National Coastal Vulnerability Assessment and Designing of Integrated Coastal Management and Adaptation Strategic Plan for Timor-Leste

Coastal Vulnerability Assessment Report

February 2018

List of Abbreviations

ADB	Asian Development Bank
AL-GIS	Agriculture and Land Use Geographic Information System
ATSEA	Arafura and Timor Seas Ecosystem Action
AUSAID	Australian Agency for International Development
CC	Climate Change
CCCBTL	Centre for Climate Change and Biodiversity Timor-Leste
CBA	Cost Benefit Analysis
CEA	Cost-Effectiveness Analysis
CHW	Coastal Hazard Wheel
CI	Conservation International
CIVAT	Coastal Integrity Vulnerability Assessment Tool
cm	centimetres
CO_2	Carbon Dioxide
COP	Conference of Parties
CTC	Coral Triangle Center
CVA	Coastal Vulnerability Assessment
CVI	Coastal Vulnerability Index
DED	Detailed Engineering Design
DEM	Digital Elevation Model
DRR	Disaster Risk Reduction
EBA	Ecosystem-Based Adaptation
ECMWF	European Center for Medium Range Weather Forecasting
ENSO	El Niño Southern Oscillation
EU	European Union
EWS	Early Warning System
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GIS	Geographical Information System
GIZ	German Corporation for International Cooperation
GoTL	Government of Timor-Leste
GPS	Global Positioning System
Ha	Hectare
HAT	Highest Astronomical Tides
ICZM	Integrated Coastal Zone Management
IFC	International Finance Corporation
INC	Initial National Communication
INDC	Intended Nationally Determined Contributions
IOD	Indian Ocean Dipole Mode
IPCC	Intergovernmental Panel on Climate Change
IPO	Interdecadal Pacific Oscillation
ITCZ	Inter-tropical Convergences Zone
JICA	Japan International Cooperation Agency
Km	Kilometre
KOICA	Korea International Cooperation Agency
LAS	Live Access Server
LAT	Lowest Astronomical Tides
M	meters

MAF	Ministry of Agriculture and Forestry
Ma.s.l	Meters above sea level
MCA	Multi-Criteria Analysis
MCIE	Ministry of Commerce, Industry and Environment
MDG	Millennium Development Goal
MED	Ministry of Economy and Development
mm	millimetres
MMI	Mercali Modified Intensity
MoF	Ministry of Finance
MoH	Ministry of Health
MoJ	Ministry of Justice
MPA	Marine Protected Area
MPI	Multidimensional Poverty Index
MPSI	Ministry of Planning and Strategic Investment
MPW	Ministry of Public Works
MSS	Ministry of Social Solidarity
MTAC	Ministry of Tourism, Arts and Culture
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NDCC	National Directorate for Climate Change
NDMD	National Disaster Management Directorate
NGO	Non-governmental organization
NZAID	New Zealand Aid Programme
PCA-Cluster	Principal Component Analysis-Cluster
PGA	Peak Ground Acceleration
PTHA	Probabilistic Tsunami Hazard Assessment
RDTL	Republika Demokratika Timor-Leste
RQD	Rock Quality Designation
SDP	Strategic Development Plan 2011-2030
SLR	Sea Level Rise
SMB	Svedrup, Munk, and Bretscheider
SMS	Short Messaging Service
SRES	Special Report on Emission Scenario
SRTM	Shuttle Radar Topography Mission
SSE	State Secretariat for Environment
SSL	Sea Surface Level
SST	Sea surface temperature
SWAN	Simulating Wave Nearshore
SWH	Significant Wave Height
TL	Timor-Leste
UNCSD	United Nations Conference on Sustainable Development
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNTL	Universidade Nacional de Timor Lorosae
US$	United States Dollar
USAID	United States Agency for International Development
USGS	United States Geological Survey
VA	Vulnerability Assessment
WMO	World Meteorological Organization

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Glossary

Accretion	:	Sediment accumulation or growth in a beach that may be either natural or artificial. Natural accretion is the build-up of land, solely by the action of the forces of nature, on a beach by deposition of water (sea water due to waves in coastal waters, or river from upland). Artificial accretion is a similar build-up of land by reason of an act of man, such as the accretion formed by a groyne or breakwater, or beach fill deposited by mechanical means.
Arc	:	A chain of volcanoes (volcanic arc) that sometimes forms on the land, when an oceanic plate collides with a continental plate and then slides down underneath it, in geological time scale.
Bathymetry	:	The measurement of depths of water in oceans, seas, and lakes; also the information derived from such measurements.
Brackish Water	:	Salty water, but less salty than seawater.
Breakwater	:	A hard engineering structure built in the sea or a coast, aimed to protect a harbour, anchorage, beach or shore area from wave energy. A breakwater can be attached to the coast or lie offshore.
Climate	:	The composite or generally prevailing weather conditions of a region, throughout the year, averaged over a series of years.
Climate Change	:	A non-random change in climate that is measured over several decades or longer. The change may be due to natural or human-induced causes.
Coastal Zone	:	A band of dry land and adjacent to ocean space (waters and submerged land) in which terrestrial processes and land use directly affect oceanic processes and uses, and vice versa (oceanic processes directly influence terrestrial processes and land use).
Coastal Inundation	:	Flooding in coastal lands by ocean waters due to elevated still water level as results of storm surge, sea level rise, and wind wave run–up.
Coastal Zone Management	:	The integrated management of issues affecting the coastal zone. Coastal Zone Management is not restricted to coastal protection works, but includes also a development in socio-economical and ecological terms.
Coastline	:	(1) Technically, the line that forms the boundary between the coast and the shore. (2) Commonly, the line that forms the boundary between land and the water. (3) The line where

terrestrial processes give way to marine processes, tidal currents, wind waves, etc.

Continental Shelf	:	(1) The zone bordering a continent extending from the line of permanent immersion to the depth, usually about 100 m to 200 m, where there is a marked or rather steep descent toward the great depths. (2) The area under active littoral processes during the Holocene period. (3) The region of the oceanic bottom that extends outward from the shoreline with an average slope of less than 1:100, to a line where the gradient begins to exceed 1:40.
Cyclone	:	A large-scale circulation of winds around a central region of low atmospheric pressure, counterclockwise in the Northern Hemisphere, clockwise in the Southern Hemisphere.
Depth (of water)	:	Vertical distance from still-water level (or datum as specified) to the bottom.
Delta	:	(1) An alluvial deposit, usually triangular, at the mouth of a river of other stream. It is normally built up only where there is no tidal or current action capable of removing the sediment as fast as it is deposited, and hence the delta builds forward from the coastline. (2) A tidal delta is a similar deposit at the mouth of a tidal inlet, put there by tidal currents. (3) A wave delta is a deposit made by large waves which run over the top of a spit or barrier beach and down the landward side.
Diurnal	:	Literally of the day, but here it means having a period or a tidal day, i.e. about 24.84 hours.
Dune	:	Usually on land: a rounded hill or ridge of sand heaped up by action of the wind. Underwater: flow–transverse bedform with spacing from under one metre to over 1,000 metres that develops on a sediment bed under unidirectional currents.
Earthquake	:	A term used to describe both sudden slip on a fault, and the resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the earth.
El Nino	:	A warming of the ocean waters along the coasts of Peru and Ecuador (the eastern tropical Pacific ocean) that is generally associated with dramatic changes in the weather patterns of the region. This event is usually along with a cooling of the ocean in the western tropical Pacific ocean waters. A major El Nino event generally occurs every 3 to 7 years and is associated with changes in the weather patterns worldwide.
ENSO	:	Abbreviation for El Nino-Southern Oscillation, a reference to the

state of the Southern Oscillation.

Epicenter : The point on the earth's surface vertically above the hypocenter (or focus); point in the crust where a seismic rupture begins.

Erosion : The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation. It is also called as coastal abrasion

Estuary : Brackish water body influenced by the tides, where the mouth of the river meets the sea.

Exposure : The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected, usually by a natural threat or hazard

Flood Plain : A flat tract of land bordering a river, mainly in its lower reaches, and consisting of alluvium deposited by the river. It is formed by the sweeping of the meander belts downstream, thus widening the valley, the sides of which may become some kilometers apart. In time of flood, when the river overflows its banks, sediment is deposited along the valley banks and plains.

Food Security : A situation that exists when people have secure access to sufficient amounts of safe and nutritious food for normal growth, development and an active and healthy life. Food insecurity may be caused by the unavailability of food, insufficient purchasing power, inappropriate distribution, or inadequate use of food at the household level.

Geomorphology : A branch of physical geography which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc.; or the investigation of the history of geologic changes through the interpretation of topographic forms.

Ground Water : Water found beneath the Earth's surface where all empty space in the rock is completely filled with water.

Intensity of Earthquake : A number (written as a Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures. Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale. There are many intensities for an earthquake, depending on where you are, unlike the magnitude, which is one number for each earthquake.

La Nina : La Nina, a phase of ENSO, is a periodic cooling of surface ocean waters in the eastern tropical Pacific along with a shift in convection in the western Pacific further west than the climatological average. These conditions affect weather patterns around the world. The preliminary CPC definition of La Nina is a phenomenon in the equatorial Pacific Ocean characterized by a negative sea surface temperature departure from normal.

Lagoon	:	A shallow body of water, as a pond or lake, which usually has a shallow restricted inlet from the sea.
Longshore Current	:	A sea current occurred in the surf zone, moving generally parallel to the shoreline, generated by ocean waves breaking at an angle with the shoreline; also called the alongshore current.
Magnitudes of Earthquake	:	a number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph. Several scales have been defined, but the most commonly used are (1) local magnitude (ML), commonly referred to as "Richter magnitude", (2) surface-wave magnitude (Ms), (3) body-wave magnitude (Mb), and (4) moment magnitude (Mw). Scales 1-3 have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes. The moment magnitude (Mw) scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types. All magnitude scales should yield approximately the same value for any given earthquake.
Mixed Tides	:	Type of tide which the presence of a diurnal wave is conspicuous by a large inequality in either the high or low water heights with two high waters and two low waters usually occurring each tidal day. In strictness, all tides are mixed, but the name is usually applied without definite limits to the tide intermediate to those predominantly semi-diurnal and those predominantly diurnal.
Monsoon	:	A thermally driven wind arising from differential heating between a land mass or continent and the adjacent ocean that reverses its direction seasonally.
Nearshore	:	(1) In beach terminology an indefinite zone extending seaward from the shoreline well beyond the breaker zone. (2) The zone which extends from the swash zone to the position marking the start of the offshore zone
Ocean Acidification	:	Term used to describe significant changes to the chemistry of the ocean. It occurs when carbon dioxide gas (or CO_2) is absorbed by the ocean and reacts with seawater to produce acid. Although CO_2 gas naturally moves between the atmosphere and the oceans, the increased amounts of CO_2 gas emitted into the

		atmosphere, mainly as a result of human activities (e.g. burning fossil fuels), has been increasing the amount of CO_2 absorbed by the ocean, which results in seawater that is more acidic.
Peak Ground Acceleration	:	The largest increase in velocity recorded by a particular station during an earthquake.
Plate	:	A slab of rigid lithosphere (crust and uppermost mantle) that moves over the asthenosphere.
Rainfall	:	The amount of precipitation of any type, primarily liquid. It is usually the amount that is measured by a rain gauge. Refer to rain for rates of intensity and the quantitative precipitation for forecasting.
Sea Level Rise	:	An increase in the mean level of the ocean surface. Relative sea level occurs where there is a local increase in the level of the ocean relative to the land, which might be caused by ocean rising, the land subsiding, or both. In areas with rapid land level uplift (e.g. seismically active areas), relative sea level can fall.
Semi-diurnal	:	Having a period or cycle of approximately one-half of a tidal day (12.4 hours).
Semi-diurnal Tides	:	Tides occurring twice daily. The predominating type of tide throughout the world is semi-diurnal, with two high waters and two low waters each tidal day. The tidal current is said to be semidiurnal when there are two flood and two ebb periods each day.
Shoreline	:	The intersection of a specified plane of water with the shore.
Slope	:	The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25, indicating one unit rise in 25 units of horizontal distance; or in a decimal fraction (0.04). It is also called gradient.
Storm	:	Any disturbed state of the atmosphere, especially affecting the Earth's surface, and strongly implying destructive and otherwise unpleasant weather. Storms range in scale from tornadoes and thunderstorms to tropical cyclones to synoptic-scale extratropical cyclones.
Storm Surge	:	An abnormal rise in sea level accompanying a hurricane or other intense storm, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone. Storm surge is usually estimated by subtracting the normal or astronomic tide from the observed storm tide.

Temperature	:	A measure of the internal energy that a substance contains. This is the most measured quantity in the atmosphere.
Tidal Range	:	The difference in amplitude (height) between consecutive high and low tides.
Tidal Wave	:	Huge sea wave caused by an oceanic disturbance.
Tide	:	The periodic rising and falling of the water that results from gravitational attraction of the moon and sun acting upon the rotating earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as tidal current, reserving the name tide for the vertical movement.
Topography	:	The form of the features of the actual surface of the Earth in a particular region considered collectively.
Trench	:	A long narrow submarine depression with relatively steep sides.
Tropical Cyclone	:	A warm-core, non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters with organized deep convection and a closed surface wind circulation about a well-defined center.
Tsunami	:	A large, high-velocity wave generated by displacement of the sea floor (such as sudden faulting, landsliding, or volcanic activity); also called seismic sea wave.
Typhoon	:	A tropical cyclone in the Western Pacific Ocean in which the maximum 1-minute sustained surface wind is 64 knots (74 mph) or greater.
Volcanic Arc	:	Arcuate chain of volcanoes formed above a subducting plate. The arc forms where the downgoing descending plate becomes hot enough to release water and gases that rise into the overlying mantle and cause it to melt.
Wave	:	(1) An oscillatory movement in a body of water manifested by an alternate rise and fall of the surface. (2) A disturbance of the surface of a liquid body, as the ocean, in the form of a ridge, swell or hump. (3) The term wave by itself usually refers to the term surface gravity wave (progressive).
Wave Direction	:	The direction from which the waves are coming.
Wave Height	:	The vertical distance between the crest (the high point of a wave) and the trough (the low point).
Wave Hindcast	:	The calculation from historic synoptic weather charts of the wave characteristics that probably occurred at some past time.
Wave Period	:	(1) The time required for two successive wave crests to pass a

		fixed point. (2) The time, in seconds, required for a wave crest to traverse a distance equal to one wave length.
Wave Rose	:	Diagram showing the long-term distribution of wave height and direction.
Weather	:	The state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, etc. Weather refers to these conditions at a given point in time (e.g., today's high temperature), whereas Climate refers to the "average" weather conditions for an area over a long period of time (e.g., the average high temperature for today's date).
Wind Rose	:	Diagram showing the long-term distribution of wind speed and direction.
Wind Waves	:	(1) ocean waves formed and growing in height under the influence of wind. (2) Loosely, any ocean wave generated by wind.

Executive Summary

Timor-Leste is a small island country. It covers the east part of Timor island, Atauro Island, Jaco Island and the Oé-cusse enclave. The country covers an area of 14,954 km^2 and has a coastline of 783 km. The coastal areas are endangered by the slow-onset of global sea level rise due to climate change. The sea level rise increases physical vulnerability in terms of coastal instability in many parts of the coastal zones. The instability of the coastline is not the only factor that affects communities, developments, and environments of the coastal area. Other hazards such as floods, droughts, landslides, strong winds, and even tsunami and earthquakes also have devastating impacts.

Physical vulnerability has implications for socio-economic, infrastructure, and ecosystem conditions of the coastal zones. It has therefore been substantial to conduct a coastal vulnerability assessment and provide a relevant GIS-based map on these conditions, whereby strategies for adaptation to the impacts of climate change have been developed. This assessment had been strengthened by extensive surveys along the coast of Timor-Leste, as well as a series of consultations and capacity building with relevant stakeholders and coastal communities, including interviews with some key government officers. This assessment fills-in gaps between the various vulnerability assessments that have been previously carried out in Timor-Leste in relation to climate change and/or the coastal zone.

Coastal Zone

The coastal zone is an area where natural (physical and ecological) and societal sub-systems of land and ocean interact in a dynamic nature. Both sub-systems are highly vulnerable to the hazards of climate change through climate stimuli such as global sea level rise. The boundaries of the coastal zone should be defined considering the coastline and offshore limits of interest, water bodies (rivers, lakes), topography and bathymetry, major ecosystem features (coastal forests and dunes among others), and land uses. The definition of coastal zone should be based on physical-ecological, administrative, and planning characteristics.

In Timor-Leste the definition of coastal zone is presented under the Base of Spatial Planning Law 2017. The definition however does not clarify the precise border of coastal area landward. And therefore, for the purpose of this study, boundaries of coastal zone were defined as “all sucos which are located along the coastline (99 sucos), and those located inland but with an elevation up to 20 m (22 sucos)”. Accordingly, a total of 121 coastal sucos are the object of this assessment. The coastal sucos are situated in 11 of 13 municipalities (except Ermera and Aileu).

Physical Characteristics of Coastal and Land Areas of Timor-Leste

Climate condition in Timor-Leste is strongly influenced by the Australian Monsoons, which characterizes the country´s rainfall patterns. The peak of the rainy season usually occurs in January or February with around 250 mm/month in average, and the dry seasons lasts from July to October with the lowest rainfall average of around 25 mm/month (TL-SSE 2014).

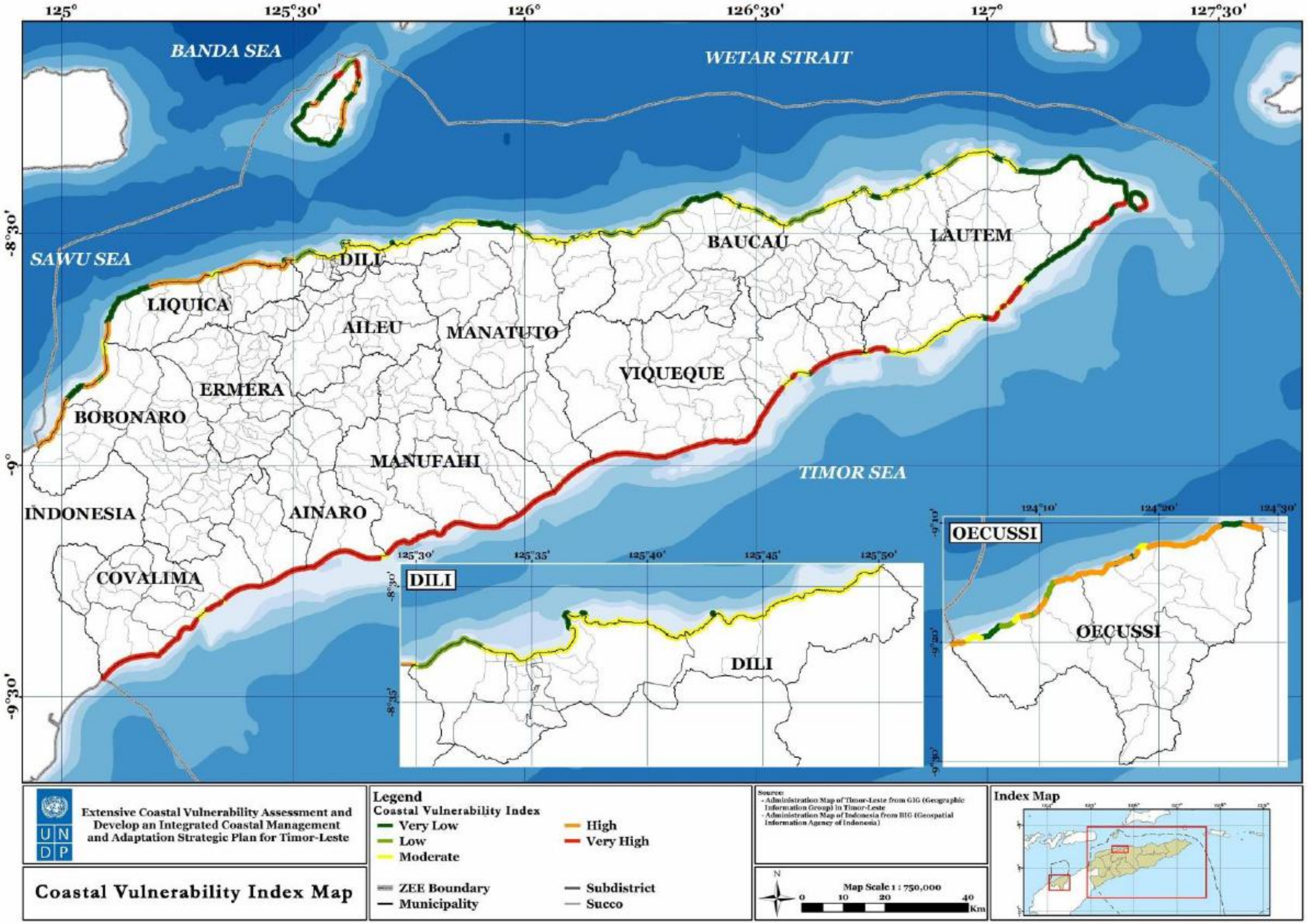
From a geomorphological perspective, Timor-Leste is a mountainous island, characterized by rugged steep terrain and small narrow valleys. About 44% of the country has a steep to very steep slope (> 40%). The soil of the country is highly erodible and characterized by infertile soils. Along the southern coast, a number of wide, yet low-lying, coastal plains can be found. River deltas, lagoons, floodplains and swamps are characteristic for this part of the coast (RDTL and CDU 2006). Findings from the geological site reconnaissance on field, carried out in May 2017, and the coastal vulnerability analysis show that most of the southern coast of Timor-Leste is highly susceptible to coastal erosion (abrasion) and/or sedimentation. Whereas the northern coast shows more variation regarding the coastal instability index: Baucau and Lautem are more resistant to erosion due to geological formation. The top three municipalities in Timor-Leste with the highest index of coastal instability are: Manufahi (98,4%), Ainaro (91,8%), Covalima (91,14%).

The geomorphological parameter indicates that the coastal instability is deemed as susceptibility. Coastal instability is influenced by the respective ocean dynamics in coastal waters such as tides and waves, as well as enhanced by the impact of sea level rise (SLR). Information on these oceanographical parameters in coastal waters of Timor-Leste have been deductively assessed from some previous studies in South East Asian – Australian waters, such as the classical work of Klaus Wyrtki (1961), and successively updated by well-verified oceanographical modelling as well as global and regional databases. Interpolation of the Global Tide Model NAO.99 provides the maximum tide range in coastal waters of Timor-Leste: 1.86m to 2.53m. In general, the maximum tide range of more than 2m occur mostly at the north-eastern coast (i.e.: from Dili to Lautem) and the south coast, whereas the values of less than 2m can be found in the north-western coast (i.e.: from Liquiçá to Bobonaro, including Oé-cusse and Atauro Island). The information on seasonal wind-induced ocean waves in Timor-Leste was obtained from the global database of Live Access Server (LAS) of Pacific Marine Environmental Laboratory NOAA-USA. The data shows that the highest annual significant wave height (SWH) at the northern coast, including the southern part of Atauro Island, is less than 0.75 m, while the SWH at the southern coast and the northern part of Atauro Island ranges between 0.75 to 1 m.

Relative SLR of the coastlines of Timor-Leste is obtained from the MRI GCM2.3 Model of the Intergovernmental Panel for Climate Change (IPCC) with SRES A1B scenario, performing carbon dioxide (CO_2) concentration projection in 2100 as 750 ppm (part per million), which ranges between 7.5 - 7.7 mm/year. On average, the values at the northern coast, including Atauro island, and at the south-eastern coast are lower than the ones at the south-western coast (from west Manufahi to Covalima). Thus, the results are comparable with the projections developed in 2011 by the PCCS.

Physical Vulnerability

The Coastal Vulnerability Index (CVI) of Timor-Leste was developed considering all geomorphological and oceanographical conditions, (see figure 1). The map indicates that 58 coastal sucos are characterized by high or very high level of vulnerability, of which 23 are distributed along the north coast and 35 along the south coast. In other words, the southern coastal zone is more vulnerable than the northern coastal zone, in terms of physical parameters of the CVI. Further physical hazards experienced by the northern and the southern coast of the country are landslide, flash flood, earthquake, tsunami, strong wind, storm surges, and drought, which are all summarized in Table 1.


125°
125°30'
126°
126°30'
127°
127°30'
-8°30'
-9°
-9°30'
BANDA SEA
WETAR STRAIT
SAWU SEA
TIMOR SEA
DILI
LIQUICA
AILEU
MANATUTO
BAUCAU
LAUTEM
VIQUEQUE
ERMERA
BOBONARO
MANUFAHI
INDONESIA
AINARO
COVALIMA
125°30'
125°35'
125°40'
125°45'
125°50'
-8°30'
-8°35'
DILI
DILI
124°10'
124°20'
124°30'
-9°10'
-9°20'
-9°30'
OECUSSI
OECUSSI
Extensive Coastal Vulnerability Assessment and Develop an Integrated Coastal Management and Adaptation Strategic Plan for Timor-Leste
Coastal Vulnerability Index Map
Legend
Coastal Vulnerability Index
Very Low
Low
Moderate
High
Very High
ZEE Boundary
Municipality
Subdistrict
Succo
Source:
- Administration Map of Timor-Leste from GIG (Geographic Information Group) in Timor-Leste
- Administration Map of Indonesia from BIG (Geospatial Information Agency of Indonesia)
N
Map Scale 1 : 750,000
0
10
20
40
Km
Index Map

Hazards experienced in coastal zones	Remarks
Landslide: Landslides may be triggered by earthquakes and/or rising of groundwater levels on the slopes which are influenced by the intensity of rainfall.	About 30% of the country area is highly susceptible for earthquake induced landslide. Where about 80% of the country area is susceptible to rainfall induced landslide. (NDMD 2012).
Flash Flood: Flash flood occurs when heavy seasonal rainfall in the upper catchment basins converges in tributaries as it descends downward resulting in the rapid flow of discharge along the water courses (NDMD 2012)	During the field observation (done in May 2017), traces of flash flood were seen at the river bank of almost all Timor-Leste’s rivers, such as in Comoro Liquiçá, Ainaro, Manatuto and Suai.
Earthquake: Earthquake in the area of Timor is triggered by the movement of the north Australian Plate colliding with the Asian Continental Plate. **Tsunami:** Timor-Leste’s is also susceptible to Tsunami.	It is estimated that Timor-Leste has a 40% chance of experiencing strong to very strong levels of ground shaking in the next 50 years, at least once. (PCRAFI 2011).
Storm Surges: Storm surge refers to the rise of water beyond the normal high tide, including large waves.	Under future climate projections the wind hazard potentially increases slightly for the 100-year return period. The event of the 100-year return period winds has a 40% chance of being equalled or exceeded once in 50 years.
Strong Wind: With the changing climate, projections tend to show a decrease in the frequency of tropical cyclones, yet the existing ones are expected to be stronger, due to the increase in the average maximum wind speed of cyclones and rainfall rates of the cyclone centre.	Causing heavy damage to • buildings, infrastructure and crops. • the sectors of education, health, housing, lifelines and transportation. (PCRAFI 2013)
Drought: Changes in rainfall and temperature patterns due to climate change may intensify drought hazard in the future.	El Niño-related droughts might occur with higher frequency. This might lead to loss of water and food security, reduced hygiene and health, and an increased risk of wildfire leading to risk to human security and loss of biodiversity.

Non-physical Vulnerability

Figures of coastal vulnerability in Timor-Leste are developed considering both, physical and non-physical characteristics, weighted equally. Non-physical characteristics are composed by three components: socio-economics, infrastructure, and ecosystem conditions in the coastal sucos. The first component is represented by population density, dependency of people in the productive age, gender, and education level, while the second includes roads and some vital nodes. The ecosystem is represented by mangrove condition.

Socio-economic aspects play a major role when defining vulnerability and influencing the adaptive capabilities of coastal communities substantially in Timor-Leste. It is recorded that 70% of the population of Timor-Leste is living in rural areas. Apart from Dili, only few more urban settlements are located directly along the coast. The coastline is mostly inhabited by rural communities, mainly dependent on (semi-)subsistence farming and fishing (GCCM 2008). Coastal municipalities with high density include Dili, with 2745 inhabitants per km^2, followed by Baucau, Oé-cusse and Covalima. Overall population density is higher in coastal sucos than in the average of the country, except Ainaro and Atauro, which are less densely populated then the average of Timor-Leste. According to the 2015 census, 39% of Timor-Leste's total population is below the age of 15; while 6% of the population is over the age of 65 (UNDP 2017). These two age groups together represent 45% of the total population and depend on the rest of the population aged 16 to 64 that are assumed being productive. Therefore, the overall dependency ration is 45%. The dependency ratio in Dili is lowest of around 35%, while the ratio in all other municipalities are between 44% and 52%; the municipalities with the highest percentage of vulnerable population are based in Viqueque, Lautem and Ainaro. Gender is another important aspect that shows vulnerability with regards to climate change: Overall women rather stay at home, have less education and are economically less independent. In general, the gender ratio between women and men in coastal sucos (based on data from the 2015 census) is 49.2%, while in some of the most rural areas in municipalities such as Lautem or Viqueque this ratio goes up to 53%.

When looking at the economic aspect of vulnerability, almost 50% of the rural population is affected by severe poverty. Coastal municipalities with the highest poverty rate include Oé-cusse (62,1%) and Ainaro (52,3%) (OPHI 2017). Education is a critical approach to reduce poverty and move towards community development, and thus simultaneously increase the adaptive capacity of the population. The Strategic Development Plan (2011) includes the education sector as a key parameter to improve the wellbeing and opportunities of the population and at the same time reach the country's economic development goals. The access rate to secondary education and above (technical schools and universities) is by far highest in Dili with almost 38%, as it is the economic and cultural hub of the country. The lowest rate for access to secondary education can be found in Bobonaro with an overall percentage of only 9%, followed by Lautem and Oé-cusse with roughly 13%. The overall result of the socio-economic vulnerability showed that the majority of sucos with high vulnerability are located in the eastern part (i.e. Baucau, Viqueque, and Lautem District) and the southern part (Covalima and Ainaro District) of Timor-Leste. A very high socio-economic vulnerability index has been identified in Macadique, Matahoi, and Vessoru sucos in Viqueque. Primary factors of this condition are: a high percentage of dependant population (non-productive age), a low number of people with secondary level of education, and a gender ratio.

Road infrastructure is important since it serves as a major link for trade, services, tourism and commerce, and is thus important for the development of Timor-Leste's economy. The SDP 2011-

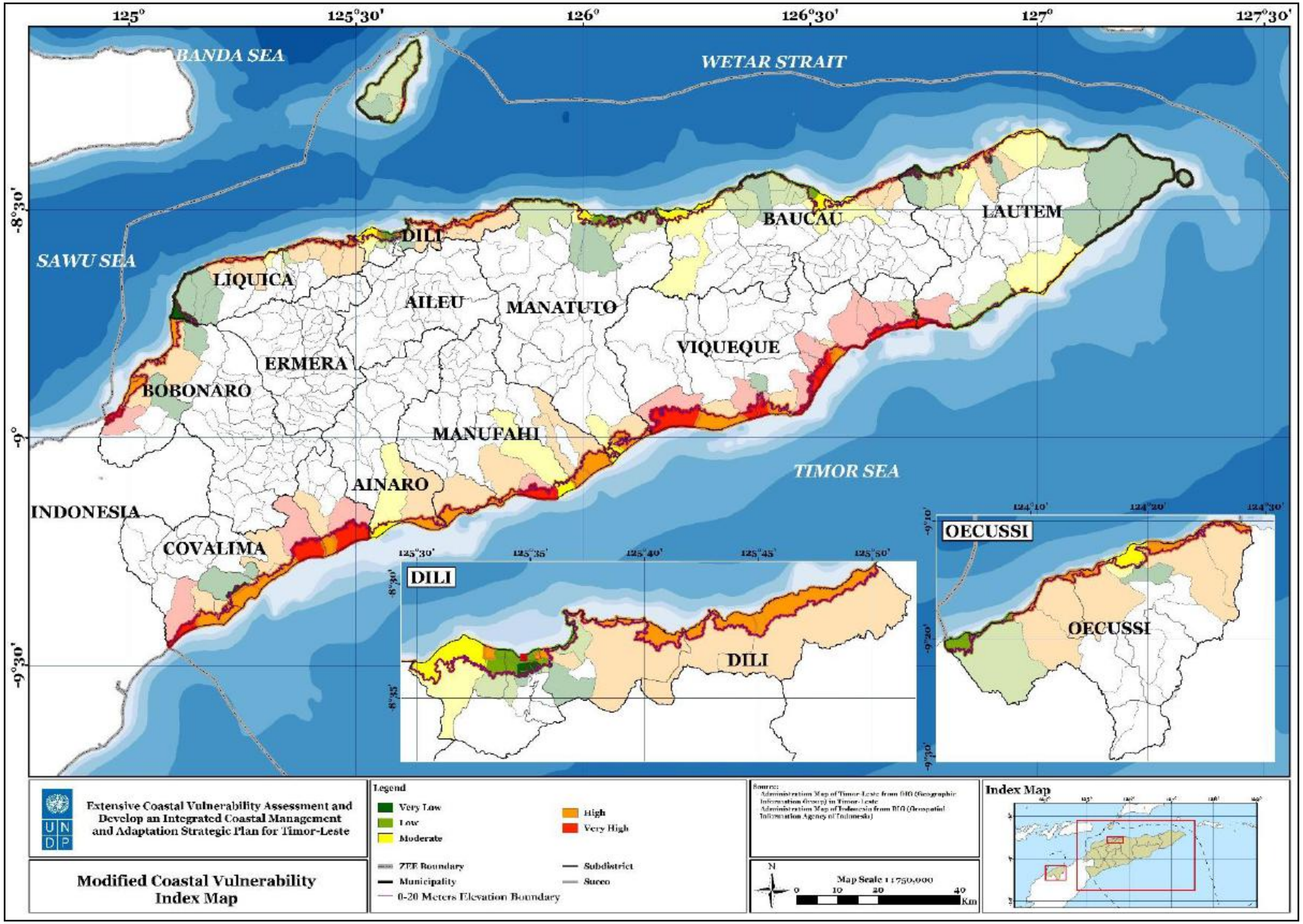
2030 focuses on infrastructure development, especially the development of a basic transportation network, including roads, air and sea transportation facilities, as well as basic infrastructures, such as health and education facilities. These infrastructures are sensitive to coastal instability, especially because their elevations and distances from the shoreline, reflecting the level of exposure to the hazard. National roads are often constructed too close to the coastline, and thus are affected by severe coastal erosion, accelerating the deterioration process of the roads. Analysis on infrastructure vulnerability shows that 23 coastal sucos are considered very highly or highly vulnerable, and mostly are located at the northern coast of Timor-Leste. Among them, 16 coastal sucos have a high vulnerability due to their road infrastructure, while the suco Comoro in the Dili District scores as very highly vulnerable due to its node infrastructures, such as education and health facilities, as well as some vital infrastructures.

In terms of ecosystem vulnerability, mangroves are considered to be a vulnerable component, which need to be restored and protected, rather than being a protective-adaptive capacity. The fragmented nature and the small size of most mangrove stands along the north and south coasts are making them less resilient. Mangroves are depleting. The reason for depletion are timber and fuel wood harvesting, forest degradation upland and disruption of hydrological circulation of sea-water into mangrove areas, which is due to road and aquaculture development along the coast. Sedimentation from upland, transported downstream during heavy rain, also plays a role in the degradation of mangroves. This process converts mangrove areas into dry sandy flats. Analysis of ecosystem vulnerability shows that there are 5 coastal sucos covered by mangrove forest in the country and thus are considered as highly vulnerable: Beco in Covalima; Duyung (Sereia) and Sabuli in Dili; Clacuc in Manufahi; and Uaitame in Viqueque.

Combination of physical and non-physical parameters

The modified CVI is developed by merging the physical CVI with the results of the socio-economic, infrastructure and ecosystem vulnerabilities, assigning the weight factors 50%, 20%, 20%, and 10%, respectively. As an overall result, 16 coastal sucos show a very high vulnerability level and 40 coastal sucos a high vulnerability level in the modified CVI. Sucos with the highest vulnerability level are located in Covalima, Viqueque, Manufahi, Lautem, and Liquiçá.

Results of CVI and modified CVI assessments show that coastal areas with high and very high levels of vulnerability are mostly located at the southern coast of Timor-Leste (40 of the 56 sucos). The main characteristics of the southern coast are instable low-lying areas which are prone to coastal instability. These conditions pose risks to these rapidly developing areas and should be considered an alert for future development. From an economic point of view, the future development of these areas are quite promising, considering the fertile soil for agriculture as well as their potential of Timor Gap oil exploitation. And therefore, future development of the southern coast of Timor-Leste needs to take into account lessons learned from the recent development of the northern coast. The north coast has experienced in the past and is still experiencing today an extensive level of development, for example, in Dili and Liquica. While development is good, but when it is not done sustainably, could increase the level of vulnerability of the people living in and around the coastal areas, especially due to the impact of climate change.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BANDA SEA
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VIQUEQUE
ERMERA
BOBONARO
MANUFAHI
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OECUSSI
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-9°30'
Extensive Coastal Vulnerability Assessment and Develop an Integrated Coastal Management and Adaptation Strategic Plan for Timor-Leste
Modified Coastal Vulnerability Index Map
Legend
Very Low
Low
Moderate
High
Very High
ZEE Boundary
Municipality
0-20 Meters Elevation Boundary
Subdistrict
Suco
Source:
- Administration Map of Timor-Leste from GIG (Geographic Information Group) in Timor-Leste
- Administration Map of Indonesia from BIG (Geospatial Information Agency of Indonesia)
N
Map Scale 1:750,000
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Index Map

1 Introduction

1.1 Background

Timor-Leste has about 783 km length of coastline. Approximately, 66% of the population live in coastal and lowland areas below an elevation of 500m (USAID 2015). The natural resources available at the coastal zone are vital for the economy of the coastal population. As population grows at a rapid rate, combined with urban development and exploitation of natural resources, coastal ecosystems are deteriorating fast. For example, mangroves were harvested for firewood, building materials, and livestock grazing. Furthermore, the Indonesian occupation brought along practices in converting mangroves to shrimp farms and taught local fishermen to destroy mangroves to find bait. This resulted to the loss of more than 80% of mangroves in 2014, compared to the 1940s (Alongi 2014).

Climate change is expected to impact all aspects of life in Timor-Leste. Satellite data indicate the rise of sea level in Timor-Leste, over the past 25 years, by about 9mm annually (PCCSP 2011), which is significantly higher than the global average of 2.8 - 3.6 of mm per year (PACCSAPP 2015). Sea level rise is expected to continue to rise. Sea-level rise combined with natural year-to-year changes (e.g. overexploitation of natural resources, uncontrolled development, degradation of mangroves and coastal forest) will accentuate the impact of storm surges as well as increase risks of coastal inundation and erosion (PACCSAPP 2015). Additionally, the physical conditions of the shoreline in combination with activities done in the upstream hills are increasing the susceptibility of coastal communities to flash floods and landslides.

Many Vulnerability Assessment (VA) studies have already been done in Timor-Leste. These studies focused on the current and projected impacts of climate change in Timor-Leste (science based) and to the perception of the coastal communities of the associated hazards and vulnerability (social and economic based). Lack of planning in infrastructure development has become significant a problem in the increased vulnerabilities. These are undoubtedly important to discuss and improve. However, it is also imperative to look into the pure physical vulnerability, i.e. coast and shoreline stability under the influence of oceanographical-geological parameters and combine them with the aforementioned aspects to be able to take appropriate decisions for adaptation strategies.

To this end, a team, consisting of vulnerability assessment experts, coastal geomorphologist/geology experts, oceanographers, coastal hazard experts, socio-economic vulnerability and adaptation experts, and GIS expert, is undertaking a Coastal Vulnerability Assessment (CVA) for Timor-Leste. This activity is part of the "Building Shoreline Resilience of Timor-Leste to Protect Local Communities and Their Livelihoods" project framework, funded by the Global Environmental Facility.

1.2 Scope and Objective

This assessment is looking at shoreline vulnerability and stability (i.e. coastal geology, geomorphology, tide and nearshore wave), coastal land uses and infrastructure. In addition, the team also analyses the socio-economic impacts of climate change on coastal ecosystems. Thus, physical as well as socio-economic aspects would be coupled with the interest of the Government of Timor-Leste (GoTL) for infrastructure development, while still maintaining ecological integrity.

The result of the coastal vulnerability assessment is expected to provide a set of recommendation for adaptation strategy to address key climate change induced challenges of the coastal community (especially sea-level rise). The recommendations for adaptation strategy are, however, presented in a separate document, served as the 2nd volume of this report. It entails provision of recommendations of integrated measures toward the impacts of climate change on coastal livelihood, development, and ecosystems.

This CVA report presents a baseline costal vulnerability assessment that includes: 1) geomorphological and/or geological coastal survey and modelling, 2) assessment of climate change and its impact on shoreline and coastal ecosystem, and 3) community socio-economic analysis. The analysis has been undertaken through an extensive survey of the coastline, community consultations in selected areas, consultations to respective stakeholders, as well as the analysis of secondary data. In addition, it includes the analysis of current development plans, policies, as well as the status of adaptation to climate change and natural resource management, especially in coastal zone.

The Coastal Vulnerability Assessment (CVA) is carried out using the modified Coastal Vulnerability Index (CVI) approach. CVI was initially introduced by the United States Geological Survey (USGS) Team in 2001. It was used to map the relative vulnerability of the coast to future sea-level rise. The CVI ranks coastal instability, mean tidal range, and mean significant wave height in terms of their physical contribution to sea-level rise-related coastal change. *The CVI highlights those areas where the physical effects of sea-level rise might be the greatest.* This approach combines the coastal system's susceptibility to change with its natural ability to adapt to changing environmental conditions.

Non-physical aspects are assessed by adding further respective layers to the CVI map. These layers are related to ecological, social and economic vulnerability (i.e.: mangrove locations, distribution of population and infrastructure map), which are accounted as infrastructure, socio-economic and ecosystem vulnerability variables. In doing so, determination of areas that are likely to be in highest risk due to climate change impacts are not only represented by physical aspects, but also based on the social, economic and ecosystem conditions. This modified CVI allows for a broader focus of the CVA. With regards to the socio-economic-ecosystem layers for the modified CVI, the team collected the necessary data in two ways: a) through literature and databases and b) through community consultations.

In the end, development of the CVA (using the modified CVI approach) involves a series of stakeholder consultations, not only to assure the quality of the results, but also to build ownership. This way, it is expected that recommendations generated from the study can be used by the GoTL to adapt to climate change, especially in coastal areas. Furthermore, capacity building is an intrinsic part of the project, comprising of development of the CVA and GIS-based CVI operational, as well as prioritization of some adaptation strategies.

1.3 Scope and methodology of this report

The report at hand focuses mainly on the analysis using CVI and modified CVI, including socio-economic, infrastructure and ecosystem vulnerability.

