Under the "Typical Habitats Factor," reefs, mangroves, and sandy beaches are evaluated, with challenges like pollution and sedimentation affecting these ecosystems (Central Environmental Authority et al., 2016; IUCN - Sri Lanka, n.d.; Ministry of Megapolis and Western Development, 2015 and Urban Development Authority, 2019).

The "Location of Species Factor" assesses fish, crustaceans, and shorebirds, all vital to the local fishing industry and biodiversity. In the "Hazards Factor," the long-term plastic pollution caused by X-press pearl accident and coastal erosion have been examined.

The "Environmental Quality Factor" analyzes water temperature, pH, dissolved oxygen, and oil and grease levels. The "Human Economic Activities Factor" accounts for tourism, fishing, aquaculture, and their impacts. These indicators help to guide the protection and sustainable development efforts in coastal areas.

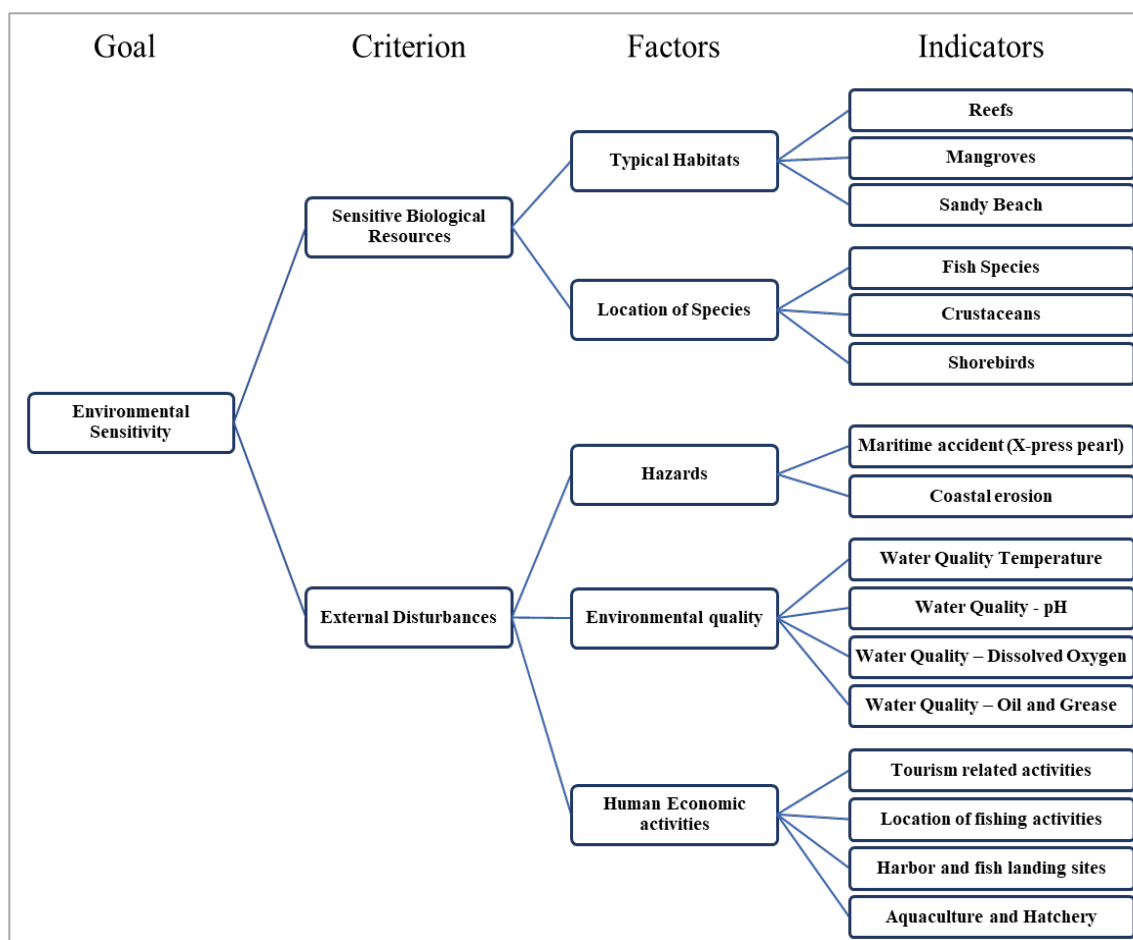


Figure 5: Indicators selected based on the framework.

3.4. Method of study

3.4.1 Data Collection

The data required for the indicators were obtained through secondary data resources, which are acknowledged at the end. Additionally, information obtained from experts in relevant departments was also considered.

