Faculty of Resource Science and Technology

Predicting Coastal Vulnerability at beaches of Buntal Bay

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Final Year Project Report ✓

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Predicting Coastal Vulnerability at beaches of Buntal Bay

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Abstract

Coastal vulnerability are condition where the coastal area are being expose to erosion and accretion due to natural processes and anthropogenic activities. A study was conducted along the coast of Buntal Bay to predict its coastal vulnerability by using CIVAT method during and post monsoon. Geomorphological changes along the coast of Buntal Bay were determined by using shoreline tracing. Vulnerability level of the beaches along the coast of Buntal Bay were determined by using CIVAT criteria; exposure, adaptive capacity and sensitivity. Awareness level of the local communities towards changes in beach were analysed by using questionnaires and interviews. North Buntal beach have a high level of vulnerability with medium adaptive capacity towards high potential impact. Meanwhile, South Buntal beach have a low level of vulnerability with high adaptive capacity towards medium potential impact. Erosion at Buntal areas was very much localized with some part of the beach experiencing erosion and some area experiencing accretion.

Keywords: Coastal Integrity Vulnerability Assessment Tool, erosion, moonsoon, shoreline tracing, beach profiling

Abstrak

Kelemahan laut adalah keadaan di mana kawasan pantai sedang terdedah kepada hakisan dan pertambahan akibat proses semulajadi dan aktiviti antropogenik. Satu kajian telah dijalankan di sepanjang pantai Buntal untuk meramalkan kelemahan pantai dengan menggunakan kaedah CIVAT semasa dan selepas musim tengkujuh. Perubahan geomorfologi di sepanjang pantai Buntal akan ditentukan dengan menggunakan kaedah sisir pantai. Tahap kelemahan pantai sepanjang pantai Buntal akan ditentukan dengan menggunakan kriteria CIVAT; pendedahan, keupayaan menyesuaikan diri dan kepekaan. Tahap kesedaran masyarakat tempatan terhadap perubahan pantai dianalisis dengan menggunakan survei dan temu bual. Utara Buntal mempunyai tahap kelemahan yang tinggi dengan keupayaan beradaptasi yang sederhana terhadap kesan potensi tinggi. Sementara itu, Selatan Buntal mempunyai tahap kelemahan yang rendah dengan kapasiti penyesuaian yang tinggi terhadap kesan potensi sederhana. Hakisan di kawasan Buntal amat setempat dengan beberapa bahagian pantai mengalami hakisan dan beberapa bahagian mengalami pertambahan.

Kata kunci: 'Coastal Integrity Vulnerability Assessment Tool', hakisan, kaedah sisir pantai, profil pantai

1.0 Introduction

In Malaysia, the coastlines consist of two different physical formations such as the mangrove and nipah-fringed mudflats, and the sandy beaches (Abdullah, 1992). The coastline of Sarawak is 1035km, characterised by long, straight sandy beaches on the east half and mangrove fringed shoreline on the west half (Department of Irrigation and Drainage, 2009). The National Coastal Erosion Study (NCES) results indicated that approximately 1380km or 29% of the Malaysian coastlines are experiencing erosion of varying degrees of severity (Department of Irrigation and Drainage, 2012). This is mainly because of the increase in the number of human population within the coastline, socio-economic and also natural processes. With the increasing population growth, the particular area will become more susceptible to coastal hazards. It has been estimated that, 23% of the world's population lives both within 100km distance and 100m elevation of the coast, and the population densities in coastal regions are about three times higher than the global average (Small and Nicholls, 2003). Sarawak have equatorial climate which experiencing two monsoons namely, northeast and southwest monsoon. The major rainy season, northeast monsoon, brings heavy rainfall to the coastal areas that often causes flooded in several states of Malaysia.

Coastal erosion seriously threatens the economic activities and human population along the coastal areas. Therefore, it is very important for the people to have environmental concerns and know the beaches very well in order to avoid coastal erosion. There were very few coastal researches had been conducted in Peninsular Malaysia, however there was one conducted in Kuala Setiu, Terengganu by Husain *et al.* (1995). According to NCES (1985), there was a coastal research study conducted along the beaches of Buntal bay.