The following methodology has been used to develop the present report:

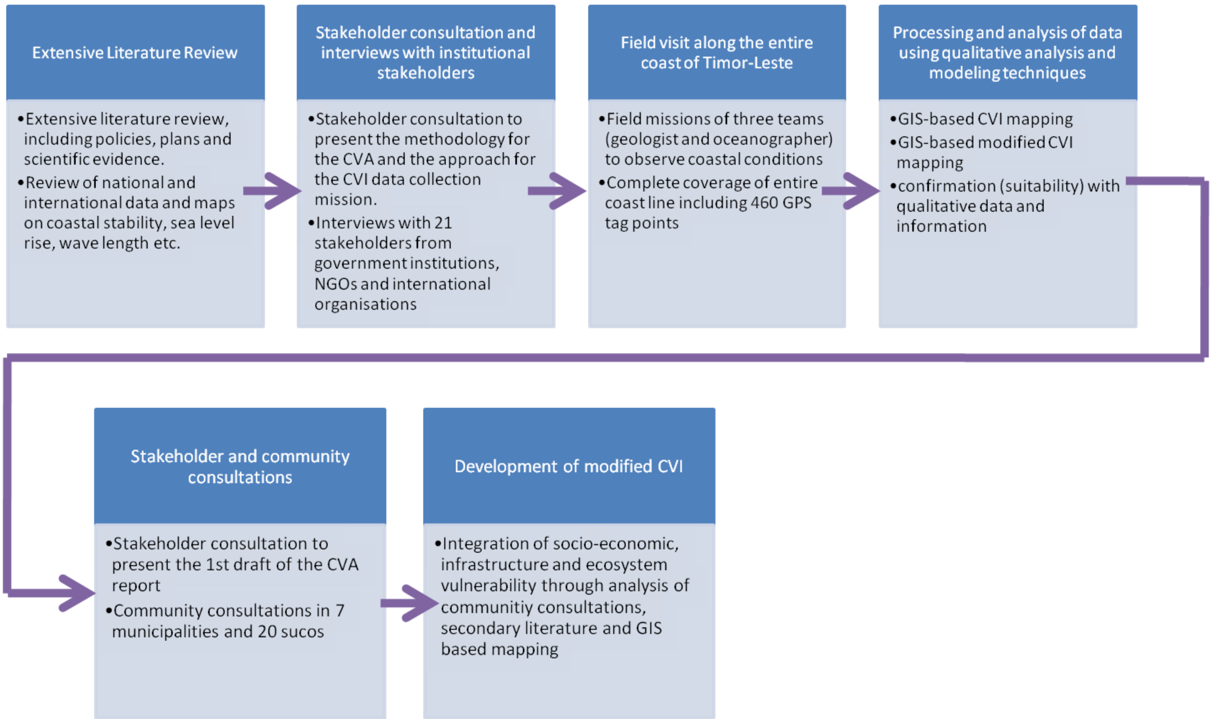


Figure 1.1 Overview of the methodology

Extensive literature review and analysis: As part of the assignment, the consultants carried out an extensive literature review of publicly available plans, policies, projects and scientific evidence related to the coastal areas of the country. The literature review included on the one hand information with regards to the institutional and political set-up, and on the other hand information related to the coastline of the country. The latter was mainly related to geographic, ecosystem, socio-economic and climate change related data, as well as with regards to scientific data necessary to analyse the different parameters for the CVI.

Stakeholder consultation and interviews with relevant stakeholders: During the first week of May, a stakeholder consultation presenting preliminary literature review, as well as the scope and objective of the assignment to relevant stakeholders took place. The half day event served to receive relevant input to the field mission that took place between the 5th and the 19th of May and helped to create more ownership for the assignment as such, as well as to introduce the consultant team to relevant stakeholders. After the stakeholder consultation, a total of 21 stakeholders have been interviewed. Of these, 12 represented officials from the national government, 3 were from local NGOs and 6 were from international NGOs (See Annex 1 for an overview of interviewees). During this phase, greater emphasis was given to stakeholders at national and sectoral level. The interviews helped the consultants to get first-hand information on how effectively coordination of coastal areas is working and on proposed developments in policy and administration. In addition, consultants also used this opportunity to collect further input for this report such as new policies or draft legislation, identification of problems and priorities for specific groups, draft reports of concrete programs and campaigns, action plans, strategies, etc.

Field survey along the coast of Timor-Leste: The field survey was done from May 5th - 19th, 2017. It aimed at understanding the physical characteristics of the coastal area in Timor-Leste, while simultaneously validating findings from literature review and inputs collected during the stakeholder consultation. This field visit has been particularly relevant for the development of the CVI. The field survey was done by three teams, each consisting of one geological expert and one oceanography expert. The three teams covered different areas, ensuring the wide coverage of the coast line of Timor-Leste. Around 460 GPS tags (waypoints) were made during the 15 days of survey. *Figure 1.2* illustrates the coverage of the survey, with the yellow dots indicating the waypoints made.

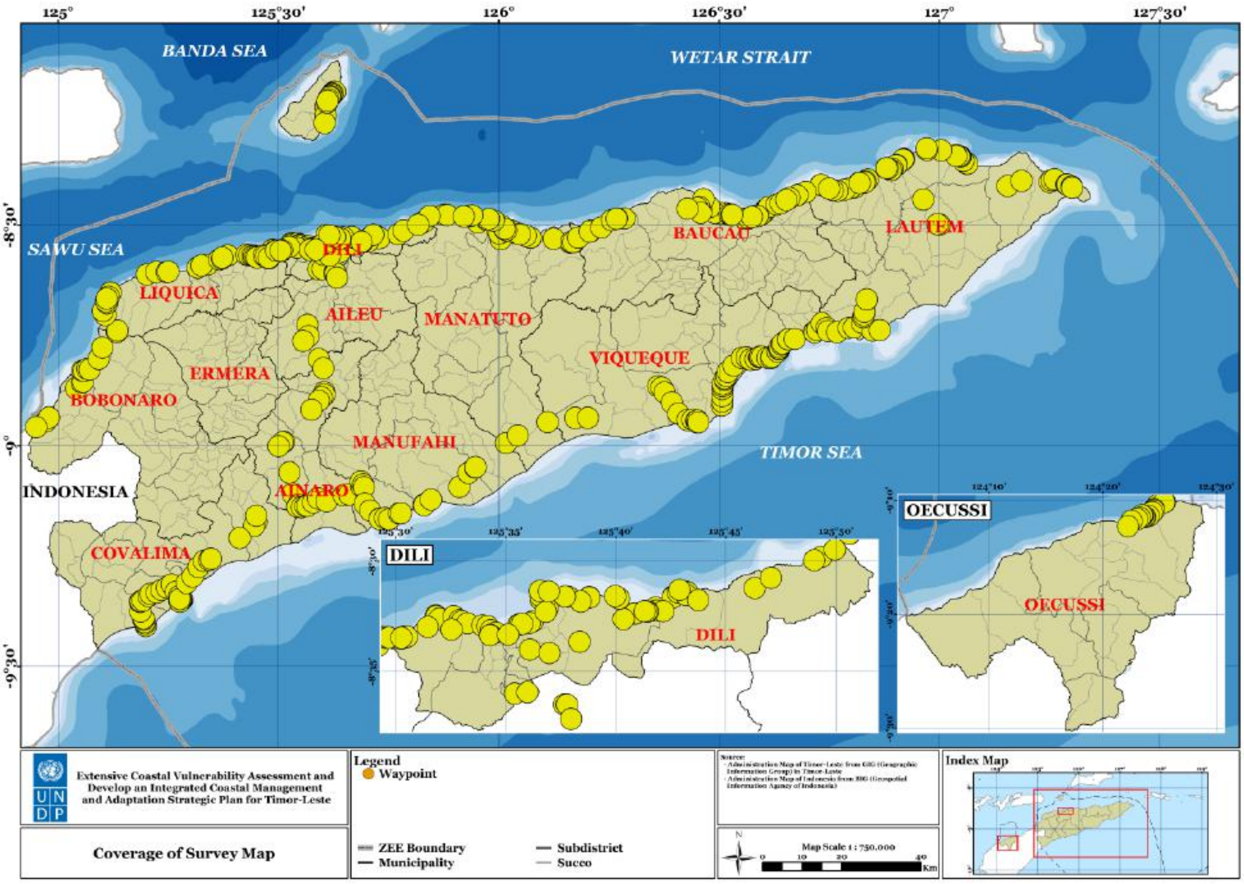


Figure 1.2 Coverage of survey and waypoints

During the survey, the teams observed mainly the geological-, riverine- and coastal-condition along the coastline of Timor-Leste. Nevertheless, during the trip, the team made observations on the vulnerability aspects of the coastal areas, especially related to important infrastructures (existing and on-going construction), perceived population density, livelihoods, and ecosystems.

Processing and analysis of data using qualitative and quantitative analysis and modelling techniques: In this phase of the assignment, analysis of data is primarily conducted by CVI followed by modified CVI. Both are based on GIS process. This process needs quantitative secondary data (including GIS) as well as statistical tabular formats such as administrative boundaries, toponymy map, thematic maps (mangrove, road, and settlements), population, GDP, etc. Unit of analysis in this GIS process is the suco. Result of quantitative (mapping) process is then confirmed by qualitative data and information that is obtained from above methodologies. The results of the GIS mappings have been confirmed with the results of the literature review, as well as the field survey and have been combined with respective qualitative data in suco level.

Stakeholder and community consultations: During the first week of August, a stakeholder consultation presenting the results of the CVI, as well as the selection of communities for community consultations took place. Afterwards 14 community consultations, comprising 8 municipalities (Liquiçá, Dili, Bobonaro, Covalima, Manufahi, Viqueque, Manatuto and Oé-Cusse) and 25 sucos took place to collect data with regards to vulnerability and adaptation strategies. Community sites were strategically chosen to include different bio-physical typologies and a geographical spread across the country. The methodology chosen for the community consultations was wholly qualitative, using a mix of focus groups discussions (FGDs) and mapping exercises as methods encouraging open-ended discussion between participants as they explored their experiences and thoughts regarding climate hazards.

Development of modified CVI: The development of the modified CVI has been based on GIS process, as well as the analysis of secondary data and statistics, and the results of the community consultations. It provides an analysis on the suco level, accompanied with overall information on socio-economic, as well as infrastructure and ecosystem information that feeds into an overall vulnerability of coastal areas combining bio-physical and other parameters as mentioned.

Overall, the Project will deliver three main outputs, entailing: 1) CVI report/maps, 2) modified CVI report/maps, and 3) Capacity Building.

The Coastal Vulnerability Assessment will be developed in several phases, described in *Table 1.1*

Table 1.1 Reporting Phases of CVA and its Description

No.	*Reporting*	*Description*
1.	Inception report	Proposed framework of the CVA (Submitted)
2.	First Draft of CVA report	Including review of physical, ecological and socio-economic condition of Timor-Leste, CVI maps, initial results of modified CVI maps, and way forward.
3.	Second Draft of CVA report and draft integrated coastal management and adaptation strategic plan	Integration of comments from stakeholders, inclusion of final modified CVI (with additional parameters on socio-economic, infrastructure, and ecosystem aspects) and results of community consultations
4.	Revised final CVA report and Strategic Plan by incorporating comments from UNDP, Government and relevant stakeholders	Integration of comments from UNDP, Government and relevant stakeholders and capacity building materials

Based on the reporting phase above, this report would be on final phase of overall reporting, integrating comments from stakeholders, inclusion of final modified CVI and results of community consultations. The outline of the CVA report is presented in Figure 1.3 below.

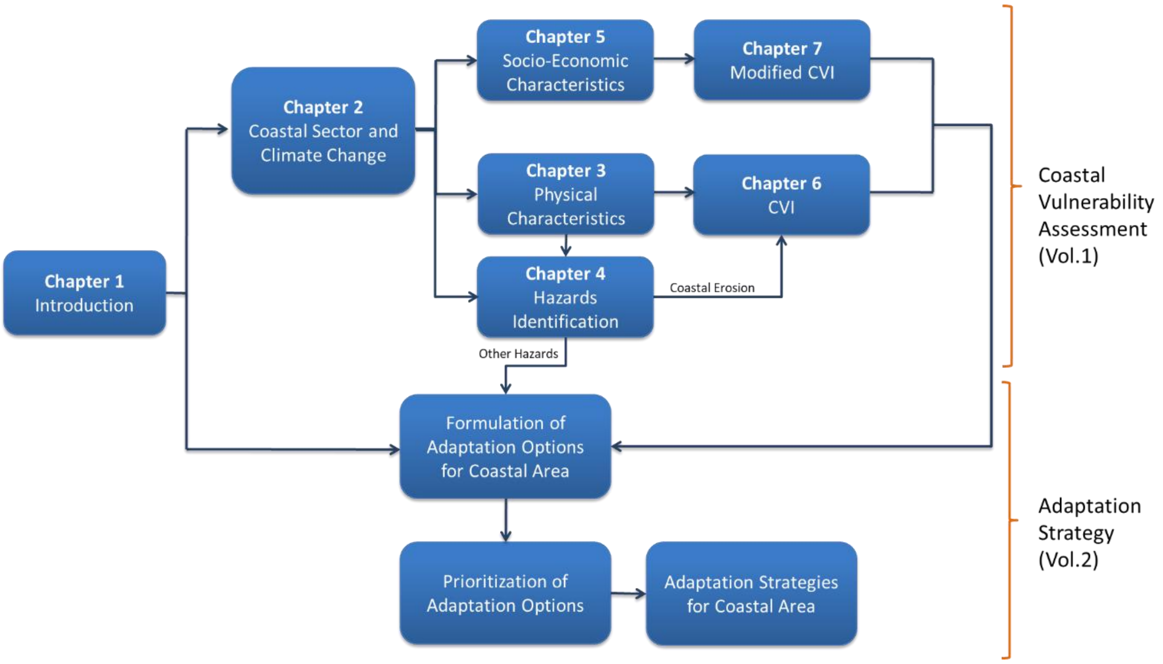


Figure 1.3 Outline flow of the report

2 Coastal System and Climate Change

This chapter provides theoretical or scientific framework on coastal system and its active interactions with the global climate change, particularly the effect of sea-level rise. The chapter begins with the definition of the coastal zone or system, followed by a description of methodology for assessing the coastal vulnerability. A number of physical and human factors influencing coastal inundation and erosion problems are presented, in a specific manner. Some relevant examples from Timor-Leste situations are also considered in the descriptions.

2.1 Definition of Coastal Zone

The coastal zone is difficult to define with exactitude, due to its dynamic nature. A simple definition describes coast as an interaction area between land and ocean. Ketchum (1972) defined the coastal zone as: "*A band of dry land and adjacent to ocean space (waters and submerged land) in which terrestrial processes and land use directly affect oceanic processes and uses, and vice versa*". Another definition illustrates coast as the junction between land and sea in which its geomorphologic formation consists of various rock materials.

According to the Fourth Assessment Report of the Intergovernmental Panel for Climate Change, the coastal and low-lying areas consist of two systems which are: natural and societal sub-systems (Nicholls, et al. 2007). These systems are depicted in the encircled dashed-line in Figure 2.1. The natural sub-system consists of land forms, such as beaches, rocky shorelines, cliff coasts, deltas, estuaries, lagoons, and their comprised coastal ecosystems such as mangroves, salt marshes and sea grasses, and coral reefs. The societal sub-system consists of infrastructures, humans and their activities. Both sub-systems are highly vulnerable to the hazards of climate change through climate stimuli such as: global sea level rise, storm surges, temperature rise, rainfall, and increase of CO_2 concentration.

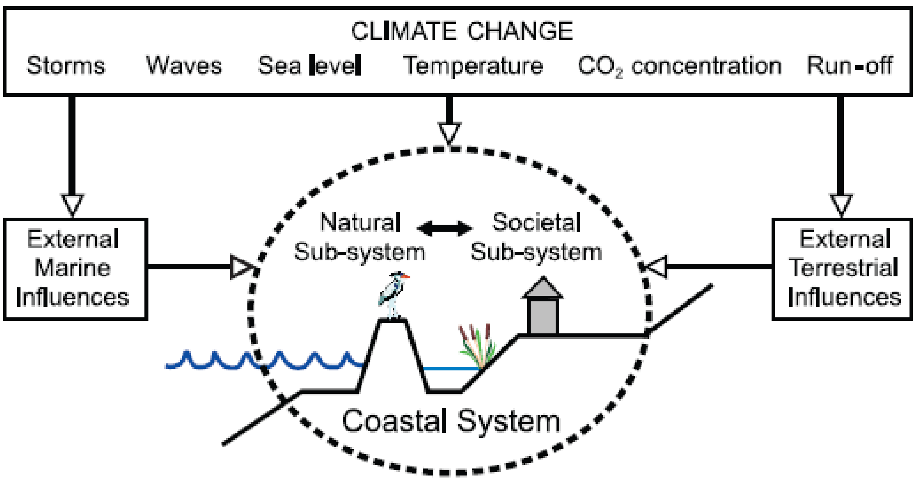


Figure 2.1 Climate Change and the Coastal System, Showing the Major Climate Change Factors, Including External Marine and Terrestrial Influences (Source: Nicholls, R.J., et.al, IPCC AR4, 2007 WG2-Ch.6)

In accordance with these definitions, the boundaries of coastal zone should be defined considering the coastline and offshore limits of interest, water bodies (rivers, lakes), topography and bathymetry, major ecosystem features (coastal forests, dunes, others), and land uses. The definition of coastal zone and its boundaries should consider at least three approaches, namely:

- *Physical-ecological approach:* Coast is a land area experiencing ocean processes such as tides and waves, and in turn a sea part experiencing land processes such as water pollution and sedimentation.
- *Administrative approach:* Inland border of a coast may be defined in accordance with land administrative boundary, such as suco border, while seaward border may relate to a national marine territory or international administrative agreement.
- *Planning approach:* The coastal zone is defined based on how far the coastal resources would be managed in responsible way

Definition of coastal zone is presented under the Base of Spatial Planning Law 2017. The definition however does not clarify the precise border of coastal area landward. And therefore, for the purpose of this study, boundaries of coastal zone were defined as "all sucos which are located along the coastline (99 sucos), and those located inland but with an elevation up to 20 m (22 sucos)". Accordingly, a total of 121 coastal sucos are the object of this assessment. The coastal sucos are situated in 11 of 13 municipalities (except Ermera and Aileu).

2.2 Coastal Vulnerability Assessment

Assessments of coastal vulnerability to impacts of climate change have been developed and applied widely. Klein and Nicholls (1999: p.183), serve as a fundamental reference for these assessments, stated:

"*Vulnerability to impacts is a multi-dimensional concept, encompassing bio-geophysical, economic, institutional and socio-cultural factors. Vulnerability is usually considered to be function of a system's ability to cope with stress and shock. In line with this, vulnerability of coastal zones has been defined as* ***the degree of incapability to cope with the consequences of climate change and accelerated sea-level rise****. Thus, vulnerability assessment includes the assessment of both anticipated impacts and available adaptation options*".

Building on the knowledge gained on vulnerability allows scientists, engineers, spatial planners, and policy-makers to develop plan of actions to deal with the potential impacts of sea-level rise. Furthermore, this knowledge serves for prioritizing corresponding efforts on coastal zone management that are required to minimize risks and/or to manage possible opportunities.

Particularly within the planning context, the results of a coastal vulnerability assessment are extremely useful as they provide detailed quantitative information on the potential impacts on various development sectors and assets, e.g.: water resources, agriculture, human health, fisheries, tourism, human settlement. In order to deliver good results, however, spatial and temporal dynamics data on bio-geophysical processes triggering those potential impacts are required. For example: flood frequency, erosion, inundation, rising water tables of ground water, saltwater intrusion, biological effects. The capacity to adapt within the timescale of natural changes depends on the technical, institutional, economic, and cultural ability of a society to prevent or cope with these impacts.

Thieler, et al. (2002) developed an index-based CVI approach for the USGS, that combines the susceptibility of a coastal system to change (i.e., natural and societal sub-systems) with its natural ability to adapt in changing environmental conditions. To this end, coastal vulnerability assessment focused on adaptation to the impacts of climate change, i.e. impacts of sea level rise to the coastal system itself such as coastal inundation and instability (abrasion, accretion) (e.g., Klein & Nicholls 1999; Thieler, et al. 2002). In the context of Timor-Leste, it is crucial to conduct coastal vulnerability assessment as such.

Various studies and assessment on vulnerability have been carried out for Timor-Leste (See. Table 2.1). The NAPA document, the Country Risk Profile of Timor-Leste and the Comprehensive National Hazard Assessment and Mapping in Timor-Leste presented assessment of physical (natural) hazards and disasters that include coastal zone. Whereas the report on "Current and Future Climate Change of Timor-Leste" and the "Initial National Communication" assessed the general physical impacts of climate change but they lack detailed discussion of impacts in coastal area.

With regards to water resources in coastal zone, the NAPA document presented the impacts of sea level rise to groundwater at the coast. But it must be noted that such an assessment requires comprehensive understanding of complex inter-dependences between coastal and water discharge systems that not only include the coastal zone but also the upland area. Similarly, report on Developing Timor-Leste's Coastal Economy: Assessing Potential Climate Change Impacts and Adaptation Options presented assessment of drinking water vulnerability that also requires understanding water sources of groundwater, rainwater and surface waters. In coastal zones, these sources are also vulnerable to contamination or intrusion by seawater due to coastal inundation, beside such threats from upland catchment areas (Hoque, et al. 2016).
Despite the numerous studies and assessment done in the country, assessment of coastal vulnerability that takes into account oceanography and geomorphological parameters and its relation to the coastal instability hazard is still missing. This study will therefore comprehensively consider both, physical vulnerability (i.e. oceanographical and geomorphological parameters induced by sea-level rise) and non-physical vulnerability (i.e. socio-economic, infrastructures, and ecosystem). This study will fill-in the gaps between the various vulnerability assessments that have been previously carried out in Timor-Leste.

Table 2.1 Various previous assessments either on physical aspect or on socio-economic, infrastructure, and ecosystem vulnerabilities related to climate change impacts in Timor-Leste

No	Document	Institution	Year	Strategic Issues	Potential Hazard or Vulnerability	Cited as
1	National Adaptation Programme of Action (NAPA) on Climate Change	UNFCCC; UNDP	2010	Adaptation of Climate Change on National Level	-Rise in sea Level and Storm activity -Increase storm activity and changes in rainfall pattern and intensity - Increase air temperature -Rise of water temperature and acidification	MED
2	Country Risk Profile: Timor-Leste	Pacific Catastrophe Risk Assessment and Financing Initiative	2011	Risk Profile in Timor-Leste on National Level	-Earthquake and Tsunami -Strong Wind	PCRAFI
3	A Comprehensive National Hazard Assessment and Mapping in Timor-Leste	National Disaster Management Directorate (NDMD)	2012	Hazards Profile in Timor-Leste on National Level	-Flood -Landslide -Coastal Erosion -Strong Wind	NDMD

No	Document	Institution	Year	Strategic Issues	Potential Hazard or Vulnerability	Cited as
4	Current and Future Climate Change	Timor-Leste National Directorate of Meteorology and Geophysics	2011	Climate condition and projection on National Level (with focus on Dili)	-Temperature will continue to increase -More Very Hot days -Changing rainfall patterns -More extreme rainfall days -Less frequent tropical cyclones	PCCS
5	Initial National Communication	State Secretariat for Environment	2014	Climate change adaptation and mitigation on National Level	-Increased air temperature -Changes in rainfall patterns and intensity -More Intense storm activity -Rise in Shallow seawater temperatures, rise in sea level and seawater acidification	TL-SSE
6	Current and Future Climate Change	Timor-Leste National Directorate of Meteorology and Geophysics	2015	Climate condition and projection on National Level (with focus on Dili)	-Temperatures and rainfall may be changing -Sea level has risen -Ocean acidification has been increasing -Temperature will increase -Changing rainfall patterns -More Very hot days -More extreme rainfall days	PACCS AP
7	Timor-Leste Strategic Development Plan 2011-2030	Government of Timor-Leste	2011	Strategic Plan for development in all sector on National Level	None	RDTL
8	Developing Timor-Leste's Coastal Economy: Assessing Potential Climate Change Impacts and Adaptation Options	AusAID, World Fish	2013	Community profile and community-based adaptation on National Level	-Lack of Fish and Income from Fishing -Lack of Access to Water -Agricultural Production Decreased -Limited Household Access to Cash	Mills et. al.
9	Building shoreline resilience of Timor-Leste to protect local communities and their livelihoods: Gender report	USAID	2015	plans for social vulnerability and gender aspects on National Level	Vulnerability of Socio-economic particularly related to gender issue	USAID
10	Building Shoreline Resilience of Timor-Leste to Protect Local Communities and Their Livelihood Mangrove Ecosystem Strategy, Design and Recommendation	USAID	2015	Coastal Vulnerability, problems, and mangrove re-afforestation, conservation and management on National Level	Vulnerability of mangrove	USAID

2.3 Factor Influencing Coastal Inundation and Erosion Problems

The coastal zone is extremely important and a strategic asset providing potential space for urban and industrial development for Timor-Leste. However, this zone is at risk due to sea level rise, contributing to increased coastal inundation and coastal erosion. These could result in ecosystem losses and affecting many urban beaches and facilities, threatening their values and functions. This risk is more apparent in the north, where the most important developments such as urban dwellings and business centres, harbour and airports, industries, local fishery, and tourism are located.

Coastal erosion hazard would seriously affect changes of shoreline due to alongshore sediment transport, where the seawater inundation would play important roles to broaden the effect toward upland depending on coastal geomorphological conditions. Shoreline changes are, therefore, strongly associated with sea level rise, waves, as well as sediment supply and loss from certain coastal areas. Sediment supply to coastal area comes from fluvial or river sand, sand washed from the sea floor, sand eroded from cliffs and rocky shores, sand eroded from backshore dunes, blowing sand eroded from the hinterland, and artificial nourishment Figure 2.2 illustrates various sediment supply factors. The imbalance between sediment supply and loss from coastal areas causes erosion/abrasion or sedimentation. These processes are generally triggered by both physical factors and human interferences.

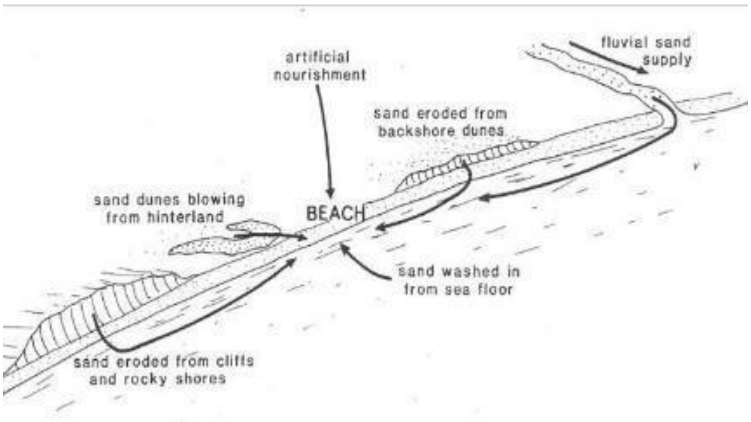


Figure 2.2 The Supply of Sand to the Beach (Source: Bird 2015)

2.3.1 Physical Factors

A wide range of physical factors, such as waves, wind, tides, nearshore currents, storm surges, landslides, sea-level rise and land subsidence change the shape of coastal morphology. Figure 2.3 summarises the physical factors responsible for coastal erosion and highlights the time and space patterns in which these factors operate. The patterns show that tides, winds, storms and waves have tenth kilometres distance or spatial scale at which the actions of these factors and occur in several days in causing coastal erosion take place. These factors are affected by climate change, both directly and indirectly, resulting in sea-level rise contributing to the rate of coastal erosion and coastal flooding.

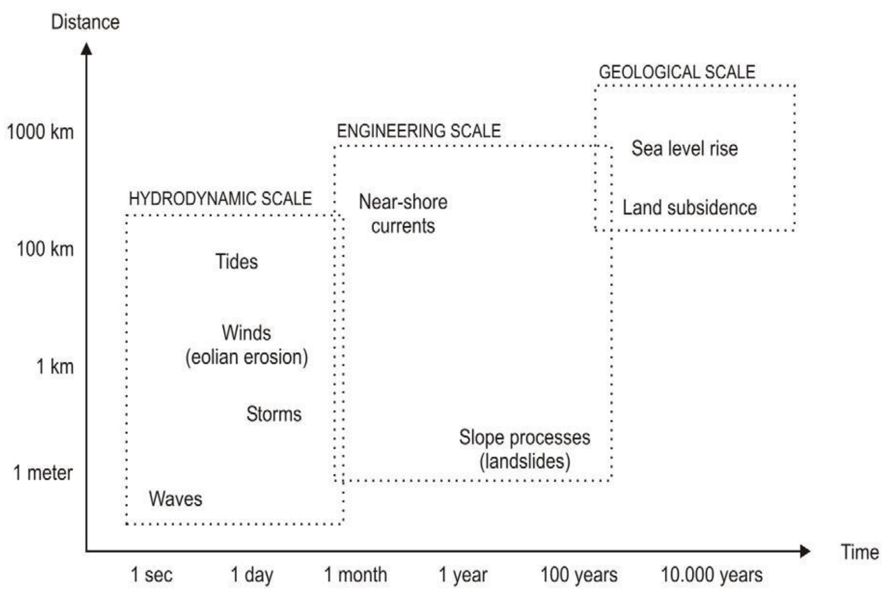


Figure 2.3 Time and Space Patterns of Natural Factors of Coastal Erosion (Source: Bird 2015)

The Australian Greenhouse Office (2005) described the influence of climate change on hazards arising in the coastal and marine areas to include:

- storms that affect rainfall and surface runoff
- storms associated with wind and pressure that can generate bog waves and surges
- sea-level changes (seasonal variability, ENSO and IOD mode)

The above-mentioned changes affect the supply of sediment, waves and swell, currents, storm tides, and sea level.

Other external factors that are not directly related to climate change are tides and tsunamis, where tides are generated by the gravitational forces of the moon and sun and tsunami waves are generated by tectonic activities, volcanism, and landslides. The hazards may interact with each other. In the case of when these forces occur at the same time, they could produce extreme conditions which can accelerate shoreline change. Another factor that influences the extent of shoreline change is coastal geomorphology, as each type of coastline has its own resistance against coastal erosion. For example, cliffs and rocky beaches have stronger resistance and are difficult to erode, while sandy beaches and muddy tidal flats have lower resistance or unstable.

A description of the natural forces that affect inundation and coastal erosion is given below (see Figure 2.4).

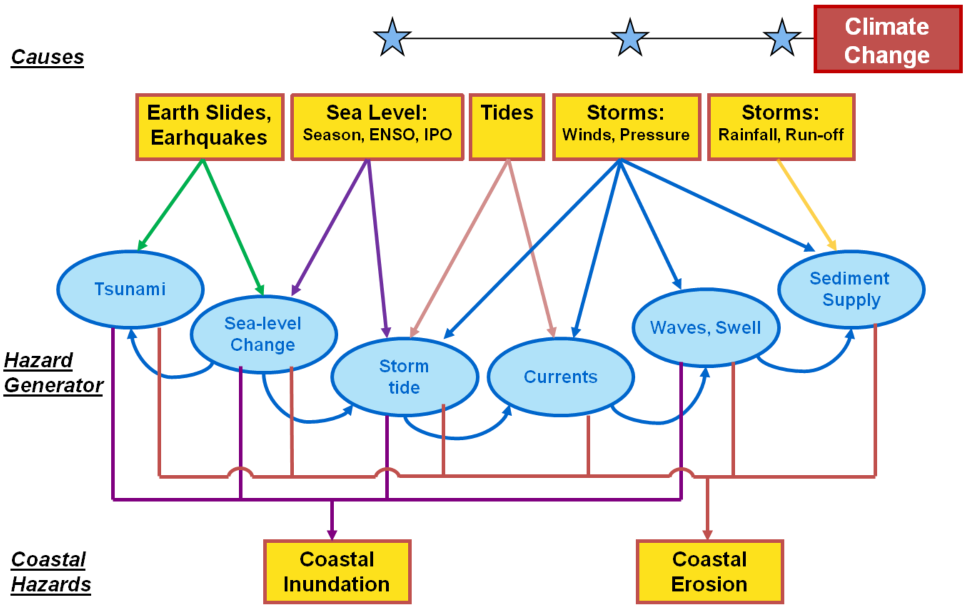


Figure 2.4 Interconnection Hazards Triggered by Climate Change towards the Coastal, Marine, and Fisheries Sectors (Adopted from the Australian Greenhouse Office 2005*)*

Ocean waves are generally generated by wind and are strongly influenced by wind speed, wind duration and fetch. Wave energy is highly dependent on the wave height and period. Beach erosion generally occurs on beaches that are exposed directly to the sea, such as at the south coast of Timor-Leste.

Wind does not only generate waves but is a driving factor of sand being blown inland or of blown sand eroded from the hinterland. Such kind of mechanism may not occur in the north coast but often in the southern coast.

Tides influence beach processes**.** During high tides, the wave energy is released, and wave can reach the base of the cliff, causing cliff undercutting. Coastal areas with a tidal range of more than 4 meters (macro-tidal) will have a higher level of sensitivity to sea-level rise compared to the coastal area with smaller tidal range (less than 1 meter).

Nearshore currents are generally generated by tides (tidal currents) and waves breaking at an angle to the shoreline (longshore currents and rip currents). These currents are contributory factors to seabed and shoreline erosion, and can be found at almost every eroded coastal area in Timor-Leste. In some places, the nearshore currents are associated with tidal currents and the coastal cell makes a more complicated process of sediment transport in the coastal area.

Storms that cause the rising of sea level (storm surges) are induced by extreme winds. The combination of high tides and storm surges produces storm tides which can devastate coastal areas like tsunamis do. Beside destruction of coastal infrastructures, storm tides can change shoreline and cut back sand dunes tens of meters, or undermine the stability of a cliff in a few hours. Storm or tropical cyclone may not directly hit the north coast and south coast of Timor-Leste, but their impacts and strong winds are still felt.

Sea-level rise is a hazard that has been much examined in relation to climate change issues. This hazard is the result of two main variables, namely thermal expansion or contraction in the sea, and the steric effects of the mass amount of water withdrawal that is contained or trapped in the ice and snow around the poles.

Topographical slope in coastal area influences the beach processes. The term “slope processes” encompasses a wide range of land-sea interactions which eventually result in the collapse, slippage, or toppling of coastal cliff blocks. These processes involve terrestrial processes such as rainfall and water seepage and soil weathering, and the undercutting of cliff base by waves forces. Such cases are widespread in Timor-Leste, in areas where the coast have steep slopes.

Land surface can move upward because of isostatic reversal, compaction and settling due to alluvial sediment accumulation in deltas. While land subsidence (downward moving) is caused by the extraction of water and oil, as well as other factors such as tectonic earthquakes. Examples of subsidence are found in Atauro Island. Uplift movement exist at Jaco Island in the eastern part of the country. Land subsidence can also be caused by sediment compaction due to excessive groundwater extraction, which potentially occurs in Dili.

2.3.2 Human Factors

Human intervention is the largest contributor to coastal destruction in Timor-Leste. Human activities accelerate coastal erosion and further land degradation, damaging measures to protect the coastline and destroying mangroves and coral reefs.

Human activities, directly and indirectly, accelerate coastal erosion and degradation, resulting in the damage of coastal protection measures as well as destruction of coastal ecosystems such as mangroves and coral reefs. These problems are accentuated by the pressures of population growth and development in recent and the future. And therefore, considerate and better planned development in natural hazard-prone areas are required.In general, it is important to provide specific concerns and awarenesses in development planning to which some following human activities may become potential causes to coastal erosion, such as:

1. Coastal hardening including hard coastal defence structures that modify coastal sediment transport patterns.

2. Existence of river water flow regulation, in some forms, might affect coastal processes that could be seen after a few decades. For example, the damming of water in the upstream or in the rain catchment areas could cause retention of millions of cubic metres of sediment per year. It would have potential result in a deficit of sediment supply at the river mouth and further causing erosion at the beach as a result of sediment balances in a sediment cell. In addition, the reduced water flow prevents sediment to reach the shore.
3. Dredging activities have increased in recent years, in Timor-Leste, arising from dredging of channels for navigational purposes and removal of seabed materials appropriate for construction.
4. Vegetation clearing in coastal area as a result of changes of land use and land cover pattern could reduce the vegetation cover on the top of the cliff, increasing infiltration of water and undermine the cliff stability. In short, reduction or even clearing vegetation in coastal areas could decline their positive role to increase the resistance of coastal erosion.
5. Excessive groundwater extraction causes land subsidence. This phenomenon may have a limited geographical scope, but its impact is irreversible and is quite significant as this leads to reduced sediment and shoreline retreat.
6. Ship-induced waves are common in causing erosions in beach and cliff.

Impacts of coastal inundation and erosion problems which are often encountered along the coast include the following phenomena:

- Destruction of sand dunes systems by large waves or storm surges.
- Collapse of houses, roads, and other facilities located on top of cliffs.
- Disruption of the function of coastal defence against coastal flooding due to sea-level rise.
- Loss of land with high economic value in coastal city.
- Possible decrease of groundwater levels due to excessive exploitation causing seawater intrusion.

Furthermore, sea level rise and coastal erosion induced by climate change, coupled with increasing numbers of inhabitants and developments in the coastal areas of the country, have dramatically increased pressures to coastal capacity. There are also additional stresses due to land-use and hydrological changes in the catchment areas, which reduce or increase sediment supply to the coast. The collateral impacts can be devastatingly negative, such as:

- Increased flooding and degradation of freshwater, fisheries, and other resources are ultimately affecting people and their socio-economic system; causing loss of properties, natural resources, and harming the environment

- Degradation of coastal ecosystems (wetlands, mangroves, and coral reefs), is seriously impacting the well-being of coastal societies;

3 Physical Characteristics of Coastal and Land Areas of Timor-Leste

This chapter describes some physical characteristics of the coastal, land and atmospheric conditions of Timor-Leste. One principle of this description is that spatial boundaries of these characteristics are often different to administrative and country boundaries, given the fact that Timor-Leste is located in between Southeast Asia and Australia regions. Therefore, many of the discussions presented in this chapter will commence with the descriptions of the regional context.

3.1 Geographical characteristics and administrative boundary

Timor-Leste is located in between Indonesia and Australia. The country is part of the Lesser Sunda Islands. It is located between 8^0 17’ and 10^0 22’S and 123^0 25’ and 127^0 19’E. The country is surrounded by the Banda Sea and Wetar Strait to the north, Savu Sea to the west and the Timor Sea to the East and South.

The country covers 14,954 km^2 of area, including Oé-cusse enclave, Atauro Island and Jaco Island. The highest altitude in the country is the peak of mount Ramelau, of 2,960 m. Geographical characteristics of Timor-Leste are responsible for Timor-Leste´s vulnerability. It is a mountainous island, characterised by rugged steep terrain and small narrow valleys. About 44% of the country has a steep to very steep slope (> 40%) (USAID 2015). The soil characteristic of the country is highly erodible and infertile soils (Ibid.).

Administratively, Timor-Leste is divided into 13 municipalities, 65 Post Administration and 442 Sucos. The municipalities are Bobonaro, Liquiçá, Dili, Baucau, Manatuto, Lautem, Covalima, Manufahi, Ainaro, Viqueque, Ermera, Aileu and Oé-cusse. Eleven (11) of these 13 municipalities are bordering the sea, the north coast or the south coast. Two municipalities, Ermera and Aileu, are landlocked. Dili was the first municipality, established in 1940. Oé-cusse, the enclaved area within the Indonesian territory, is the youngest municipality, given the status of municipality in 1973. Viqueque, on the southern coast, is the largest municipality covering an area of 884 km^2. Dili, as the country’s capital, has the highest population number (277,279) with the smallest area (364 km^2).

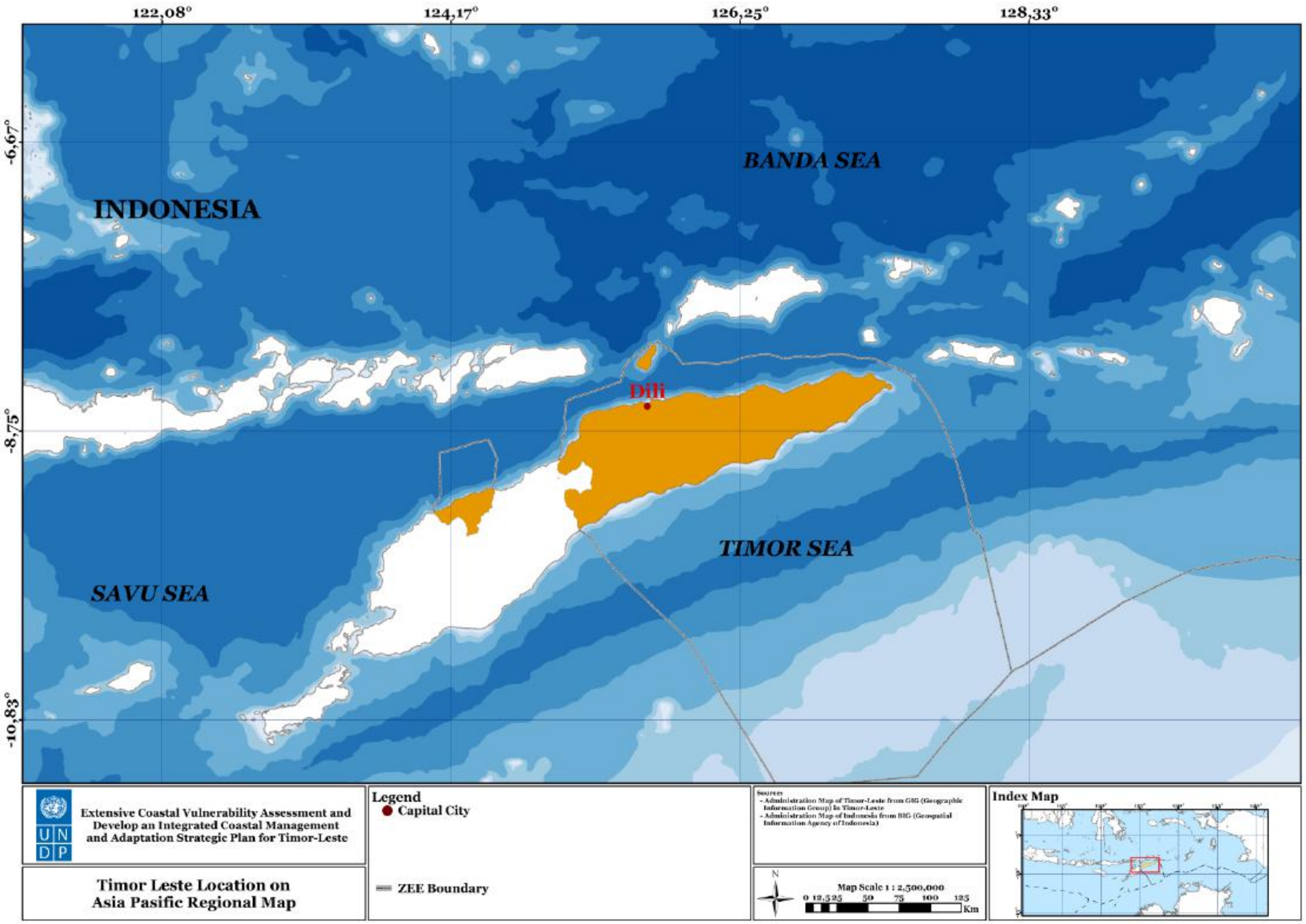


Figure 3.1 Location of Timor-Leste in a region-wide map

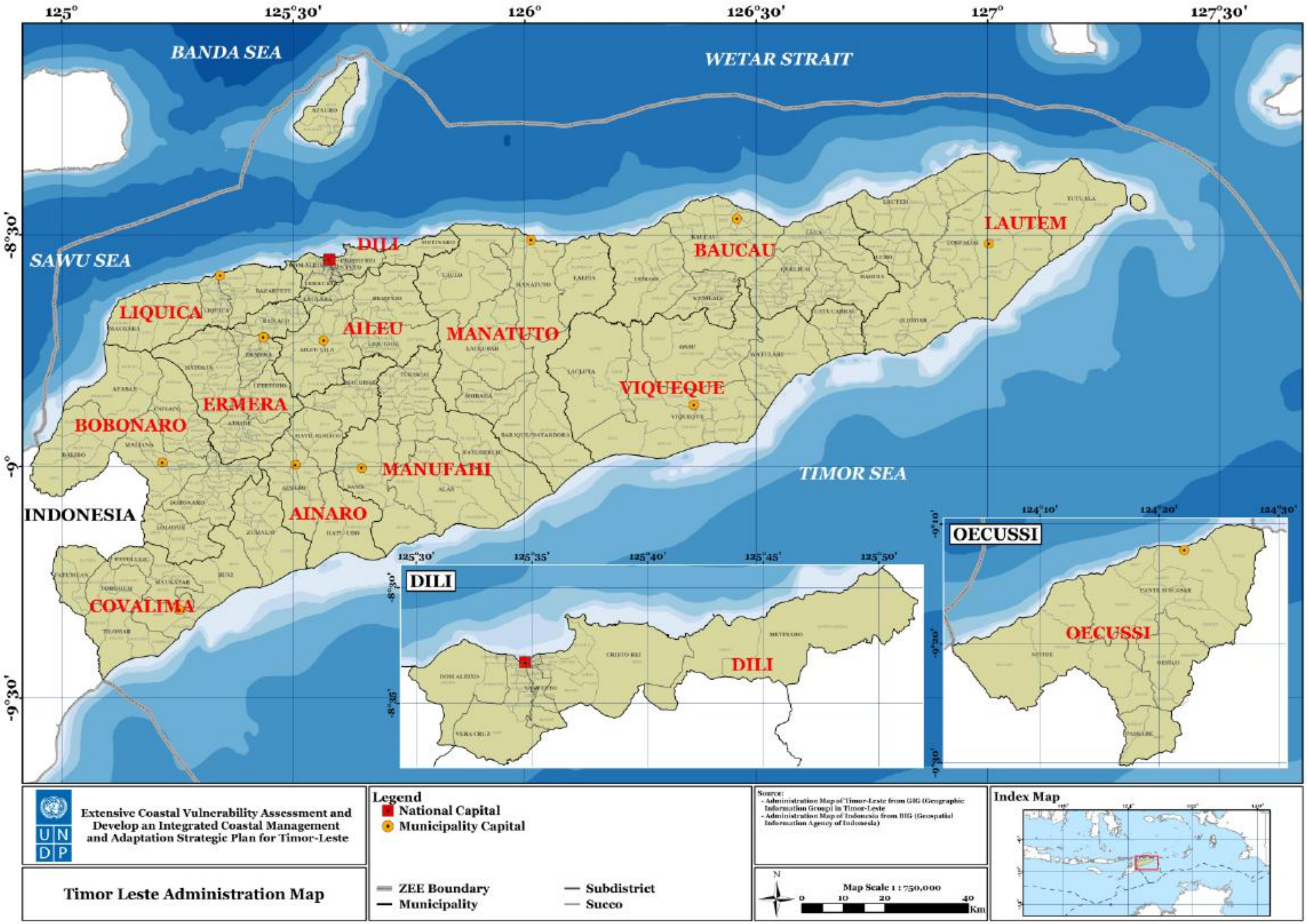


Figure 3.2 Administrative Boundaries of Timor-Leste

3.2 Geomorphological and Geological Condition

3.2.1 Geomorphology, Topography, and Bathymetry

The topography of Timor-Leste is characterized by steep terrain. Almost 50% of the country area has a slope of 40% or greater (UNDP and RDTL 2006). The central of Ramelau mountain range (with several peaks over 2,000 m) controls the landscape of the country. This mountain range separates the two coastal zones of Timor-Leste. A number of wide, yet low-laying, coastal plains can be found along the southern coast. These plains are suitable for agricultural activities along the coast and are mostly cultivated or covered by plantations. But they are also very susceptible to coastal inundation. The coastal bathymetry is shallow with heavy wave and turbid nearshore water, as well as a wide and gently sloping continental shelf (Sandlund, et al. 2001). River deltas, lagoons, floodplains and swamps are characteristics for this part of the coast (RDTL and CDU 2006).