Table 2. Acknowledgment of Secondary Data

Secondary Data Sources
SEIA report for Colombo Port City project. - (Ministry of Megapolis and Western Development, 2015).
Colombo – Negombo ESI report. – (Central Environmental Authority et al., 2016).
Distribution and abundance of Black Sea urchin (<i>Stomopneustes variolaris</i>) on the West coast of Sri Lanka - (Balawardhana et al., 2022).
Study of the abundance and reproductive seasonality of the sea urchin <i>Stomopneustes</i>

variolaris in Negombo, Sri Lanka - (Udeshika & Dissanayakex, 2019).
X-Press Pearl Maritime Disaster Sri Lanka – Report of the UN Environmental Advisory Mission. – (Partow, et al., 2021).
Data from the Department of Coast Conservation and Coastal Resource Management.
Master Plan on coast conservation & tourism development within the coastal zone from Negombo to Mirissa in Sri Lanka. - (Coast Conservation Department & Ministry of Mahaweli Development and Environment, 2018).
Google Maps (Hotels in Negombo - Google Maps, n.d.)
The present status of a multi-gear shrimp fishery of the western coast of Sri Lanka: gear-based species diversity and selectivity - (de Croos & Pálsson, 2013).

Table 3: Classification of data

Classification/ Data	Very Low sensitivity (1)	Low sensitivity (2)	Moderate sensitivity (3)	High sensitivity (4)	Very High sensitivity (5)
Coral Reefs	Absence	-	-	-	Presence
Mangroves	Absence	-	-	-	Presence
Sandy Beach	Absence	-	-	Presence	-
Fish Species	Absence	-	-	Presence	-
Crustaceans	Absence	-	-	Presence	-
Shore Birds	Absence	-	-	Presence	-
Maritime accident	Absence	-	-	-	Presence
Coastal Erosion	-	$-0.5 > \text{EPR} < 0.5$	$-1 > \text{EPR} < -0.5$	$-2 > \text{EPR} < -1$	$\text{EPR} > -2$
Water Quality – Temperature	-	25.60 – 27.90	27.91 – 30.40	30.41 – 36.40	< 36.41
Water Quality	-	7.41 – 7.85	7.86 – 8.34	8.35 – 8.78	8.79 – 9.64
Water Quality – Dissolved Oxygen	-	$\text{DO} > 8$	$6 < \text{DO} < 8$	$4 < \text{DO} < 6$	$\text{DO} < 4$
Water Quality – Oil and Grease levels	-	< 2.00	2.01 – 19.87	19.88 – 42.20	> 42.20
Tourism related activities	Absence	-	-	Presence	-
Location of fishing activities	Absence	-	Presence	-	-
Harbor and Fish landing sites	Absence	-	-	Presence	-
Aquaculture and Hatchery	Absence	-	Presence	-	-

3.4.2. Data Processing and Reclassification

Out of the 16 indicators, 11 indicators were categorized based on presence and absence. The remaining 5 indicators were categorized according to classes. The data were then reclassified into 5 categories as shown in Table 3. These data were reclassified with the help of the experts who had involved in providing data and weights for the AHP assessment.

3.4.3. Evaluation of importance

Different indicators have different levels of importance in terms of their contributions the sensitivity assessment (Gan et al., 2018; Hu et al., 2019; Shi et al., 2018). In order to

address this, Analytical Hierarchy Process (Saaty, 1977) was used. An evaluation was carried out with the participation of 5 experts at which each expert marked the level of importance of each indicator according to their opinion. The scoring options provided for them to choose from are as mentioned below (Ni et al., 2022).

- 1: i and j are equally important.
- 3: i is slightly more important than j.
- 5: i is more important than j.
- 7: i is much more important than j.
- 9: i is absolutely more important than j.
- 1/3: i is slightly less important than j.
- 1/5: i is less important than j.
- 1/7: i is much less important than j.
- 1/9: i is absolutely less important than j

Where “i” represents the base indicator for comparison, and “j” represents the alternate indicator being compared to “i”. The comparison is done between all the criteria, factors and indicators of the created framework.

Feedback responses were used to calculate the geometric mean, resulting in a single value (Stević et al., 2017). This value was used to develop a pairwise comparison matrix, with the sum of column values calculated. The normalized pairwise values were then generated by dividing each column's elements by its sum value. Criteria weights were calculated by averaging the elements in each row (Stević et al., 2017).