However, the data of coastal erosion in Buntal area was almost 30 years back, therefore it is very important to conduct a new research and predict the coastal erosion or coastal vulnerability particularly along beaches of Buntal Bay. One of the significant of this study is that it contributes data for various organizations such as Department of Irrigation and Drainage (DID) in order to prevent future erosion. Besides, the data obtained can help the coastal planners, resource managers and property owners to identify appropriate and inappropriate areas to place building structures. The objectives of this study were:

1. To determine the geomorphological changes along beaches of Buntal Bay.
2. To identify the vulnerability level of the beaches along beaches of Buntal Bay.
3. To determine the awareness level of local community to general vulnerability.

2.0 Literature Review

2.1 Coast of Buntal

Buntal, is a typical Malay fishing village setting which is located at the mouth of the Sarawak River. This village is located about 45-minute drive from Kuching and it is located not far from Santubong. According to the local people, million years ago, a river in this village had received an abundance of pufferfish or locally known as 'ikan buntal' Therefore, the name of the village is called 'Kampung Buntal'. Because of the strategic position, Buntal has become a shelter place for the local people particularly during the monsoon season. Coastal protection work such as rock revetment has been conducted at Kampung Buntal in 2008 in order to protect the shoreline from erosion (Department of Irrigation and Drainage, 2012). Fishing is the main activity where most of the local people work as fishermen for a living. Most of them derive their primary income from fishing, with increasing participation in tourism activities. It is one of the famous places among locals and tourists for seafood cuisine. This village provides a view of part of the Bako-Buntal Bay IBA where it is known to be an important wintering ground for migratory birds (Orienstein *et al.*, 2010).

2.2 Coastal Geomorphology

Coastal zone defined as the interface where land meets the ocean including the shoreline environments as well as adjacent coastal waters where its components consist of coastal plains, wetlands, beaches, reefs, mangrove forests and others (Post and Lundin, 1996). The coastal zone also defines as an area of variable width that extends seaward to the edge of continental shelf where human activities may influenced the ecosystems and natural processes (Hail, 1980). Coastal geomorphology involves study of coastal features such as rocky shores, beaches, estuaries and their evolution over time. Meanwhile, coastal geology focused on the rock formations, structures and the sediments found in the coastal areas and thus provide a background for coastal geomorphology. Coastal areas are very important as they provide ecological, cultural, and economic benefits such as urbanization, tourism, shipping, agriculture, recreational and port activities. However, increased in the population growth and development also increased the vulnerability of coastal regions. Coasts are influenced by many factors including natural or man-made activities. Different types of coasts can be recognized by the dominant events occur there such as erosion and accretion.

2.3 Erosion Categories

Based on The National Coastal Erosion Study (1985), about 29% (1390km) of the coastlines in Malaysia are experiencing erosion of varying degrees of severity. The distribution of eroding coastlines of Malaysia is shown in Table 1 below. Coastal erosion sites have been classified into the following categories:

a) 145km of critical erosion areas where shore-based facilities are in imminent danger (Category 1)
b) 246km of significant erosion areas where the facilities are expected to be endangered within 5 to 10 years if no remedial action is taken (Category 2)
c) 975km of acceptable erosion areas that are generally undeveloped with consequent minor economic loss if coastal erosion continues unchecked (Category 3)

Table 1: Distribution of eroding coastlines of Malaysia (NCES, 1985)

Area	Length of coastlines	Category 1	Category 2	Category 3	Total length of eroding coastlines	
	(km)	(km)	(km)	(km)	(km)	(%)
Peninsular	1972	255.8 (78)	164.5 (43)	618.9 (52)	1039 (173)	73
Sabah	1802	15.3 (7)	6.5 (4)	304.3 (14)	326.1 (25)	23
Sarawak	1035	17.3 (8)	22.3 (10)	9.6 (7)	49.2 (25)	3
Total	4809	288.4 (93)	193.3 (57)	932.8 (73)	1414.5 (223)	29

() – Number of sites

For Buntal, the shoreline condition falls under category 1 which is critical erosion as shown in Figure 1. The shoreline retreat was approximately 2m per year since 1986. For this area, an immediate action or the short term strategy such as the hard engineering solution (seawalls, revetments, break water) are required to control or to reduce the erosion. In this study area, rock revetments have been built along the shoreline in order to prevent erosion (refer Table 2). Since the coastline of the study area is aligned in the northwest to southeast direction, it is open to wave attack from South China Sea during Northeast monsoon (Department of Irrigation and Drainage, 2009). Therefore, it is subject to relatively rough monsoonal weathers. Most of the deltaic and estuarine areas are fringed by mangrove forests.