Meanwhile, the northern coasts are mainly characterized by the steep mountains falling directly into the sea, making for rocky and steep coast along most of the shoreline. Narrow coastal plains can be found only in some areas around Manatuto and Dili. In contrast to the south, the coast water is clear with calm wave, however the nearshore littoral zone is very narrow, and the sea floor sharply drops off to the deep sea (RDTL and CDU 2006). Arid woodlands are the dominant vegetation type along most of the north coast.

The topography of Timor-Leste influences weathering, depth, erodibility, infiltration and leaching of soil (Sandlund, et.al 2001). The topography map of Timor-Leste is presented in Figure 3.3. The most sloping areas are predominantly in the westernmost part, where the main land reliefs are also located. In the remaining area of Timor-Leste there are several extreme slopes associated with local phenomena, such as the abrupt ridges of the plateaus in the eastern zone and the cliffs of the North coast. A combination of slope classification by the Government of Timor-Leste with finding on the slope classification and its potential use, resulted as the following (MPW 2017):

a. > 30% → covering 60% of the country's territory. Despite the fact that steep hillsides are cultivated, it is deemed unsuitable for sustainable cultivation. Erosion may occur, and the change of vegetation may increase the susceptibility or risk of landslide.
b. 10% - 30% → covering 20% of the country's territory. Usually located in the great valleys. It is best used for grazing, as soil erosion cannot be controlled under permanent or shifting cultivation.
c. < 10% → covering 20% of the country's territory. Mainly located along the entire Southern coast. These slopes are suitable for cultivation provided that any incipient erosion is controlled. However, due to low laying areas, they could be susceptible for inundation caused by up-hill activities and sea water.

The slope map of Timor-Leste is presented in Figure 3.4.

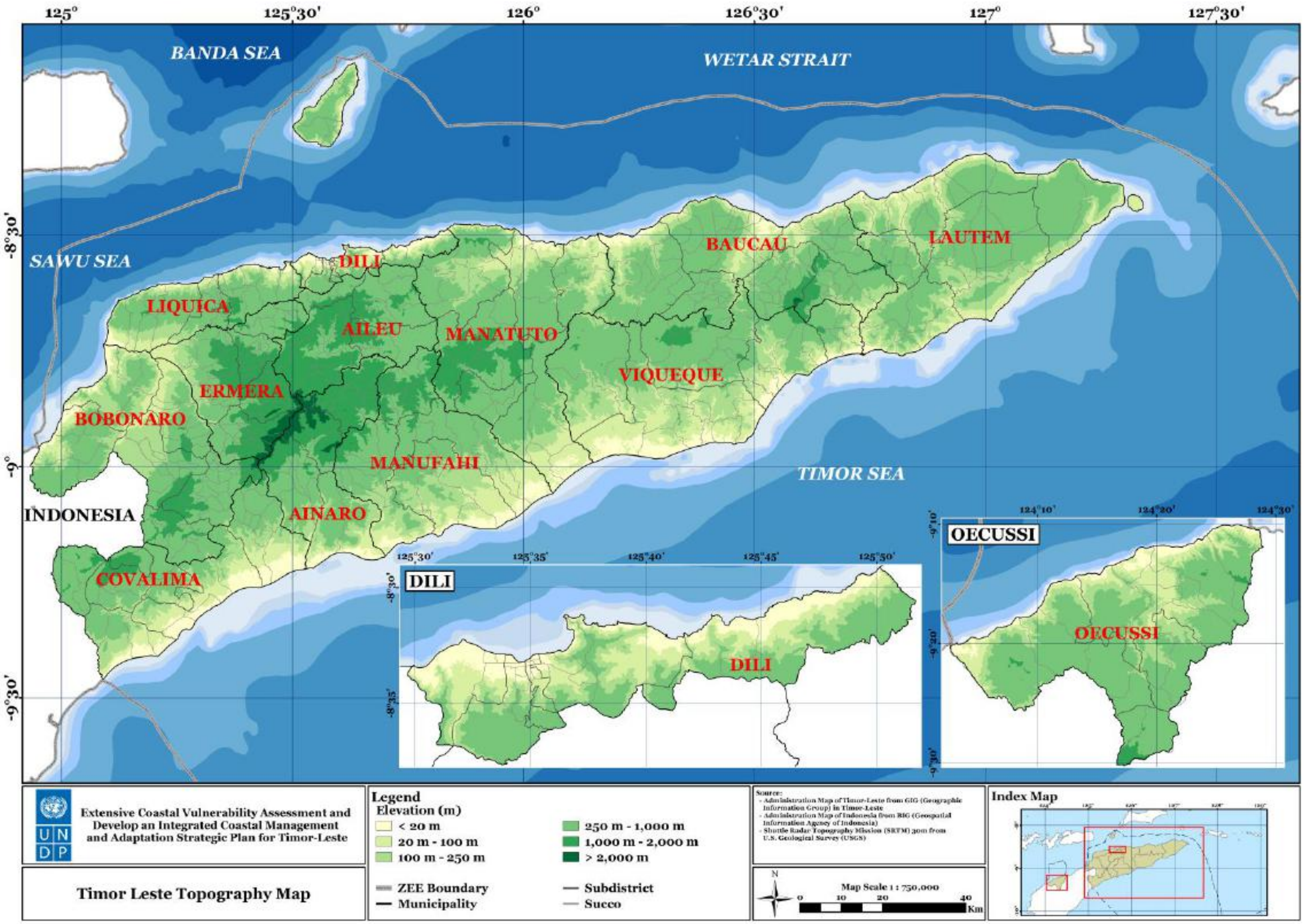


Figure 3.3 Topography of Timor-Leste (Source: Team elaboration)

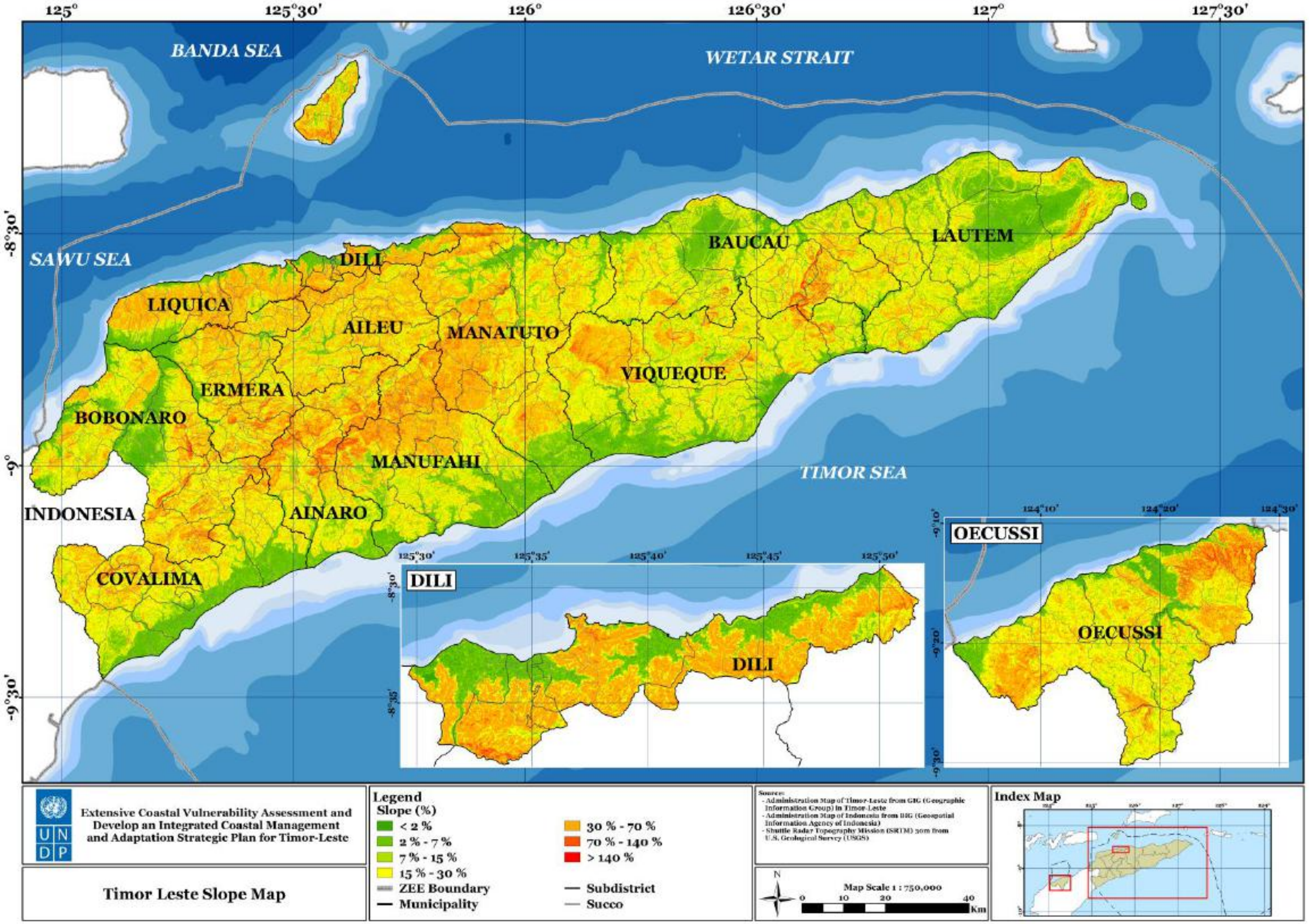


Figure 3.4 Slope Map of Timor-Leste (Source: Team elaboration)

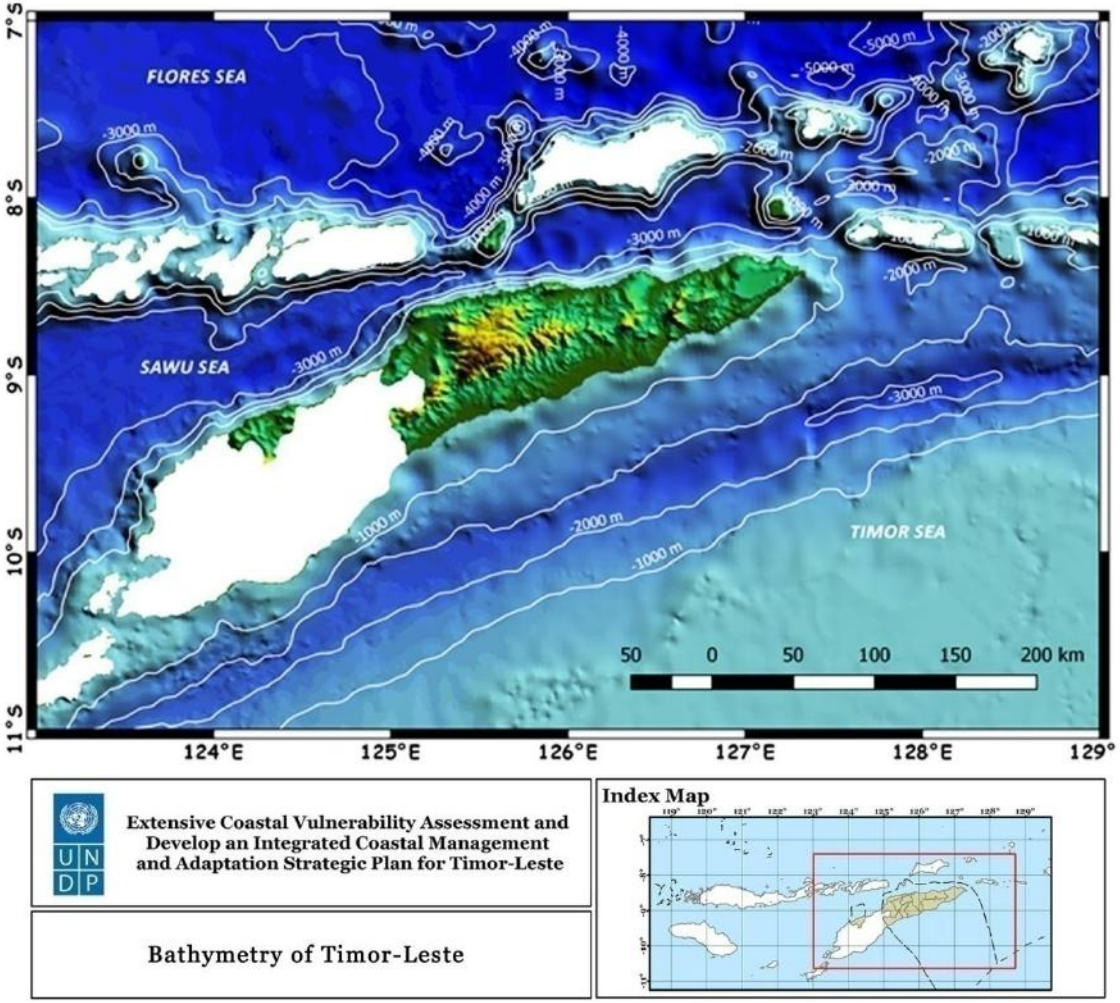


Figure 3.5 Bathymetry of Timor-Leste (Data Source: GEBCO 30sec)

3.2.2 Tectonic Setting – Regional Geology and Bathymetry

Timor Island is located in between the Banda Volcanic Arc and the Australian Continental Shelf, which can be found 200m below sea level. Geologically, it consists of Outer Banda Non-Volcanic Arc and Banda Volcanic Forearc, which is overridden by Australian Continental Margin (Charles 2011). The geological, including bathymetry, conditions of Timor-Leste are closely related to the geology of Banda Arc and North Australian Continental Margin (Ibid.). Banda Volcanic Arc composes the islands of Sumbawa, Flores and Wetar in the north. Recent regional geology condition of Banda Arc is presented in *Figure 3.6* while detailed bathymetry of Timor-Leste is presented in Figure 3.5.

Savu Basin, serving as the Banda Forearc basin, is found in between Banda Volcanic Arc and Timor Island. Its depth is more than 1,000 meters below the sea level. The "Timor Through" is located in the southern part of Timor Island, more than 3,000 meters below sea level. Just up-north the Timor Island, the Wetar thrust serves as a northern limit of a new tectonic collision zone. Based on this regional geology, it was concluded that the Australian continental margin collided with the Asian forearc about 4 million years ago and Indian Ocean crust subducted northwards at the Banda Trench from about 12 to 4 million years ago, making geology of Timor structurally complex (Charles 2011; MPW 2017). Geologically, Timor-Leste is part of the Australian continental plate. And thus, despite the adjacent location to Indonesia, Timor´s geological condition is different than Indonesia which is mostly of volcanic origin (Sandlund, et al. 2001).

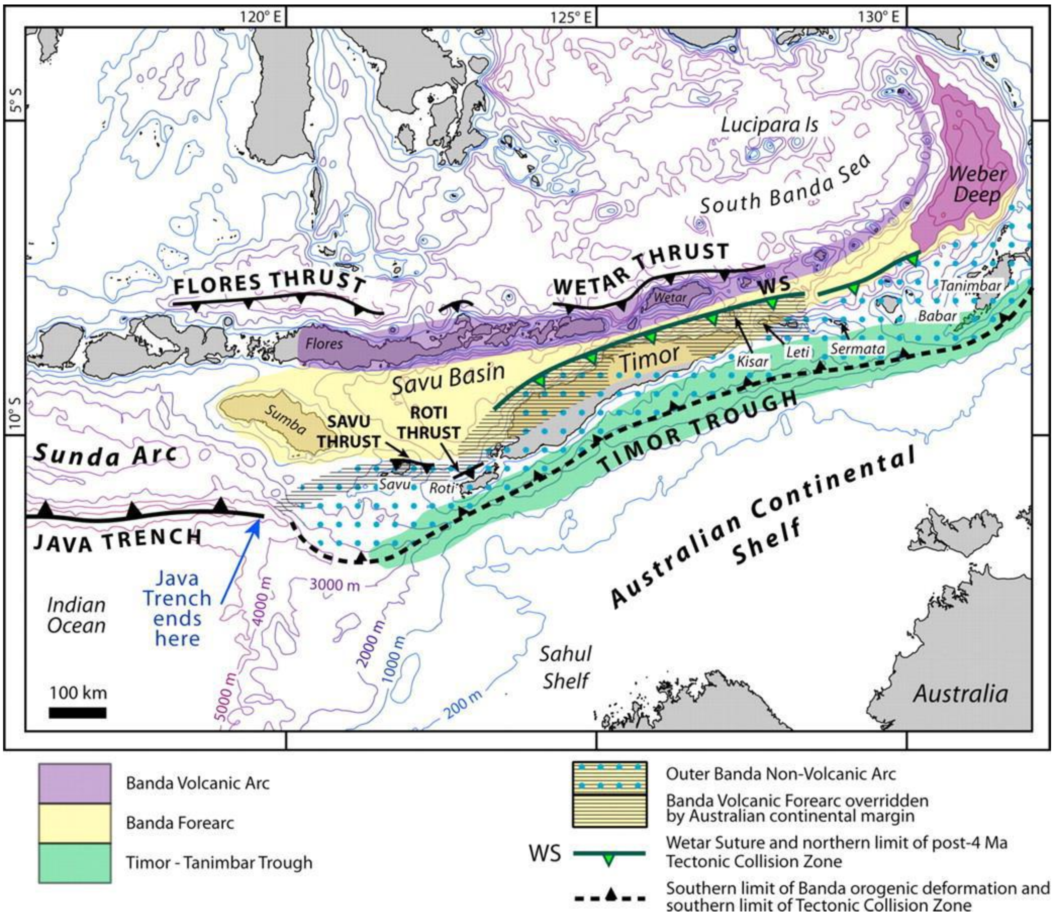


Figure 3.6 Regional Geology of Banda Arc and Australian Continental Margin (Source: Charles 2011)

3.2.3 Geological Condition of Timor Leste Coastal

The geological materials of Timor Island consist of material from the Australian Margin, comprising (Charles 2011):

- Authocthon and Para-Autochthon material from Australian Continental Margin Sequence and Gondwana Sequence; as well as,
- Banda Terrane Allochthon and Aileu Metamorphic Complex Allochthon.

To understand better the geology of the Timor-Leste's coastal zone, four geological maps were used and analysed, namely:

1. Geological Map of Kupang-Atambua Quadrangles (by K. Suwitodirjo and S. Tjokrosapoetro 1996),
2. Geological Map of the Dili Sheet (by S. Bachri and L. Situmorang 1994),
3. Geological Map of Baucau Quadrangle (E. Partoyo, B. Hermanto and S. Bachri 1995),
4. Geological Map of Alor and Wetar Sheets (Y. Noya, G. Burhan, S. Koesoemadinata, and S. A. Mangga 1997).

Based on the geological maps, geological formations of Timor-Leste were analysed and ordered from the youngest to the oldest, to help determining the level of coastal instability[1]. As results, 26 geological formations were identified. These formations were then adjusted by referring to the Digital Elevation Model data. It is assumed that formations within the altitude of 0 – 20 meters are composed by alluvium sediment. Accordingly, it is identified that 15 formations are located at the coasts, namely; Coastal and River Alluvium (Qa/Qal), Suai Formation (Qs), Surobeco Formation (Qps), Bacau Formation (Qpb/Ql), Ainaro Formation (Qpa), Old Volcanic Products (Qtv), Noele Formation (QTn),Bobonaro Formation (Qtb/Tmb), Aliambata Formation (Tma), Wailuli Formation (Jw), Aitutu Formation (Tra), Cribas Formation (Pc), Atohoc Formation (Pat), Manamas Formation (Tmm), and Aileu Formation (Pa). These findings were validated by the expert team during the field survey alongside the coast in May 2017. Detailed distribution of coastal geological conditions of Timor-Leste is presented in Figure 3.7. These formations were used for the CVI analysis, to determine the level of coastal instability.

[1]For a complete list of geological formations please see Annex 6

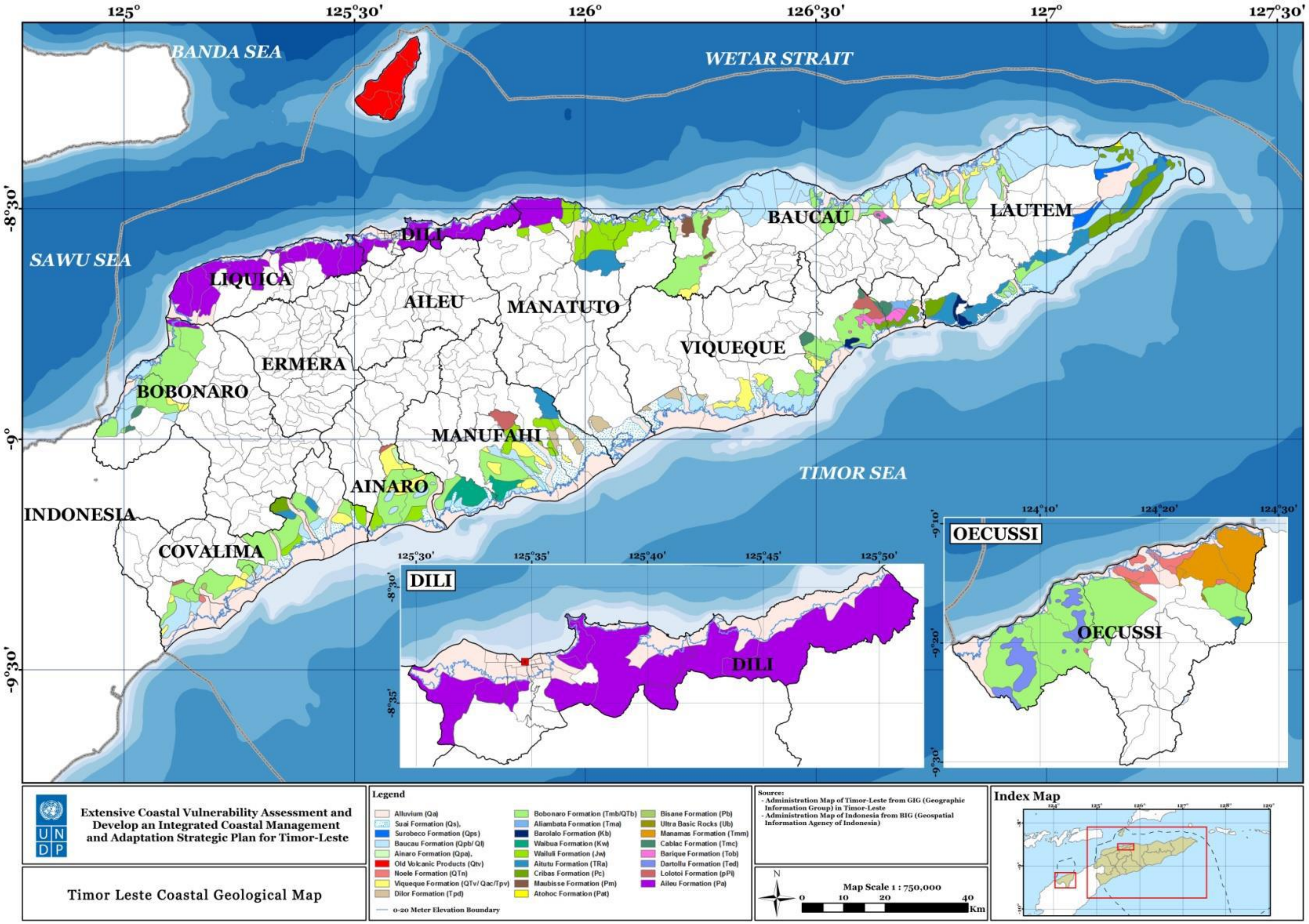


Figure 3.7 Geological Formation along the Coast of Timor-Leste (Source: Team elaboration)

3.3 Climate Condition

The climate condition in Timor-Leste is part of humid, tropic, and warm, with high temperature and rainfall, and the climate is characterized by the alternation of two monsoons. They are varying due to the position of Inter-Tropical Convergences Zone (ITCZ) of unstable air and heavy rainfall, which migrate in the north and south over Indonesia (see Figure 3.8), crossing the equator in May and November each year. When the position of ITCZ is in the north, trade winds from June–September will prevail (PACCSAP 2015). Whereas, when ITCZ is in the south, westerly monsoon winds in December–March will prevail (Ibid.) The position of ITCZ, consequently, results in wet season from December to May and a dry season from June to November (Ibid.)

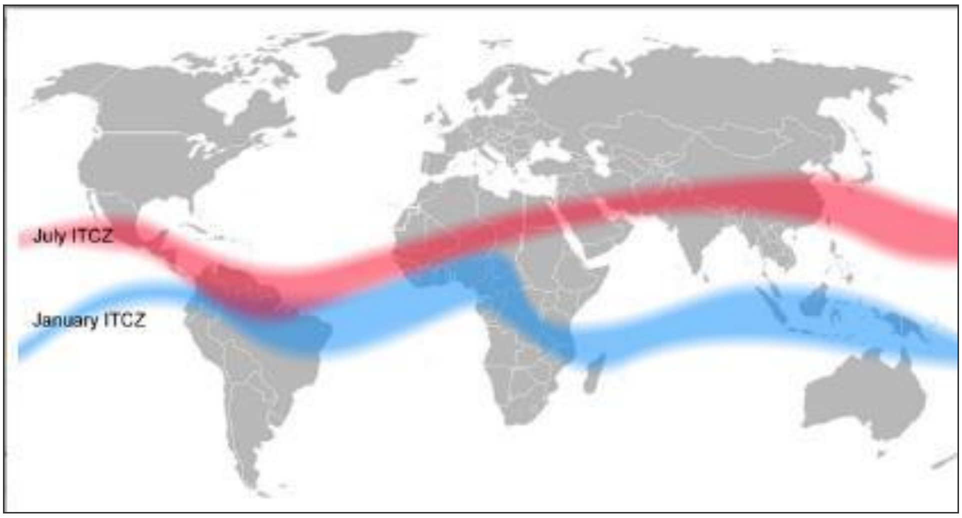


Figure 3.8 The position of ITCZ (source: *http://www.india-karnataka.info/ITCZ*)

Timor-Leste is one of several countries located in the Maritime Continent region and part of the Pacific small island countries, and thus climate condition in Timor Leste is influenced by dynamical atmospheric circulation in these regions. Based on historical rainfall and temperature record, the region is divided into three different climatic zones, i.e. (i) north coast region, characterized by average mean temperature of more than 24 ^{0}C, annual rainfall amount less than 1,500 mm, with a dry season lasting for around five months; (ii) mountainous region, characterized by average mean temperature less than 24 ^{0}C, annual rainfall amount more than 1,500 mm and dry season lasting for four months; and (iii) South coast region, characterized by average mean temperature more than 24 ^{0}C, annual rainfall amount of about 2,500 mm, and dry season lasting for only three months (Kirono 2010 in TL-SSE 2014).

3.3.1 Temperature

The climatology of monthly mean temperatures in Timor-Leste varies across different areas (see Figure 3.9). Based on the climatology of mean temperatures of 11 climate stations located in different altitudes, the highest monthly mean temperature generally occurs during the peak of the rainy season when the optimum solar radiation occurs and there is intensive heating the surface. During the wet season, the mean temperature ranges from around 20°C to 30°C. During the dry season, the temperatures are lower, ranging from 16°C to 27°C (TL-SSE 2014).

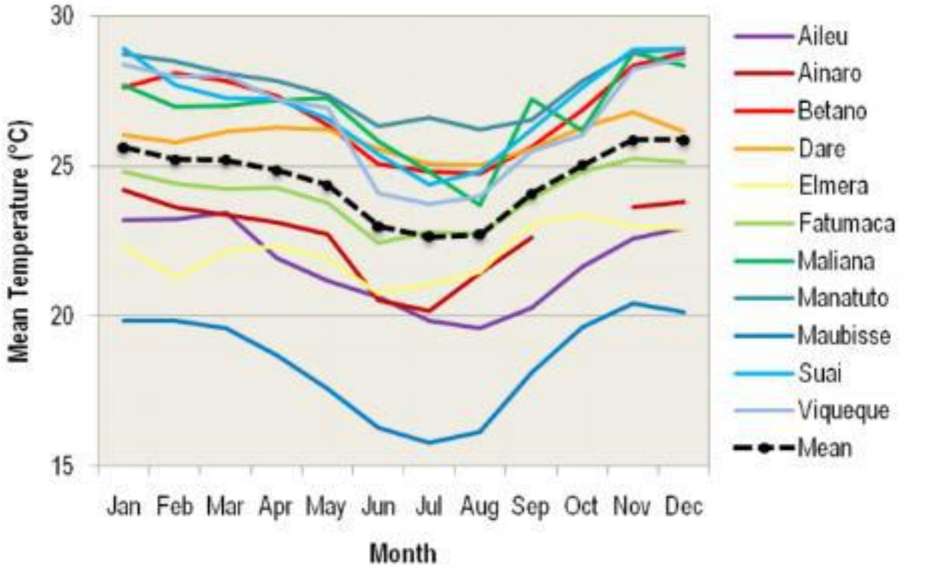


Figure 3.9 Monthly mean temperature climatology in 11 climate stations in Timor-Leste Black-dashed (Source: TL-SSE 2014)

3.3.2 Rainfall

The rainfall pattern in Timor-Leste is strongly characterized by the Australian Monsoons. In time description, the peak of the rainy season usually occurs in January or February, around 250 mm in average. The dry season occurs from July to October with the lowest rainfall average around 25 mm (Figure 3.10).

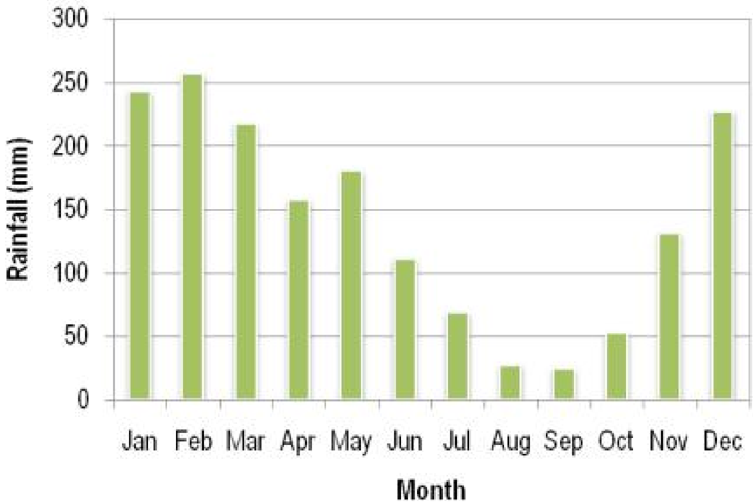


Figure 3.10 Monthly rainfall climatology in Timor-Leste based on the average rainfall climatology in 36 rain gauge stations in Timor-Leste (Source: TL-SSE 2014)

In spatial distribution, the Initial National Communication of Timor Leste reported that (TL-SSE 2014):

1) rainfall patterns in Timor-Leste vary from the driest area in the north-eastern part to wetter areas in the western part of the country,

2) there are five dominant rainfall types found in the country based on the PCA-cluster analysis of monthly rainfall climatology (see Figure 3.11).

The differences between these types are mostly found in the amount of their **wet season rainfall**, elaborated as follow:

- Type 1 rainfall region represents areas in the western part of the country with the highest rainfall during wet season, especially in February and March, reaching around 400 mm in average.
- Type 2 rainfall region is also located in the western part adjacent to the Type 1 location. In this region, the characteristic Monsoonal rainfall is dominant with the rainfall peak reaching around 275 mm, especially in December, January and February.
- Type 3 rainfall region has a peak rainfall around 225 mm and is found adjacent to the north coast region, running from the west to the east of the main region as well as in the separated region in the west. The south-western part of the country also has the same Type 3 characteristic.
- Type 4 rainfall region is located mainly in the centre of the country with a rainfall peak lower than the previous types, i.e. around 175 mm.
- Type 5 rainfall region is characterizing most of the north coast region. It has the lowest rainfall compared to the other four rainfall types. The peak of wet season rainfall in a Type 5 area is not more than 150 mm.

Based on the nature of mountainous elevation along north east to south west orientation, the country's rainfall climate is categorized into six agro-climatic zones, as presented in Figure 3.12 (Fox 2003). Rainfall along the northern coast is very low (<1,000 mm/annum), throughout the central and elevated areas is low to moderate (1,500-2,000 mm/annum), and in high altitude areas which are mostly in the west of the country is relatively high (>2,500 mm/annum) (Keefer 2000 in Barnett 2003).

The monthly rainfall pattern is different between northern and southern areas. The northern area has a unimodal rainfall pattern with distinct wet and dry seasons in which the wet season begins around December and ends around March/May. The southern region has a bimodal rainfall pattern, i.e. two rainfall peaks starting in December and again in May (Barnett 2003 in TL-SSE 2014). This area has a longer wet season, i.e. between 7 and 9 months.

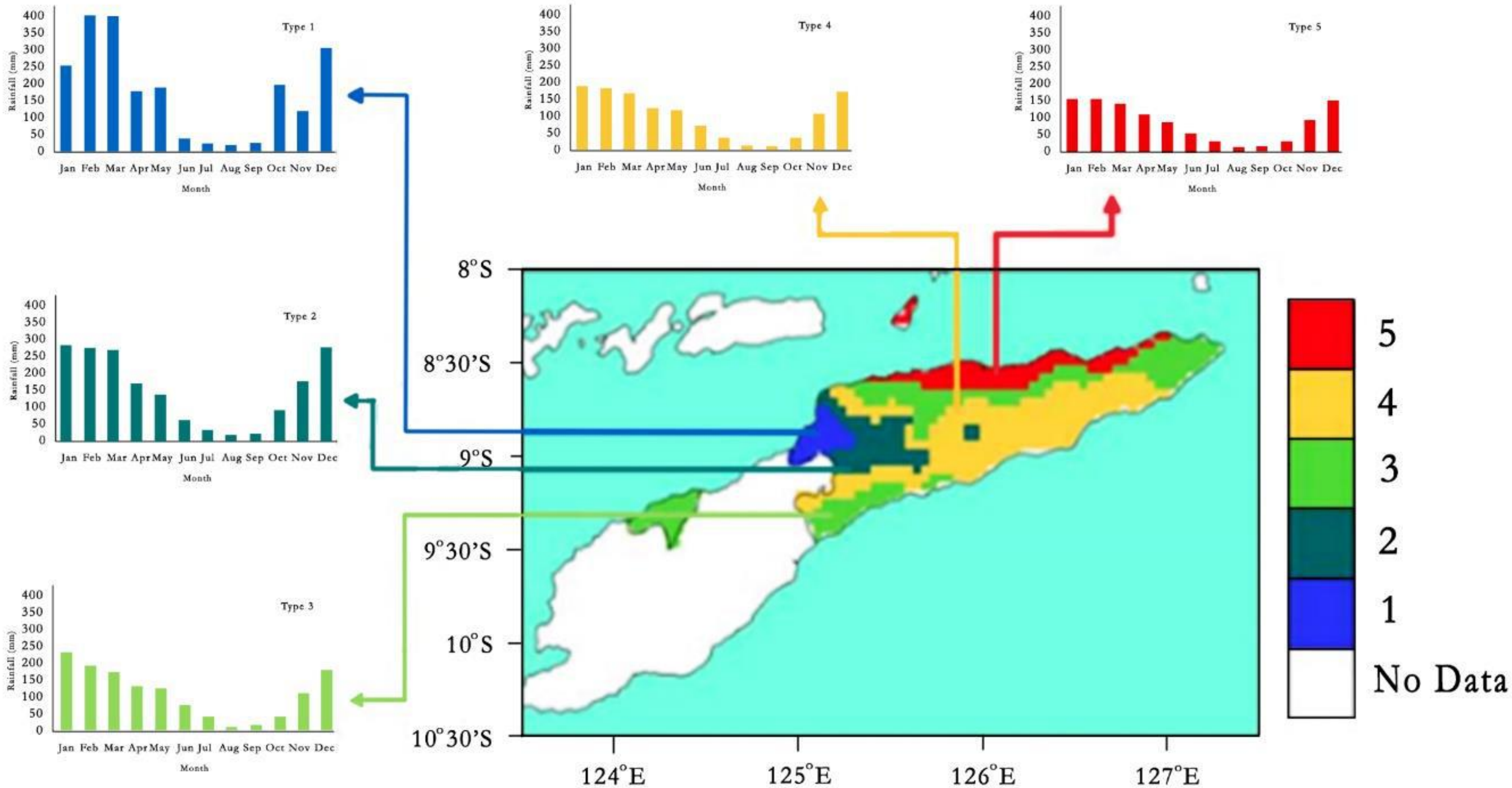


Figure 3.11 Pattern of monthly rain fall climatology in Timor-Leste based on cluster analysis (Source: TL-SSE 2014)

No	Zone (Percent land area)	Area (%)	Altitude (ma.s.l.)	Annual rainfall (mm)	Months of Rain
1	North Coast Lowlands	10	<100	<1000	4-5
2	Northern Slopes	23	100-500	1000-1500	5-6
3	Northern Uplands	20	>500	> 1500	6-7
4	Southern Uplands	15	>500	>2000	9
5	Southern Slopes	21	100-500	1500-2000	8
6	South Coast Lowland	11	<100	<1500	7-8

Figure 3.12 Rainfall Types in Timor-Leste (Source: TL-SSE 2014)

These spatial distributions of rainfall were confirmed by the the annual rainfall across Timor Leste taken from the webportal of the Seeds of Life Program by the MAF (see *Figure 3.13*). It shows that the rainfall distribution across Timor Leste is uneven. The northern coasts (Atabae, Liquica, Dili, Manatuto, and Vemase) including Oecussi and the nothern part of Atauro Island have low annual rainfall of less than 1,200 mm/year. Meanwhile, the southern coast (Suai, Betano, and Viqueque) and area with higher elevation (Baucau, Remevio, Gleno, Hatolia, Maliana, Venilale, and Lospalos) have moderate annual rainfall ranging from 1,200 - 2,000 mm/year. The mountainous region in central Timor Leste (Aileu, Maubisse, Ainaro, Same, and Soibada) and Iliomar have high annual rainfall of more than 2,000 mm/year.

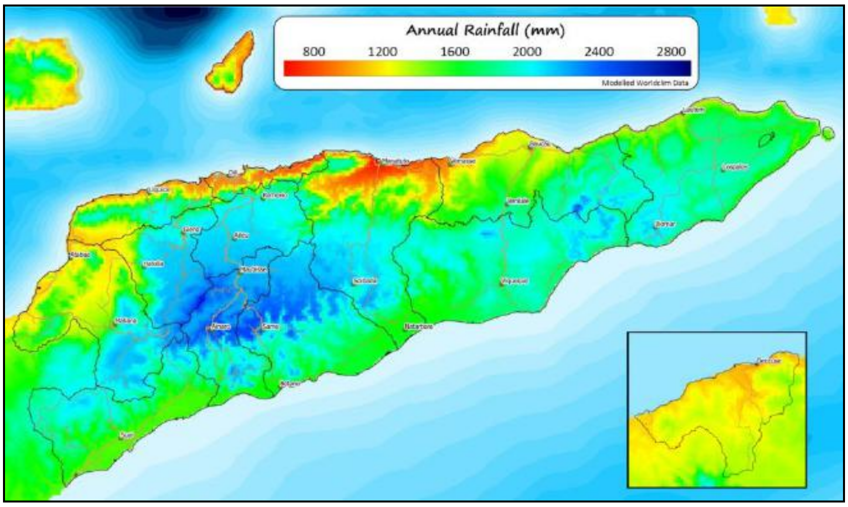


Figure 3.13 Map of Annual Rainfall in Timor Leste (Source: Seeds of Life - MAF, 2012)

Furthermore, an annual precipitation map on PCA-cluster analysis provided by AL-GIS, MAF (see *Figure 3.14*) also shows that northern coast of Timor Leste has lower rainfall than southern coast. The differences in rainfall pattern represented spatial variations of the rainfall received by these two areas. Elevation differences also cause uneven rainfall distribution in Timor Leste, which higher elevation areas, especially mountainous areas (uplands) have higher annual rainfall amounts compared to lower areas (slopes and coast lowlands).

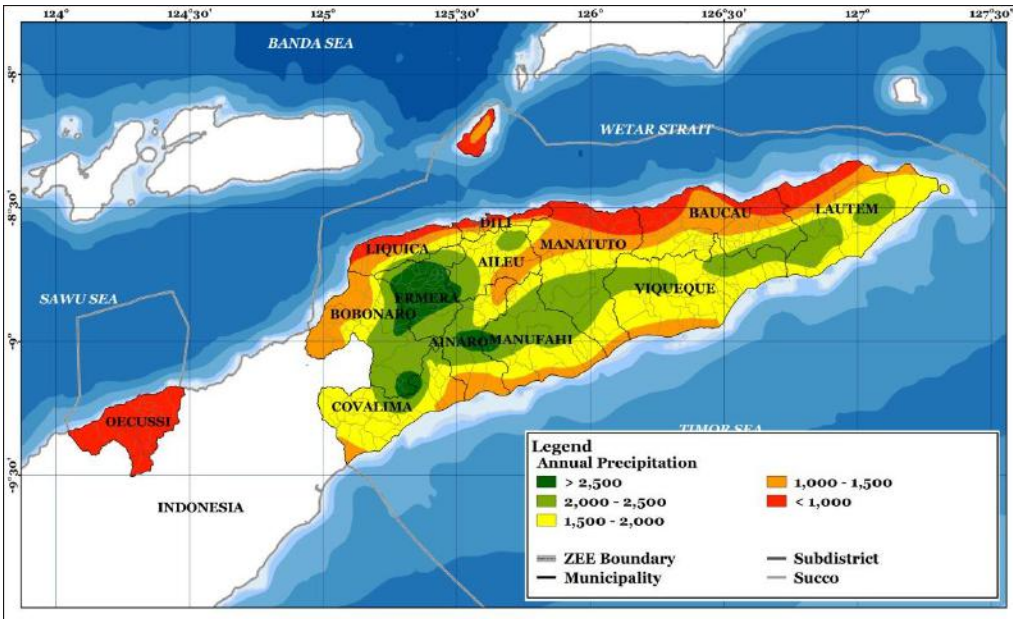


Figure 3.14 Annual Precipitation Map (Source: AL-GIS)

3.3.3 Wind

Knowledge about the nature of the wind is very important in studying the patterns of coastal processes, because of the following reasons:

- Winds generate ocean waves. And these waves generate forces that can cause abrasion;
- Wave front, generated by winds, forms an angle to the shoreline that will cause a longshore current. This is very important in the calculation of sediment transport in alongshore direction and shoreline change phenomenon.