A consistency ratio was assessed to ensure that the values were within the acceptable range (below 0.1), requiring revisiting the pairwise matrix. Each column value was multiplied by the criteria value, and a weighted sum value was obtained by summing the row values (Stević et al., 2017). A ratio of the weighted sum value and criteria weight was computed for each row. λ_{max} was determined as the average of these values. The Consistency Index (C.I.) was calculated using a formula, and the consistency ratio was derived by dividing the consistency index by the random index, ensuring the framework's reliability and robustness (Stević et al., 2017).

3.4.4. Overlaying of Indicators

To overlay the indicators to get the result, a weighted summation was performed (Butt et al., 2019; Hu et al., 2019; Ni et al., 2022). Using the weighted sum tool in Arc GIS, the layers were multiplied with the relevant weights obtained through AHP to get the final overlaid map result. The following equation (Eq1) was used:

$$S = \sum_{i=1}^n W_i X_i \quad \text{Eq1}$$

Where S denotes the sensitivity level, W_i denotes the weight of the indicator obtained through AHP, X_i is the classified value of the indicator, and n denotes the number of

indicators used for the sensitivity assessment (Butt et al., 2019; Hu et al., 2019; Ni et al., 2022).

3.5. Analysis of results

After developing the map, the sensitivity levels of the case study area were identified. Subsequently, the areas that needed to be prioritized, as well as those that were relatively stable were described and discussed (Hu et al., 2019).

4. Results

4.1. Results obtained from AHP.

An evaluation was carried out with five experts to identify the weights that each criterion, factor, and indicator contributes to the sensitivity. The table below shows the final weights obtained from the AHP survey.

Table 4. Final weights of indicators

Target	Criteria	Factor Level	Indicator Level	Global weights
Environmental Sensitivity	Sensitive Biological Resources (0.75)	Typical Habitats (0.75)	Reefs (0.43)	0.242
			Mangroves (0.43)	0.242
			Sandy Beach (0.14)	0.079
		Location of Species (0.25)	Fish species (0.43)	0.081
			Crustaceans (Shrimp, Sea Urchins) (0.43)	0.081
			Shorebirds (0.14)	0.026
	External Disturbances (0.25)	Hazards (0.53)	X-press pearl maritime accident (0.83)	0.110
			Coastal erosion (0.17)	0.023
		Environmental quality (0.33)	Water Quality - Temperature (0.19)	0.016
			Water Quality - pH (0.24)	0.020
			Water Quality – Dissolved Oxygen (0.24)	0.020
			Water Quality – Oil and Grease (0.33)	0.027
		Human activities (0.14)	Tourism-related activities (0.25)	0.009
			Location of Fishing activities (0.25)	0.009
			Harbor and fish landing sites (0.25)	0.009
			Aquaculture and Hatchery (0.25)	0.009

4.2. Results of combined maps

4.2.1 Sensitivity assessment of sensitive biological resources and external disturbances.

The sensitivity maps were prepared based on the data obtained and the weights

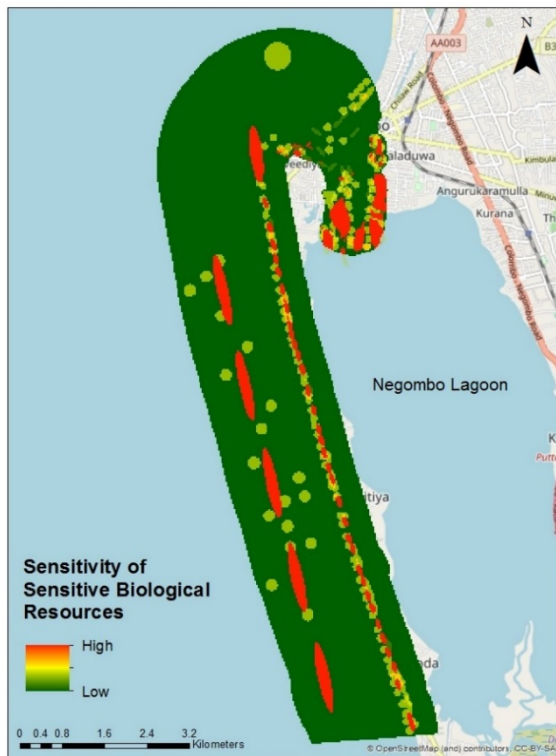


Figure 6: Map of sensitive biological resources

allocated by the experts in the AHP process. According to the framework created for the environmental sensitivity as assessment of coastal zones, areas, where there is high endogenous sensitivity, signify that the level of ecological significance in that area is high. Figure 6 shows the sensitivity levels of sensitive biological resources in the considered coastal zone.