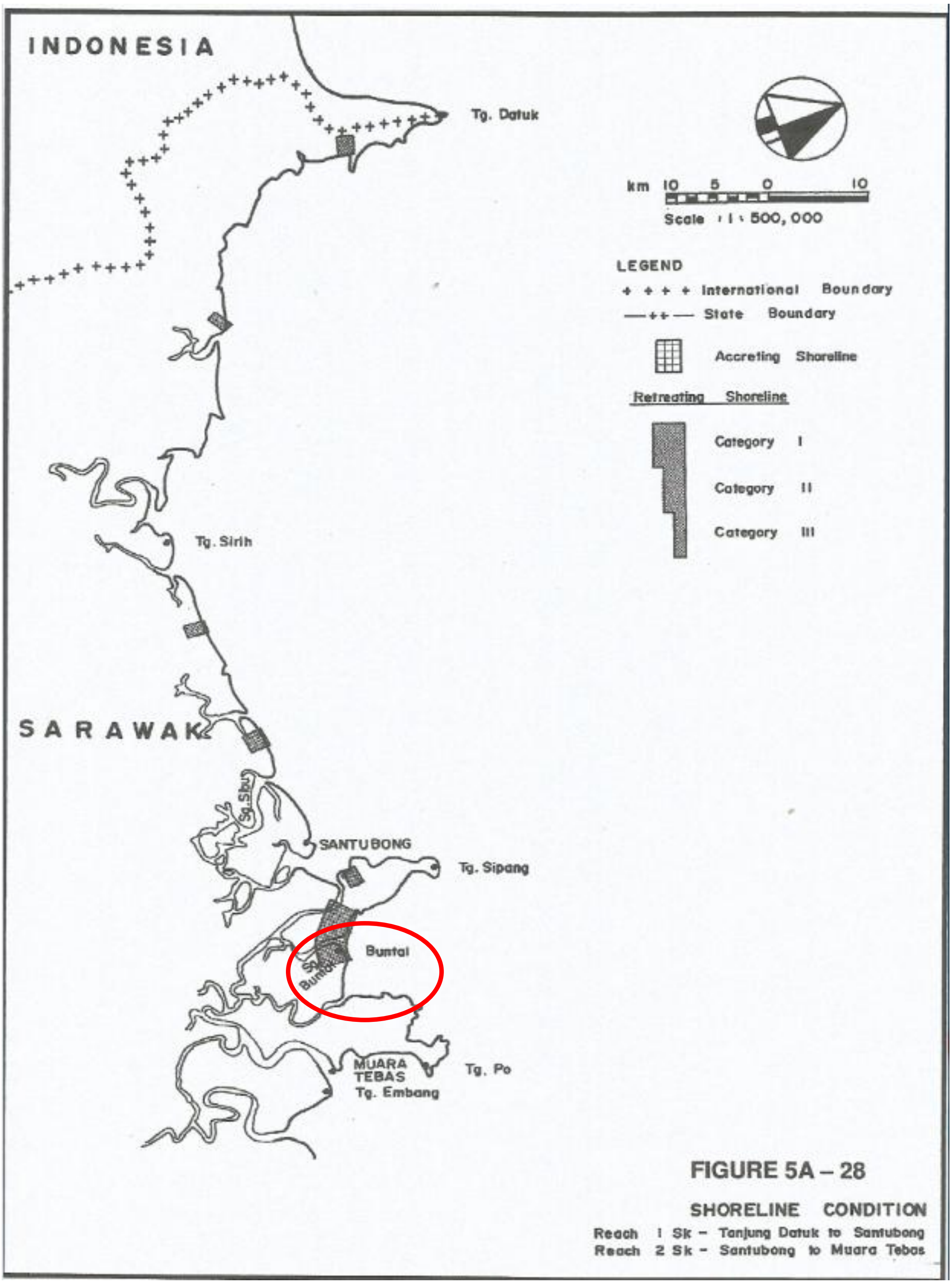

Figure 1: Buntal shoreline with classification of erosion categories (Department of Irrigation and Drainage, 2009).