In addition to directly affecting the coastal processes, wind patterns also influence circulation of sea water including distribution of suspended particles/materials in the water. Analysis on wind patterns were conducted by using the European Centre for Medium-Range Weather Forecasts – ECMWF global datasets (www.ecmwf.int) in Dili, Com, and Suai site for the 10 year-period of 2007-2016, for the parameters of daily maximum wind speed and direction (Figure 3.15).

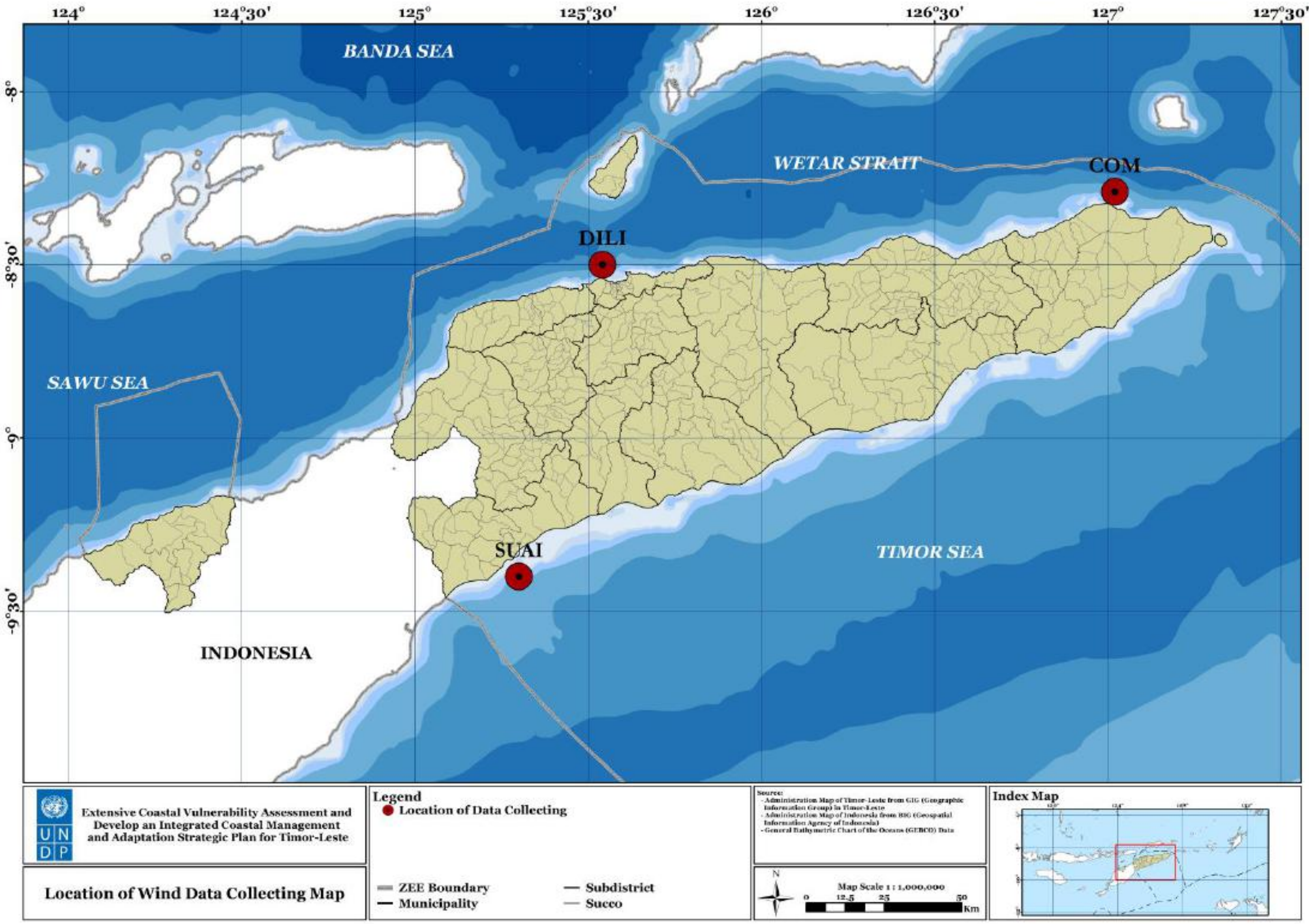


Figure 3.15 European Centre for Medium-Range Weather Forecasts (ECMWF) Wind Data Collecting Position in Dili, Com, and Suai, Timor-Leste.

Generally, temporal patterns of the wind at Dili, Com, and Suai and the surrounding areas of Timor Leste can be divided into four patterns based on the existing monsoonal season, namely:

- Northwest Monsoon Season (December, January, February)
  In Northwest Monsoon Season the wind was blowing predominantly from the West. The probability of occurence is 35.76% in Dili, 39.88% in Com, and 31.11% in Suai. The dominant wind speed is 1-3 m/sec in Dili (72.57%), 3-5 m/sec in Com (32.96%) as well as Suai (37.12%). This is due to the influence of the northeast trade winds where the wind comes from the high-pressure area in latitude 30^0 N to the low-pressure region at the equator.
- First Transitional Season (March, April, May)
  Influence from the movement of the sun position from the southern to the northern latitude in March, April and May results in changes of the trade wind direction transitionally. During the transition season, the domination of West trade wind decreases. And thus, the dominant wind direction is coming from Southeast, with ocurrence's probability of 38.58% in Dili and 45.59% in Com. And from East, the probability of occurence is 43.28% in Suai. The dominant speed is 1-3 m/sec in Dili (75.39%), 5-7 m/sec in Com (33.17%), and 3-5 m/sec in Suai (41.73%).
- Southeast Monsoon Season (June, July, August)
  Continuation of the wind direction pattern occurs during the Southeast monsoon season.The wind comes predominantly from the Southeast, with occurrence's probability of 71.77% in Dili and 84.87% in Com. And from the East, the probability of occurence is 58.57% in Suai. The southeast trade wind is developed, due to the high-pressure areas formed at the 30^0S latitude. The dominant speed is 1-3 m/sec in Dili (61.10%); 5-7 m/sec in Com (47.46%) and Suai (52.13%).
- Second Transitional Season (September, October, November).
  Influence from the movement of the sun position during September to November from the northern to the southern latitude results in the changes of dominant wind direction. The dominant wind coming from the East has occurrence's probability of 36.56% in Dili and 45.32% in Suai. And from the Southeast, the probability of occurence is 45.87% in Com. The dominant wind speed is 1-3 m/sec in Dili (76.65%), 3-5 m/sec in Com (39.66%), and 5-7 m/sec in Suai (34.72%).

To this end, it is concluded that the average annual pattern for the wind climate during last 10 years shows that southeast is the dominant wind direction in Dili and Com with probability of occurrence reaches 36.36% and 45.43% respectively, that is then followed by the East wind in Suai with an probability of occurence of 38.37%. Dominant wind speed in Dili is ranging from 1 m/sec to 3 m/sec with a frequency of 71.42%. It is followed by the wind speed in Com at 5-7 m/sec, with the probability of 34.01% and wind speed in Suai at 3-5 m/sec with the probability of 35.21%.

Tabulation of wind statistic data and windrose for the 10 year-period of 2007-2016 are presented in Annex 7. Furthermore, the wind patterns (speed and direction) for the year 2016 are also presented in Annex 7. The seasonal wind patterns are shown in Figure 3.16.

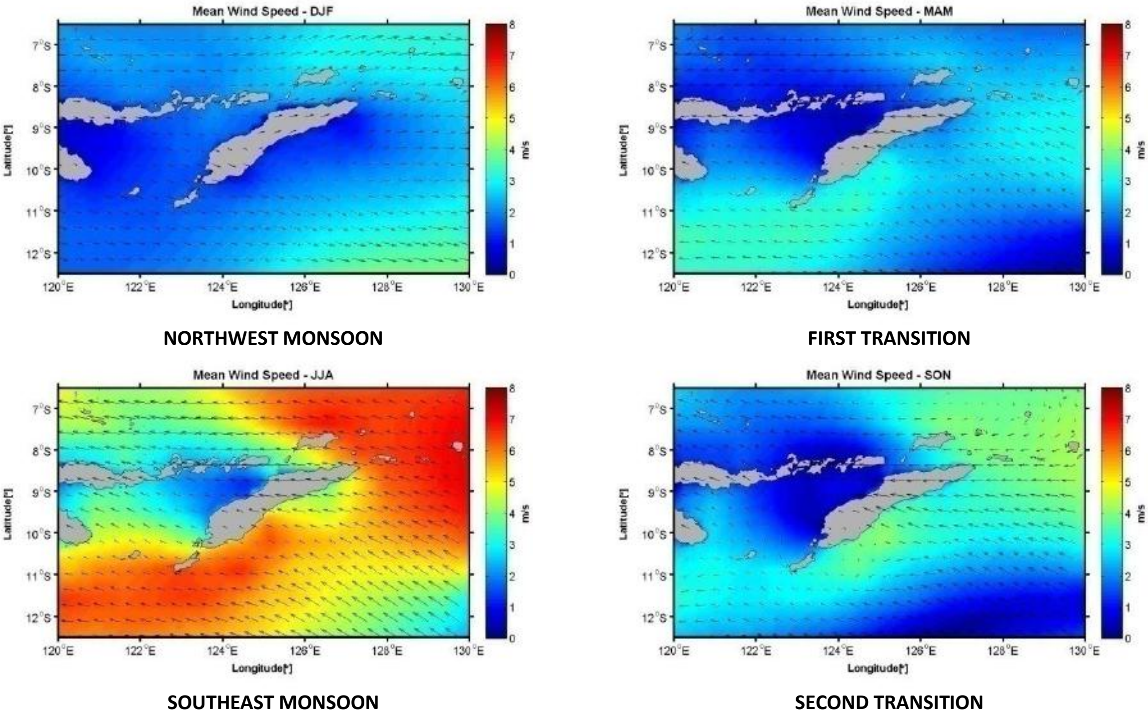


Figure 3.16 Seasonal Wind Patterns in Timor Leste

3.4 Ocean Condition

Similar to the climate condition, spatial and temporal distributions of ocean dynamics in Timor-Leste surrounding waters (i.e., Timor Sea, Wetar Strait and Sawu Sea) are influenced by regional dynamics between Pacific and Indian Oceans. Wyrtki (1961) presented a fundamental description of physical oceanography, i.e. sea level variations, ocean current, tides, waves as well as ocean properties such as temperature and salinity, in the Southeast Asian water including Timor-Leste. To this end, discussions on physical characteristics of the ocean condition will be opened by the regional descriptions and influence, prior to describing the condition in Timor-Leste.

3.4.1 Sea Surface Temperature and Acidity

The research team analysed the results of previous studies of large-scale (internationally) gridded Sea-Surface Temperature datasets (HadISST, HadSST2, ERSST and Kaplan Extended SST V2; Volume 1), to be used as representation of Timor-Leste sea surface condition. This was done, due to the absence of monitoring or observation on Sea-Surface Temperature (SST) parameter in Timor-Leste. It must be noted that that ocean condition of Timor-Leste cannot be separated from its surrounding, as it is a global dynamic.

It is indicated that there is a gradual warming of sea water temperatures around Timor-Leste since the 1970s, at approximately 0.16 ^{0}C per decade. Projections indicate that the annual average air temperature and sea-surface temperature will further increase. Air temperature is projected to increase between 0.5 – 1.1 ^{0}C by 2030 under very high emission scenario (PACCSAP 2015). This increase will result in a rise of the number of hot days and warm nights, and a decline in cooler weather. The historical and projected average of sea surface temperature for Timor-Leste (using regional scale) is presented in Figure 3.17.

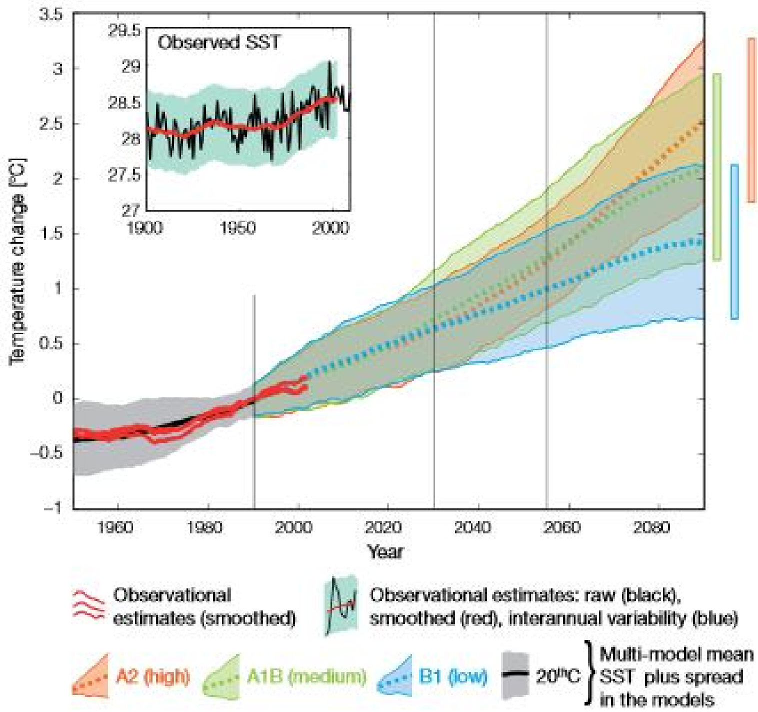
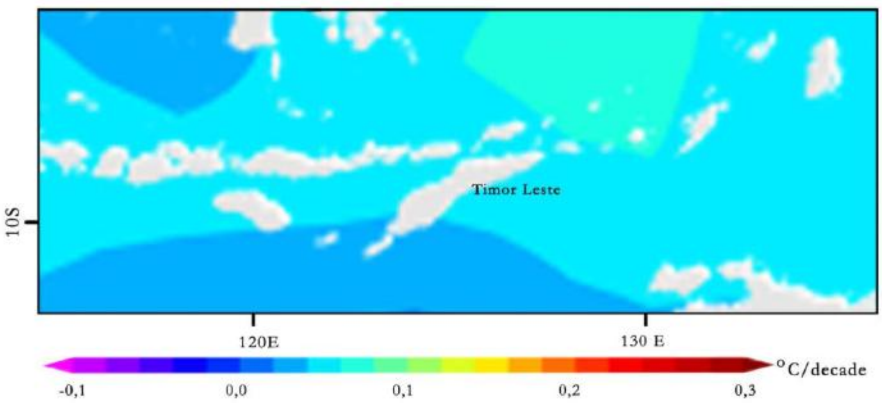
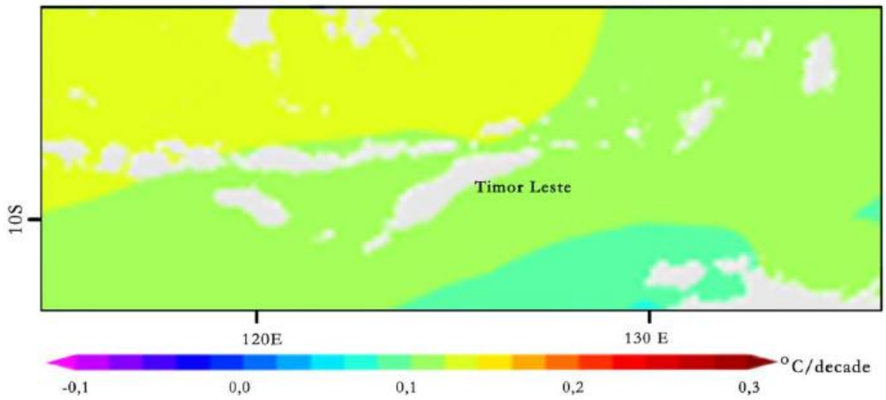


Figure 3.17 Historical and simulation of mean sea surface temperature in Timor-Leste (Sourc: PCCSP 2011)

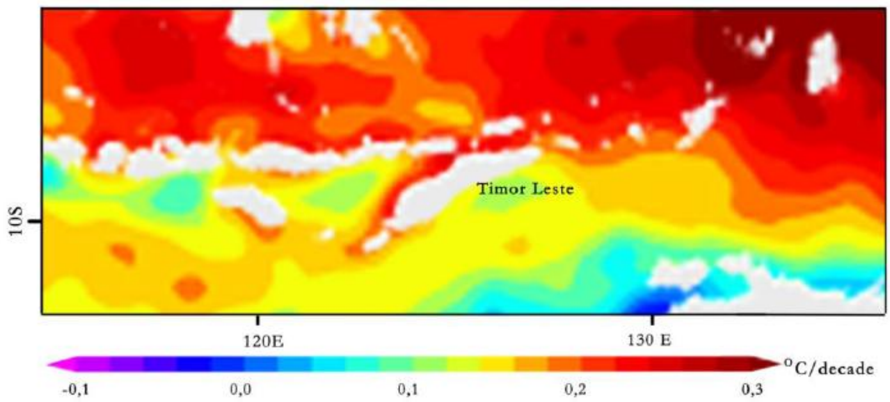
The evolution of SST rise over the Timor-Leste water as a part of ocean dynamics in the Indonesian seas was done by Sofian (2015) and is depicted in Figure 3.18. The average SST has an increasing trend from 0.075 ^{0}C/decade, at the beginning of 20thcentury, to 0.22 ^{0}C/decade in the recent decades. Figure 3.18 (c) illustrates the variation of SST rate of 0.05 to 0.3 ^{0}C/decade. The average trends of the increasing SST rate in Timor-Leste sea water is ranging from 0.18 to 0.22 ^{0}C/decade. If this trend continues, the SST rise will reach 0.6 to 0.7 ^{0}C, and 1 to 1.2 ^{0}C in 2030 and 2050, respectively. Furthermore, SST is expected to increase by 1.6 to 1.8 ^{0}C in year 2080 and reach 2 to 2.3 ^{0}C in year 2100.



a. SST rise rate from 1900 to 1960 with the mean rise rate of 0.075 ^{0}C/decade



b. SST rise rate from 1960 to 1990 with the mean rise rate of 0.11 ^{0}C/decade



c. SST rise rate from 1990 to 2014 with the mean rise rate of 0.22 ^{0}C/decade

Figure 3.18 The evolution of SST rise based on the data of NOAA OI (Sofian 2015)

With the global rise of emissions, acidity levels of sea water will continue to increase over the 21st century. And such a condition also applies for Timor-Leste (PCCSP 2011). Data show that since the 18th century the level of ocean acidification has been slowly increasing in Timor-Leste's waters.

Furthermore, the sea levels gradually rise under influences of the expanding warm ocean water and the melting of glaciers and ice sheets. Satellite data indicate the sea level has risen near Timor-Leste by about 9 mm annually since 1993, larger than the global average of 2.8–3.6 mm per year (PCCSP 2011). This higher rate is deemed to relate to the natural fluctuations which are caused by phenomena such as the El Niño-Southern Oscillation. The sea level around Timor-Leste is expected to continue to rise. A study done by the PCCSP in 2011 indicated that under a very high emission scenario sea level may rise between 9–18 cm by 2030 (Ibid.).

3.4.2 Ocean Current

The regional sea surface current patterns including sea water around Timor-Leste fluctuate in accordance to the Asian Monsoon and the Australian Monsoon, respectively due to modulation of the monsoonal wind. However, the regional (even global) deep water circulations under the influence of thermohaline factors remain constant following global ocean dynamics. The Timor-Leste sea water is mainly influenced by the North Pacific pathway of the thermohaline circulation. The current within the thermocline depth (from 150m to 400m) shows the southeast-ward from the West Pacific to the Indian Ocean (Gordon 2006 in Sofian 2015) as shown in Figure 3.19.

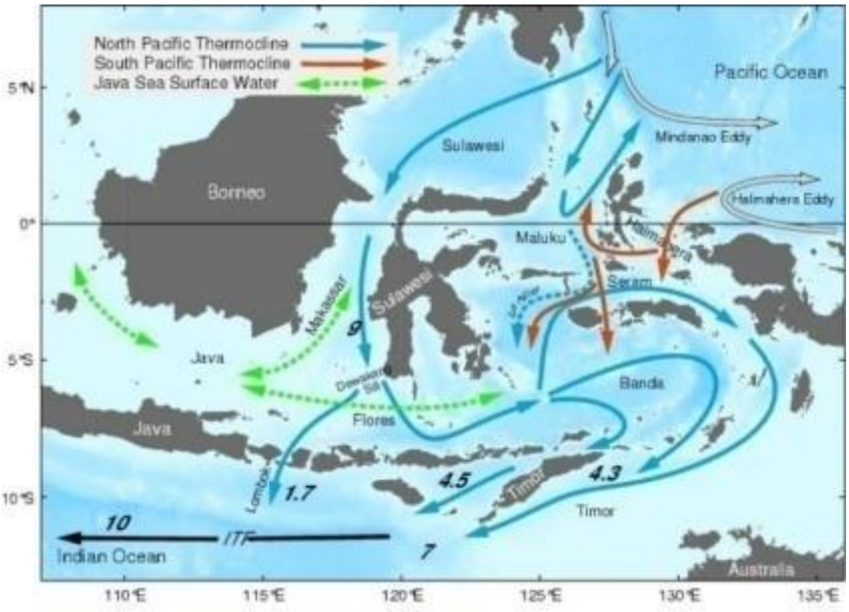


Figure 3.19 Sketch of surface and thermocline currents in the Indonesian Sea. The dashed lines indicate the surface current, and the solid lines indicate the currents within the thermocline depth (Source: Gordon 2006 in Sofian 2015).

Due to the wind forcing and the bathymetric features, the sea surface currents around Timor-Leste move north-eastward during the peak of Asia Monsoon. The sea levels heighten about 0.7-0.8 m above its mean during the season. During the peak of Asian Monsoon, the sea surface currents around Timor-Leste move south-westward, and the sea level is rising about 0.5-0.6 m above its mean.

3.4.3 Tides

Being part of the Indo-Australia ocean water region, the tide level and/or dynamics of Timor-Leste are not directly caused by gravitational forces of the moon and sun, but also influenced by the propagation of tidal waves from the Indian Ocean and Pasific Ocean.

The complexity of tides is characterized by spatial distribution of Formzahl number representing tidal type. The tidal type based on Formzahl number calculation are classified as follows:

1. Formzahl numbers of $F < 0.25$ indicate semi-diurnal types, with occurrences of two high water levels and two water levels daily that are approximately the same height.
2. Formzahl numbers of $0.25 < F < 1.5$ show mixed semi-diurnal dominant type, with occurrences of two high water levels and two low water levels daily with various tidal ranges that attain their maximums when the declination of the Moon has reached its maximum.
3. Formzahl numbers $1.5 < F < 3.0$ indicate the mixed diurnal dominant type with occurrences of pre-dominantly one high water level a day, following maximum declination of the Moon.
4. Formzahl numbers $F > 3.0$ indicate diurnal type with occurrences of one high water a day with a uniform tidal range.

Three locations were selected as samples to predict the tidal variations around Timor-Leste. These are Dili in north-west part, Com in north-east part, and Suai in south-west part as shown in Figure

3.20. The observation is done by using tidal data from 1 January 2016 up to 31 December 2016 at the three locations, obtained from the Indonesian Geospatial Information Agency[2].

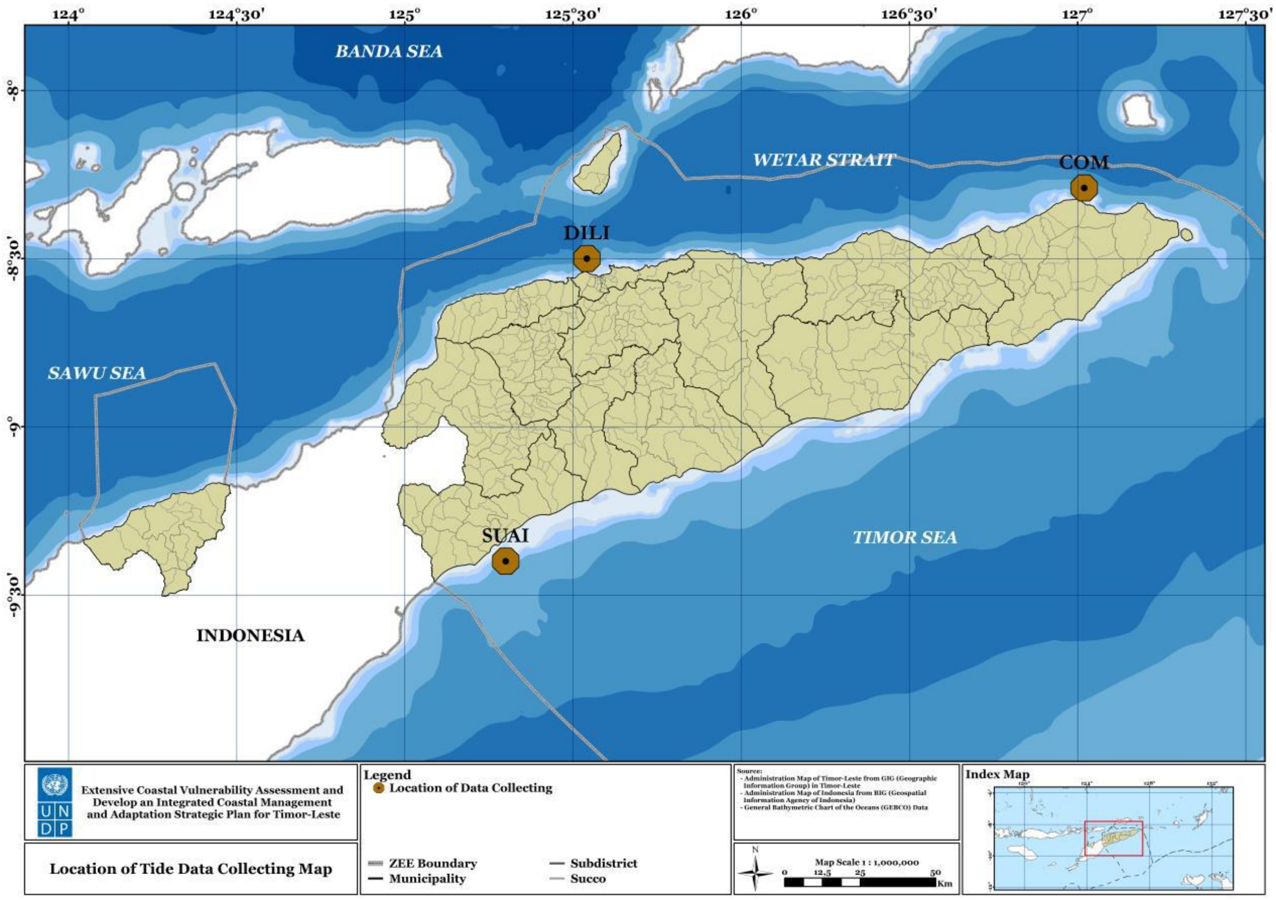


Figure 3.20 Location of tidal data collecting stations at Dili, Com, and Suai

The prediction resulted as the following (see Figure 3.21):

- Dili (126° E, 9° S): The maximum tidal range is about 2.826 m, while the significant one is 2.3208 m.
- Com (127° E, 8.7° S): The maximum tidal range is about 2.9542 m, while the significant one is 2.4152 m.
- Suai (125° E, 9° S): the maximum tidal range is about 3.713 m, while the significant one is 3.026 m.

The Formzahl number in Dili and Com are about 0.62-0.63, while one in Suai is about 0.49. These numbers show that the tide character of the Timor Sea water is semi-diurnal type, with tidal ranges variation of about 1.5 - 2.0 m in Flores Sea (northern water of Timor-Leste) and around 2.0 - 4.0 m in Timor Sea (southern water of Timor-Leste).

[2]tides.big.go.id

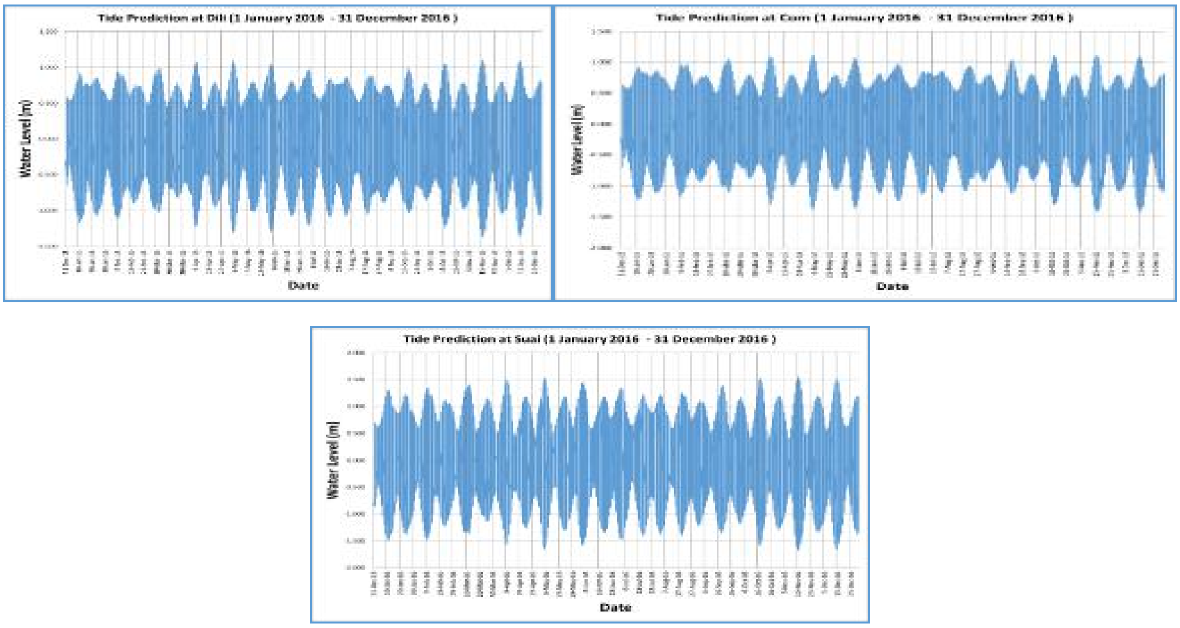


Figure 3.21 Tidal prediction at Dili (top-left), Com (top-right) in northern coast and Suai (bottom)in southern coast of Timor-Leste

Table 3.1 Tidal Component of Tide in Dili, Com, and Suai

Location	Param.	K1	O1	M2	S2	N2	P1	MS4	K2
Dili	Ampl. (cm)	27.11	17.79	52.83	18.31	10.48	8.97	0.01	5.80
	Phase (°)	186.35	171.47	130.60	180.00	107.45	193.42	112.05	174.68
Com	Ampl. (cm)	27.75	18.39	55.72	18.90	11.41	9.18	0.01	6.35
	Phase (°)	189.13	174.53	141.39	197.79	117.34	196.20	108.15	188.65
Suai	Ampl. (cm)	30.58	19.02	68.67	33.03	12.76	10.12	0.02	11.45
	Phase (°)	189.75	176.63	110.18	158.70	87.54	196.82	99.25	150.21

3.4.4 Ocean Waves

Ocean wave heights in Timor-Leste sea water is influenced by the seasonal wind. Figure 3.22 and Figure 3.23 show the spatial distributions of significant wave height (SWH) during the Asian- and Australian- monsoon. During the Asian monsoon, the SWH in Timor-Leste sea waters is about 0.75 m while during the Australian monsoon the SWH is about 1.5-1.75 m.

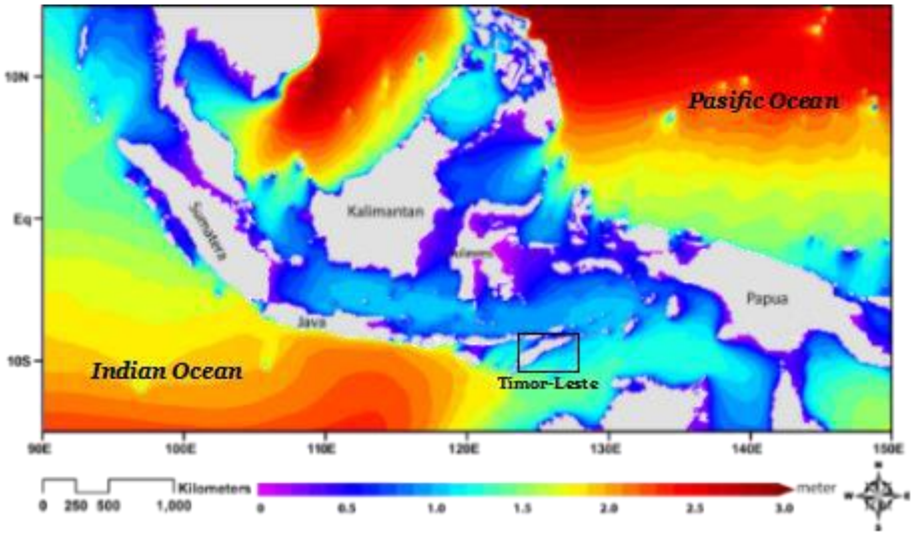


Figure 3.22 SWH in January during the peak of Asian Monsoon (Source: Sofian 2014)

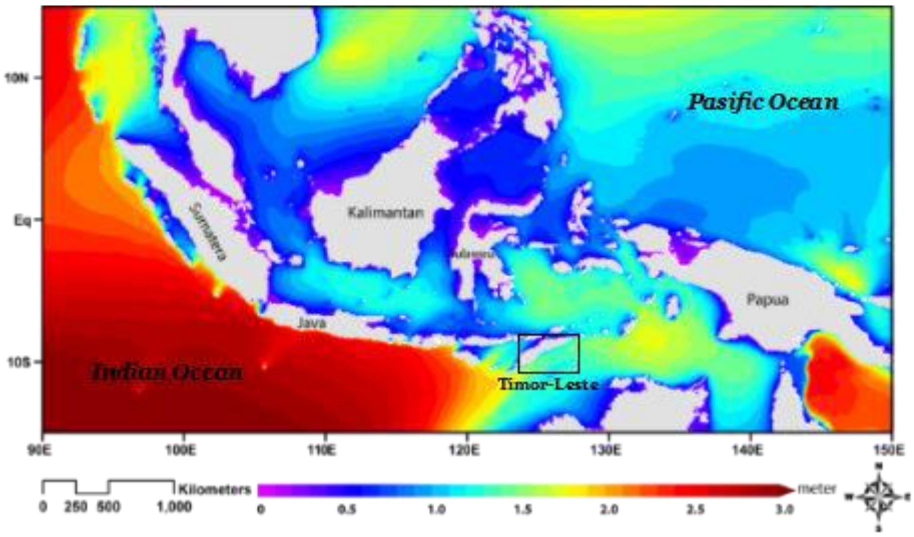


Figure 3.23 SWH in August during the peak of Australian Monsoon (Sofian 2014)

The wind wave condition in Dili, Com, and Suai are based on the result of wave hindcasting. The Sverdrup, Munk, and Bretschneider (SMB) Method was applied, using the data from 2007-2016. The result can be divided into four patterns based on the related monsoonal wind season, namely:

- Northwest Monsoon (December, January, February)
- First Transitional Season (March, April, May)
- Southeast Monsoon (June, July, August)
- Second Transitional Season (September, October, November)

Analysis revealed that the dominant wave comes from the East with the probability of occurrence about 18.48% in Dili, 18.59% in Com, and 38.96% in Suai. Dominant annual wave height is ranging from 0.2-0.6 meters in Dili, 0.6-1 meters in Com, and range of 1-1.4 meters in Suai. The dominant period is ranging from 5-7 seconds with a probability of occurrence about 31.21% in Dili, 7-9 seconds with probability of 14.61% in Com, and 9-11 seconds with probability of 38.95% in Suai.Detailed description of SMB Method and Calculation results are presented in Annex 8. The results were presented in monthly, seasonally and all ten years Tables and waveroses.

The wave characteristics were simulated by using SWAN (Simulating WAves Nearshore) to proceed the distribution of wave heights and wave directions at the surrounding Timor Island (see Figure 3.24). The monthly patterns are presented in Annex 8.

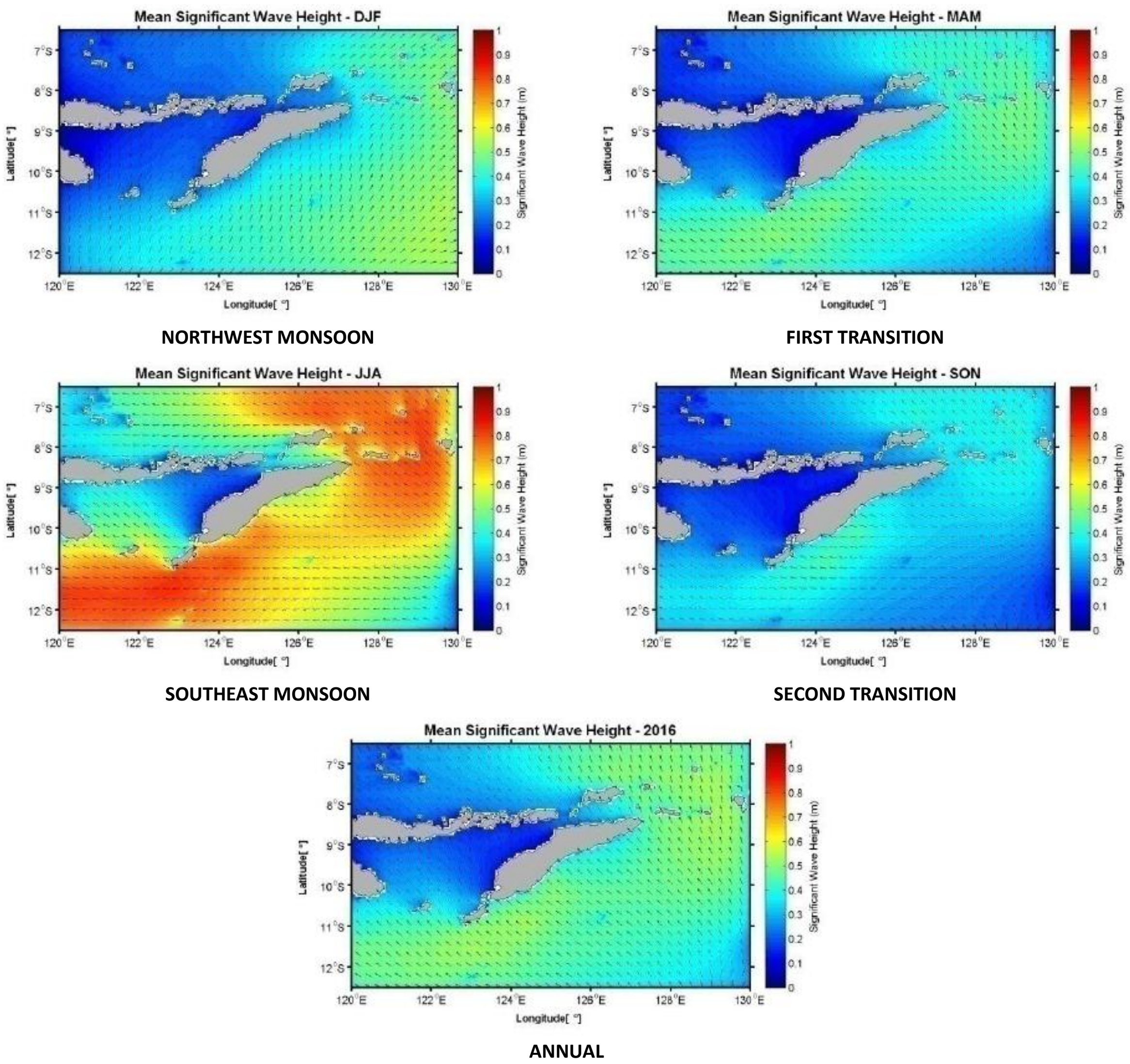


Figure 3.24 Seasonal Wave Patterns in Timor Leste

3.5 Land Use

In Timor-Leste, 63.2% of the total area in 2012 is covered by forests (MAF 2017). This includes 21.2 % of dense forest, 37.7% of sparse forest and 4.3% of very sparse forest (4.3 %). However, at the same time forest degradation and deforestation are deemed critical issues. From 2003 to 2012, decrease in forest cover varied between 1-30% depending on the municipality (Ibid.). The distribution of forest between the North and the South of the island differs substantially. The northern coast, beside of Lautem, is dominated by areas of dry forest. The south of the island is occupied mainly by wet lowland forest, separated from the shoreline by narrow strips of coastal forest and cultivated areas, except in the Southeast area where the rainforest stretches to the coast line (MPW 2017).

According to Initial National Communication in 2015, only 0.2% of the total land is used for settlement areas, potentially caused by the challenging terrain, lack of connectivity as well as access to resources such as water and farming land. Urban settlements can only be found in Dili and Costa, Oé-cusse, inhabited by 20% of the population. While other types of settlements would follow the country's terrain (dispersed in the higher altitude and concentrated in lower altitude) and availability of infrastructure, such as road network and water lines (MPW 2017). The detailed land use information is presented in Table 3.2.

Table 3.2 Detailed Land Use Information (TL-SSE 2014)

Category	Land Use/Cover	Area (Ha)	Percent
Forest Land	Dense Forest	312.930,67	21,2%
	Sparse Forest	556.199,74	37,7%
	Very Sparse Forest	63.173,45	4,3%
Grassland	Grassland/Shrubs	403.247,22	27,4%
Crop Land	Rice Field	41.387,36	2,8%
	Dry Farm	22.152,57	1,5%
Settlement	Settlement	2.988,57	0,2%
Other Land	Water Body	22.877,31	1,6%
	Bare Land	48.717,01	3,3%

About 27 % of the total land area is covered with grasslands and 4.3% is used for crop land. Agriculture areas are mainly located in rural areas, comprising community crop land and land for agribusiness. Data by the MPSI in 2013 showed that the designated agribusiness areas are usually covered with strategic crops such as coffee, located mainly in the North Coast. Meanwhile, community crop areas are mainly located in the south coast of Manufahi and Viqueque, and the north coast of the Manatuto Lautém.

Issues related to land -ownership and -use have been a challenging highlight since the independence of the country. The absence of a legal basis, apart from the customary land law, to determine the ownership of land made the issue become more complex. In 2016, the GoTL published a decree on "Basic Law for Land Use", which is fundamental to promote harmonious and integrated development for all sectors and regions. The spatial planning document for Timor-Leste is currently in the final draft stage and awaiting approval.

3.6 Ecosystem

The marine and coastal zone around Timor-Leste consists of shallow seas with coral reef and other valuable marine resources, such as fish, seagrasses, seaweeds, coral reefs etc. Vegetation surrounding the coast of Timor-Leste are usually mangroves (especially in the northern coast) and coastal forests. About 42% of all villages in Timor-Leste have a coastal border, including the enclaved municipality of Oé-cusse (TL-SSE 2014).Therefore, land areas close to the sea serve as important resources for the population's subsistence, including the coastal plains, mangrove forest and marine ecosystems.

Timor-Leste is located within the Coral Triangle, which is the world's richest and most diverse marine life. The Nino Konis Santana National Park in Timor-Leste includes a large oceanic area covering nearly 350 km² of coral reef (CTC 2017). The country is a home for more than 1.200 species of reef fish and 400 reef-building coral species (Ibid.). Many of the Timor-Leste's marine ecosystem are under threats. Illegal fishing in Timor-Leste results in an estimated loss of 40 million US$ annually to the country's economy (ADB 2014). Furthermore, under Indonesian occupation, the transmigration program brought with them unsustainable fishing practices, such as dynamiting the coral reefs, utlitilzation of cyanide and harvesting of sea cucumbers. As of now, with the growing population density along the Timorese coasts, especially in the north, pressures on the marine resources are inevaitable. These can come in two ways, 1) through direct harvesting of the resources and 2) through the increased coastal erosion which is due to natural and anthropogenic factor.

With regards to mangrove, fragments of mangrove forest are mainly located in the north coast of Timor-Leste, especially in the regions between Tibar and Manatuto (GoTL 2015). Only few mangrove fringes are located in the south. Distribution of mangrove along the Timorese coast indicates smaller patches along the north coast, usually near to river mouth, small inlets or small bays, as these places allow sufficient shelter and required nutrients for survival. Furthermore, the fragmented nature and small size of most mangrove stands, along the north and south coast are making them less resilient. An ATSEA study in 2006 revealed that the biggest mangrove patch (with a size of over 24 km² is located in Metinaro (ATSEA 2006). This patch may be just large enough to remain self-sustaining, but only if conservation plans are put in place very soon (Alongi 2014).