Another criterion considered under the sensitivity assessment framework is the external disturbances that already have or may influence sensitive biological resources. So, if the exogenous sensitivity is high, it means that the level of external disturbance in that area is also high. Figure 7 shows the level of influence of the external disturbances in terms of sensitivity.

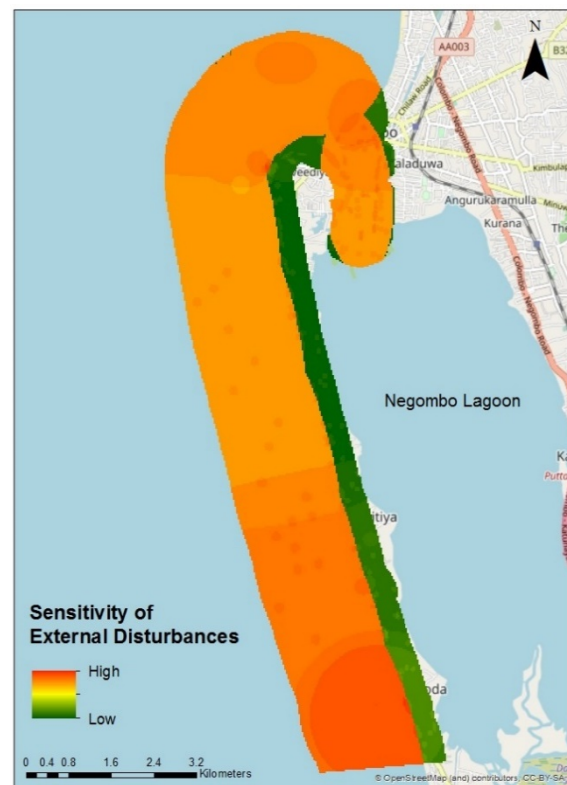


Figure 7: Map of external disturbances

4.2.2. Environmental Sensitivity of the Coastal Zone of Negombo

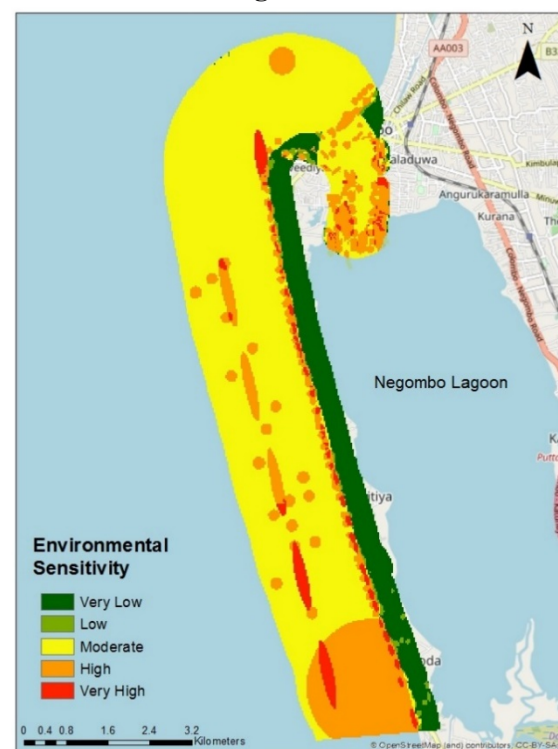


Figure 8: Environmental sensitivity map of Negombo coastal zone.

After overlaying all the indicators, the output of the environmental sensitivity map of the coastal zone of Negombo could be depicted as shown in the map below.

The areas that have very high sensitivity have both high levels of sensitive biological resources and high levels of external disturbances. This indicates that these areas were of high ecological significance and at the same time have already or are likely to be influenced by disturbances caused by hazards, environmental quality change and human activities. Accordingly, these areas are the ones that represent a need for focus in terms of management. When considering areas with high levels of sensitivity, there could be two scenarios. One could be that the ecological significance (endogenous sensitivity) is somewhat less, or it could be that the impact of external disturbances on the area is less compared to the areas with very high sensitivity. Areas with medium levels of sensitivity suggest that the biological aspects of these areas are undergoing several problems or may be sensitive to certain pressures. The areas that represent low and very low sensitivity are the regions that have relatively stable conditions, with the possibility that problems do occur but at a much lower rate. In these areas, the ecological influence could be quite low as well. The table shows the area according to each sensitivity level within the selected coastal zone area of Negombo.