Table 2: Coastal Erosion Control Protection Works (DID, 2009)

Coastal Erosion Control Protection Works					
No	Project Location	Year of Completion	Length/Type of Protection Works	Malaysian Plan	Fund
1	Kampung Buntal Lama	2008	168m - Rock Revetment	6 MP	Federal
2	Kampung Buntal Lama (Phase II), Kuching	2010	Rock Revetment	9 MP	Federal

2.4 River Mouth of Buntal

River mouths are classified into three categories depends on the combination of the seriousness of physical, economic and social aspects that affects the fishing communities (NRMS, 1994). Primary concern is usually the siltation of the river mouth. For river mouth of Buntal, it falls under category 2 which is significant. This is due to the very serious condition of physical aspects, serious level in economic condition and fair social condition. For category 1 and 2, counter measures usually will be considered in order to reduce the siltation problem. Therefore, rock revetments can be found at the coastline of Buntal. The list of river mouth is shown in Table 3 while degree of seriousness of each aspect is given in Table 4(a), 4(b) and 4(c). While, for the list of the three categories are as follows:

Category 1 (Critical)

River mouths that fulfilled the following combinations are included in Category 1:

Combination 1: River mouth condition is very serious in both physical and economic aspects.

Combination 2: River mouth condition is very serious in both physical and social aspects, but it is serious in the economic aspect.

Combination 3: River mouth condition is serious in physical aspect, but very serious in economic aspect and very serious/serious in social aspect.

Category 2 (Significant)

Except the river mouths in Category 1, those which fulfill the following combinations fall under Category 2:

Combination 1: River mouth condition is more than serious in both physical and economic aspects.

Combination 2: River mouth condition is very serious in the physical aspect, but it is fair in the economic aspect and very serious or serious in the social aspect.

Combination 3: River mouth condition is fair in the physical aspect, but it is very serious in the economic aspect and very serious or serious in the social aspect.

Category 3 (Acceptable)

The remaining river mouths not categorized under either Category 1 or Category 2 belong to Category 3.

Table 3: List of River Mouth by Category (Category-2: Significant)

Name	Physical Condition	Economic Condition	Social Condition
Buntal	Very Serious (VS)	Serious (SE)	Fair (FA)

Table 4(a): Physical Aspects

Seriousness	Condition
Very Serious	The assumed minimum depth in the river mouth is shallower than the draft of the largest boat.
Serious	The assumed minimum depth in river mouth is in the range between the draft of the largest boat and the clearance plus draft of the largest boat.
Fair	The assumed minimum depth in the river mouth is deeper than the draft of the largest boat plus clearance.

Table 4(b): Economic Aspects

Seriousness	Number of Fishermen
Very Serious	> 200
Serious	200 – 50
Fair	< 50

Table 4(c): Social Aspects

Seriousness	Condition
Very Serious	Existence of very strong complaint
Serious	Existence of fairly strong complaint
Fair	No Complaint

2.5 Beaches

Beaches are temporary land that consists of an accumulation of unconsolidated sediments ranging from fine sand to large cobbles which have been transported and deposited by waves and currents (Davidson-Arnott, 2010). Most of them are exposed to the open or stormy seas but some are sheltered in bays or behind islands or reefs. Beach systems deal with the interactions between beaches and coastal processes such as waves, currents, tides and winds. Beach sediments consist of many materials such as boulders, cobbles, pebbles, gravel, sand, very fine silt and sometimes clay. Some of them consists fragments of coral, shells and shell debris. The action of waves and currents with beach sediments will produce certain textural characteristics. Those particles that have been subjected to waves action and currents for a long time tend to be smooth and soft, while those particles which are angular indicates that they are 'new' to the beach (Davis and FitzGerald, 2004).