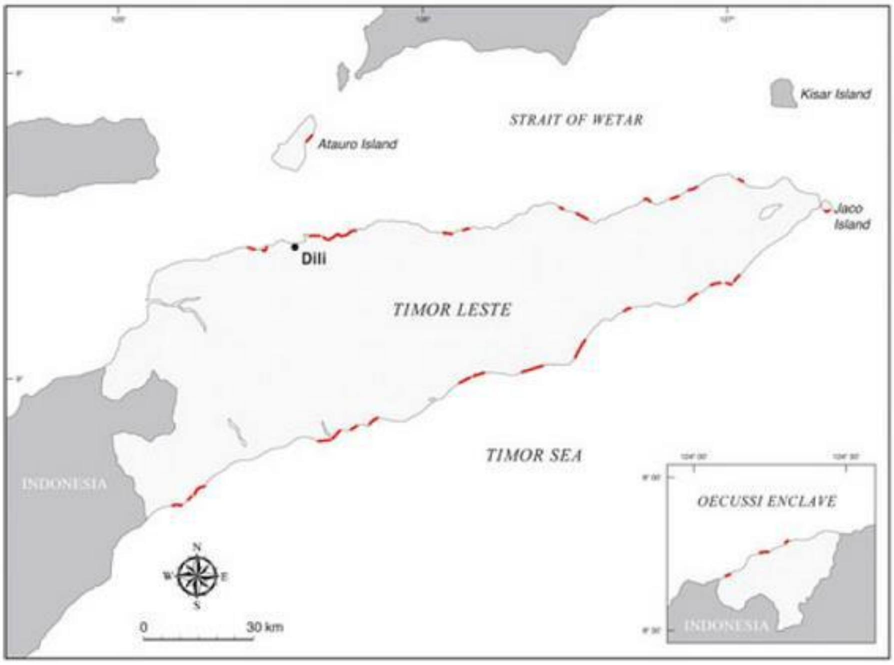


Figure 3.25 Map of Mangrove fragments along the Timorese Coast (Source: Alongi 2014)

Mangrove cover in Timor-Leste is decreasing at an alarming rate. In 2013, it was estimated that, only 1,300 hectares of mangrove were left, decreasing from 9,000 ha in 1940 (Alongi 2014). This trend is particularly worrisome as mangroves play an important function in protecting and stabilizing the shoreline and are considered a key species in tropical coastal ecosystems.

Tree harvesting for timber and fuelwood, infrastructure development and in some cases establishment of aquaculture are commonly known as the cause of depleting mangrove. However, based on the team's field observation as well as literature review, it must be noted that sedimentation from the upland and coastal development play a significant role in the degradation of mangroves. It changes mangrove ecosystem into dry sandy flats. The coastal configuration and physiography of Timor-Leste, unlike other islands of the Indonesian archipelago and the north coast of Australia, does not include the salient coastal contours, physiographic features and coastal processes, for significant mangrove development (i.e. extensive low-lying coastal plains, sheltered waters, sedimentary processes) (FAO 2005; Boggs, et al. 2009). Furthermore, rivers in Timor-Leste flow intermittently and hence, large estuarine systems are generally absent.

To this date, restrictions for development along the shoreline are limited, and hence, adding pressures to the coastal areas. Infrastructures which are vital for tourism are set up adjacent to the main beaches. In some urban areas such as Manatuto, housing construction projects are built along the shoreline. These developments are potentially impacting and degrading ecosystems, such as coral reefs and mangroves, as well as are at risk to be impacted by the changing climate through for example inundation due to sea level rise. The important nursery and feeding ground function of mangroves as well as seagrass beds for fish, marine mammals and marine turtles have been lost over extensive areas. Mangrove loss has mainly been a result of harvesting timber and fuel wood, and in some instances hinterland mangroves have been removed for the establishment of brackish water shrimp and/or fish ponds. Mangrove cover is nowadays small in Timor-Leste and has been in steady decline (Boggs, et al. 2009), and mangrove ecosystems are confined mainly to the region between Tibar and Manatuto.

In addition to mangrove, coastal forests were found along the north and south coast. It is estimated that coastal forest is occupying approximately 1,000 ha along the north, in small patches (Boggs, et al. 2009). Based on the expert team's observation, given the natural condition of the country, these coastal forests may have a higher rate of survival than the mangroves.

To date, the GoTL has designat two marine protection areas (MPAs): 1) The Nino Koni Santana National Park and 2) Atauro Island. At the same time issues such as increasing number of endangered animals (such as turtle, molluscs and coral) due to pollution, coastal development, mangrove deforestation and unsustainable fishing methods are becoming critical factors in depleting coastal ecosystems. Furthermore, a mapping study done in 2009, revealed that there was limited extent of coral reef, sea grass and mangrove habitats, particularly on the north coast (Boggs, et al. 2009), underscoring the needs for effective conservation management.

4 Hazards Identification

Geographically, Timor-Leste is located in a region particularly sensitive to the impact of climate change and El Niño. Changes in rainfall pattern and increasing rainfall may impact agricultural productivity and water availability, as well as inducing more occurrences of landslide, soil erosion and local flooding. Sea Level Rise may increase coastal erosion and destruction of infrastructure as well as salinization of water sources (MCIE 2016)[3]. The country is also facing frequent events such as strong tropical windstorms, landslides, flash flood, and events such as earthquakes and tsunamis. As an impact, economic losses from these climate change hazards are predicted to reach 10% of Timor-Leste's annual GDP by 2100, making it one of the worst hit in the Pacific region (ADB 2013).

4.1 Coastal Erosion

At the coast, wave energy, tidal current, and wind interact with coastal geomorphological structure and coastal sedimentation through erosion, sedimentation, and sedimentation transport. Excessive coastal erosion could result in significant economic-, social-, and ecological- losses. To estimate coastal sediment transport rates, many components need to be considered such as the co-existing wave-current environment, variations in the mean water level (tide, set-up and set-down), cross-shore and alongshore components, breaking wave effects (turbulence and undertow), bathymetric influence (mean slope and bed forms) as well as other geomorphic influences (NDMD 2012). Timor-Leste's coastline is susceptible to coastal erosion.

Figure 4.1 presents the rate of erosion susceptibility at the coastline of Timor-Leste. As depicted, the southern coast is more susceptible to coastal erosion due to the wilder and heavier waves. Moreover, rising of sea level also plays a role in the exacerbated rate of coastal erosion. In the end, coastal erosion hazard as a part of coastal instability by coastal vulnerability index approach in Chapter 5.

[3]Pictures of observation are presented in the photo album

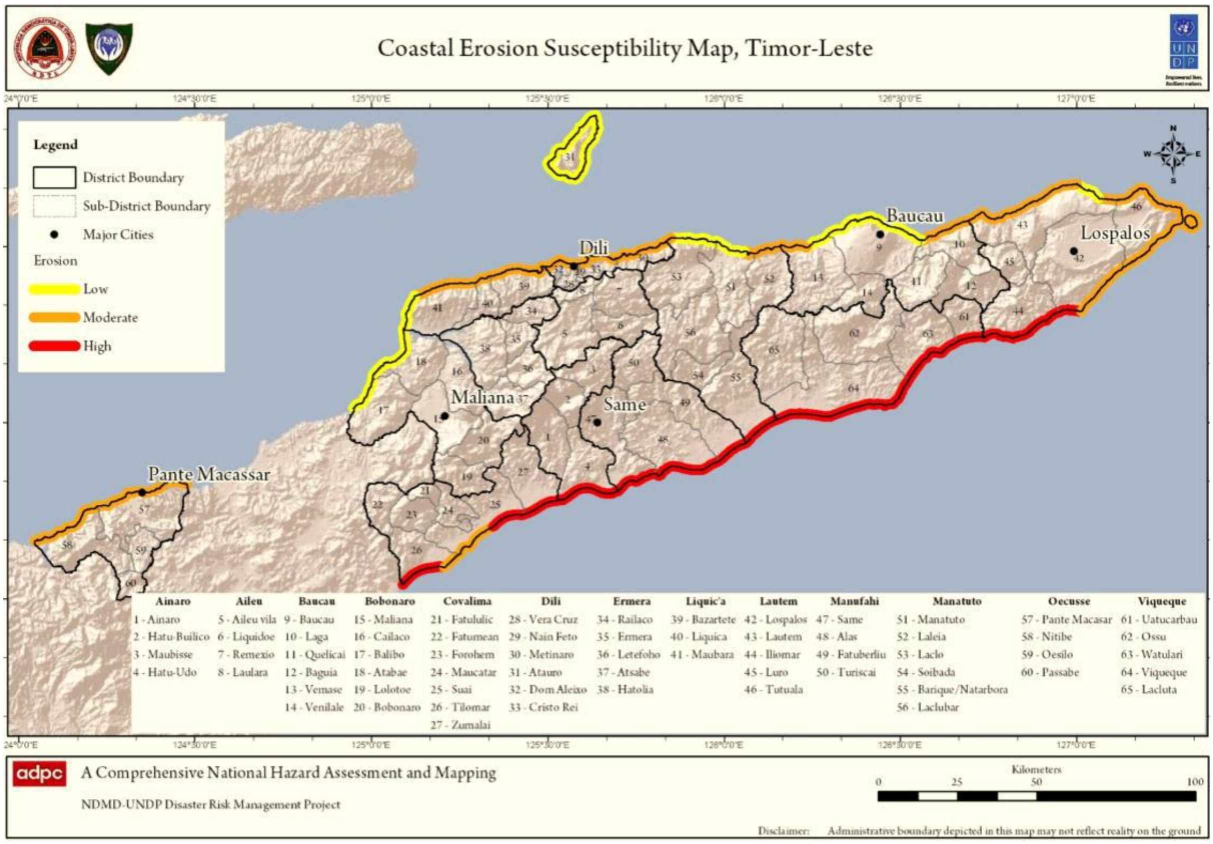


Figure 4.1 Coastal Erosion Susceptibility Map, Timor-Leste (Source: NDMD 2012)

4.2 Landslide

Landslides may be triggered by earthquakes and/or increasing of groundwater "saturation" on the slopes that are naturally controlled by the intensity of rainfall. Landslides are also determined by the strength of soil and/or rock mass including the presence of discontinuities such as bedding planes, cracks and faults as well as slope height and slope angle.

The earthquake induced landslide susceptibility map is presented in Figure 4.2. It shows that the country is at medium- to high- risk of facing earthquake induced landslide. Risk for earthquake induced landslides is higher in the northern coast, with particularly high risk at the coast of Manatuto and Baucau.

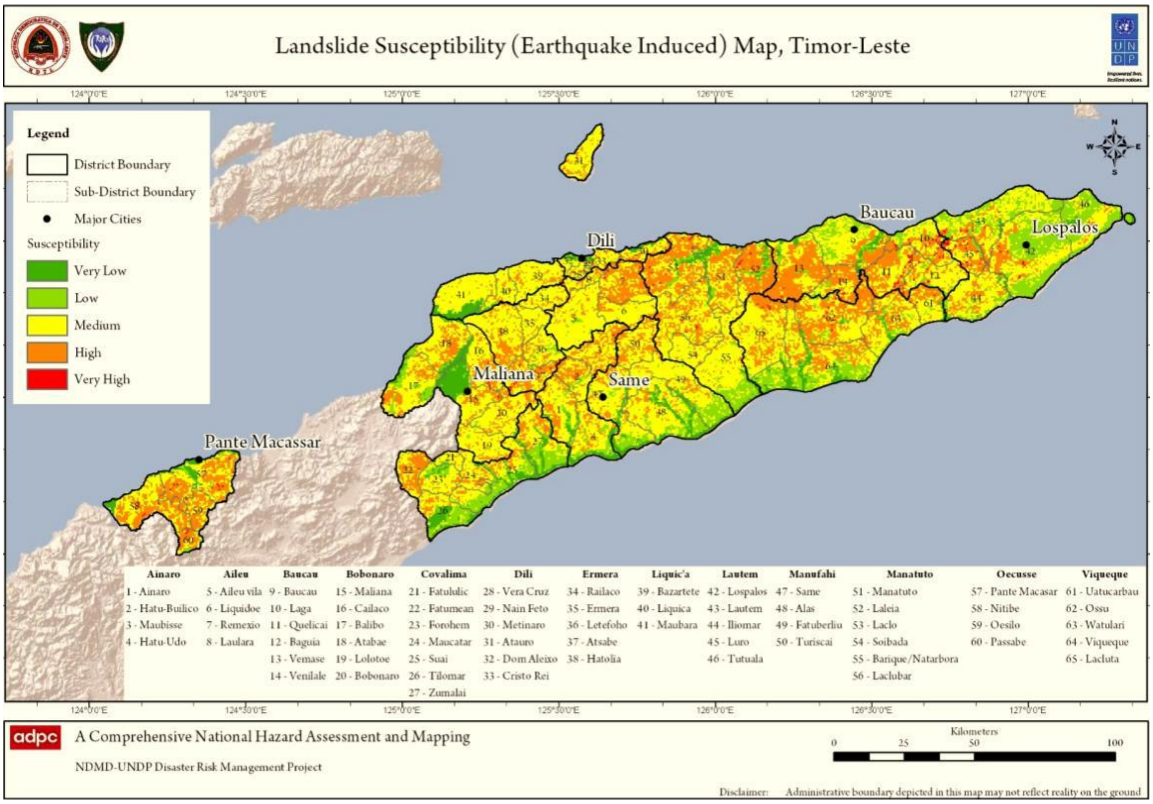


Figure4.2 Landslide Susceptibility Map of Timor-Leste - Earthquake Induce (Source: NDMD 2012)

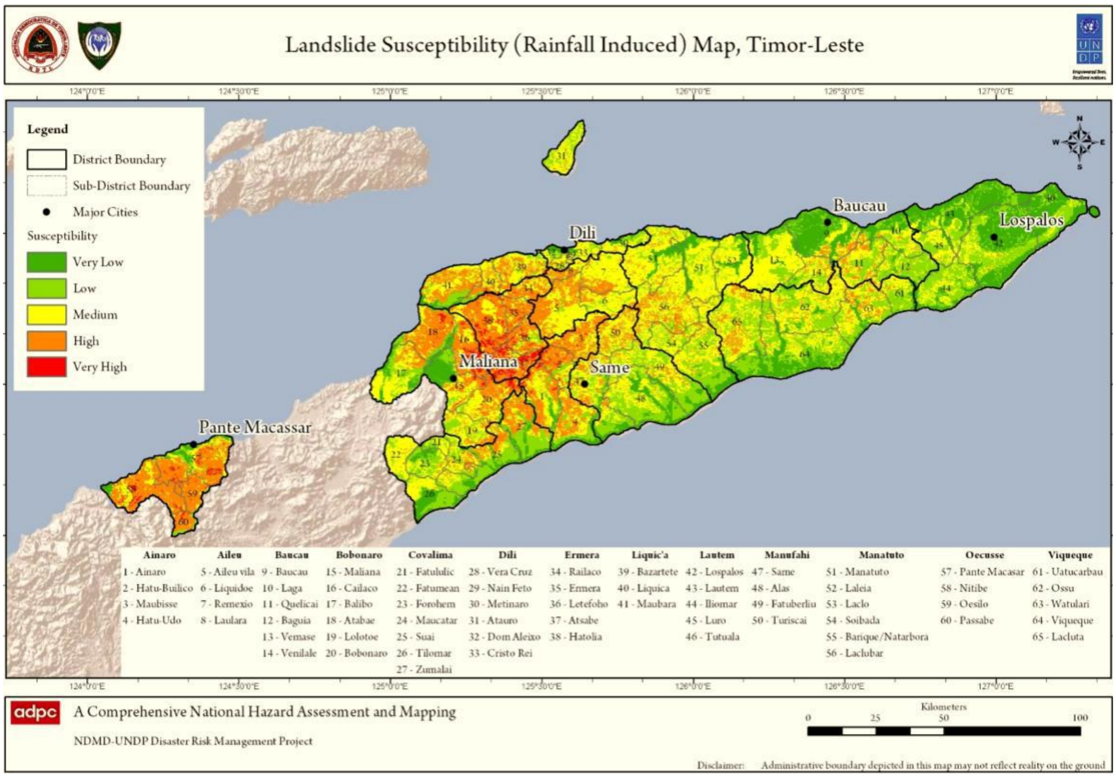


Figure 4.3 Landslide Susceptibility Map of Timor-Leste - Rainfall Induce (Source: NDMD 2012)

One among many concerns related to the changes of rainfall and temperature patterns are their effect on landslides (which consequently could trigger flash flood). The areas at high risk of rainfall induced landslide are mainly located in the eastern part of the country. Areas with high risks are spread from the north coast to some concentration of very high-risk areas in the middle (Foho Tatamailau mountain) and to the southern coast (see. Figure 4.3). About 80% of the country area is susceptible to rainfall induced landslides in the country. However, with regards to the coastal area, these are concentrated mainly in the north-eastern coast (NDMD 2012). This fact is mirrored by the team's observation during the survey. Traces of rainfall induced landslides are found especially often in Liquiçá. Almost all municipalities in Timor-Leste are susceptible to landslide due to both earthquake and rainfall, except Lautem municipality.

4.3 Flash Flood

According to the report *"A Comprehensive National Hazard Assessment and Mapping in Timor-Leste"* flash flood is one of the two types of floods known in the country. Flash flood occurs when heavy seasonal rain water in high catchment basins converges in tributaries as it descends downward resulting in the rapid rise of discharge along the water courses (NDMD 2012). Areas along rivers, flood plains or areas of alluvial deposit along the shoreline are potentially flash flood hazard areas.

Flash flood could also occur due to a dam failure. Where a river is naturally dammed by landslide materials, and water accumulates in the upper course of the river, dam failure may occur and causing flash flood. In this circumstance, flash flood occurs irrespective of the seasons.

In accordance with the landslide susceptibility level (at Medium-, High-, and Very High-susceptibility) it can be concluded that:

- Areas along the river, crossing those landslide susceptibility zones have potential to be affected by flash flood event.
- Areas defined as Medium-, High-, and Very High- susceptibility, where downstream are in lowland area; also have potential to be affected by flash flood.

Based on the team's observation in May 2017, flash flood traces are seen in almost all Timor-Leste's rivers, such as Comoro River and Rivers in Liquiçá, Ainaro, Manatuto and Suai.

4.4 Earthquake

Earthquakes in the surrounding area of Timor are triggered by the movement of the north Australian Plate colliding with the Asian Continental Plate. There are two thrust faults in Timor island trending NE – SW (Harris 2006), as shown in Figure 4.4. The earthquake sources for Timor-Leste area are presented in Figure 4.5.The Megathrust Earthquake Sources of Timor-Leste are as follow:

a. Flores Back Arc Thrust Fault with probable maximum magnitude is M 7.8
b. Timor Back Arc Thrust Fault with probable maximum magnitude is M 7.5
c. Sunda Normal Thrust Fault with probable maximum magnitude is M 8.3

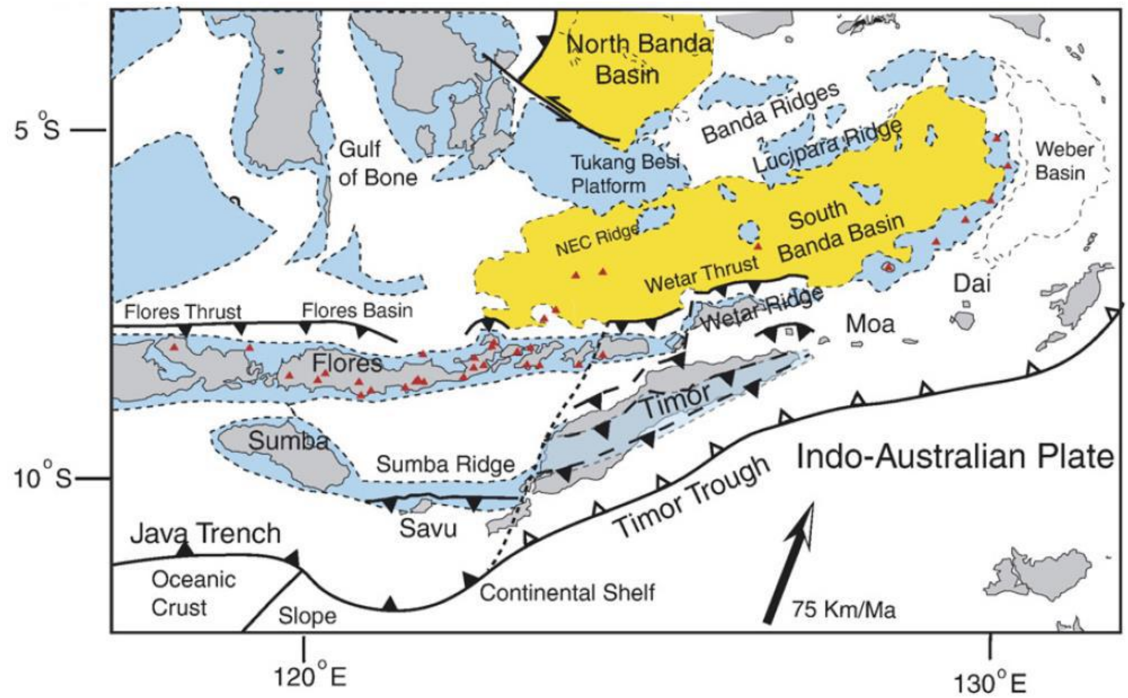


Figure 4.4 Tectonic Setting (Harris 2006)

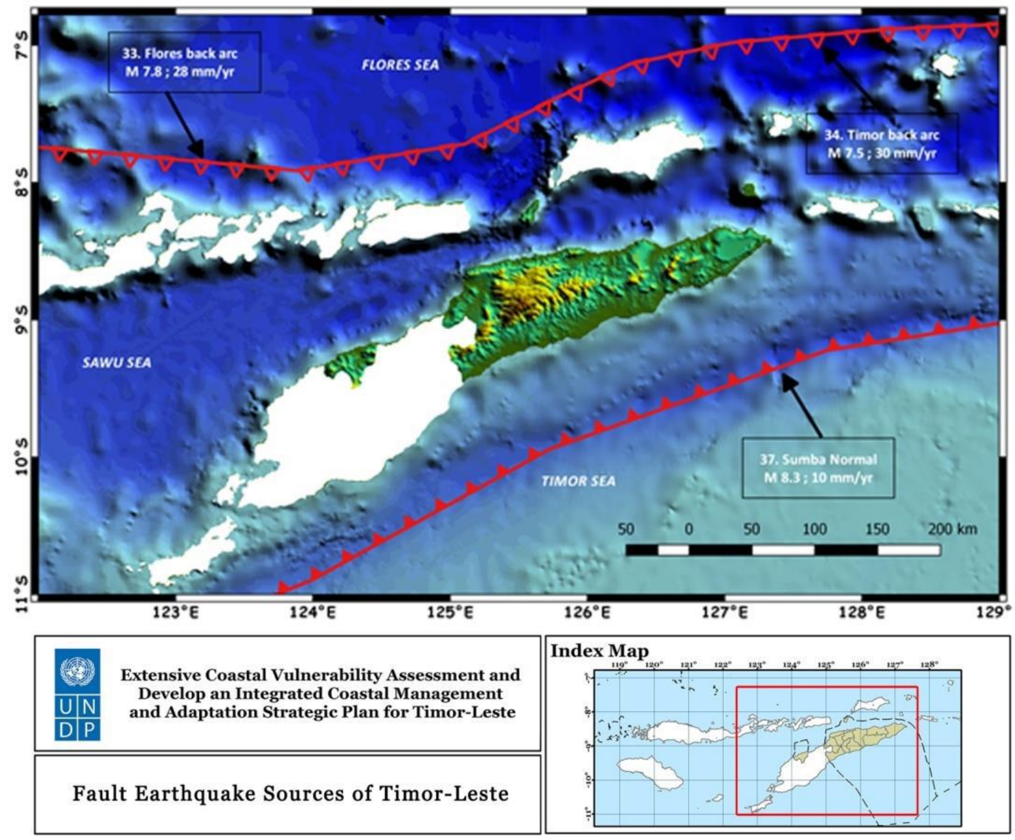


Figure 4.5 Fault Earthquake Sources of Timor-Leste (source: modified from Irsyam, et.al. 2010)

Moreover, there was a record of some earthquake hypocenter within 30 km depth (Miller, et al. 2017). This record is presented in Figure 4.6. Accordingly, it can be assumed that the two thrust-faults are active faults. However, this assumption must be treated as preliminary and require further investigation.

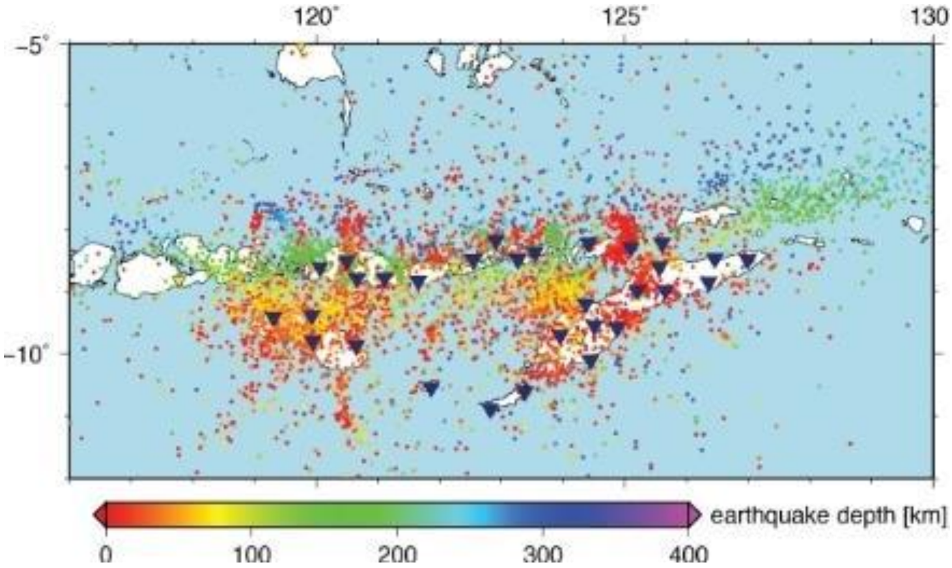


Figure 4.6 Preliminary Seismicity Catalogue March 2014 - August 2016 (Miller, et al. 2017) of Timor-Leste and its Surrounding Area

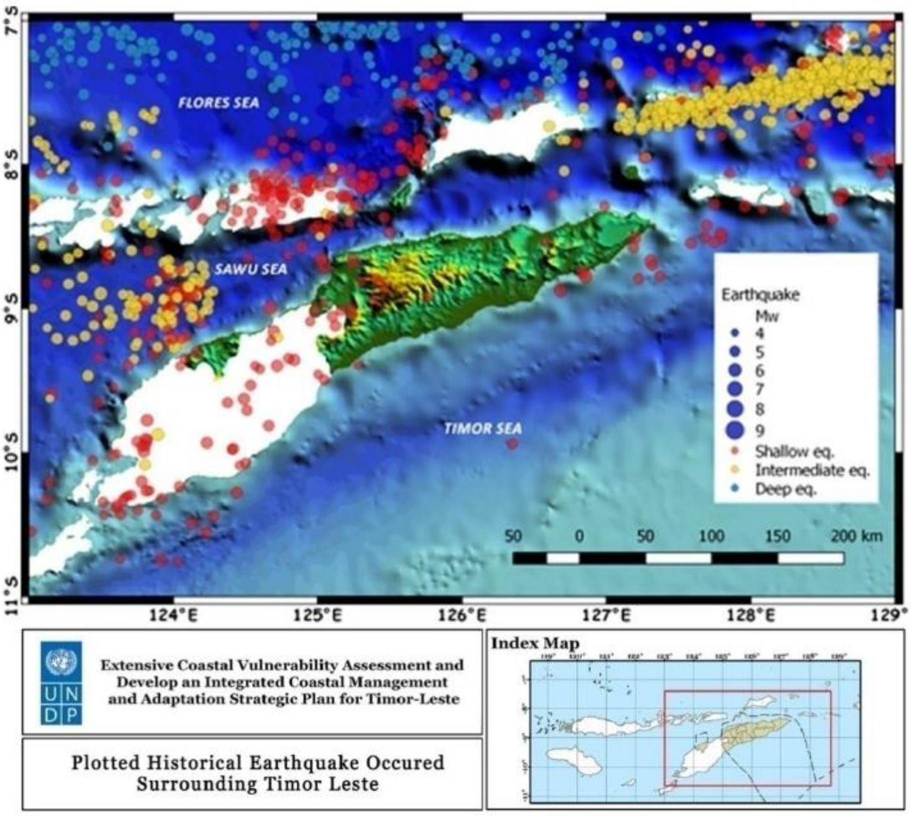


Figure 4.7 Plotted historical earthquake occurred around Timor-Leste (Source: Engdahl Catalogue 1964-2008)

Energy from the earthquake focus, or the so-called hypocenter, travels to all direction, causing the earth shaking in Timor-Leste. It is the expressed in a qualitative scale as Mercali Modified Intensity

(MMI).Or in quantitative scale as Peak Ground Acceleration (PGA). The PGA for Timor-Leste is estimated from the Indonesian PGA Map. It is estimated in a range of 0.4 – 0.5 **g** for 2 % probability in 50 years or 2,500 years return period, and 0.2 – 0.3 g for 10 % probability in 50 year or 475 years return period (Irsyam, et.al. 2010). This estimation was found similar with the report "Probabilistic Seismic Hazard Assessment for Pacific Island Countries", stating that the PGA for 475 years return period is 0.18 – 0.34 g (Rong, et.al 2012).

The earthquake hazard level in most of the eastern part was identified as having a MMI level of VII, higher the western part with MMI level of VI (NDMD 2012). This explains the higher susceptibility of earthquake-induced landslides in the eastern part of the country.

4.5 Tsunami

Timor-Leste's susceptibility to earthquake increases its susceptibility to Tsunami. It is estimated that Timor-Leste has a 40% chance in the next 50 years of experiencing, at least once, strong to very strong levels of ground shaking (PCRAFI 2011). These levels of shaking are expected to cause damage, ranging from light to moderate to well-engineered buildings and even more severe damage to structures built with less stringent criteria.

The following presents a number of tsunami events that have occurred in the surrounding of the Timor Island (*Table 4.1*):

- In 1814, an earthquake occurred and immediately generated a tidal wave, bursting in Kupang Bay (Wichmann 1918; Sieberg 1932; Lida, et al. 1967; Cox 1970; in Soloviev and Go 1984). This earthquake is assumed to felt in Timor-Leste.
- In 1857, May 13, there was a strong earthquake in Timor Island. The tremor lasted at least 15 seconds at Dili. People were thrown to the ground. The walls of the fort partially collapsed. The ground cracked on the coast. At Gera, situated 20 km (12 miles) east of Dili, there was a stronger earthquake, settling the ground at many places. Mud flowed out of cracks. On Kambing Island (now Atauro Island), there was an exceptionally strong earthquake. The hill on which the settlement of Makadade is situated (on the southern shore of the island) subsided. The Earthquake reported to cause tsunami. In Dili Bay, the water rose and fell 3 m (10 feet) four times. At Liquiçá, a tidal wave surged onto the land and completely inundated the village. Also, strong oscillations in sea level were observed in Ambon(Perrey 1858, 1860 a; Wichmann 1918; Sieberg 1932; Heck 1934, 1947; Ponyavin 1965; Lida, et al. 1967; Berninghausen 1969; in Soloviev and Go 1984).
- In 1891, October 5. There was an earthquake in Timor and the adjacent islands. In Kupang, there was a very strong undulating movement, strong shocks at Babau, Pariti and Amasari, and several shocks at Ende. A strong earthquake for 20 seconds at Atapupu, followed by many aftershocks. Oscillations in the sea level also occurred during the first shock. The water rolled onto the coast of the bay with great force several times and rolled back at 5 minute intervals (Figee, Onnen 1893 a; in Soloviev and Go 1984).
- In 1908, March 23.There was a strong earthquake all over Timor Island. In Atapupu, oscillations lasted for about 3 minutes. In Kupang, the earthquake was considerable and was felt on the islands of Roti and Sawu (Anon. 1910).
- The most recent tsunami event occurred in 1995, induced by an earthquake with the magnitude of 6.9 according to the Richter scale. The event killed 11 people and 19 others were injured (PCRAFI 2011). It also claimed economic tolls, in terms of communities' assets

and properties. The team validated this finding while conducting interview with the local community at the coast of Dili.

Table 4.1 Resume of historical tsunami event surrounding Timor Island

Date			Coordinates of Focus (or Site of Phenomenon)					
Year	**Month**	**Date**	**Lat**	**Lon**	**Depth of Focus (km)**	**EQ. Mag (M)**	**Authenticity of Tsunami**	**Tsunami Intensity**
1814	-	-	Timor I., Kupang		-	-	-	-
1857	May	13	8 S	115.5 E	50	7	D	2
1891	Oct	5	9 S	124 E	80	6.6	L	0.5
1908	Mar	23	10 S	129 E	-	7	E	-
1995	May	14	8.3S	125.1 E	-	6.9	-	-

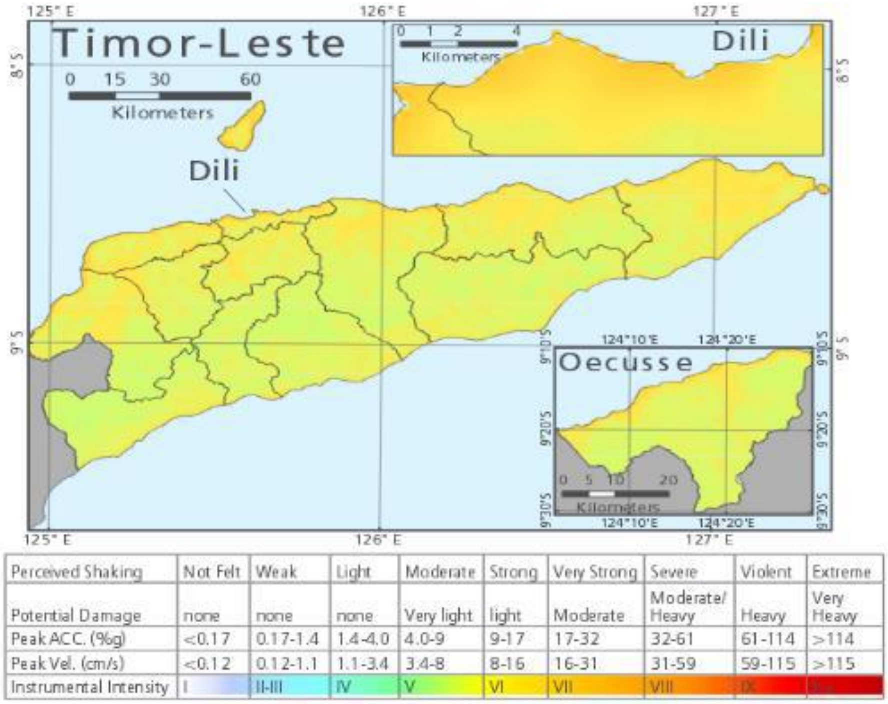


Figure 4.8 Peak horizontal acceleration of the ground (Note: 1g is equal to the acceleration of gravity) that has about a 40% chance to be exceeded at least once in the next 50 years(Source: PCRAFI 2011)

The probability of a major tsunami or earthquake affecting the country has heightened dramatically since the massive ocean floor uplift in December 2004 in the Indian Ocean which substantially increased the seismicity of the region (RDTL 2006).

Probabilistic Tsunami hazard Assessment (PTHA) of Indonesia have been studied by Horspool, et al. (2014). Since Timor-Leste is located in the domain study, nearby Nusa Tenggara Timur Province and southern part of Maluku Province, the team conducted interpolation for Timor-Leste. The results are presented as follow:

- The probability of experiencing tsunami with 0.5 m- 3.0 m a year at Timor-Leste is greater than 10%. Whereas the probability of experiencing tsunami with 0.5 m- 3.0 m a year is greater than 2% to 10%.

- The maximum tsunami height at the coast of Timor-Leste for a 100-years return period is 3-5 meter at northern coast and southern coast. Whereas, for a 500-years return period is 5-10 meter at the southern coast and 3-5 meter at the northern coast.
- The distribution of tsunami height for a 500-years return period is 5-10 meter along the southern coast, and 3-5 meter at northern coast of Timor-Leste.
- Areas susceptible to highest tsunami waves are spread across the country. They are located on the eastern and northern side of Timor-Leste, including Lautem, Baucau, Viqueque, Manatuto and Dili, and Island of Atauro as well as at the southern side such as Cova Lima, Manufahi and Viqueque.

4.6 Strong Wind and Storm Surges

Tropical cyclones have affected the country on multiple occasions, with annual average loss due to cyclones representing about 0.09% of the GDP (PCRAFI 2013). With the changing climate, projections tend to show a decrease in the frequency of tropical cyclones, yet the existing ones are expected to be stronger, due to the increase in the average maximum wind speed of cyclones and rainfall rates of the cyclone centre (PACCSAP 2015). As such, in more extreme events, economic loss can increase from72% to 260% in the worst climate change scenario (PCRAFI 2013).

Timor-Leste is situated south of the equator. This area is known as a cyclone belt, where increased storm activities are expected in the future. The country has been a subject to tropical cyclones on multiple occasions in the past few decades (PCCSP 2011). Timor-Leste is also affected by tropical storms, which is potentially as dangerous as a cyclonic activity. The tropical cyclone season in the Timor Sea normally runs from November to April. Many tropical storms and cyclones originate or pass through the Timor Sea. The tropical cyclone activity around Timor-Leste is influenced by the El Niño and La Niña, usually affecting the eastern side of the country. These tropical cyclones are usually formed in the Banda, Arafura, Timor or Sawu Seas surrounding the island of Timor and then move in a South-Westerly direction (GoTL 2010).

The tropical cyclone season in the Timor Sea normally runs from November to April. Many tropical storms and cyclones originate or pass through the Timor Sea. In the 41-year period between 1969 and 2010, 31 tropical cyclones passed within 400 km of Dili, an average of less than one cyclone per season (PCCSP 2011). However, under future climate projection the wind hazard would potentially increases slightly for the 100-year return period, as shown in *Figure 4.9*. The 100-year return period winds, which represent an event that has a 40% chance of being equalled or exceeded once in 50 years, are capable of generating damage which could cause heavy loss to buildings, infrastructure, and crops (PCRAFI 2013).

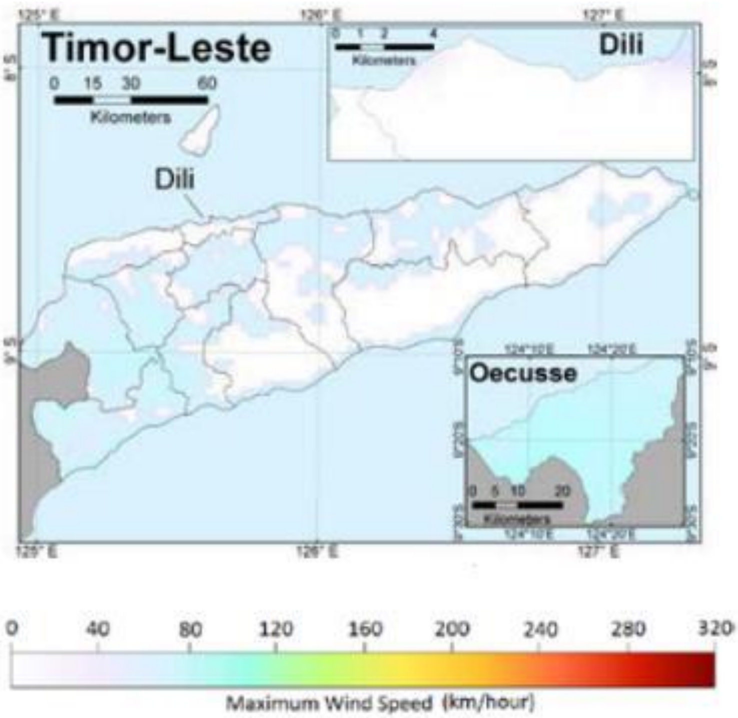


Figure 4.9 Future wind speed projection (Source: PCRAFI 2013)

The Australian tropical cyclone database indicates that since the 1970s there has been a decrease in the number of tropical cyclones in the region, largely due to an increase in El Niño events (Kuleshov, et al. 2008). However, studies also indicate that the strongest tropical cyclones are getting stronger (Elsner, et al. 2008). Cyclone occurrence shown in Figure 4.10 was calculated based on the number of occurrences of cyclones per year in a 2x2 degree grid cell.

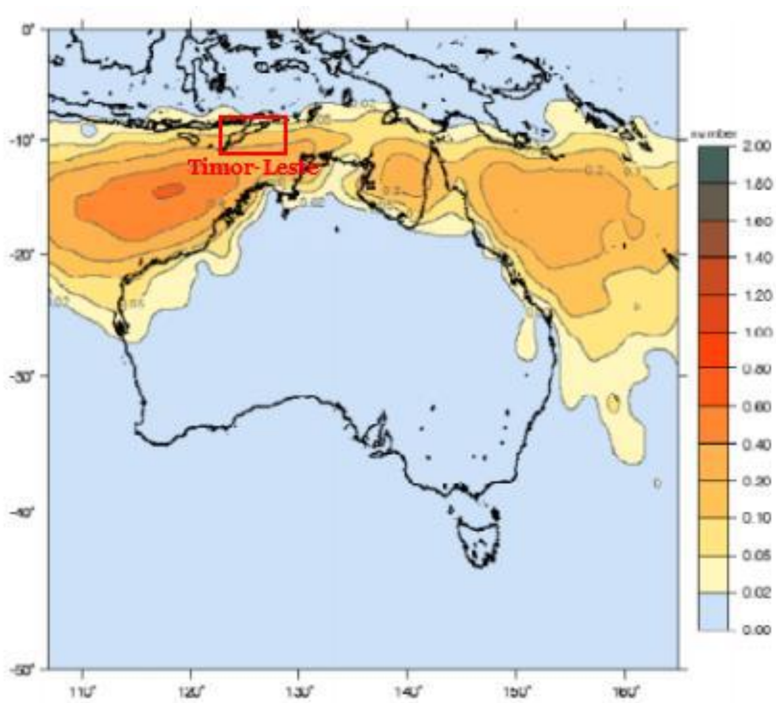


Figure 4.10 Annual distribution of Cyclones in the Australian region (Source: Abb 2010 based on BoM data set)

Beside strong wind, another impact of the cyclone on seawaters is the occurrence of storm surges as a kind of large waves. There are no previous studies on the responses of the cyclone on ocean surge dynamics in Timor-Leste, including the storm surges generated from Banda, Arafura, Timor or Sawu Seas surrounding the island of Timor. However, as an illustration, the team presents a case of storm surge generated by the Haiyan tropical cyclone when hitting the Philippines on November 6th, 2013. The large waves propagate multi-directionally, including toward the Banda Sea and then Timor-Leste sea water, as shown in Figure 4.11. In this case, although Timor-Leste is located far from the source location of the typhoon, the north coast of Timor-Leste still experienced the storm surge impacts of about 0.5-0.75 m.

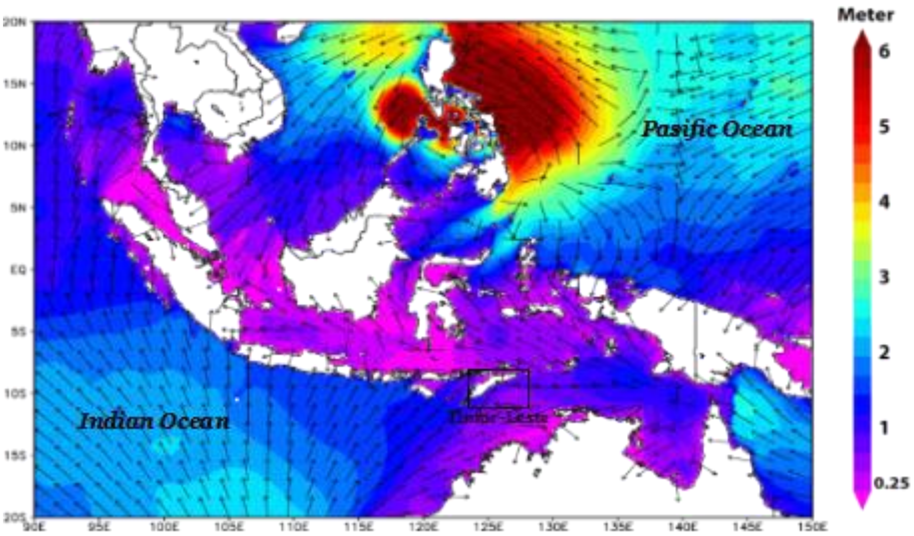


Figure 4.11 The significant wave height (SWH) and its direction during the Haiyan typhoon hitting the Philippines in November 6, 2013 (Source: Sofian 2014)

4.7 Drought

Drought, or meteorological drought, refers to the shortage of water resulted by a prolonged period of an unusually low rainfall. The situation impacts a large number of people, both physically and socio-economically. The sub-normal rainfall sometimes occurs in a certain period due to natural climate variability such as El-Nino. But there has also been a great concern about the slow-onset climate change resulting in drought hazard.