Table 5: Extent of each sensitivity levels

Sensitivity Levels	Extent (km ²)	Percentage (%)
Very Low	5.08	13.5
Low	0.37	1
Medium	23.82	63.1
High	7.17	19
Very High	1.30	3.4

4.3. Discussion

When the sensitivity map developed by the UDA is compared with the map developed in this study, a difference between the two maps can be visualized. The sensitivity map by the UDA shows the coastal area as the low sensitive only. However, from the maps produced in this study, additional

information can be found as mentioned below.

- Areas that have very high sensitivity that have or are prone to many problems due to the presence of highly sensitive biological aspects and external disturbances (Hu et al., 2019)
- Areas that have high to moderate sensitivity that either have low biological sensitive aspects with high external disturbances or vice versa which require maintenance (Hu et al., 2019).
- Low to very low sensitive areas that have low biological sensitivity and low external disturbances, which are potential areas to carry out sustainable development (Hu et al., 2019).

According to the points mentioned above, having a framework that considers not only sensitive biological aspects, but also external disturbances is a good method to assess sensitivity.

5. Conclusion and Recommendations

Environmental sensitivity or stability refers to the way that an environment reacts to different stressors and influences. Environmentally sensitive areas are vital for preserving long-term biological diversity and safeguarding local and regional natural resources such as soil and water. Urban communities frequently encounter the dilemma of balancing economic development with environmental conservation. They understand that uncontrolled development can result in the permanent loss of these crucial areas.

Therefore, identifying ecologically sensitive areas in urban contexts is crucial for ensuring the safety and ecological balance of urban ecosystems. Moreover, urban development plans are imperative for pinpointing environmentally sensitive locations and implementing land-use strategies and regulations to conserve them. It is important to remember that sensitivity

is not a direct or primary criterion when mapping environmentally sensitive areas. Instead, it is a derived value that cannot be directly measured, illustrating the connection between the environmental stress applied and the resulting response. The critical point of this identification process involves predicting the relationship between stress and response. This is mainly accomplished by comparing them with environmental units elsewhere, where we already possess knowledge about how specific stresses lead to particular responses.

The accuracy of an environmental sensitivity map is determined on two critical factors: (1) the availability and relevance of information for comparison and (2) the degree of similarity between ecosystems and stress factors with known responses and those under consideration for the development of the map. The coastal area of Sri Lanka provides various ecosystem services and at the same time is exposed to various challenges, usually due to improper management (IUCN-Sri Lanka, n.d.). Sensitivity analysis helps to ensure better urban development and environmental protection as it helps to make more sustainable spatial planning decisions (Gan et al., 2018). The sensitivity map developed for the Negombo area does not show much detail making it difficult to identify areas that have problems to be managed, and areas that have potentials for sustainable development.

This study carried out a sensitivity assessment to mend this gap. Initially, a framework was created through a literature review. Considering the three main factors: biological sensitivity, ecological process sensitivity and utilization factors, a framework was developed for the assessment of the coastal zone sensitivity. Under these sensitive biological resources (including biological factors) and external disturbances (including ecological process factors and utilization factors) were considered.

16 indicators were selected, and they have been indicated in the spatial maps were developed using GIS-based analysis. AHP method was used to obtain weights for the indicators so that their level of importance could be identified. The observations from the maps enabled the areas to be divided into very high, high, moderate, low and very low sensitivity zones.

Areas, where the sensitivity was very high, are priority areas for management as the sensitive biological aspects and external disturbances were both high. In certain areas, either the external disturbance was high, or the sensitive biological aspects of the area were high. Accordingly, after identifying the proper reason behind the level of sensitivity, action could be taken to either maintain the status of the biological aspect or regulate the external disturbance in that area. Some areas were identified as very low to low sensitivity making their potential areas for sustainable development.

One of the limitations encountered in this research was the non-availability of data. To address this limitation, the remote sensing technology was used to acquire data for a subset of critical indicators. This measure might have enhanced the comprehensiveness of the dataset, reducing the impact of data limitations on the research. Another limitation identified is that the outcome of the sensitivity map that depended significantly on the opinions of individual experts.

To overcome this limitation, organizing meetings with experts from diverse backgrounds can be considered. While this collaborative approach may be time consuming, it is likely to produce more accurate and well-informed weightage. Experts can engage in discussions and reach a consensus on the relative importance of different indicators, reducing the impact of individual subjectivity and enhancing the overall credibility of the weightage. As for recommendations, the areas where the management practices are currently carried out could be identified and

then compared with the map to see if the practices are being carried out for the identified areas and if further management measures need to be ensured.

7. References

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