2.5.1 Beach Erosion

Erosion of the beaches occurred when they lose more sediment alongshore, offshore or to the hinterland than they received from the various sources. Beaches with high energy will have steeper slopes, larger sand particles and are more vulnerable to erosion (Sharma, 2009). Factors of beach erosion can be induced either by natural processes or human activities. Example of natural process is storm waves. During stormy condition, sand will be transported offshore due to formation of destructives waves. Destructive waves are high energy waves that consist of strong backwash and weak swash. Strong backwash will remove beach material while weak swash ashore little material. So, more materials will be removed than being deposited on the coast. One of the major factors of human activities is sand mining. Sand mining directly from a beach will removes the sand permanently from coastal system. This causes total destruction of the coastal ecosystem including beach, dunes and coastal wetlands. This process destroys the riverine vegetation, pollute water sources and reduce diversity of animals in the ecosystem (Byrnes and Hiland, 1995). Thus, these areas will become more susceptible to coastal hazards.

2.6 Vulnerability Assessment (VA)

Vulnerability is a measure of the degree to which a human or natural system is unable to cope with adverse effects of climate change including climate variability and extremes. According to the IPCC vulnerability is a function of the character, magnitude, and rate of climate change to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2001). Exposure means the nature and amount to which the system is subjected to climate change. It is one of the major elements of vulnerability where it quantifies the intensity or severity of the physical environment conditions driving changes in the present state of the biophysical system. Examples are sea-level rise, waves and storm surge, sea-surface temperature, and rainfall. Sensitivity is the degree to which a system or particular area and people is being affected, either adversely or beneficially by climate changes. Sensitivity defined as here-and-now bio-physical attributes of the coast that predispose it to erosion and inundation as a result of stronger waves and higher sea levels, and are grouped into intrinsic and extrinsic variables (Siringan *et al.*, 2013). The geomorphology, slope, shoreline trends and natural buffers are examples of intrinsic sensitivity. Examples of extrinsic sensitivity are beach mining and structures on the foreshore such as groins and seawalls. Adaptive capacity (AC) is ability of a system to respond and adapt to the consequence associated with the changes in climate. Systems with high adaptive capacity are better in dealing with the climate change impacts. As an example, if potential impact

(PI) or exposure is high and the adaptive capacity is low, therefore, it is highly vulnerable. However, if the exposure is high and adaptive capacity is high, then it is low vulnerability. The sensitivity and exposure may be taken together to yield Potential Impact (Allison *et al.*, 2009). Potential impact here means how much are the potential of an area being subjected to the climate change. The potential impact is calculated based on the level or threat of the exposure of that particular are. The relationships among the three components are shown in Figure 2.

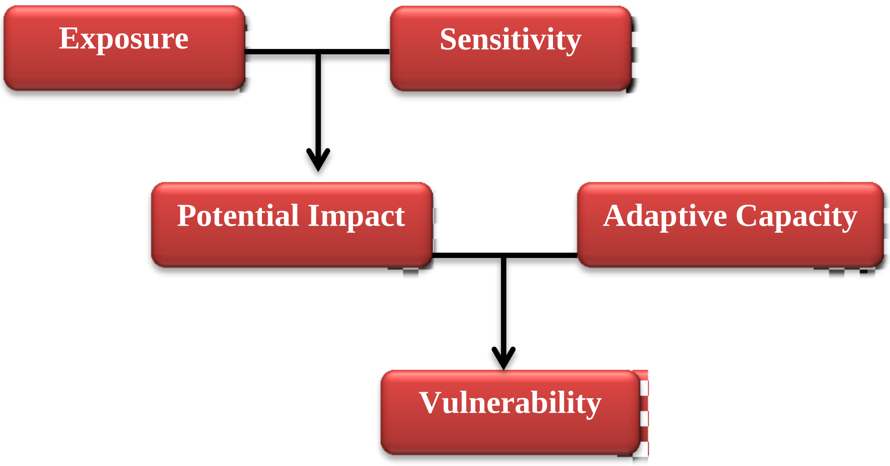

Figure 2: Relationship of Exposure, Sensitivity and Adaptive Capacity

(Alino *et al.*, 2013)