Drought becomes one issue in Timor-Leste coastal zone, as it is impacting water availability for the coastal communities[4].This section, however, will focus on the existences of the driest months. The analysis of dry months is based on the note by Peel et.al. (2007). According to Koeppen climate classification, Timor-Leste experiences tropical savannah climate type (*Aw*), meaning that the country has a pronounced dry season. The feature is characterized by monthly average rainfall of less than 60 mm and less than 1/25 of the total annual rainfall, during the driest months. Analysis was done on the probability of occurrences, using the available long-period data records of rainfall, and compared it with the 60 mm threshold.

Rainfall data records were obtained from 12 daily-observed stations provided by the Ministry of Public Work, Transport and Communication (MPW-TC). Metadata of each observation station

[4] It must be noted, however, that impact assessment on drought should also address groundwater and surface water sources (Hoque, et.al. 2016)

comprises of daily rainfall measure (mm), daily-rainfall type (rain/trace), daily-rainfall count (1/0), daily-rainfall qa (Y/N), and daily-period of observation (1/0). For the analysis, only daily rainfall data were used. Pre-analysis to observe the availability of data set was also carried out. To measure the rainfall data, percentages of data availability in a certain period of observation have become one main concern with regards to data quality, prior to the analysis.

Availability of the rainfall data are described in Table 4.2.

Table 4.2 Availability of data in the rainfall records of 12 daily-observed stations (source: MPW-TC)

No	Station	Overall Period of Observation	Availability (%)
1	Atauro	Start: 02/01/1953; End: 12/31/1974 (21,9 years)	98,70%
2	Dili	Start: 01/01/1952; End: 02/28/2017 (65,1 years)	61,28%
3	Iliomar, Lautem	Start: 01/01/1953; End: 31/12/1974 (21,9 years)	96,80%
4	Laga, Baucau	Start: 01/05/1956; End: 31/12/1974 (18,7 years)	78,59%
5	Lautem	Start: 01/04/1958; End: 02/07/1989 (31,2 years)	52,74%
6	Liquica	Start: 01/05/1956; End: 31/12/1974 (18,7 years)	88,79%
7	Lospalos, Lautem	Start: 01/01/1953; End: 01/12/1975 (22,1 years)	99,84%
8	Manatuto	Start: 31/01/1874; End: 30/09/2015 (115,7 years)	19,74%
9	Oecussie	Start: 01/01/1956; End: 01/03/2000 (44,1 years)	47,45%
10	Suai, Covalima	Start: 01/01/1965; End: 01/01/1974 (8,9 years)	98,30%
11	Tutuala, Lautem	Start: 01/10/1956; End: 31/12/1974 (18,2 years)	99,43%
12	Viqueque	Start: 01/05/1956; End: 20 /05/2013 (57,1 years)	32,53%

Manatuto station has the lowest availability of data was. There is absence of data between the year 1874 to 1952. Moreover, rainfall data from 1999 to the end of the observation period are missing from Oe-cusse station. Due to data availability, analysis was done using the 10 years the time-slice, instead of 30 years as recommended by the World Meteorological Organization (WMO) definition of Climatological Standard.

It is discovered, that the rainfall data from these 12 stations can be divided into three spatial distribution patterns according to their similarities of the rainfall distribution of occurrence probability. This is in line with the finding elaborated in chapter 3.3.2. The three-monthly rainfall spatial distribution patterns represent the west side of the north coast, the west side of the south coast, and the east side of the north and south coasts (i.e. east coast). The rainfall spatial distribution pattern in west side of north coast is characterized by highest portion of the minimum range of 0-5 mm/month. It displays a rather different picture to the east coast and the west side of the south coast, which tend to show highest probability of the maximum range of more than 200 mm/month.

a. Monthly rainfall pattern representing west side of north coast condition. This pattern is provided by 7 rainfall stations, i.e., Oecussi, Atauro, Liquica, Dili, Manatuto, Laga, and Lautem.

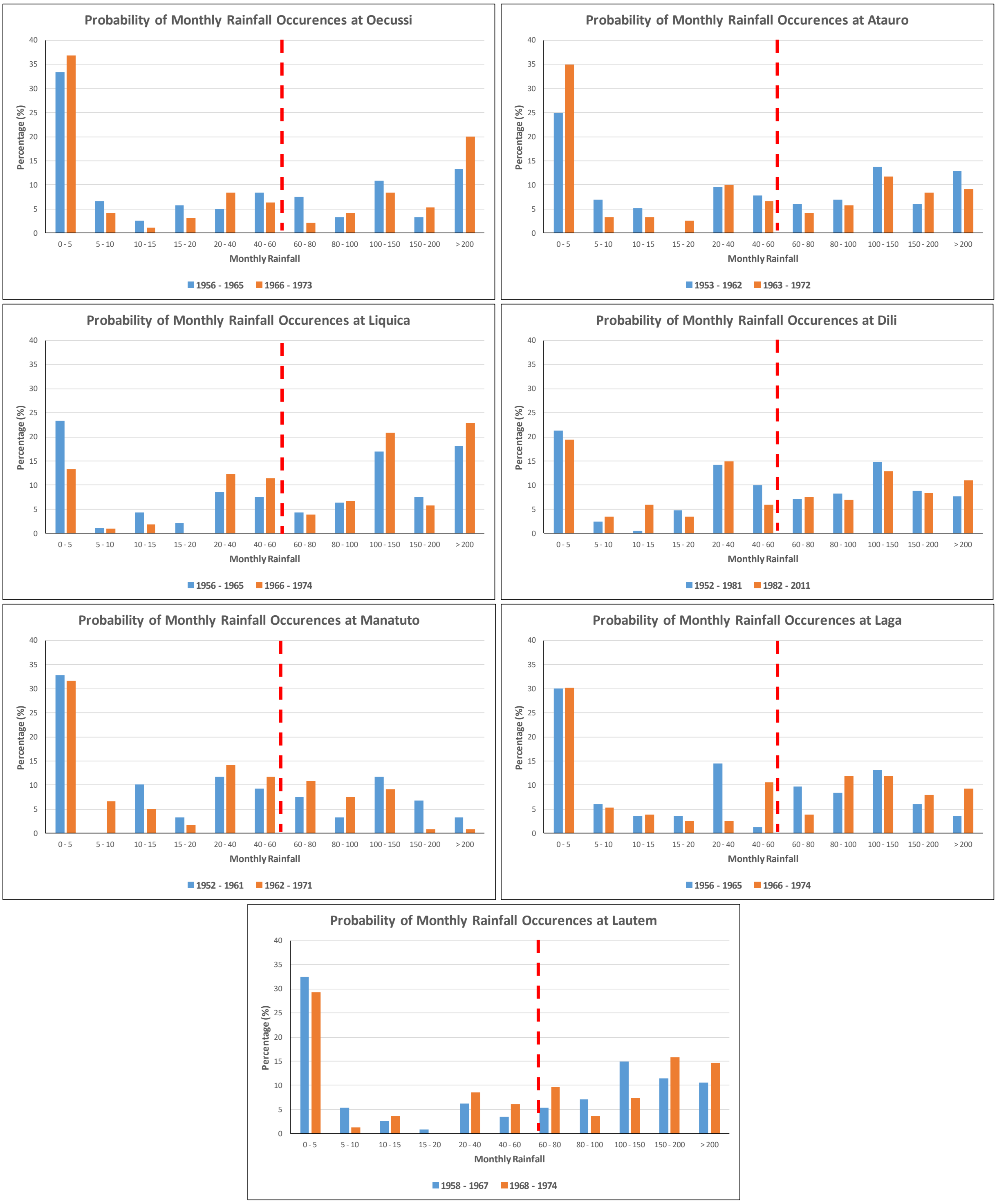


Figure 4.12 Monthly rainfall pattern in west side of north coast

b. Monthly rainfall pattern representing west side of south coast condition. This pattern is provided by 2 rainfall stations, i.e., Suai and Viqueque.

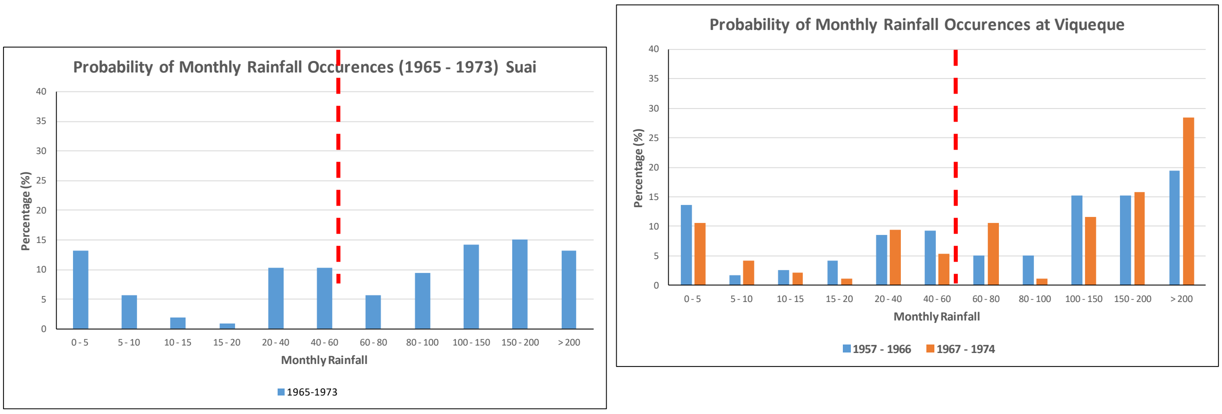


Figure 4.13 Monthly rainfall pattern in west side of south coast

c. Monthly rainfall pattern representing east coast condition. This pattern is provided by 3 rainfall stations, i.e., Lospalos, Tutuala and Iliomar.

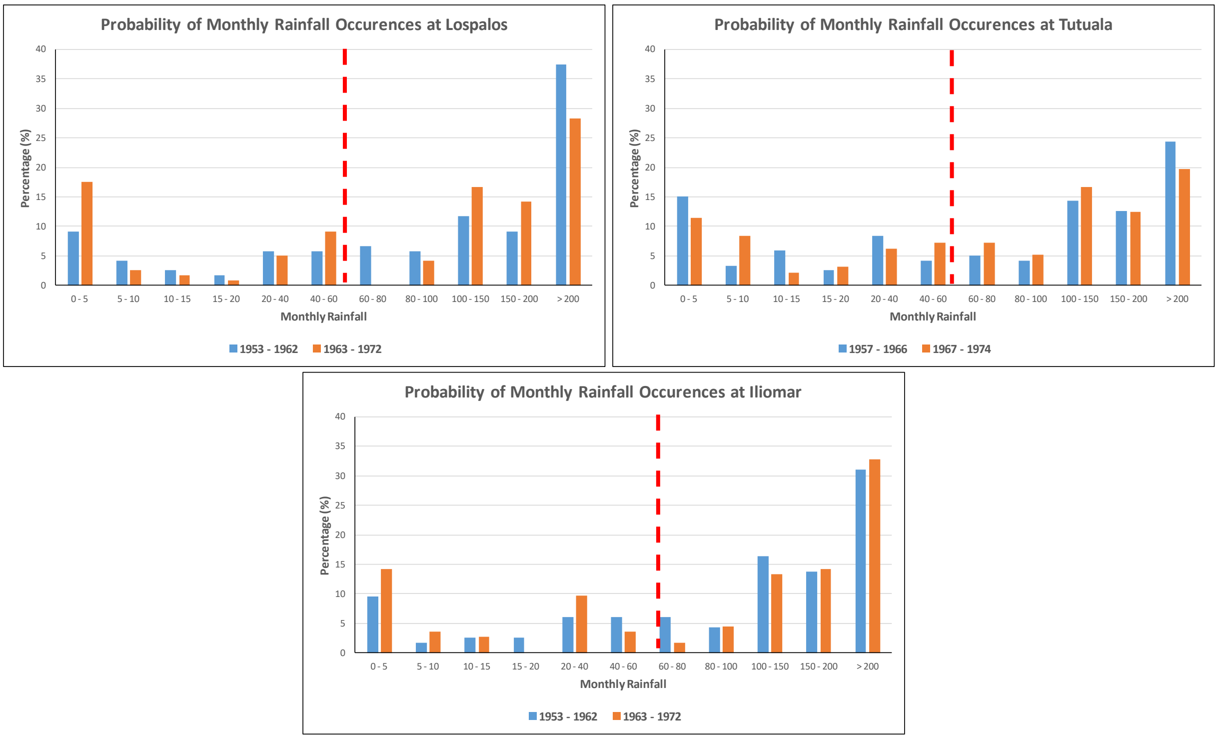


Figure 4.14. Monthly rainfall pattern in east coast

According to Koeppen climate classification, the entire coasts of Timor-Leste coasts experience the tropical savannah climate type, evidenced by drought. Moreover, almost all of the northern coasts (from Oecussi to Lautem) show the highest probability of the lowest-range of monthly rainfall occurrences, indicating the high susceptibility of (meteorological) drought. During the observation periods, little changes of the occurrence probability of monthly rainfall have been observed.

5 Socio-Economic Characteristics

The following section presents trends as well as specific development challenges, such as social and economic development, education, infrastructure (sanitary, transport, communication) and environmental sustainability. In addition to this chapter, a more profound analysis of socio-economic characteristics of Timor-Leste will be provided in Chapter 6.

5.1 Socioeconomic Development

Since its independence in 2002, the Government of Timor-Leste (GoTL) focuses its efforts on alleviating poverty, consolidating security and stability, and building institutions of State, which were necessary to create the base for a new country. The country has reached a level of political stability in less than a decade and is rich in natural resources, such as petroleum, fish stocks, marine ecosystems, and stunning natural beauty. Efforts of the Government are now directed at developing its economy. This is clearly articulated in the Strategic Development Plan of Timor-Leste for 2011-2030. The plan reflects the medium- and long- term development challenges of the country while simultaneously paving a path to achieve its vision for 2030 as a country with a diversified economy and equipped with high quality infrastructure.

5.1.1 Demography

The country is inhabited by a population of 1,183,643, the ratio between male and female population being almost 1:1 (MoF 2015). Nowadays, approximately two thirds of the population live in the low lands, from the coastline up to 500 meters above sea level (USAID 2015). Low-lying areas in Timor-Leste are generally more arable and also better connected to transportation and communication networks.

The Timorese are racially mixed people composed of Melanesian, Polynesian and Malay genetic elements(IMF 2005). The country consists of a number of distinct ethnic groups, but there are no distinct physical features among people except in language (Ibid.). There are 16 languages and between 34 and 36 dialects. The national language is Tetum, understood by more than 80% of the population (MoF 2010). About 40% of the population is able to understand and use Indonesian, approximately 5% able to understand Portuguese, and about 2% English (Ibid.). The population is predominantly Roman Catholic (97.5%), followed by Protestant (2%) and Muslim (0.24%). The remaining 0.26% are comprised of Hindu, Buddhist and animist minorities (MoF 2015).

Timor-Leste used to be among the countries with the highest population growth in the world at around 3-4 percent per year, until 2009. Since 2010, the population growth is slowing down to 2.1% per year in 2015 (MoF 2015). Timorese Women give birth to an average 5.7 children, decreasing from 2010 where it was still 7.8 (Ibid.). This results in a high percentage of young population, more than 40% of all citizens are under the age of 15 (Population Pyramid 2017).

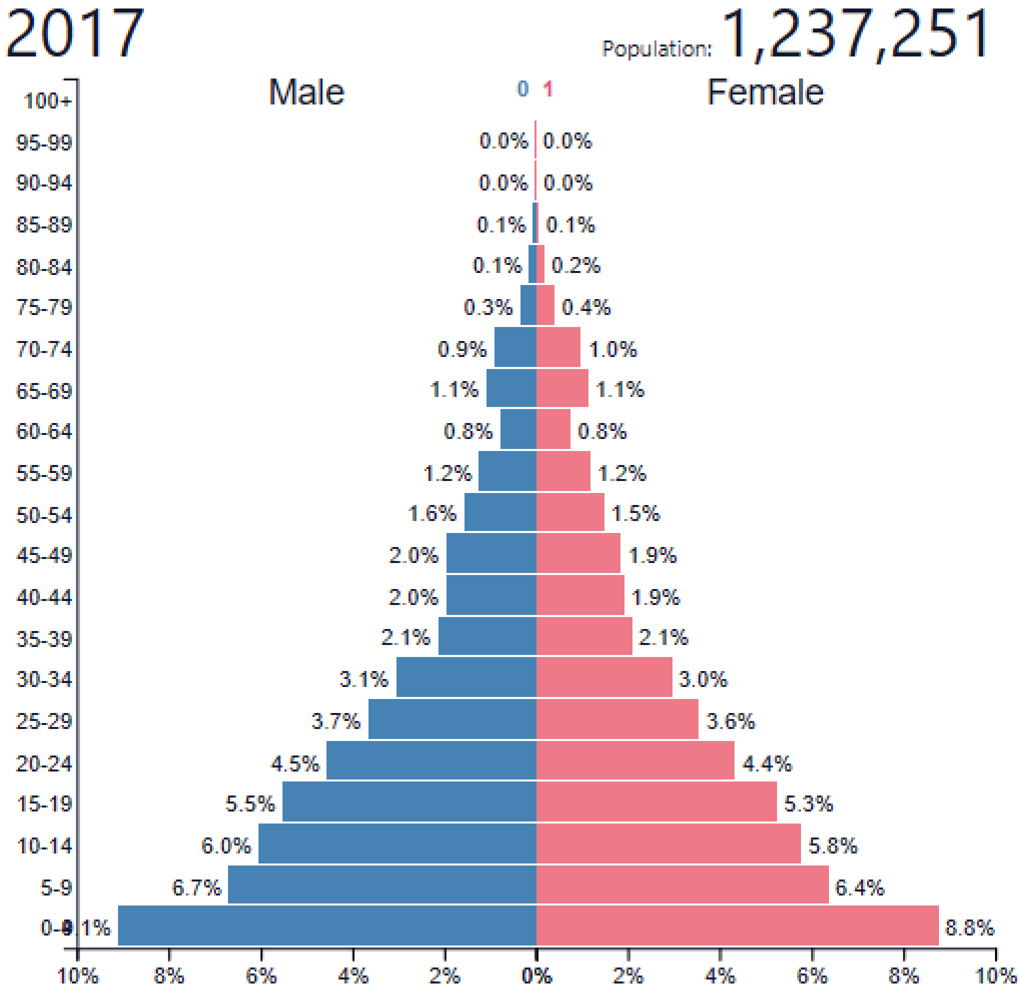


Figure 5.1 Population Pyramid of Timor-Leste (Population Pyramid 2017)

While this rate poses challenges to the country's development, it also provides opportunities as this generation will become the backbone of the country's emerging economy and development. All municipalities record increasing population growth figures, albeit with different intensities. Highest population growth can be found in Dili, maintaining its position as the main point of concentration of the resident population in the country. At the same time, some secondary cities, such as Baucau, Liquiçá and Oé-cusse, are rapidly urbanizing as well. Despite this urbanization, it must be noted that as of 2015, 70% of the population of Timor-Leste is still living in rural areas. Only few urban settlements are located directly along the coast, except in Dili. The coastline is mostly inhabited by rural communities, mainly dependent on (semi-)subsistence farming and fishing (GCCM 2008).According to the Oxford Poverty and Human Development Initiative Country Briefing 2017: Timor-Leste, almost 50% of the rural population is affected by severe poverty, represented by Multidimensional Poverty Index (MPI). The index takes into account education, health and living standards as the main three dimensions which are equally weighed. Coastal municipalities with the highest poverty rate include Oé-cusse (62.1%) and Ainaro (52.3%)(OPHI 2017)

5.1.2 Economic Structure and Livelihood

Based on the multidimensional poverty index[5], 68.1% of the population in Timor-Leste can be classified as multidimensionally poor. (OPHI 2017) At the same time, 41.8% of the population lives below the national poverty line, showing that income poverty is only one of the factors contributing to poverty in the country (ADB 2015).

Economic activity in Timor-Leste is dominated by the agriculture sector. In terms of GDP, in 2014, the service sector contributed about 61.6% to the total country GDP, Agriculture 19.8%, followed by the industry sector at 18.6% (WB 2017). Over 80% of the population are active in and highly dependent on the agriculture sector (GoTL 2010), yet contribution to GDP is deemed low. Limited agricultural productivity is not only caused by the climatic and physical condition combined with unsustainable agricultural practices as well as access to irrigation infrastructure, but also due to the local nature of subsistence farming. Small cash crops, such as coffee, provide some rural households with an income, but most families farm for their own consumption. Poor connectivity hampers access to markets which ultimately leads to unpredictable income for many rural families depending on the agriculture sector. Development of the agriculture sector will not only serve as an important source of income and employment but will also crucially contribute to improve food security (MoI 2017).

Despite the long coastline, the fisheries sector is currently still underdeveloped. The number of families involved in full time fishing and marine-based activities is relatively small (ATSEA Program 2012). Fishing communities are mainly concentrated on the north coast, e.g. Dili, Liquiçá, Baucau, Bobonaro and Lautem. Most fishing activities are limited to low-technology inshore fishing leading to low productivity and lack of competitiveness in the market. Expansion of the industry can have positive impacts on income and employment of coastal communities, contribute to economic development of the country as well as increase food security. However, it must be done in a controlled manner to avoid overexploitation.

Tourism is one of the sectors which is growing yet needs to be explored further. While most of the tourism infrastructure is concentrated in urban areas, mainly rural tourism spots are growing, which is notably shown in Atauro- and Jaco- Island. The southern coast, despite having potential for new tourism spots (including mountain tourism), lacks connectivity, which is the major challenge to attract tourists. Tourism is a labour-intensive industry that can generate income and employment to coastal communities. On the one hand, it could reduce the vulnerability of coastal communities as income and adaptive capacity of coastal communities would increase due to the development of a new economic sector. On the other hand, when not done sustainably, the expansion of the tourism industry may alter coastal landscapes and impact coastal ecosystems such as creating damage to reefs, which would increase vulnerability and decrease adaptive capacity(GCCM 2008).

Timor-Leste can draw on abundant reserves of gas and oil. The industry is growing, shown by the increased income from this sector from $175 million in 2004 to $2.28 billion in 2008, and $2.73 billion in 2010(RDTL 2011). The growing oil and gas industry pose a positive impact to the development of major infrastructure, especially with regards to connectivity. The north coast is generally better connected to the transportation network than the south coast. However, with the big Tasi Mane Petroleum project in the southern coast of Timor-Leste, massive road construction is

[5]A person is considered poor if she is deprived in at least 1/3 of the weighted indicators in the areas of education, health and living standards.

currently on-going. The Strategic Development Plan 2011-2030 articulates plans to improve the road quality and in some areas new roads are planned to be constructed. The plan serves to promote rural development, industry and tourism, as well as to provide access to markets. With such a plan in hand, the southern coast will face a new era of development which on the one hand will positively impact livelihoods, especially with regards to access to public services as well as income. However, if uncontrolled it poses risks of coastal degradation which would endanger the indigenous livelihood and further marginalize the poor segment of the population.

Access to basic infrastructure

Access to safe water and sanitation is a vital element to improve social and economic development of the country. The SDP reported that lack of safe water and sanitation facilities could lead to an average loss of 2% of Gross Domestic Product per year (RDTL 2011). Furthermore, the same document also shows that limited access to safe water and poor sanitation have been one of the two main causes of infant and child mortality in the country.

The recent census shows that there are more than 200,000 private households in the country that acquire drinking water from about 11 main sources(MoF 2015). More than 40% of the total households have access to drinking water via the public tap, especially in Dili, Bobonaro, Baucau. About 14% of the households acquire access to drinking water from the river, lake and/or irrigation channel, counting for almost 30,000 households. The statistics show that such a practice is commonly done in Baucau and Viqueque. The impact of climate change will certainly exacerbate the already existing problem with water availability and even quality (in the case of sea water intrusion). Despite the fact that the country is still struggling to meet its target to provide clean water for everyone, especially for those who live in the rural areas.

Education

Education is a critical approach to reduce poverty and move towards community development, and thus will simultaneously increase adaptive capacity of the population. In this context, the Strategic Development Plan (2011) includes the education sector as a key parameter to improve the wellbeing and opportunities of the population and at the same time reach the country’s economic development goals. Since independence in 2002 there has been a tremendous progress in the education sector of the country(RDTL 2011). Nevertheless, reducing inequality gaps of education quality between the urban and rural areas and/or improving the relevance of education to acquire practical skills would certainly be beneficial in improving employability and reduce vulnerability (UNDP 2017 b).

According to the 2015 census, the percentage of population in coastal sucos receiving education varies between 55.55% in Oecussi and 77.34% in Dili (MoF 2015). Several factors are relevant to understand these discrepancies, for example the long distances to schools in more rural areas, poor quality of education and absence of qualified teachers especially in rural areas, as well as widespread poverty leading to many children being malnourished and frequently sick(UNDP 2017 b). In general terms, Dili, the capital and centre of political and economic heart of Timor-Leste show the best numbers in any specific category in the sector: primary and secondary education, academic education as well as vocational training.

As presented in Table 5.1, when it comes to secondary education and above (technical schools, and universities), access in Dili, as the economic and cultural hub of the country is the highest by far

(37.86%). Lowest average rate of population receiving secondary education can be found in Bobonaro with an overall percentage of only 9%, followed by Lautem and Oecussi with roughly 13%. At the same time the access to education facilities varies immensely between the different Sucos in the coastal areas of a same district.

Table 5.1 Percentage of population receiving education (Source: Own elaboration based on Census Data 2015)

DISTRICT	% of population receiving education in coastal sucos	% of population receiving secondary education and above in coastal sucos
Ainaro	62.26%	14.43%
Baucau	66.19%	19.18%
Bobonaro	59.12%	8.65%
Covalima	67.78%	17.71%
Atauro	69.27%	14.58%
Dili	77.34%	37.86%
Lautem	64.69%	13.10%
Liquiçá	61.69%	16.14%
Manatuto	71.27%	17.50%
Manufahi	66.91%	14.20%
Oé-cusse	55.55%	13.36%
Viqueque	61.41%	11.87%

In addition to providing good quality primary and secondary and decreasing the differences in the sector between urban and rural areas, a further challenge for the sector represents the increasing number of young Timorese that need to be integrated in the system.

5.1.3 Social and Cultural Structure

Poverty reduction has always high priority on the policy agenda of Timor-Leste. The National Development Plan from 2002 focuses on two overriding goals: 1) Reducing poverty in all sectors and regions of the nation, 2) Promoting economic growth that is equitable and sustainable, improving the health, education and well-being of everyone. To do so, the GoTL has developed strategies ranging from policy development to detailed budget allocations to assure the achievement of these goals. It is reported that approximately two-thirds of the total budget was allocated to sectors related to poverty reduction, such as infrastructure, human development, security, etc (SIDA 2005). These efforts are now reflected in terms of the country's success in reducing the number of population living in poverty from 50.4% in 2007 to 41.8% in 2014 (MoF 2016). Improvements are especially seen in aspects, such as school attendance, access to electricity and nutrition. Furthermore, in the last three years the country has experienced double-digit economic growth and a general improvement in people's welfare (RDTL 2011).Nevertheless, to assure elimination of poverty in 2030, the country should continue these efforts by, for example, increasing access and quality of health services, improving social security, sustainably managing the environment and natural resources, improving public infrastructures as well as encouraging economic activities outside of the Dili.

Patriarchal structures are deeply rooted in the society, and play an important role in shaping vulnerability of women in the country. Despite the fact that the country's constitution grants equal rights in terms of ownership to both men and women, this right is rarely exercised by women. Study on "Developing Timor-Leste's Coastal Economy: Assessing Potential Climate Change Impacts and Adaptation Options" prevails the limited access to cash possessed by women (Mills, et al. 2013), especially relevant for large purchases (e.g. fishing gear), investment (e.g. starting small businesses) and engaging in livelihoods that were not solely dependent on the men fishing (USAID 2015). This lack of ownership and access to cash leave many Timorese women to depend on the male members of the family. Timorese women are known as being highly engaged in agricultural work, however only 20% of these women are being paid for their work. The high rate of subsistence farming in the country may play a role in this percentage. According to the census done in 2015, it is reported that 31,9% of women in Timor-Leste have never been to school(MoF 2015). Meanwhile, about 50% have some primary education, 33% have some secondary education or have completed secondary school, and about 9% of women have more than secondary school education (Ibid.). Supported by the country government's rigorous efforts and commitments in improving access to and quality of education, data shows that female school attendance, both primary and secondary education, increased over the years.

With regards to customary law in the local community, there is a need to support the collection and recording of information on customary practices. Tara Bandu, for example, is one of the traditional ceremonies still being practiced. It is a traditional Timorese custom that enforces peace and reconciliation through public agreement (TAF 2013). The custom was oppressed during the Indonesian occupation, however nowadays it has become a priority of the 5th Constitutional government as a part of efforts to strengthen local governance through effective conflict resolution in social, political, economic and even ecological (environment) matters (AUSAID 2014). In addition to Tara Bandu, there are many others customary ceremonies being practiced by local communities and coastal communities that have developed a special relationship with the coastal and marine environment. The communities, especially in the eastern part of the country, still conduct traditional rituals and prayers for good harvest and safe return from the sea. In Tutuala, for example, ceremonial harvesting of sea worms marks the beginning of a new agricultural calendar (McWilliam 2002).

Customary law is a central element to land tenure issues in Timor-Leste. Formalization of the land tenure system in Timor-Leste has been one of the most challenging processes in the country. Timor-Leste faces three types of land-reform challenges: farm land now under customary practices; urban land in need of zoning and clear property rights; and government land that can be used for public and private investment such as tourism or petroleum development. The country's SDP 2011-2030 articulated that the reform of land tenure law is crucial for long-term private sector development of agriculture, particularly for commercial crops such as coffee and other potential agro-industries that need to attract investment. However, it must be noted that customary land tenure system has been perceived to have contributed to sustainable and equitable natural resource management for centuries (Batterbury, et al. 2016). To this end, meaningful recognition of traditional customs for land tenure system is a pre-requisite for a conflict free resolution, while still promoting equality and sustainability in development of rural areas.

Experiences in the application of traditional practices

In the of context costal protection, customary laws that are already part of the local culture and can be enforced by community members themselves empower the communities and, if good established, can have very effective results. Examples for the use of Tara Bandu have been observed during field visits, as well as community consultations. On Atauro Island, for instance, Biqueli and Beloi have successfully implemented these laws to protect mangrove areas and fish-stock. People on Atauro Island have always been in contact with these practices, which is an important factor contributing to the success of its implementation. On Timor-Leste mainland, however, these practices have been prohibited during occupation time and younger generations are not familiar with them anymore. In Clacuc, Manufahi a local NGO started a project to implement Tara Bandu in the area without succeeding, due to lack of communication. Participants explained that the rules were decided on the sub-district level without participation of the community itself, thus the community felt they knew too little about it and could not see the relevance.

6 Coastal Vulnerability Index

Climate change adaptation in coastal areas requires integrated information that represents coastal vulnerability and risk to climate change on particular areas and levels such as national, regional or local. For this study, the Coastal Vulnerability Index (CVI) developed by Thieler and Hammar-Klose (2000) has been applied as a tool to display vulnerability due to coastal instability andsea-level rise at the national level. In this context, the index describes some of the physical paramentercausing the vulnerable condition of the Timorese coasts. These physical parameters are: sea level rise, wave height, tide range and coastal instability. Further vulnerability parameters such as infrastructure, socio-economic, and ecosystem which are influenced by those physical parameters will be described in the next chapter as partof the modified CVI assessing the comprehensive level of risk of climate change and/or global sea-level rise.

6.1 Methodology

The Coastal Vulnerability Index (CVI) was initially used by the United States Geological Survey (USGS) to assess the impacts of sea-level rise and coastal changes especially on some national parks in the western and eastern coasts of the United States and the Gulf of Mexico in 1999. The CVI is anelementary measure of physical vulnerability on a nation-wide coastal scale. The index allows the physical parameters to be related in a quantifiable manner. It highlights those regions where the various effects of sea-level rise on the coastal instability or destruction are expectedly the greatest.

Originally, this method considers six physical parameters that are all related to potential coastal destruction hazards (or coastal destruction susceptibility), namely: coastal geomorphology, coastal slope, sea level rise, current coastal erosion rate, ocean tides and waves (see: Thieler, Williams and Beavers 2002 for USGS).

Table 6.1 Physical parameters included in the Coastal Vulnerability Index

No	Parameter	Unit	Description
(a)	Coastal geomorphology	-	Indicates the relative erodibility of different landform types in a portion of shoreline
(b)	Shoreline erosion and accretion rates	m/years	Indicates how fast a portion of shoreline has been eroding or accreting to indicate the shoreline changes
(c)	Coastal slope	%	Link to susceptibility of a coast to inundation by flooding and to potential rapidity of shoreline retreat or advance, considering that low-sloping coastal regions should retreat faster than steeper regions
(d)	Sea-level rise	mm/years	indicates how the global (eustatic) sea-level rise as well as local isostatic or tectonic land motion affect a portion of shoreline
(e)	Tide range	meter	Contributes to both, permanent and episodic coastal inundation hazards
(f)	Wave height	meter	Indicates the wave energy that drives the coastal sediment budget influencing coastal abrasion and accretion hazards, as well as indicates the penetration of the hazards toward inland

The following equation is used to calculate the Coastal Vulnerability Index:

$$CVI = \sqrt{(a*b*c*d*e*f)/6}$$

Table 6.2 shows the six physical parameters used by USGS in 2000, ranked from 1 (very low vulnerability) to 5 (very high vulnerability). It includes both quantitative and qualitative information. Thus, numerical values are assigned a risk ranking based on data ranges. However, for the coastal geomorphology parameter rankings are defined according to the relative resistance of a given landform to erosion.

Table 6.2 Coastal Vulnerability Index used by USGS (USGS 2000)

No	PARAMETER	Unit	Rank				
			Very Low	Low	Moderate	High	Very High
			1	2	3	4	5
(a)	Coastal Geomorphology		Rocky, cliffed coasts; Fiords; Fiards	Medium cliffs; Indented coasts	Low cliffs; Glacial drift; alluvial plains	Cobble beaches; Estuary; Lagoon	Barrier beaches; Sand Beaches; Salt marsh; Mud flats; Deltas; Mangrove; Coral reefs
(b)	Coastal Slope	%	>0.115	0.115-0.055	0.055-0.035	0.035-0.022	<0.022
(c)	Relative sea-level rise	mm/ year	<1.8	1.8-2.5	2.5-3.0	3.0-3.4	>3.4
(d)	Shoreline erosion/ accretion	m/ year	>2.0	1.0-2.0	-1.0-+1.0	-1.1- -2.0	<-2.0
(e)	Mean tide range	m	>6.0	4.1– 6.0	2.0 – 4.0	1.0 – 1.9	<1.0
(f)	Mean wave height	m	<0.55	0.55-0.85	0.85-1.05	1.05-1.25	>1.25

The physical parameters used by the USGS cannot be directly applied to all circumstances. Thus, appropriate modifications are required to ensure a coherent and suitable approach in the local context. The Coastal Vulerability Index for for this project has, thus, been developed in analogy to the CVI applied in Indonesia in 2010. In doing this, the consultants use an approach that combines oceanographical-geological similarities and regional influences in the ocean dynamics between Pacific Ocean and Indian Ocean to the Timorere coastal waters. Thus, the following equation is used to calculate the Coastal Vulnerability Index for Timor-Leste:

$$CVI = \sqrt{(a*0.43)*(b*0.14)*(c*0.14)*(d*0.29)/4}$$

The respective parameters and values are presented in Table 6.3

Table 6.3 Coastal Vulnerability Index adopted for Timor-Leste (Source: Own elaboration)

No	PARAMETER	Unit	Rank				
			Very Low	Low	Moderate	High	Very High
			1	2	3	4	5
(a)	Coastal Instability		Poor, fair, good, and very good rock of rock mass rating system	Very poor rock of rock mass rating system	Very loose to loose of coarse grain non cohesive soil, consist of gravel, cobble, & boulder of alluvial deposits	Cohesive soil consists of clay &silt of loose sediments of alluvial deposit, and dense to very dense/ weakly consolidated sediment of clay, silt, sand	Very loose to loose of fine grain non-cohesive soil, consist of sand of alluvial deposits
(b)	Relative sea-level rise	mm/ year	<7.3	7.3–7.4	7.4 – 7.5	7.5 – 7.6	>7.6
(c)	Maximum tide range	m	>4.0	2.0 – 4.0	1.5 – 2.0	1.0 – 1.5	<1.0
(d)	Mean significant wave height	m	<0.75	0.75 – 1.0	1.0 – 1.25	1.25 – 1.50	>1.5

In the context of this assignment, the consultants aggregated three specific physical parameters (i.e: coastal geomorphology, shoreline erosion/accretion rates and coastal slope) into a single one regarded as coastal instability. This results from the theory that all of these single variables have geomorphological interrelations with the state of the coastal instability (abrasion or accretion) as a vulnerability factor in the coastal areas. The ranking system of this derived parameter is based on geological maps, adjusted by topographic maps and complemented by judgements of geology experts involved in the field observation survey conducted in May 2017.

Using the classical work of Klaus Wyrtki (1961) on the physical oceanography of Southeast Asian Waters, including Timor-Leste, it is deemed that sea-level rise, tides and waves parameters in Timor Leste coastal waters have similar scoring as the Indonesian case (2010). This knowledge was harnessed as the basis for judgement in developing the maps of three oceanographical parameters (see Chapter 3), used as the data to develop the respective rank system (see Table 6.3). It is noted that oceanography data required for CVI should have long period of observation and should be distributed in all parts of coastline of Timor Leste. That waythe team mainly use results of respective spatial-temporal distributed mathematical models (based on computer simulations). These models had been verified using some observed data or other qualitative information of respective parameters in some available stations including in the model area.

The values of CVI as presented in Table 6.3 were classified into five classes by using Natural Breaks method in GIS processing as follows: Very Low (with an index range of 0.00 – 0.126), Low (0.126 – 0.178), Moderate (0.178 –0.219), High (0.219 –0.244), and Very High (0.244 – 0.340)

Methods and data used in determining the level of vulnerability of each variable are described in the table:

Table 6.4 Methods and data used per parameter

No	PARAMETER	METHOD	DATA & SOURCES
(a)	Coastal Instability	• Determination of scale based on coastal geomorphology, coastal slope and sediment materials (*proxies*) • Mapping, inter-polation, and analysis by using GIS • Adjustment and correction using field observation data	• Geological Map with resolution 1: 250,000 (Indonesian Research & Development Center for Geology 1996) • Administrative Boundary Map (Municipality till Suco) • Topographic data generated from Shuttle Radar Topography Mission (SRTM) NASA data with resolution of around 30 m • GPS Check-Points and photos in May 2017
(b)	Relative sea-level rise	• Using IPCC Model by the Special Report on Emission Scenario (SRES) A1B with projection of CO_2 in 2100 as 750ppm (part per million) • Mapping, interpolation, and analysis by using GIS	• The IPCC Model and scenario by using MRI CGCM2.3 (Japan) model as inputted data • Verification by using the tidal stasion data from Indonesian Geospatial Information Agency for model verification.
(c)	Mean tide range	• Calculation of Highest and Lowest Astronomical Tides (HAT and LAT) by using a tidal hydrodynamics model • Mapping, inter-polation, and analysis by using GIS	• Data Global Tidal Model NAO.99 (Japan) in TOPEX/ Poseidon, Jason satellite altimetri database (2004) as boundary condition data for the model • Verification by using the tidal stasion data from Indonesian Geospatial Information Agency for model verification.
(d)	Mean wave height	• Calculation of Significant Wave Height • Mapping, interpolation, and analysis by using GIS	Data from Live Access Server (LAS) Pacific Marine Environmental Laboratory NOAA

6.2 Results based on Parameters

6.2.1 Sea Level Rise

According to the results of the model MRI CGCM2.3, the relative sea-level rise of the coastal strip of Timor-Leste is characterized as follows:

- between 7.5 and 7.6 mm/year in the northern coast, including Atauro island
- between 7.5 and 7.6 mm/year from Lautem until east Manufahi)
- between 7.6 - 7.7 mm/year from west Manufahi to Covalima

The model includes relevant information such as sea surface temperature and sea surface height with SRES A1B scenario, performing carbon dioxide (CO_2) concentration projection in 2100 as 750 ppm (part per million). Thus, the results are comparable with the projections made in 2011 by the PCCS. Slight differences in the results of this study are only due to the application of spatially distributed data format instead of the spatially average data format. In doing this, it is possible to differentiate the rate of sea level rise between the north and the south coast.

In accordance with the classification values assigned in Table 6.4 for the parameter sea level rise, the coastline of the country is splited in:

- high relative sea level rise (<7.6 mm/year): Oé-cusse, Bobonaro, Liquiçá, Dili (including coastline of Atauro Island), Manatuto, Baucau, Lautem, Viqueque, and some part of Manufahi,
- Very high relative sea level rise (>7.6 mm/year): Ainaro, Covalima and parts of Manufahi.

Figure 6.1 and Figure 6.2 illustrate the distribution of the relative sea level rise along the coastline of the country.