2.7 Wave, Monsoon and Sea Level Rise

Waves are the major factors that contribute to erosion. Waves can both erode rock and deposit sediment. For example, waves that break or hit against hard rocky coasts or solid sea walls are reflected and will brings sediment to seaward. Meanwhile, wave that arrive and break at an angle to the coastline will move the water and sediment along the shore. Motion of waves can only be felt to a depth of 1/2 times the wavelength. Therefore, waves can only erode if the water along a coastline is shallower than 1/2 times the wavelength. In Malaysia, there are two monsoons, Southwest Monsoon from late May to September, and the Northeast Monsoon from November to March (Ministry of Science, 2013). During Northeast monsoon, waves are larger than normal due to the strong onshore winds and cause comparatively more damage (Hussain and Yaakob, 1988). Hence, this causes the waves to have more energy and reach the coast easily and increases rate of erosion. As sea level increases, the shape of coastline change and cause increased in the frequency and depth of tidal flooding and erosion. This would also cause a change in sedimentation type and pattern. Coastal erosion accelerates on beaches where the sea level rise will deepen near shores water and thus allowing larger waves to break on the coastline. Sea level rise will cause submergence and increased flooding of the coastal land and saltwater intrusion into surface waters. Flooding would damage coastal infrastructure and agricultural areas, while erosion can lead to a loss of buildings and gives large impact to coastal communities, tourism and recreation activities.

2.8 Importance of Mangroves

Mangroves trees can be found along tidal mudflats and saline coastal habitats in tropics and subtropics regions. In this study, mangroves are important as they play an important role in maintaining the coastal ecosystem and they provide a variety of environmental supports. Mangrove plantations in the vulnerable areas could be beneficial for long-term coastal protection both to continuous erosion and to severe hazard such as tsunami (Naohiro *et al.*, 2012). Plantation of mangroves in shoreline area result in rapid accretion as mangrove roots and pneumatophores function as the sediment trappers and help to slow the water movement. Mangrove vegetation acts as a buffer against cyclone, storm surge and other natural disaster by reducing the wave energy and stabilizes the sediment (Barua *et al.*, 2010).

2.9 Tools for Measuring Coastal Vulnerability Assessment

The coastal vulnerability assessment tools were developed as guidance in the coastal climate change adaptation planning by measuring the vulnerability of coastal systems to a variety of climate-related hazards. The tools were designed based on the framework suggested by the Intergovernmental Panel on Climate Change (IPCC) where the vulnerability assessment is a function of three elements: (1) exposure to climate change effects, (2) sensitivity, and (3) adaptive capacity. The current tools for coastal vulnerability assessment are:

a) Integrated Coastal Sensitivity, Exposure, and Adaptive Capacity to Climate Change (ICSEA-C-Change)
b) Coastal Integrity Vulnerability Assessment Tool (CIVAT)
c) Tool for Understanding Fisheries Resilience (TURF)

The Integrated Coastal Sensitivity, Exposure, and Adaptive Capacity to Climate Change Vulnerability Assessment Tool (ICSEA-C-Change), a tool for broad and integrated scope of climate change vulnerabilities. It provides coastal communities the means to understand their relative vulnerabilities to climate change impacts, including sea level rise, ocean warming, increased storminess, extreme rainfall events, and resulting sedimentation of coastal waters (Licuanan *et al.,* 2013). This tool helps to evaluate criteria relevant to coastal integrity, biodiversity and fisheries concerns and centralizes information and evaluates the data available for CIVAT and TURF.

Tool for Understanding the Resilience of Fisheries (TURF) is a tool for assessing climate change vulnerability of coastal fisheries in the tropic. It has high (fine) resolution of analysis and comprises of three major components; fisheries aspects, reef ecosystem features (habitat), and socio-economic attributes. TURF considers different climate hazards, specifically storm surge, waves and sea surface temperature (SST). The communities that are highly dependent on fishing more vulnerable to climate-related factors such as elevated sea surface temperature (SST), increasing storm frequency, and wave surge, among others (Allison *et al.*, 2009). The aim of this tool is to appreciate the potential impacts and vulnerabilities of fisheries ecosystems at the village level.

Coastal Integrity Vulnerability Assessment Tools (CIVAT) is a tool to measures the vulnerability of the physical coast by analysing the natural and anthropogenic factors in relation to sea level rise and waves impact. This vulnerability assessment tool has high (fine) resolution of analysis. Waves and sea level changes are considered as the main agents of erosion. This tool is designed to "combine the coastal system's susceptibility to change with its natural ability to adapt to changing environmental conditions, yielding a relative measure of the system's natural vulnerability to the effects of sea-level rise" (Aboudha and Woodroffe, 2006) Therefore, based on the comparisons between the available coastal VA tools in Table 5, CIVAT is chosen in this study because it is more detailed vulnerability assessment tool which focus specifically on the coastal integrity. Moreover, this tool has high resolution analysis and it is simple where non-specialists such as coastal managers can implement the method.

Table 5: Advantages and Disadvantages of Coastal VA tools

Tools	Advantages	Disadvantages
ICSEA-C-CHANGE	• Effective communication tool • Offers comparison of general vulnerabilities across sites • Scopes available information for other coastal VA tools • Guide identification of general adaptation measures, assist in improving adaptive management	• Low (coarse) resolution of analysis • Cannot provide specific adaptation options
TURF	• High resolution of analysis • Reveals specific Sensitivity and AC factors relating to different fisheries aspects • Provide guidance in developing specific CC adaptation strategies to sustain fisheries management	• Requires fisheries expert to guide data collection and analyse data
CIVAT	• High resolution of analysis • Reveals specific Sensitivity and AC factors relating to coastal integrity • Provide guidance in developing CC adaptation strategies to maintain coastal integrity	• Requires coastal geologist to guide data collection and analyse data

3.0 Materials and Methods

3.1 Study site

Figure 3 shows the study sites along the beaches of Buntal Bay. The study area is located on the east coast of the Santubong-Buntal peninsular, approximately 25km north of Kuching. The coastline stretches from Tg. Batu headland in the northwest to Muara Buntal in the southeast for a total length of about 7.5km. In this study sites, it was divided into two parts, North Buntal beach (Station A) and South Buntal beach (Station B). There were four times of beach profiling conducted at station A while two times of beach profiling at station B. the sampling was done twice which was during the northeast monsoon (November) and after northeast monsoon (March). The general descriptions of the study sites are shown in Table 6.