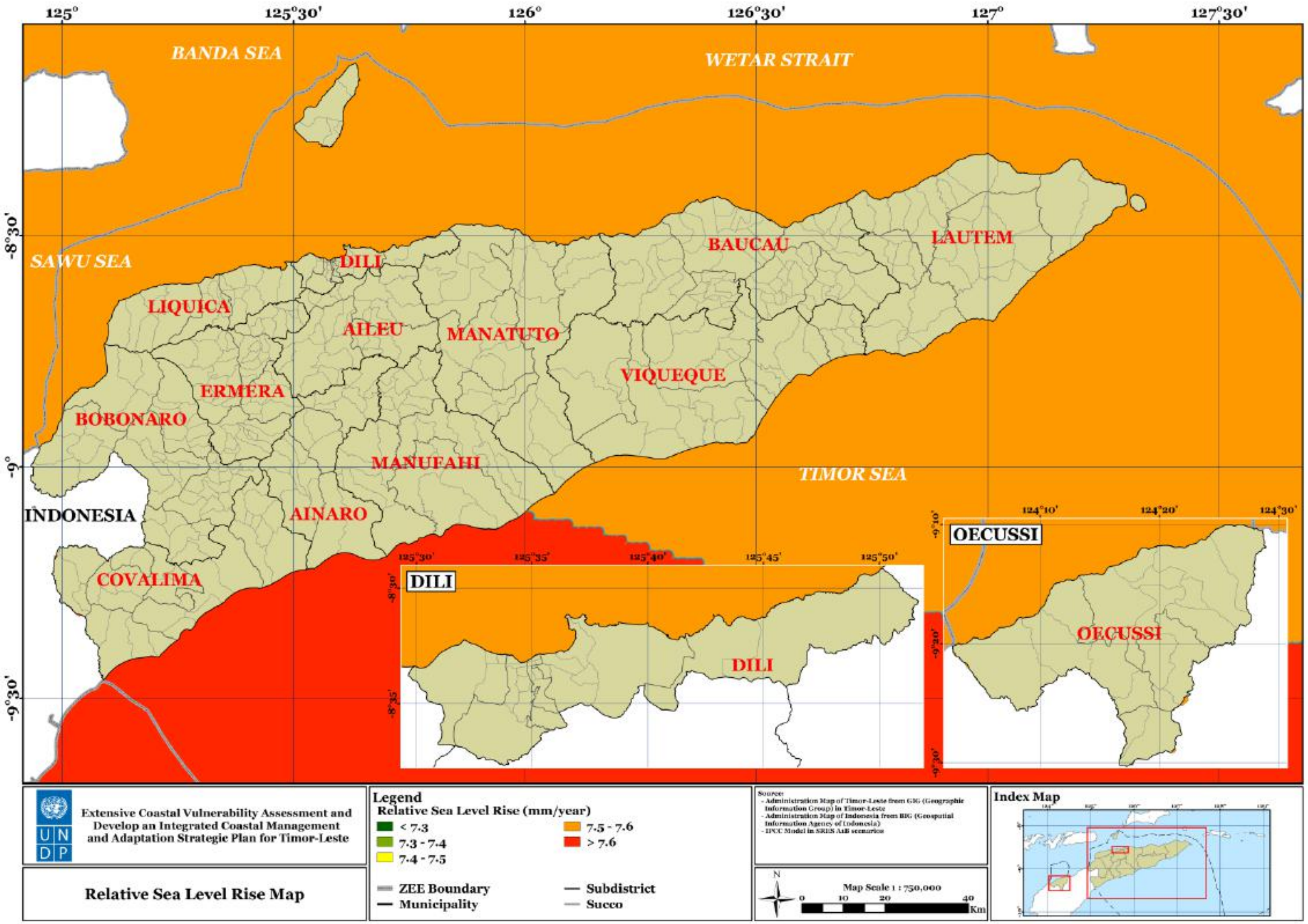


Figure 6.1 Spatial Distribution Map of Relative Sea-Level Rise in Timor Leste

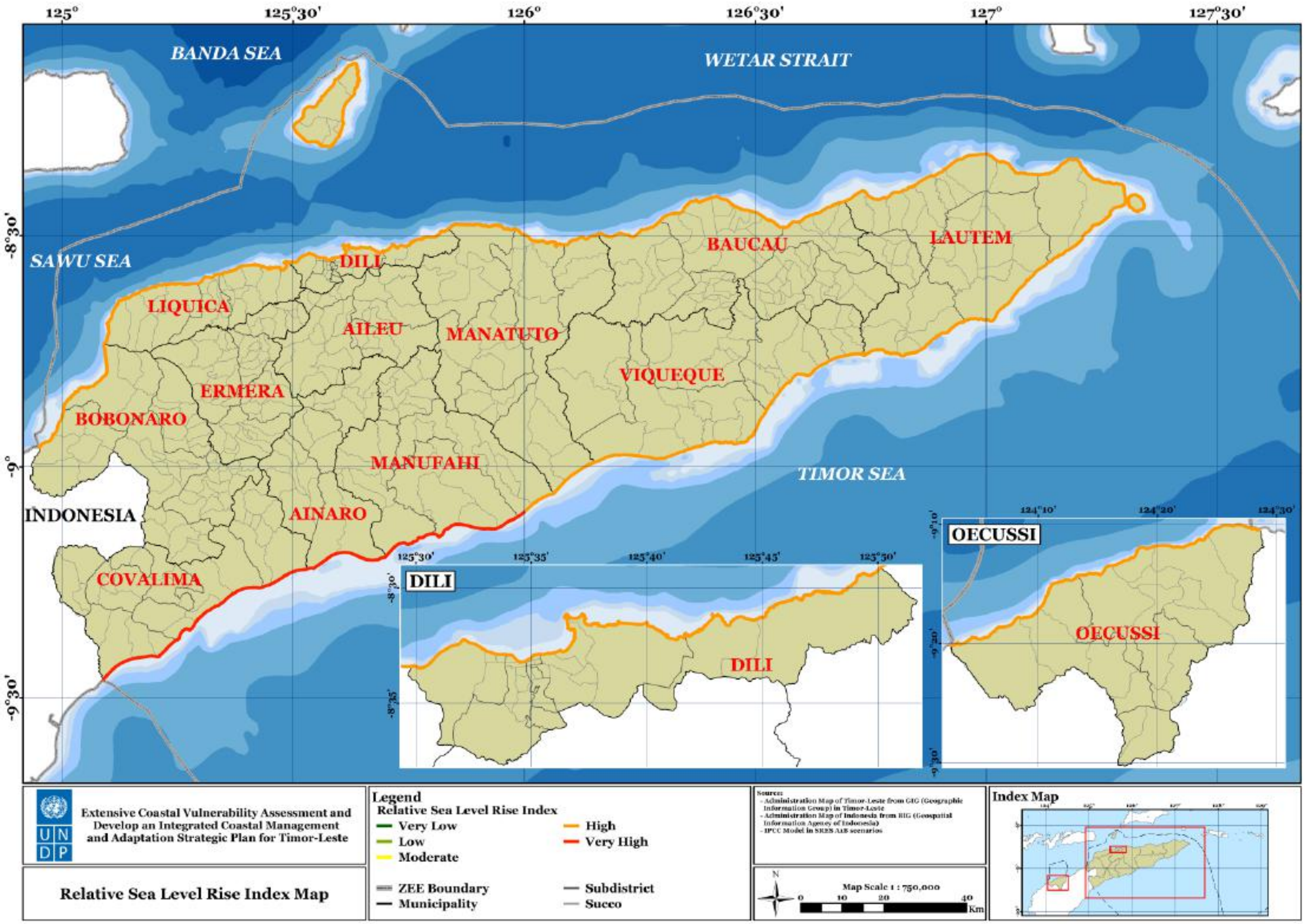


Figure 6.2 Relative Sea Level Rise Index Map

6.2.2 Tide Range

The interpolation of the Global Tide Model NAO.99 provides the values for the maximum tide range of Timor-Leste. These values range from 1.86m to 2.53m. On average, however, values along the coast are more than 2m. This occurs, for example, mostly in the north-eastern coast (i.e.: from Dili to Lautem). The areas with values less than 2, can be found in the north-western coast (i.e.: from Liquiçá to Bobonaro, including Oé-cusse and Atauro Island). The differences are caused by several influencing factors such as seabed topography, width of strait, the condition of bay, total area of seas and bottom friction.

Based on the values of the paremeter maximum tide range assigned in the Table 6.4, less than 2 m is categorized as moderately vulnerable (see yellow areas on Figure 6.3.) and from 2 m onwards is categorized as low vulnerable (see green areas on Figure 6.3). According to these values, only the north-western coast is characterized by a moderate level of vulnerability. Figure 6.4 illustrates the distribution of the values of this parameter.

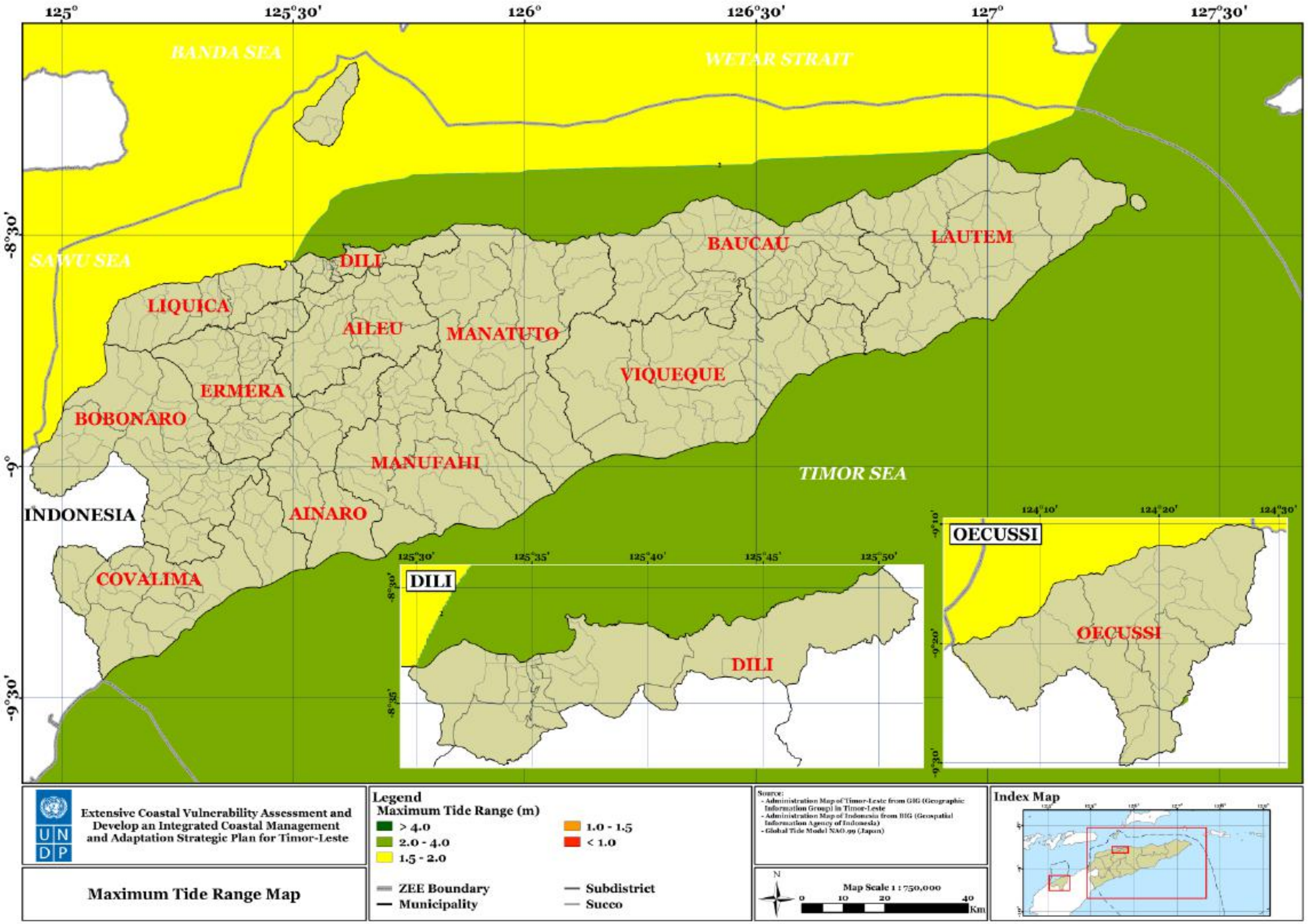


Figure 6.3 Spatial Distribution Map for Maximum Tide Range Model in Timor-Leste

Figure 6.4 Maximum Tide Range Index Map

6.2.3 Wave Height

The data regarding spatial Significant Weight Height (SWH) for this assignment, was obtained by the consultants from the Live Access Server (LAS) Pacific Marine Environmental Laboratory NOAA through the online platform of the Geospatial Information Agency of Indonesia. The analysis of this data provides the following information:

- for the northern coast, including centre and southern part of Atauro Island the highest annual SWH is less than 0.75 m
- for southern coast and northern part of Atauro Island the highest annual SWH ranges between 0.75 to 1 m

Figure 6.5 gives a representation of these results. The difference of Significant Wave Height between the north and the south coast can be explained through the influence of wind. The southern coast, for instance, is facing the open sea and thus exposed to the wind waves coming from the Timor and the Banda Sea. In the norther coast, the opposite is the case. In addition, monsoons also contribute to the differences in the value of SWH. During Asian Monsoon, significant wave height increases in northern area and decreases in southern area. The situation is completely different during the Australian Monsoon. This highest annual SWH reaches its highest level during the Australian Monsoon from June to July.

Based on the values for the SWH parameter presented in Table 6.4, SWH value of less than 0.75 is categorized as very low (see green areas in Figure 6.5) and ranging from 0.75 m to 1 m is categorized as as low vulnerable (see light green areas in Figure 6.5). Considering only SWH parameter, this research shows that the northern coast has low susceptibility while the most areas in the southern coast have a relatively higher susceptibility. Figure 6.6 gives an illustration of the distribution of SWH along the Timorese coastline.

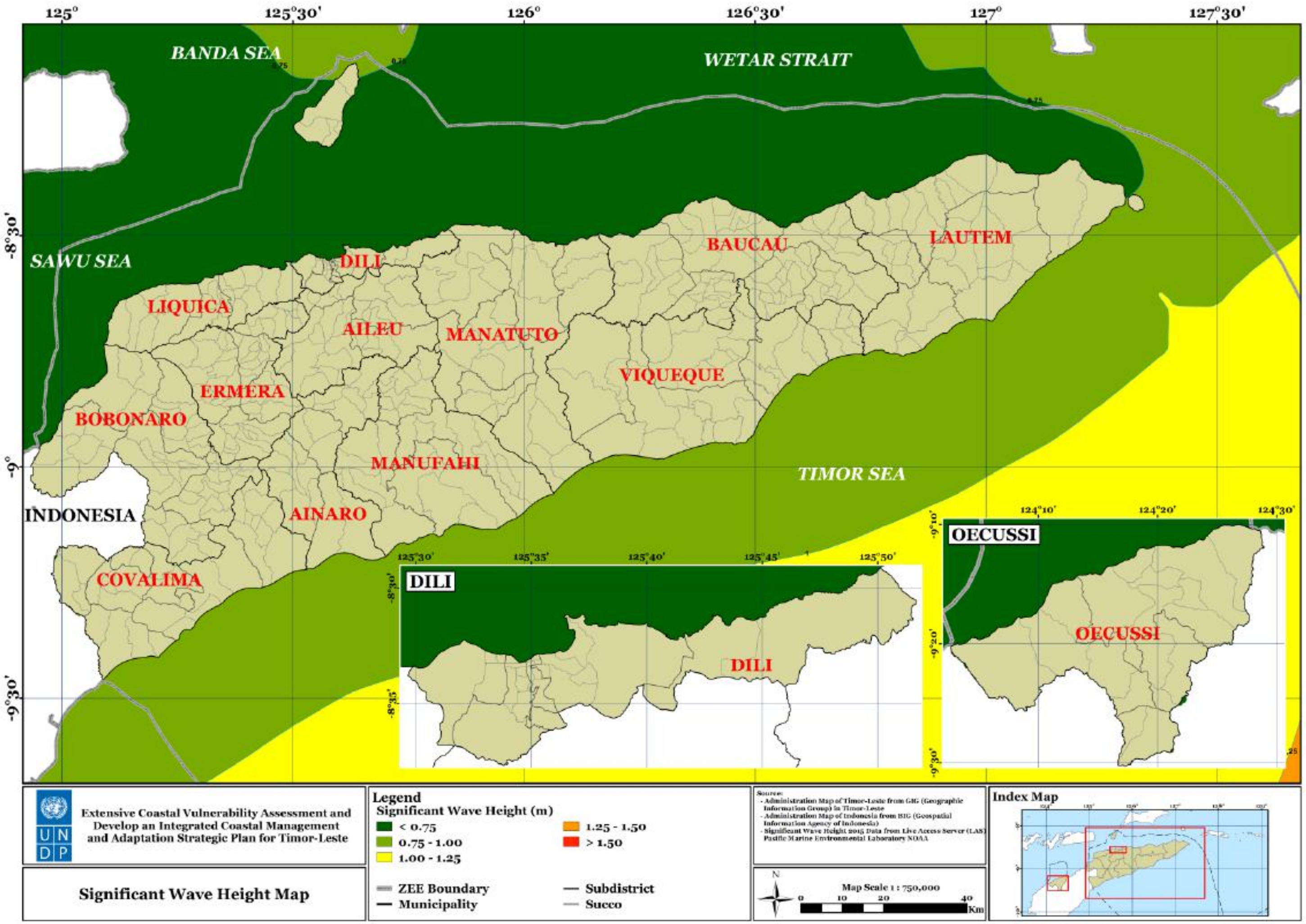


Figure 6.5 Spatial Distribution Map of Significant Wave Height in Timor-Leste

Figure 6.6 Significant Wave Height Index Map in Timor-Leste

6.2.4 Coastal Instability

The rock mass rating system results from geological site reconnaissance and desk study of geological conditions of the shoreline of Timor-Leste.The classification of Coastal Instability ranking from 1 to 5 (very low to very high) is shown in Table 6.5.

There are significant differences between coastal instability index results in the southern and the northern area of Timor-Leste. Most of the southern coast of Timor-Leste has a very high index (very unstable coast) susceptible to erosion. The northern areas have more variation on coastal instability index withBaucau and Lautembeing more resistant to erosion due to geological formation. Eight of the municipalities in Timor-Leste have a very high index in coastal instability: Manufahi (98.4%), Ainaro (91.8%), Covalima (91.14%), Viqueque (87.16%), Manatuto (64.71%), Liquiçá (63.04%), Bobonaro (62.75%), and Oé-cusse (56.72%). The other three municipalities Baucau, Dili, and especially Lautem are more resistant to erosion shown by the coastal instability index.

Table 6.5 Coastal Instability ranking from 1 to 5 (very low to very high)

Coastal Instability	Geomorphology or Geotechnical Parameter	Soil And Rock Mass along Shoreline in Timor-Leste
1	**Poor, Fair, Good and Very Good Rock** of Rock Mass Rating System **(Very low instability / Very Stable)**	1. **Surobeco Formation (Qps)** thickly bedded limestone, contain of gastropods and algae, travertine and chalky limestone locally. Deposited in lacustrine environment. Up to 20 m thick and Pelistoce to Recent age**.** 2. **Ainaro Formation (Qpa),** Old river deposits forming terraces; consist of polemict conglomerate, sand and clay; weakly consolidated, based on the stratigraphic position supposed to be Pleistocene – Holocene in age; approximately 100 m thick. 3. **Old Volcanic Products (Qtv),** consist of lavas, breccias and pumiceous sandy tuff. Lavas locally show columnar joints, 350 m thick and Pliocene to Pleistocene in age. This old volcanic product can be found iniAtauro island 4. **Noele Formation (QTn),** consist of cross bedded conglomerate, sandstone and siltstone. 300 m thick and Pliocene to Pleistocene in age. It was supposed in shallow marine to delta environment and it is found in Covalima and Oucusse districts 5. **Baucau Formation (Qpb and Ql)**, consist of reefal limestone, calciruditeangcalcarenite, up to 100 - 300 m thick and suggesting Pleistocene to Holocene in age. Deposited in the shallow marine environment. 6. **Aliambata Formation (Tma),** consist of poorly bedded limestone, contains abundant foraminifera, it was deposited in a shallow marine environment. More than 100 m thick and Early Miocene in age 7. **Aititu Formation (TRa),** manly composed of well bedded calcilutite with chert nodule, locally alternating with marl or calcareous shale and calcarenite, contains abundant radiolarian and halobia fossil and minor ammonites. It was deposited in an epineritic environment. Up to 1.000 m thick and Late Triassic in age 8. **Cribas Formation (Pc),** consist of sandstone with clay ironstone nodules and limestone, shale. It was deposited in an epineritic environment. Up to 500 m thick and Late Permian in age. 9. **Atohoc Formation (Pat),** consist of quartz sandstone, black shale, calcilutite, and the amygdaloidal basalt at the upperpart. It was deposited in shallow marine environment, up to 600m of thickness and Permian in age 10. **Manamas Formation (Tmm),** consists of volacanic products, Miocene in age and it can be found in Oucusse district 11. **Aileu Formation (Pa),** consists of phyllite, schist, amphibolites,

Coastal Instability	Geomorphology or Geotechnical Parameter	Soil And Rock Mass along Shoreline in Timor-Leste
		slate, meta-sandstone, shale, few volcanic rocks and limestone. Thickness up to hundreds of meters and Late Early Permian to Upper Jurassic in age. Aileu formation can be found ini districts of Liquica, Dili, Manatuto and Lautem
2	**Very Poor Rock** of Rock Mass Rating System **(Low Instability)**	1. **Bobonaro Formation (QTb/ Tmb)**, consist of chaotic rocks of boulder size fragments within scaly clay matrix, contain foraminifera and it was deposited in deep marine environment. Thickness is different from one to another places and Upper Miocene to Recent (?) in age 2. **Waululi Formation (Jw),** consist of shale, sandstone predominates in lower part with minor limestone intercalations contains belemnites and ammonites. It was deposited in shallow marine environment. 600 up to 1.000 m thick and Early to Middle Jurassic in age.
3	**Very Loose to Loose of non-cemented Coarse Grained Non-Cohesive Soil,** consist of GRAVEL, COBBLE and BOULDER of Alluvial Deposits **(Stable)**	1. **Coastal Alluvium #1 (Qa/ Qal)** – consist of loose and non-cemented sediments of non-cohesive soil, such as sand, gravel, cobble and boulder, more than 10 m thick and Holocene to Recent in age 2. **Suai Formation (Qs)** – Medium dense to Hard or non- cemented to light cemented sediment, consist of loose to weakly consolidated sediments of clay, silt, sand, gravel and cobble in size, contains of foraminifera and mollusc fossils, 100 up to 600 m thick and suppose Pleistocene to Holocene in age. Gentle deformation
4	**Cohesive Soil,** consist of CLAY and SILT of loose sediments of Alluvial Deposits and **Non-cemented of Dense to very Dense or weakly consolidated sediments** of clay, silt, and sand **(Instable)**	**Coastal Alluvium #2 (Qa/Qal) –** consist of loose and non-cemented sediments of cohesive soil, such as clay, silt and very fine sand (mangrove and swampy area), can be more than 10 m thick and Holocene to Recent in age
5	**Very Loose to Loose of Non-cemented of Fine Grained Non-Cohesive Soil,** consist of SAND of Alluvial Deposits **(Very Instable)**	**Coastal Alluvium #1 (Qa/ Qal) –** consist of loose and non-Cemented sediments of non-cohesive soil, such as sand, more than 10 m thick and Holocene to Recent in age

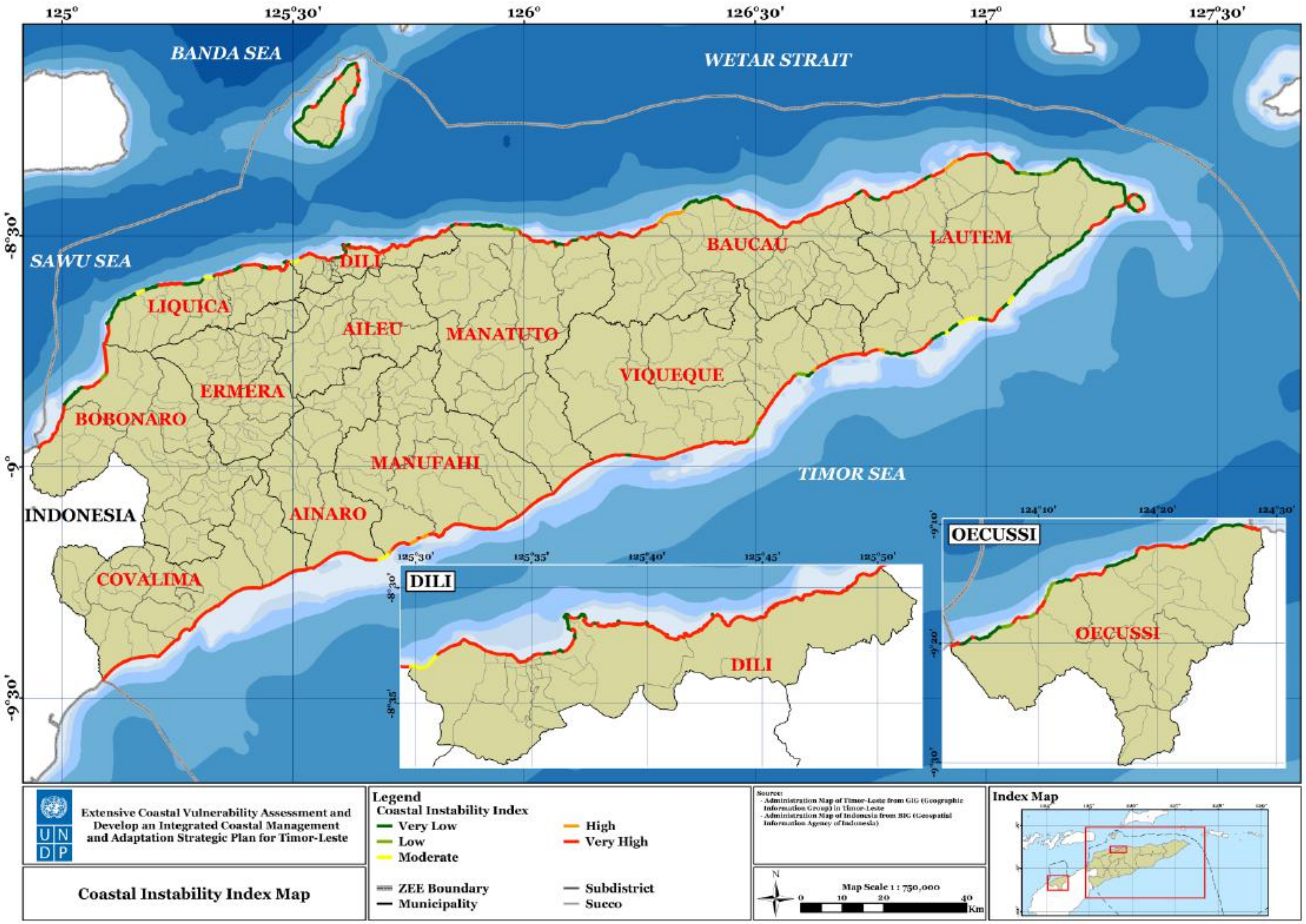


Figure 6.7 Coastal Instability Index Map

6.3 Coastal Vulnerability Index for Timor-Leste

As described in the methodology, the consultants have modified the Coastal Vulnerability Index to ensure a coherent and suitable approach to the Timore context resulting in the following equation:

$$CVI = \sqrt{(a*0.43)*(b*0.14)*(c*0.14)*(d*0.29)/4}$$

The three oceanographic parameters (i.e.: relative sea-level rise, maximum tide range, and significant wave height) tend to have regional influences. The coastal instability parameter, however, takes into account geological parameters and their local distribution. Therefore, the first three parameters have proportions of 20% each (i.e., 60% of oceanographic parameters in total) and the coastal instability parameter has a proportion of 40%.

The specific objective of this assignment is to assess the level of vulnerability in coastal areas. Therefore, the boundary of study site needs to be defined. The definition of the consultants includes all sucos located along the coastline (99 sucos) as well as those sucos located inland with an elevation up to 20 m (22 sucos). According to this definition, a total of 121 coastal sucos are the object of this assessment. With this definition, the results of the CVI are overlaid on the coastal suco map in order to generate a CVI value for each suco. In some cases, this approach results in more than one CVI value for the same suco. In such a case, the consultants consider only the highest percentage of CVI value.

Figure 6.8 presents the CVI value distribution along the coastline of Timor-Leste. In accordance with the distribution illustrated in this figure, the southern coast is physically more vulnerable than the northern coast. From the total of 121 coastal sucos, 58 sucos are characterized by high and very high level of vulnerability. Of those 58 sucos, 23 are distributed long the north coast and 35 are located along the south coast.

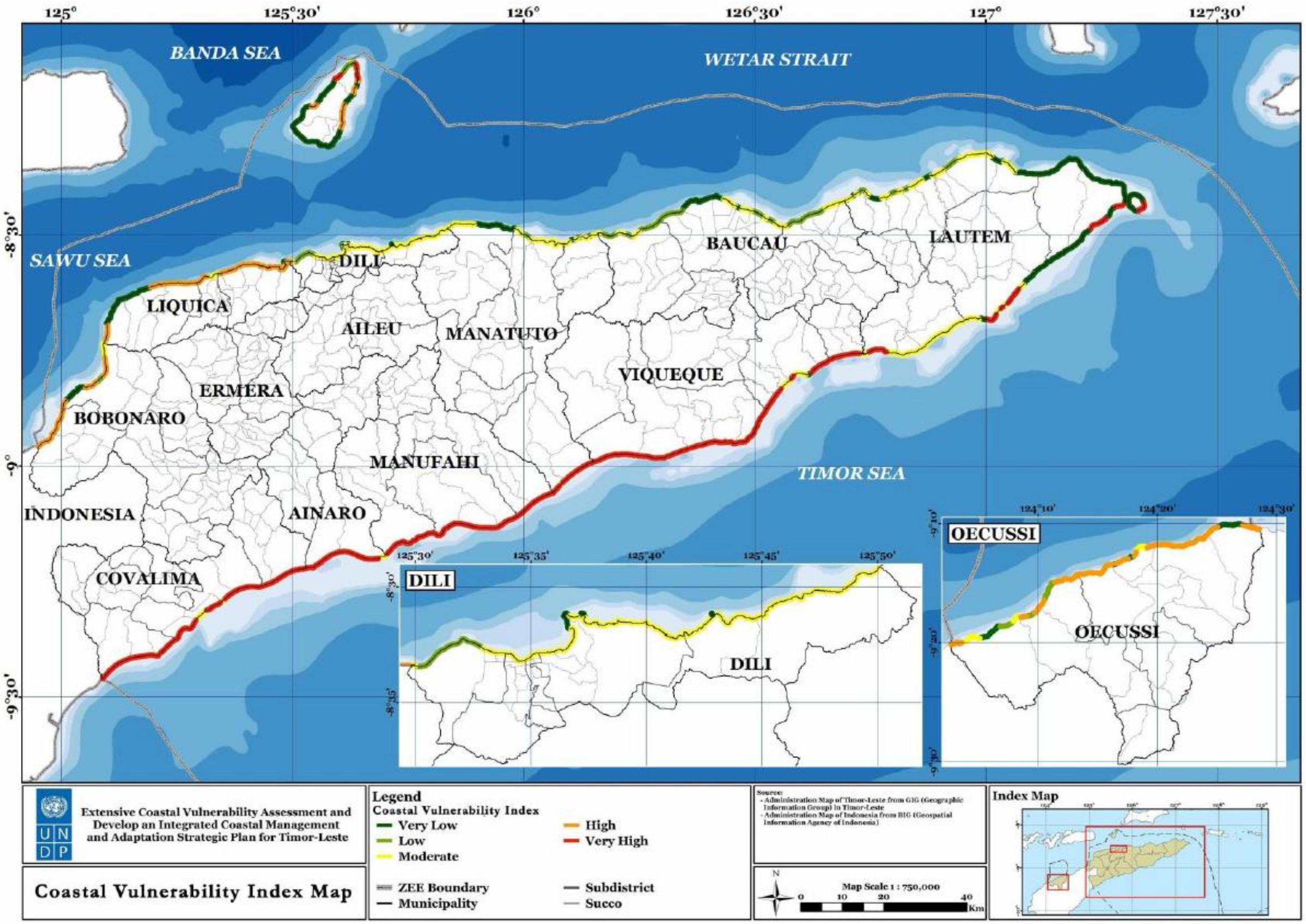


Figure 6.8 Coastal Vulnerability Index Map of Timor-Leste

Table 6.6 CVI value distribution: Sucos with Physically High Level and Very High Level of Vulnerability

CVI SORTED BY HIGH AND VERY HIGH RANK								
DISTRICT	SUB DISTRICT	SUCO	TIDE	WAVE HEIGTH	SEA LEVEL RISE	COASTAL STABILITY	AGGREGATE	CVI CLASSIFICATION
BOBONARO	BALIBO	BATUGADE	3	1	5	5	0,244949	4
		SANIRIN	3	1	5	5		4
DILI	ATAURO	ATAURO VILA/MAUMETA	3	1	5	5		4
		BELOI	3	1	5	5		4
		BICELI	3	1	5	5		4
LIQUICA	BAZARTETE	LAUHATA	3	1	5	5		4
		MAUMETA	3	1	5	5		4
		MOTAULUN	3	1	5	5		4
		TIBAR	3	1	5	5		4
		ULMERA	3	1	5	5		4
	LIQUICA	DATO	3	1	5	5		4
	MAUBARA	VATUBORO	3	1	5	5		4
		VATUVOU	3	1	5	5		4
		VAVIQUINIA	3	1	5	5		4
OECUSSI	NITIBE	BENE-UFE	3	1	5	5		4
		SUNI-UFE	3	1	5	5		4
		USI-TACO	3	1	5	5		4
	PANTE MACASAR	COSTA	3	1	5	5		4
		LIFAU	3	1	5	5		4
		NIPANI	3	1	5	5		4
		TAIBOCO	3	1	5	5		4
AINARO	HATU-UDO	FOHO-AI-LICO	2	2	5	5	0,282843	5
		LEOLIMA	2	2	5	5		5
COVALIMA	SUAI	BECO	2	2	5	5		5
		CAMENA?A	2	2	5	5		5
		LABARAI	2	2	5	5		5
		SUAI LORO	2	2	5	5		5
	TILOMAR	CASABAUC	2	2	5	5		5
		LALAWA	2	2	5	5		5
		MAUDEMO	2	2	5	5		5
	ZUMALAI	RAIMEA	2	2	5	5		5
		TASHILIN	2	2	5	5		5
DILI	ATAURO	BELOI	3	2	5	5	0,34641	5
		BICELI	3	2	5	5		5
LAUTEM	ILIOMAR	TIRILOLO	2	2	5	5	0,282843	5
	LOSPALOS	LORE I	2	2	5	5		5
	TUTUALA	TUTUALA	2	2	5	5		5
MANATUTO	BARIQUE/NATARBORA	AUBEON	2	2	5	5		5
		UMA BOCO	2	2	5	5		5
MANUFAHI	ALAS	DOTIC	2	2	5	5		5
		MAHAQUIDAN	2	2	5	5		5
		UMA BERLOIC	2	2	5	5		5
	FATUBERLIU	CAICASA	2	2	5	5		5
		CLACUC	2	2	5	5		5
	SAME	BETANO	2	2	5	5		5
VIQUEQUE	UATUCARBAU	IRABIN DE BAIXO	2	2	5	5		5
		UANI UMA	2	2	5	5		5
	VIQUEQUE	BIBILEO	2	2	5	5		5
		LUCA	2	2	5	5		5
		MALURO	2	2	5	5		5
		UMA QUIC	2	2	5	5		5
		UMA UAIN LETEN	2	2	5	5		5
		WATU DERE	2	2	5	5		5
	WATULARI	BABULO	2	2	5	5		5
		MACADIQUE	2	2	5	5		5
		MATAHOI	2	2	5	5		5
		UAITAME	2	2	5	5		5
		VESSORU	2	2	5	5		5

According to the analysis, 37 sucos are physically very vulnerable. Of those 37 sucos, only two are located in the north, i.e. sucoBeloi and Biceli in Atauro Island. The other 35 sucos are located on the southern coast. Based on the analysis of each parameter and the results of the aggregated CVI, coastal instability parameter may play a major role as a determinant of CVI value, especially given the locality of influence and consequently the weighing system used.

Table 6.6 also illustrates the significant contribution of coastal instability to the aggregate CVI values. However, it must be understood that the index of oceanographic parameters in the northern coast are always lower, i.e. lower rate of sea level rise, calmer wave and lower tide range. As such balancing the erodibility rate of the northern coast and thus the coasts are physically less vulnerable.

To this end, generally it can be concluded that the south coast region is more vulnerable than the north coast, in terms of physical parameters of CVI. However, inclusion of the social, economic and ecological parameters will change these results. The combination of CVI together with social, economic and ecological parameters will be presented in Chapter 7.

7 Modified Coastal Vulnerability Index

The objective of the CVA study is not merely to assess the level of physical vulnerability represented by the CVI along the coastline of Timor-Leste, but also to define and formulate strategies for climate change adaptation and an integrated coastal management plan for coastal sucos in the country.

To comply with this goal, the CVI has been expanded to include non-physical indicators. That way the strategies can be developed in accordance with the profile of vulnerability and risk.

To better understand vulnerability in the context of coastal areas, as well as to reflect the importance of other data and information required for the development of adaptation strategies, data from the modified CVI have been complemented with community consultations and other secondary literature.

7.1 Methodology

The CVI developed by USGS is based on the Vulnerability Concept of IPCC AR-3 (2001), where:

(1) "Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes",

or

(2) "Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity".

Based on the second definition, the "V" (vulnerability) is formulated as:

$$V\ (vulnerability) = \frac{E\ (exposure) \times S\ (sensitivity)}{AC\ (adaptive\ capacity)}$$

Following this concept, climate change and/or climate variability are included within E (exposure), coastal instability is included in S (sensitivity) and AC (adaptive capacity) is represented by economic and ecological parameters of sensitivity.

The CVI provides the data of Exposure and Sensitivity for coastal areas of Timor-Leste. In this context sea level rise combined with tidal range and wave characteristics are classified as ***Exposure,*** while, coastal instability which is composed of slope, geomorphology and erodibility is considered as ***Sensitivity***. The CVI (as purely physical parameters) does not cover parameters for adaptive capacity. These parameters still need to be defined to be able to calculate the V (vulnerability) according to the formula presented above.

The modified CVI was developed in two steps, a) developing vulnerability index, b) developing modified CVI by merging CVI with vulnerability results.

The analysis of the socio-economic characteristics of Timor-Leste (see Chapter 5) has shown that critical indicators causing vulnerability of people living in coastal areas are infrastructure, the socio-economic structure as well as the ecosystem exposed to coastal hazards. Based on this result, the index of vulnerability was defined by including proxy data for each of these vulnerability indicators.

Figure 7.1 provides an illustrative overview on vulnerability indicators included in this project.

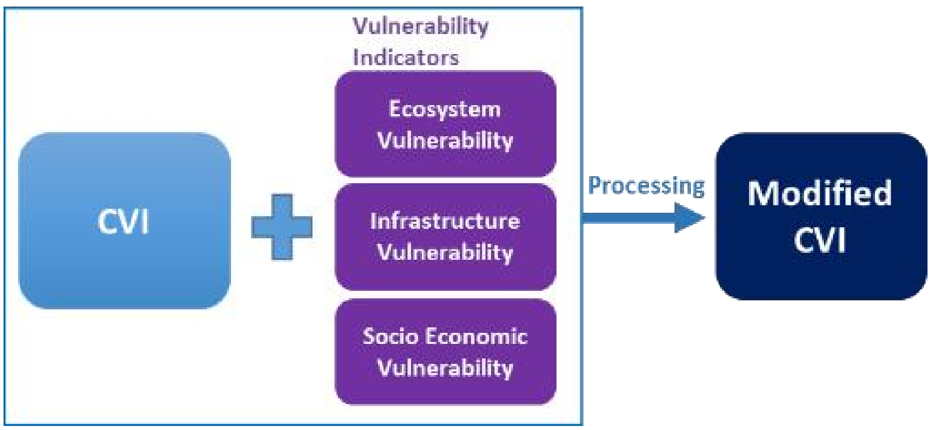


Figure 7.1 Concept in Developing Modified CVI

In the framework of this report, *the results of the CVI are perceived hazards* as they relate to the potential threat of coastal destruction. Results contain physical threats of coastal erosion and/or accretion/sedimentation due to coastal erodibility or instability and dynamical oceanographic processes (wave, tide and sea level rise).

The CVI is then modified or extended as to adopt other vulnerability indicators, i.e. infrastructure vulnerability, socio-economic vulnerability (population density, level of education, etc.) as well as ecosystem vulnerability.

Table 7.1 Indicator and Data Source Used

Vulnerability indicator	Proxy data sources used
Infrastructure	Road length and node infrastructures
Socio-economic	Population density, dependency ratio, gender ratio and education level
Ecosystem	Mangrove forest area

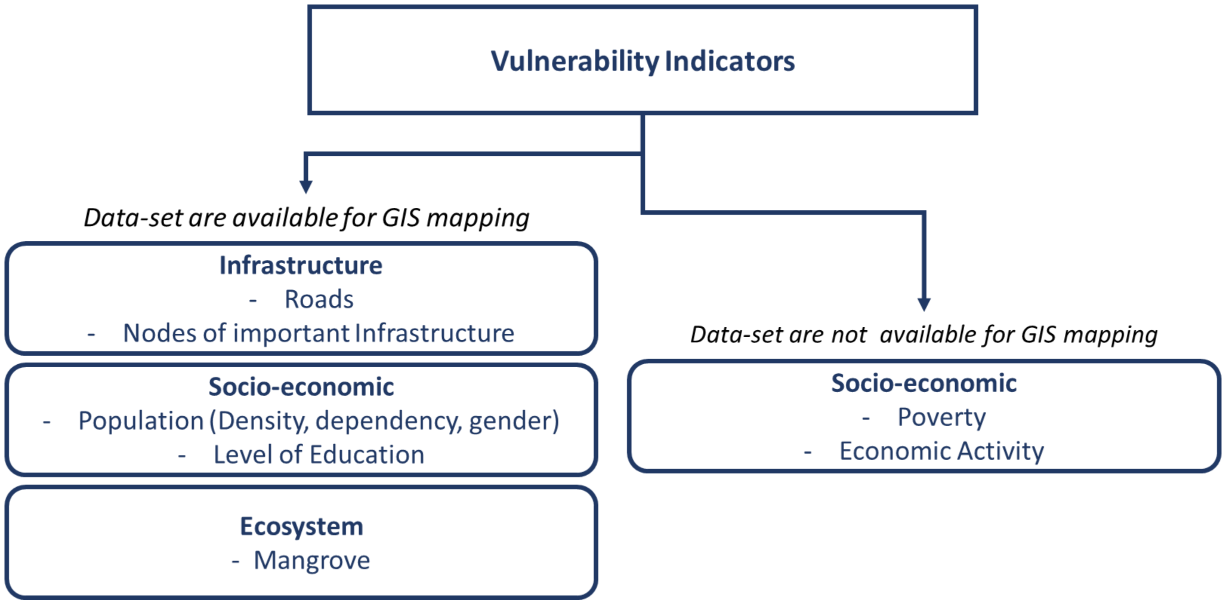


Figure 7.2 Data availability for modified CVI

As depicted in Figure 7.2, there are two types of vulnerability indicators being analysed. For the first one data to allow GIS mapping analysis is available, for the second one there is no data available to allow GIS mapping analysis. To close this gap, data availability was complemented by analysis based on literature review and expert's observation of the situation on-site during field visits and the results are included in the report in text form.

The data used for each indicator are classified to represent "very low" until "very high" vulnerability depending on the impact exerted on the system. The value of each indicator is multiplied by the indicator's weight. Subsequently, the final vulnerability for each selected indicator is represented in the following equation.

$$V_x = aX_1 + bX_2 + cX_3 \ldots$$

V_x = Vulnerability value

$X_1, X_2, X_3 \ldots$ = Vulnerability Indicator

a, b, c,…… = Weight for each Indicator

The final vulnerability value is calculated through the equation above and again classified from "very low" until "very high". The spatial distribution mapping for the vulnerability assessment is conducted in GIS for all spatial related processes producing a final vulnerability map. The weight for each indicator is set based on expert judgement, following the principle of Analytical Hierarchy Process. It is done in accordance with the project aim, strategic issues in the country, and observation in the field. The more important an indicator is to the issue, the higher its weight.

The weighing of vulnerability indicators is presented in Figure 7.3. It shows that the CVI results, which are regarded as perceived coastal hazards, are weighed the same as the vulnerability index (both 50%).

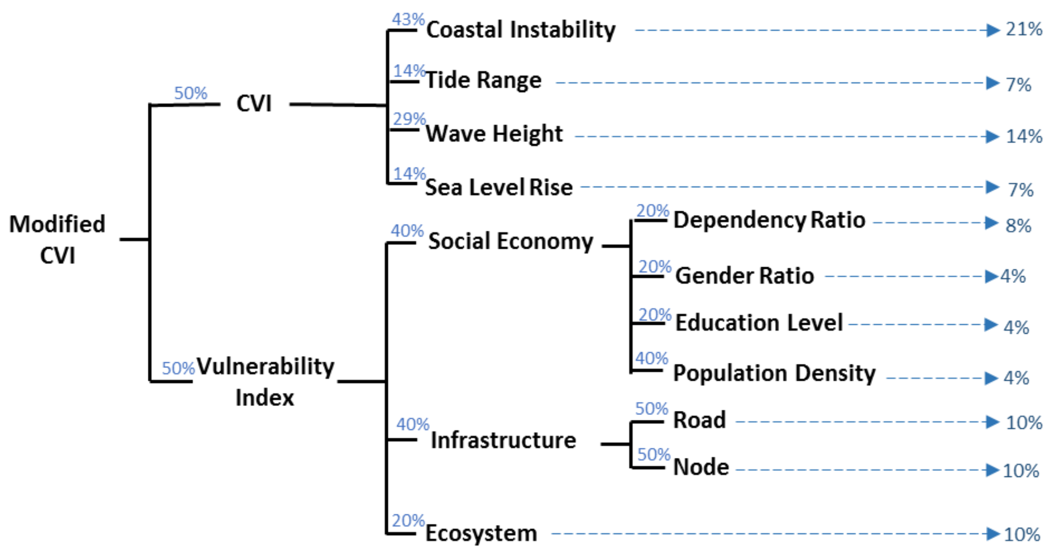


Figure 7.3 Indicators Weight on Developing Modified CVI

7.2 Vulnerability Assessment

As stated above, the vulnerability index is composed by integrating three components: socio-economic vulnerability, infrastructure vulnerability and ecosystem vulnerability. In total, seven proxy data sources will be used to define these indicators:

1. Socio-economic vulnerability will be defined by population density, dependency ratio, gender ratio, and education level;
2. Infrastructure vulnerability includes road infrastructure and node infrastructure;
3. Ecosystem vulnerability is represented by mangrove forest area

Details for each indicator with consideration, indicator explanation and constraints are shown in the following table.