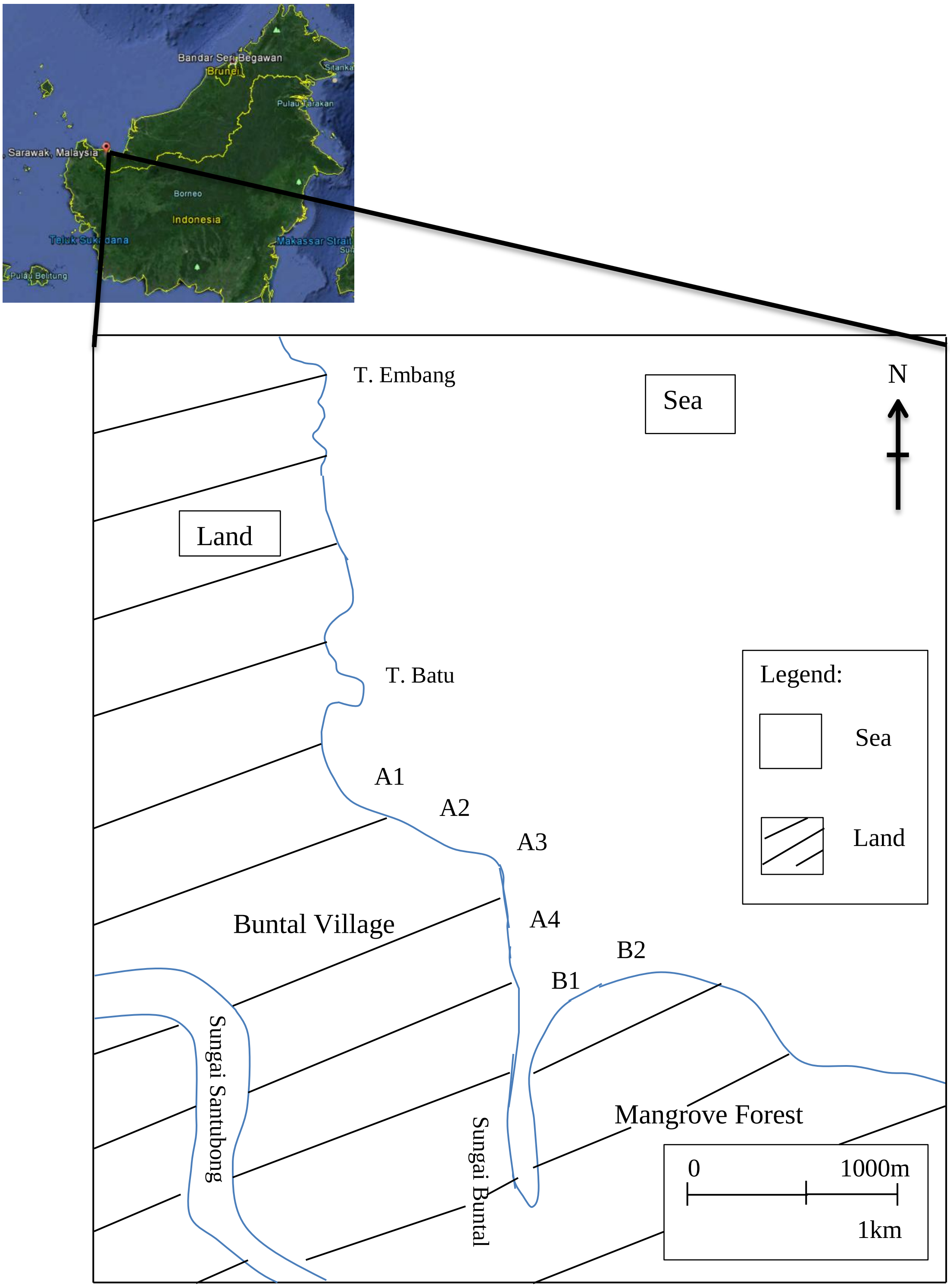

Figure 3: Map of study sites along beaches of Buntal Bay (Adapted form Sarawak Marine Department; 2004)

Table 6: Description of general surrounding of each beach

Location	Station	General Descriptions
North Buntal Beach	A1	Hilly and rocky land Vacant land Private chalet
	A2	Village houses
	A3	Scattered village houses Coconut plantation
	A4	Seafood restaurants Village houses
South Buntal Beach	B1	Coconut plantation
	B2	Near river mouth of Buntal

3.2 Process of sampling

Before the sampling starts, the location and length of the beach were measured. All the equipment such as measuring stakes, GPS, measuring tape and camera were checked to make sure they were in good condition. During the sampling, the general surrounding of the study sites were observed and pictures were taken. Any signs of erosion or accretion were observed and recorded. After the sampling was done, all the data obtained were analyzed to get the final results. The methodologies will be explained in Figure 4.

Figure 4: Flowchart of sampling

3.3 Data Recording

Data of coastal vulnerability from the study sites will be obtained using CIVAT. It is the most appropriate tool to measure the vulnerability compared to ICSEA-C-Change and TURF because this tool can help to identify the specific adaptations options to improve the coastal integrity. Coastal integrity refers to the overall state of the coast resulting from its geologic history (e.g., regional setting, geomorphology), bio-physical processes (e.g., waves, tides, storms) that continuously shape and re-shape it, and human activities (Siringan *et al.*, 2013). Two procedures that need to be carried out are beach profiling and shoreline tracing.

3.3.1 Beach Profiling

Beach profiles provide useful information for the coastal monitoring studies and management processes. The beach profile method was adapted from Emery (1961). This method was used in order to determine the steepness of the beach gradient. Two pairs of