Table 7.2 Vulnerability Indicators

INDICATOR	PROXY DATA	DESCRIPTION	MEASUREMENT	INDICATOR SOURCE	CONSTRAINTS	EXPLANATION
Socio-economic	Population Density	This component indicates the number of people potentially impacted by hazards in the area	Ratio between population and road length (road length is used as a proxy of developed area, considering that settlements are built alongside	Census data published by the GoTL 2015	Population density cannot be calculated based on settlement area. Thus, population density is	A higher ratio indicates higher vulnerability, as a higher number of people would be affected by climate change impacts.

INDICATOR	PROXY DATA	DESCRIPTION	MEASUREMENT	INDICATOR SOURCE	CONSTRAINTS	EXPLANATION
			the road)		calculated by using road length, since developed areas are situated along roads.	
	Dependency Ratio	This indicator shows the amount of people of the non-working age compared to those of the working age.	Dependency ratio measures the number of dependents, population aged zero to fourteen and over the age of sixty-five in relation to the total population aged fifteen to sixty-four.	Census data published by the GoTL 2015	-	A higher ratio indicates higher vulnerability, as the population faces higher burdens in supporting the non-working population.
	Gender Ratio	Ratio between women and men determines the level of adaptability because women often face social constrains, receive less education and are excluded from political and household decision-making processes. (UNDP 2013)	Gender ratio between men and women	Census data published by the GoTL 2015	-	A higher gender ratio indicates higher vulnerability as a bigger part of the population would be vulnerable to the effects of climate change.
	Education Level	Education level in the context of adaptation to climate change defines how somebody prepares for and responds to the impacts of climate change.	Ratio between people who receive secondary education with people who do not receive secondary education	Census data published by the GoTL 2015	-	In this study people not receiving secondary education are classified as more vulnerable.
Infrastructure	Infrastructure (Road)	A harmed infrastructure network such as damaged main roads affects the society's activities and leads to economic loss.	Index that combines the information on road length, road type and elevation	Data using shapefile of road infrastructure of Timor-Leste from www.Openstreetmap.org and	-	The road infrastructure indicator combines three information: road length, road type, and road elevation (based on DEM Data 0-20 Meters)

INDICATOR	PROXY DATA	DESCRIPTION	MEASUREMENT	INDICATOR SOURCE	CONSTRAINTS	EXPLANATION
				Digital Elevation Model (DEM) Data		To develop road vulnerability, road length is multiplied with road class, which consists of road type and elevation. Therefore, the unit for road infrastructure is Km Road Class has a value 1 – 5 (very low - very high)
	Infrastructure (Nodal)	Critical infrastructure is crucial in case of emergencies. Vulnerability increases if important infrastructure is damaged by natural disasters.	Number of critical infrastructure (Airport, Helicopter Land Zone, Seaport, Health Facility, Education Facility and bridges)	Data obtained from Timor-Leste District Atlas.	-	The higher the numbers of node infrastructure in an area of up to 20 meters, the more vulnerable the area.
Ecosystem	Mangrove Area	Mangroves are considered an ecosystem exposed to coastal hazards	Percentage of coastline covered by mangroves	Data using shapefile of mangrove area of Timor-Leste From Google Earth	-	The higher the percentage of mangrove areas the higher the vulnerability

All of the indicators are classified from very low to very high level, grouped according to the range for each class as shown in the following table.

Table 7.3 Vulnerability Indicators Rank

No	Vulnerability Indicators	Unit	Rank				
			Very Low	Low	Moderate	High	Very High
			1	2	3	4	5
(a)	Road Infrastructure	Km	0.031 - 7.712	7.713 - 19.928	19.929 - 37.371	37.372 - 65.206	65.207 - 165.120
(b)	Node Infrastructure	Unit	0-2	3-8	9-17	18-29	30-49
(c)	Population Density	People/Km	0-113	114-215	216-399	400-916	917-1775
(d)	Dependency Ratio	%	37-60	61-82	83-96	97-110	111-132
(e)	Gender Ratio	%	81-91	92-95	96-100	101-105	106-114
(f)	Education Level	%	36-51	20-35	14-19	9-13	3-8
(g)	Mangrove Area	%	0-5	6-19	20-30	36-55	63-86

The vulnerability index comprised of infrastructure vulnerability (weighted 40%), socio- economic (weighted 40%) and ecosystem vulnerability (weighted 20%). Weight for each indicator was determined based on expert judgement. Reasoning behind the weight setting of indicators are stated below:

a. Socio Economic Vulnerability: Coastal hazards in this study are categorized as slow-onset hazard (Coastal Instability and Sea Level Rise). While communities emphasized impacts on livelihoods and other socio-economic aspects, they do not always relate this directly to coastal hazards, but rather to other factors such as flooding, landslides and droughts. Socio-economic vulnerability is therefore one of the important factors to take into consideration while formulating adaptation strategies. Population density has been assigned twice the weight of the other socio-economic indicators as it reflects the number of people that will be affected, while the other indicators focus on the characteristics of those affected, as well as their capabilities to respond to or cope with hazards.

b. Infrastructure Vulnerability: infrastructure in Timor-Leste, especially road infrastructure and some critical facilities is mostly located near the shoreline. According to the information gathered during field survey conducted by the team, several roads are damaged by the effects of erosion, high wave and storm incidents. Roads in the country are highly important to 1) mobilize the population and 2) for goods' distribution acting as a major driver for economic expansion. In this context, the main road in the north is used for the transportation of goods between Timor-Leste and Indonesia. In addition to transportation facilities, node infrastructures have a vital function to protect citizens in moments of emergencies. Schools are often used as shelter and health facilities offer medical treatment. For these reasons and considering the serious risks of infrastructure alteration for the population, the weight for this indicator has been adjusted by increasing its value to 40%.

c. Ecosystem Vulnerability: mangrove forests are a vital asset and resource for Timor-Leste. Degradation of these areas represents exposure rather than serves as adaptive capacity that reduces coastal vulnerability. The condition of mangrove forest in Timor-Leste also keeps degrading and as a consequence the function of mangrove to protect shoreline is decreasing. Ultimately, considering the vital role of these areas for the country, mangrove vulnerability is accounted as one vulnerability component in this assessment. Due to the limited availability of ecosystem data suitable for the GIS process, mangrove has been selected as the only proxy used for the ecosystem vulnerability.

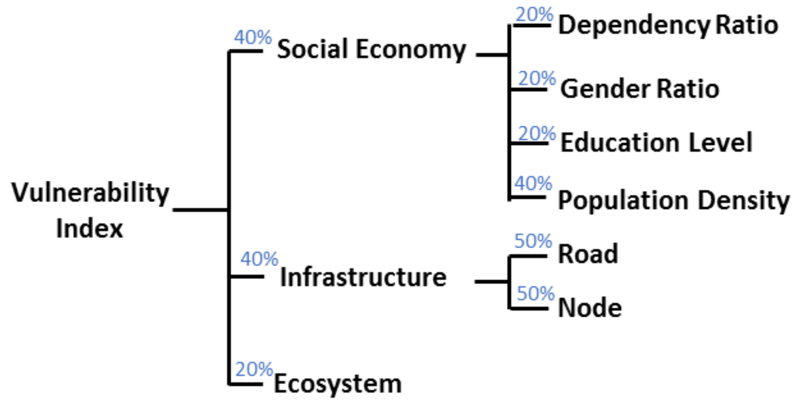


Figure 7.4 Indicators Weight on Vulnerability Index

7.2.1 Analysis of Socio-Economic Vulnerability

Socio-economic aspects play a major role when defining vulnerability of the coastal areas of Timor-Leste. They are a key pillar determining the vulnerability of those living in coastal areas and influence the adaptive capabilities of coastal communities substantially. The following describes different relevant socio-economic factors and the role that they are playing in coastal areas of the country. There are 4 indicators representing socio-economic vulnerability for this study: population density, dependency ratio, gender ratio, and level of education.

Population Density

In 2015, the total population of Timor-Leste was 1,183,643 inhabitants, rising by 29 percent since 2004 and an annual growth rate of 2.6 percent (UNDP 2017 b).

One important aspect to define vulnerability in coastal areas is the population density, as the number of people affected by climate change impacts differs substantially depending on the people living in coastal areas and adaptation strategies need to be adjusted accordingly. Coastal area is represented by sucos located along the coast and within 20m of elevation. Population density in Timor-Leste is at an average of 80 per square kilometre. In coastal sucos this population density varies significantly depending on the different municipalities. Coastal municipalities with high density include Dili, with an overall population of more than 230,000 and a density per square kilometre of 2,745, followed by Baucau, Oé-cusse and Covalima. Overall population density is higher in coastal sucos than in the average of the country, with only Ainaro and Atauro being less densely populated then the average of Timor-Leste.

Table 7.4 Population density in coastal municipalities

Name of municipality	Population in coastal sucos	Ha of sucos in coastal sucos	Density per Ha	Density per km^2
Ainaro	10,299	24,820	0.41	41.49
Atauro	9,274	14,245	0.65	65.10
Baucau	46,891	4,319	10.86	1,085.66

Name of municipality	Population in coastal sucos	Ha of sucos in coastal sucos	Density per Ha	Density per km^2
Bobonaro	14,179	4,282	3.31	331.15
Covalima	40,168	4,619	8.70	869.66
Dili	230,928	8,412	27.45	2,745.21
Lautem	26,785	8,976	2.98	298.41
Liquiçá	42,758	8,455	5.06	505.71
Manatuto	17,447	7,200	2.42	242.31
Manufahi	15,289	4,829	3.17	316.63
Oé-cusse	32,042	3,580	8.95	895.10
Viqueque	34,759	6,295	5.52	552.16

Within the modified CVI framework, for calculating population density vulnerability, road length has been used as a proxy to population density. Road length is one important factor to define the status of development of a region. Taking that into account, population density is calculated based on number of population divided by road length. The higher the population density, the more vulnerable in the context of exposure to coastal hazards.

When analysing the different coastal sucos based on this measure, a number of sucos scattered in several municipalities have a high population density. In the northern part, almost all sucos located in Dili (Becora, Culu Hun, Bairro Pite, Fatuhada, Acadiru Hun, Santa Cruz, and Macarenhas) can be considered of high population density. In the southern part, especially Viqueque (Macadique and Matahoi) counts for a number of highly populated sucos.

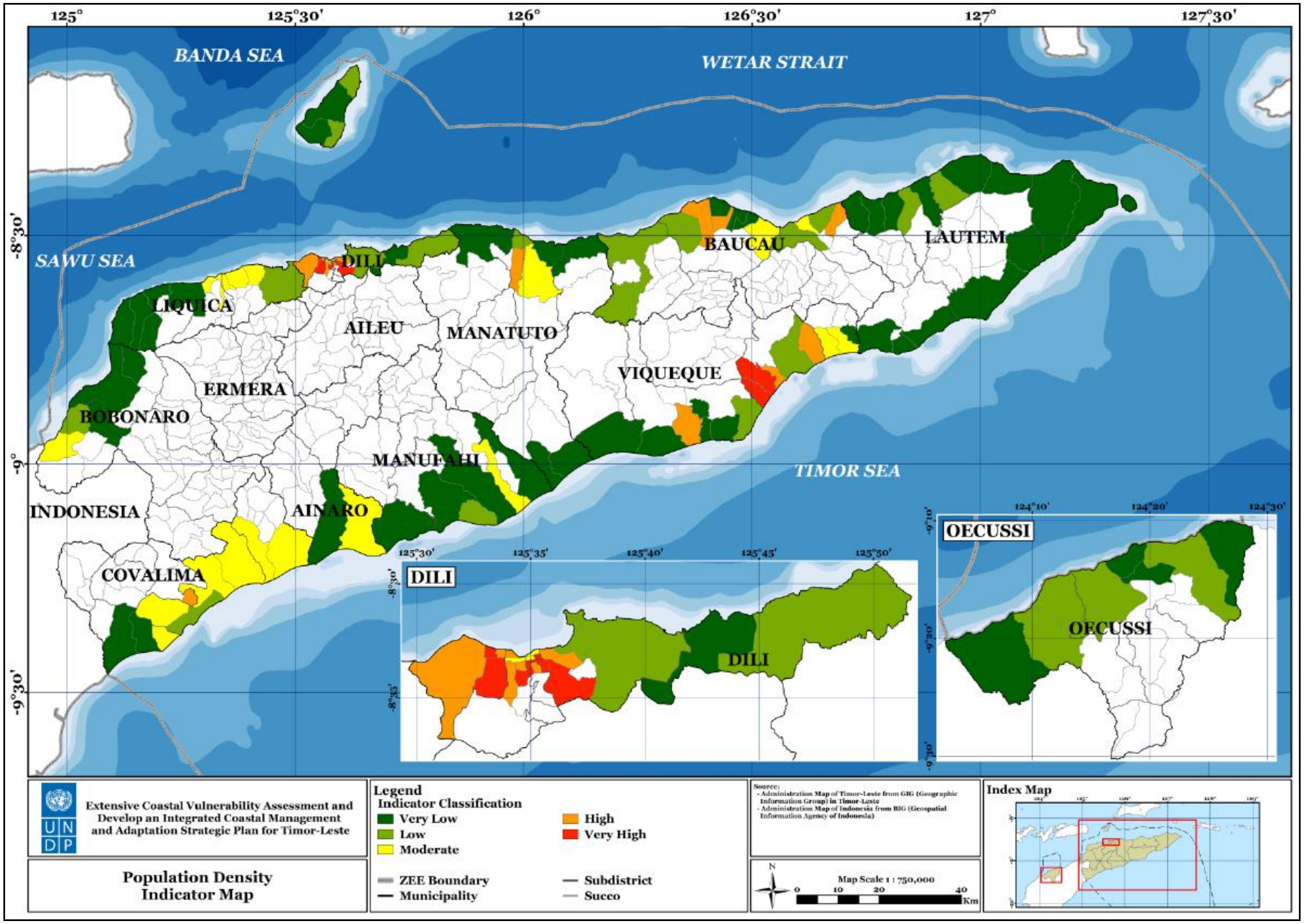


Figure 7.5 Map of Population Density Indicator

Dependency Ratio

As part of the population of the coastal sucos, there are some groups of people that are overall more vulnerable than others. This accounts for example for young people (below the age of 15), older people (over the age of 65). Timor-Leste is the sixth youngest country in the world and has one of the Asia-Pacific region's youngest populations, with a median age of 19.6. According to the 2015 census, 39 percent of Timor-Leste's total population is below the age of 15; only 6 percent of the population is over the age of 65 (UNDP 2017 b).

When describing vulnerable population by age, dependency ratio is used as a measurement. Dependency ratio measures the number of dependent population (i.e.: aged zero to fourteen and over the age of sixty-five) to the total population aged fifteen to sixty-four. This indicator shows the amount of people of nonworking age compared to the number those of working age. The high ratio in this study means the population are more vulnerable because the working population faces a greater burden in supporting the non-working population.

In many coastal areas, out-migration to more urban centers leave those of more vulnerable to climate change, such as children and elderly, as well as women behind, while the economic more productive population moves towards places such as Dili. In this sense, census data from the 2015 census show that in Dili the percentage of the population more vulnerable to climate change due to the age range is of around 35%, while in all other municipalities this percentage is between 44% and almost 52%, the municipalities with the highest percentage of vulnerable population being based in Viqueque, Lautem and Ainaro. (MoF 2015)

Municipality	% of Population 0-14 in coastal sucos	% Population between 15-65 in coastal sucos	% of Population older than 65 in coastal sucos	% of vulnerable population by age range
Ainaro	40.51%	50.27%	9.22%	49.73%
Baucau	38.74%	55.24%	6.02%	44.76%
Bobonaro	41.91%	52.08%	6.01%	47.92%
Covalima	37.95%	55.52%	6.53%	44.48%
Atauro	38.13%	55.27%	6.60%	44.73%
Dili	33.50%	64.52%	1.97%	35.48%
Lautem	43.76%	48.62%	7.61%	51.38%
Liquiçá	38.07%	56.32%	5.61%	43.68%
Manatuto	38.17%	55.99%	5.84%	44.01%
Manufahi	39.12%	54.18%	6.70%	45.82%
Oé-cusse	41.11%	53.60%	5.30%	46.40%
Viqueque	41.20%	49.53%	9.27%	50.47%

Overall the results show that vulnerability with regards to dependency is highest in the Eastern and South- Eastern part of Timor-Leste, with the most vulnerable sucos being: Rairobo in Bobonaro, Illiomar II, Trilolo, Baduro, Com, and Muapitine in Lautem, Irabin de Cima, Maluro, Watu Dere, Babulo, and Vessoru in Viqueque. The results for dependency ratio are represented in Figure 7.6.

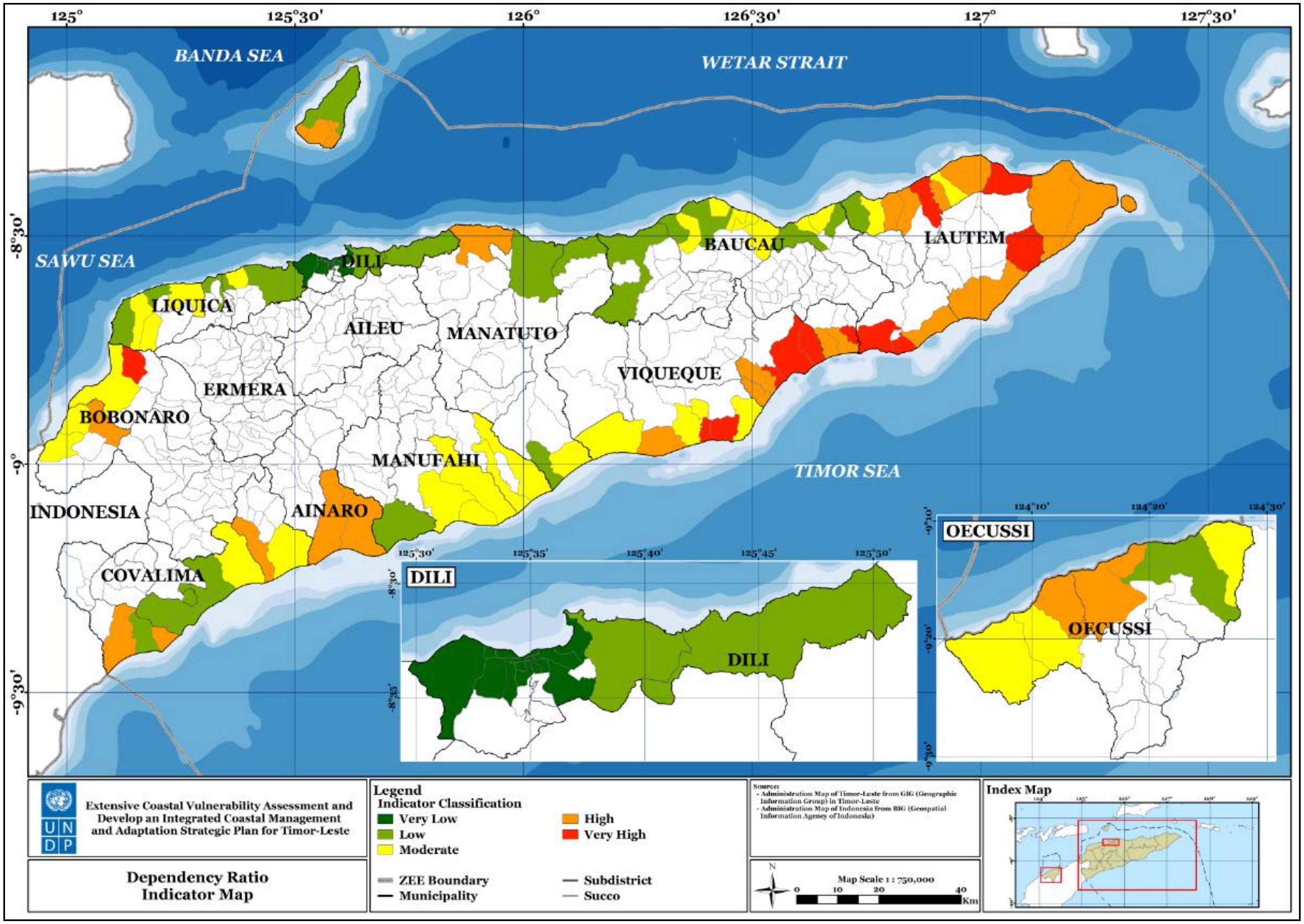


Figure 7.6 Dependency Ratio Indicator Map

Gender Ratio

Gender is another important aspect that shows vulnerability with regards to climate change. Overall women would rather stay at home, have less education and are economically less independent, which also makes them more vulnerable to the impacts of climate change. In general terms, the gender ratio between women and men in Timor-Leste is 48.84%. In coastal sucos this ratio (based on data from the 2015 census) is 49.22%. In some of the most rural areas in municipalities such as Lautem or Viqueque this ratio goes up to 53%, as can also be seen with regards to the level of vulnerability by suco. The result for gender ratio is represented in Figure 7.7.

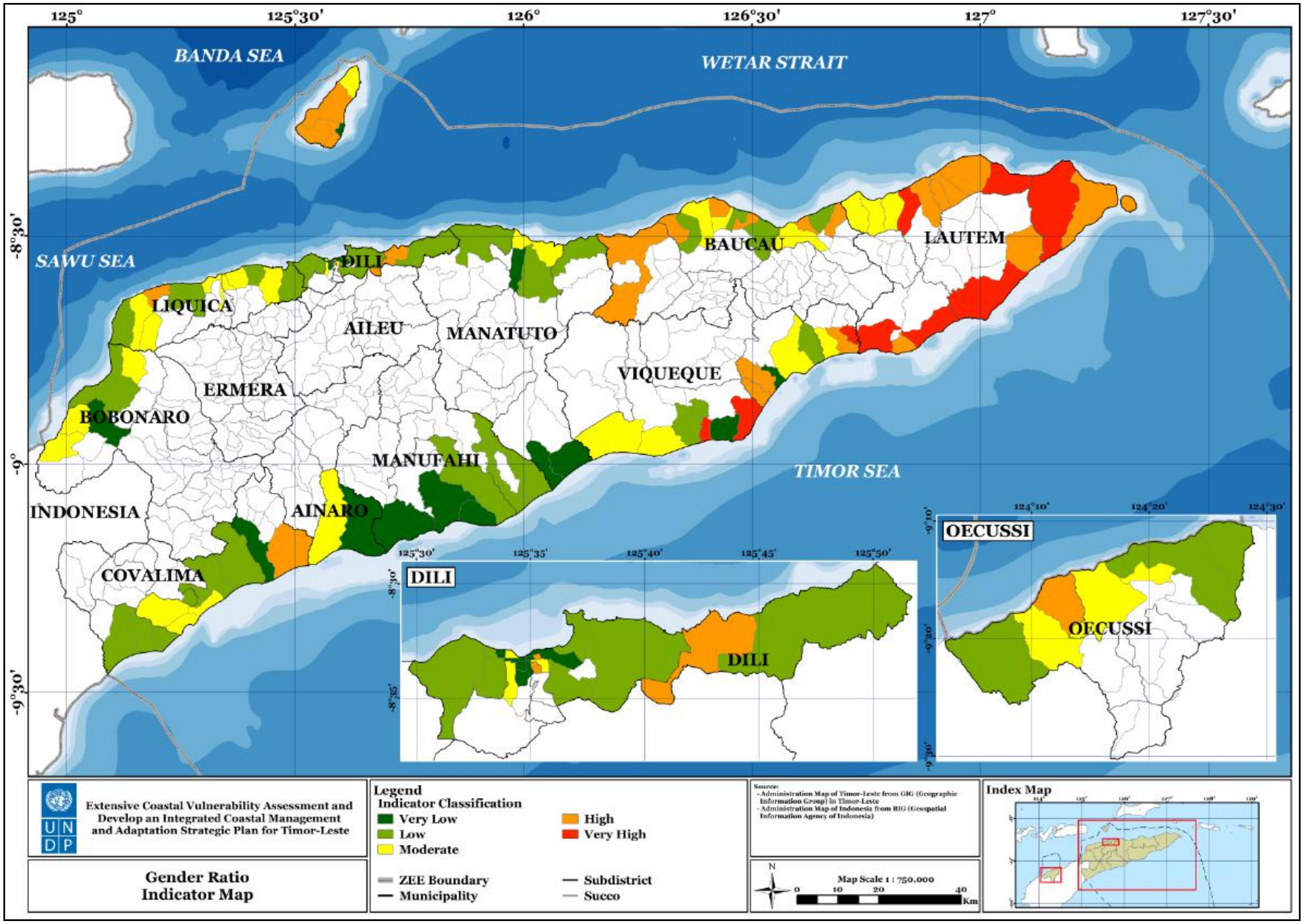


Figure 7.7 Gender Ratio Indicator Map

Education Level

Education is one of the most important means of reducing vulnerability and increase adaptive capacity of the population because it plays an important role with respect to coping with hazards. Education improves people´s awareness of the natural hazards that affect their community and the ability to cope with them. To improve education is one of the Government´s priority goals. The main challenge to improve the quality of education is reducing urban - rural inequalities with regards to access to education and relevance of education (e.g. acquisition of practical skills would improve employability and reduce vulnerability) (UNDP 2017 b).

According to the 2015 census, the percentage of population in coastal sucos receiving education varies between 55.55% in Oé-cusse and 77.34% in Dili.

Several factors are relevant to understand these discrepancies (UNDP 2017 b):

- access to schools / long distances to schools in more rural areas,
- poor quality of education and absence of qualified teachers especially in rural areas,
- widespread poverty leading to many children being malnourished and frequently sick

When it comes to secondary education and above (technical schools and universities), the access rate is by far highest in Dili with almost 38%, as it is the economic and cultural hub of the country. Lowest average rate of population receiving secondary education can be found in Bobonaro with an overall percentage of only 9%, followed by Lautem and Oé-cusse with roughly 13%. At the same time the access to education varies immensely between the different sucos in the coastal area of a same municipality. For example, the access rate to secondary education in the municipality Covalima varies between 24% in Debos and 9% in Raimea.

Municipality	% of Population receiving education in coastal suco	% of population receiving secondary education and above in coastal sucos
Ainaro	62.26%	14.43%
Baucau	66.19%	19.18%
Bobonaro	59.12%	8.65%
Covalima	67.78%	17.71%
Atauro	69.27%	14.58%
Dili	77.34%	37.86%
Lautem	64.69%	13.10%
Liquiçá	61.69%	16.14%
Manatuto	71.27%	17.50%
Manufahi	66.91%	14.20%
Oé-cusse	55.55%	13.36%
Viqueque	61.41%	11.87%

Vulnerability with regards to the level of education is generally high, especially in rural areas. This is reflected in the educational vulnerability map by suco, see Figure 7.8. Sucos with the highest vulnerability with regards to the educational level are mostly located in Bobonaro and Oé-cusse.

Adaptation capacity in urban vs. rural areas

Consultations in Dili and in Costa, Oé-Cusse (both urban areas) confirm higher educated individuals and households. When asking about the activities that enable them to cope with the consequences of natural hazards, participants in urban areas demonstrated better knowledge about the causes of the hazards in their communities and therefore also a better risk perception. Moreover, the collected information suggests that they are more capable to react upon an event and undertake preparedness activities. In Dili, for example, the community started a Recycling Program to avoid that garbage blocks the drainage channel of the community. Both, in Dili and in Costa, participants showed to have better access to information on weather and climate and also on the development trends and options for their communities.

In rural areas, however, the options to respond to hazards are limited. People react by trying to safe their few belongings, moving their farming fields to new areas safe from hazards or in extreme situations even moving an entire settlement to a safer place. In this sense, the presence of extensionists or NGOs conducting specific projects and promoting concrete methods seems vital. For instance, in places such as Atauro Island, Betano and Clacuc, where MAF extensionists and NGOs are strongly active, participants recognized the importance of protecting mangroves forest and the local environment as a necessary prerequisite to cope with and also secure their communities from natural hazards. Education must therefore be considered as a key aspect in reducing community vulnerability and enhancing its adaptation capacity.

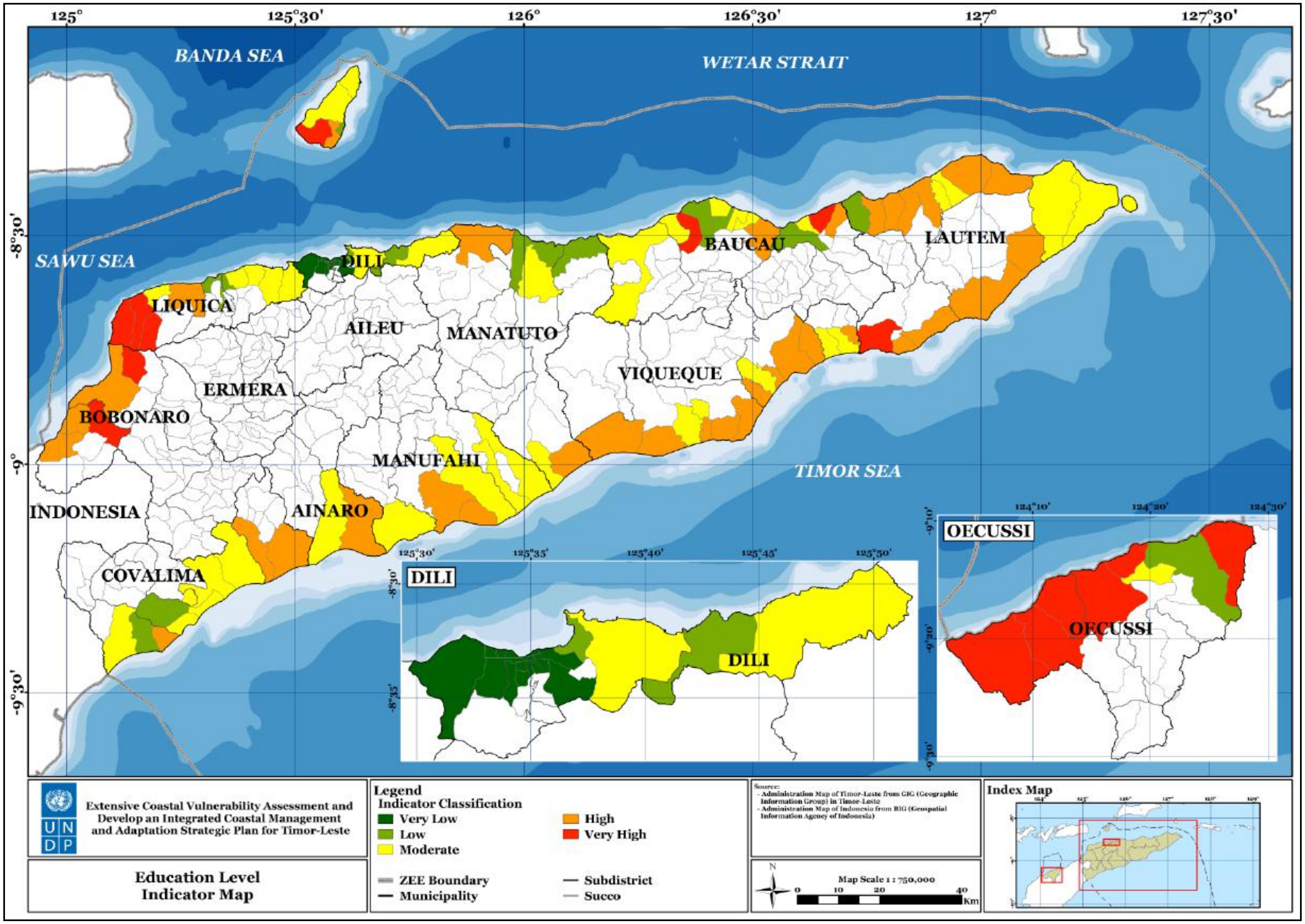


Figure 7.8 Vulnerability based on Education Level

Economic information:

Economic vulnerability and economic aspects play a major role, when it comes to vulnerability to climate change and the adaptive capacity. The impacts of climate change increase the vulnerability of poor people, as they will be the first to suffer the consequences due to limited adaptive capacity. In this sense, many communities in Timor-Leste, as a least developed country, do not have the possibility to cope with the effects of climate change, especially not in coastal areas.

On the suco level, detailed information on economic vulnerability, income distribution and other economic factors is not being gathered or availability is still limited. Therefore, data from the municipality level, as well as specific information such as poverty level and main economic activities have been selected for the analysis. These are not included in the calculation of the modified CVI, considering that the information cannot be compared on the coastal suco level. Yet, they are significantly relevant for the development of adaptation strategies.

Poverty

Similar to previous described socio-economic dimensions, the poverty data also varies significantly between the urban and the rural population: 14% of the urban population is affected by severe poverty whereas 46% of the rural population is affected by the same phenomenon. This is reflected in Dili having the least rate of people affected by severe poverty (8%). Coastal municipalities with the highest poverty rate include Oé-cusse (62.1%) and Ainaro (52.3%) (OPHI 2017).

Overall there is an important income gap between urban and rural populations and in urban areas, as well as those with the possibility to sell fish, livestock and cash crops in comparison to those that receive their income from crop sales. This explains higher income level in the northern coastal areas and the southern coast in comparison to for example Oé-cusse, where limited access to markets reduces access to income (MoI 2017).

Poverty data availability for modified CVI calculation

The Multidimensional Poverty Index (MPI) published by Oxford Department of International Development (OPHI 2017) comprises the newest data available on the economic condition of Timor-Leste. This index has been developed based on 10 indicators from the fields of health, education and living standards. For Timor-Leste, only the results of the MPI for the national and the municipality level are available. Thus, applying the MPI results as an indicator for the objective of this assignment, would deliver a distorted impression.

For instance, the results point out that Dili scores very low on the MPI Index. Consequently, all sucos in Dili will score exactly the same. This information, however, is not accurate enough. Community consultations and field survey have shown great disparity between communities within the same municipality and urban versus rural population. Atauro Island, which included in the results of Dili, for example, greatly differs from the estimations published for the population in Dili.

With that in mind, including the MPI Index as an indicator on the municipality level would suggest misleading knowledge.

Economic Activity in Coastal Areas

When comparing the data for economic activity in Timor-Leste, results show that overall 53% of all people are economically inactive, while 45% are employed. In coastal areas, the percentage of the inactive population (10 years and over) varies between almost 70% in Lautem and 42% in Ainaro (MoF 2015). The percentage of women being economically inactive is even higher, with a percentage of over 60% (Ibid.). Economically inactive population means those that are neither employed nor looking actively for work. The higher percentage of women defined as economically inactive can be explained by the highly patriarchal society of Timor-Leste, which affects the participation of women in economic activities. Also, economic inactivity would include any activities related to unpaid care work and subsistence agriculture, which are both a heavy burden but not considered an economic activity in the sense of the statistics (UNDP 2017 b).

Table 7.5 Percentage of Economically Inactive Population in Coastal Areas

MUNICIPALITY	% of economically inactive population in coastal areas
AINARO	42.74%
BAUCAU	59.61%
BOBONARO	49.87%
COVALIMA	51.01%
ATAURO	45.57%
DILI	61.09%
LAUTEM	68.92%
LIQUIÇÁ	55.30%
MANATUTO	61.22%
MANUFAHI	54.74%
OÉ-CUSSE	45.73%
VIQUEQUE	52.03%

Access to income for women

According to our study, both, women and men, are affected in a similar manner by natural hazards. There are, however, some specific issues such as income generation. Traditionally, women in rural areas are in charge of the activities surrounding the house. That means women are responsible for the gardens, planting and harvesting crops for own consumption around or close to the house. Only in few cases of surplus, women sell their products in the nearby markets or along the roads. However, this might also be difficult is some areas, due to limited accessibility. This division of labor makes it difficult for women to access regular income and makes them dependent on men's economic activities.

Women empowerment

Interestingly, in some places suco leaders confirmed a new trend: women start to create small businesses for selling products, which gives them the opportunity to even earn more money than men. In one specific case, women in Aubeon, started jointly growing maize, which is collected and sold by a cooperative in Natarbora. The project has been so successful that a second group, composed mainly of men, emulated the activity. In other areas like on Atauro Island and Costa, Oé-Cusse, it has been expressed that some women start earning more money working in the growing tourism sector. Women working in this sector that participated in the consultation were even able to communicate in English. Access to financial resources empower women and allow their families to improve their living conditions and support them in responding to climate change impacts and cover from them.

Major economic activities in coastal areas are agriculture and fishery. Most people are employed in these sectors and they are the most important income sources and livelihoods for the economically inactive population, especially when it comes to subsistence of the population. 75% of the population depend on subsistence agriculture (G. C. GCCM 2008).According to the livelihood profiles developed by the Consolidated Livelihood Exercise for Developing Resilience; there are 5 livelihood profiles that can be differentiated in coastal areas in Timor-Leste:

1) Large scale fishing, agriculture and tourism in Atauro,
2) Northern coastal agriculture and fishing,
3) South Eastern coastal agriculture and large-scale livestock,
4) Southern coastal agriculture and
5) Oé-cusse coastal agriculture and large-scale livestock.

Urban areas and fishing communities such as in Atauro Island or Dili are the most resilient to climate change, which can be traced back to higher incomes due to access to small industrial activities and tourism combined with diversified livelihoods. Vice versa, communities that are depending on a few highly- climate sensitive commodities and do not have sufficient access to income are the most vulnerable (MoI 2017).

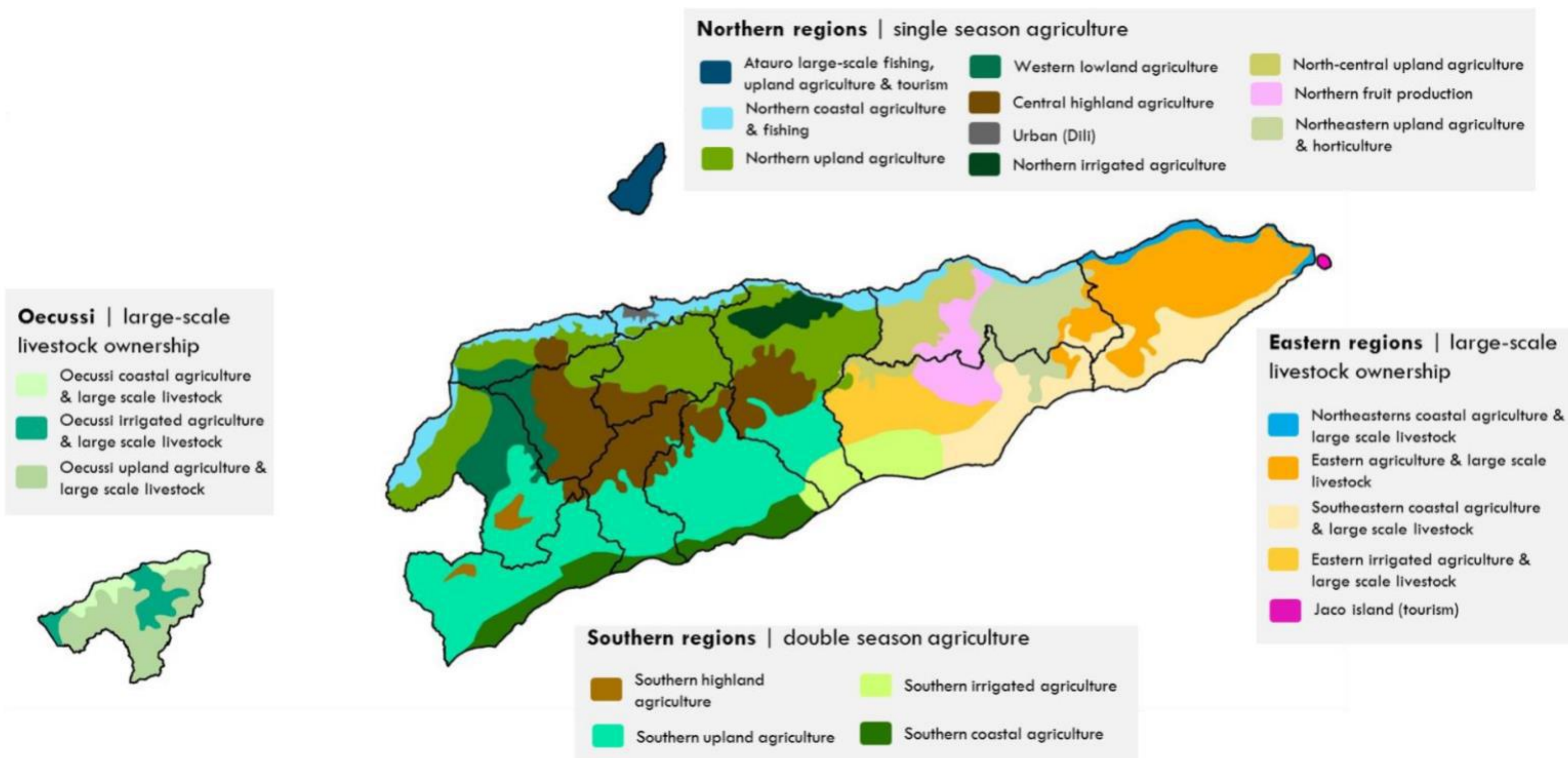


Figure 7.9 Agricultural Land Use (Source: MoI 2017)

The percentage of employed people in agriculture and fishery is of more than 70% in Ainaro, Manufahi, Manatuto and Viqueque. Only in Dili and Baucau this differs, with Dili as the major economic hub of the country accounting for only 13% of agricultural and fishery workers, and Baucau still accounting for almost 50% of the entire workforce.

Table 7.6 Percentage of Employed People in Agriculture and Fishery

MUNICIPALITY	Total	Skilled agricultural and fishery workers	% of employed people in agriculture and fishery
AINARO	22,775	17,753	77.95%
BAUCAU	39,521	17,753	44.92%
BOBONARO	35,359	24,125	68.23%
COVALIMA	24,130	14,744	61.10%
DILI	74,077	9,614	12.98%
LAUTEM	18,470	11,966	64.79%
LIQUIÇÁ	24,227	16,766	69.20%
MANATUTO	15,369	11,143	72.50%
MANUFAHI	19,471	13,875	71.26%
OÉ-CUSSE	27,175	16,858	62.03%
VIQUEQUE	25,768	19,621	76.14%

Both agriculture and fishery are sectors that are vulnerable to the effects of climate change. At the very same time, they provide income opportunities for low income and poor communities that are highly vulnerable to the effects of climate change.

Dependence on agriculture and fishery for subsistence and livelihood

Data collected for this project demonstrates that communities rely mainly on agriculture and fishery for subsistence and livelihood, except in urban areas.

Regarding fishery, participants expressed their concern on declining activities due to intensifying effects of strong wind and waves. There is consensus in all communities that lately (difficult to define precise year) wind and wave intensity have been increasing. As small boats are used for this activity, fishing off shore becomes very dangerous. The only option left for this people is to shift their activities and focus only on farming. Furthermore, in two locations, Atauro Island and Costa, Oé-cusse, some participants also expressed that their fishing activities are at risk not only due to changes in the climate, but also because fish stock is declining, and the remaining fish are too small. This last issue has been linked to changes in the coral reefs but also to individual fishers coming from other areas and fishing 'illegally'. In Aubeon and in Clacuc fish ponds for aquaculture have been identified as part of a project from MAF to create new opportunities for people affected in this regard.

All communities highlighted that agriculture is strongly affected by natural hazards, especially due to flooding/drought events and a shift of the rainy season. These challenges are directly linked by the participants to changes in the climate in general, affecting the production of their main crops such as rice and maize and consequently affecting food security. Moving to new farming areas is the main adaptation activity undertaken within the communities. Often communities feel they neither have enough knowledge nor information nor financial resources to respond and act upon these challenges appropriately.

Examples of small actions undertaken by communities:

- the use of natural fences to protect fields and irrigation channels,
- reforestation projects along rivers to stabilize riverbanks or
- implementation of customary laws to protect important assets and resources.

Still, communities expect the government to take action on these issues affecting their economic and social livelihoods.

Socio- Economic Vulnerability Index

The socio-economic vulnerability index has been developed merging the results of the different indicators based on the weighing as described in Chapter 7.1. The result has been reclassified into different vulnerability levels from very low to very high.

The results show that in total there are three sucos, which have a very high socio-economic vulnerability index and seventeen sucos that have a high socio-economic vulnerability index.

All of the sucos with very high vulnerability index are characterized by

- high population density,
- high population dependency ratio,
- high gender ratio and
- low education level.

Three sucos, which have a very high socio-economic vulnerability index are located in the southern part of the country: Macadique, Matahoi, and Vessoru in Viqueque.

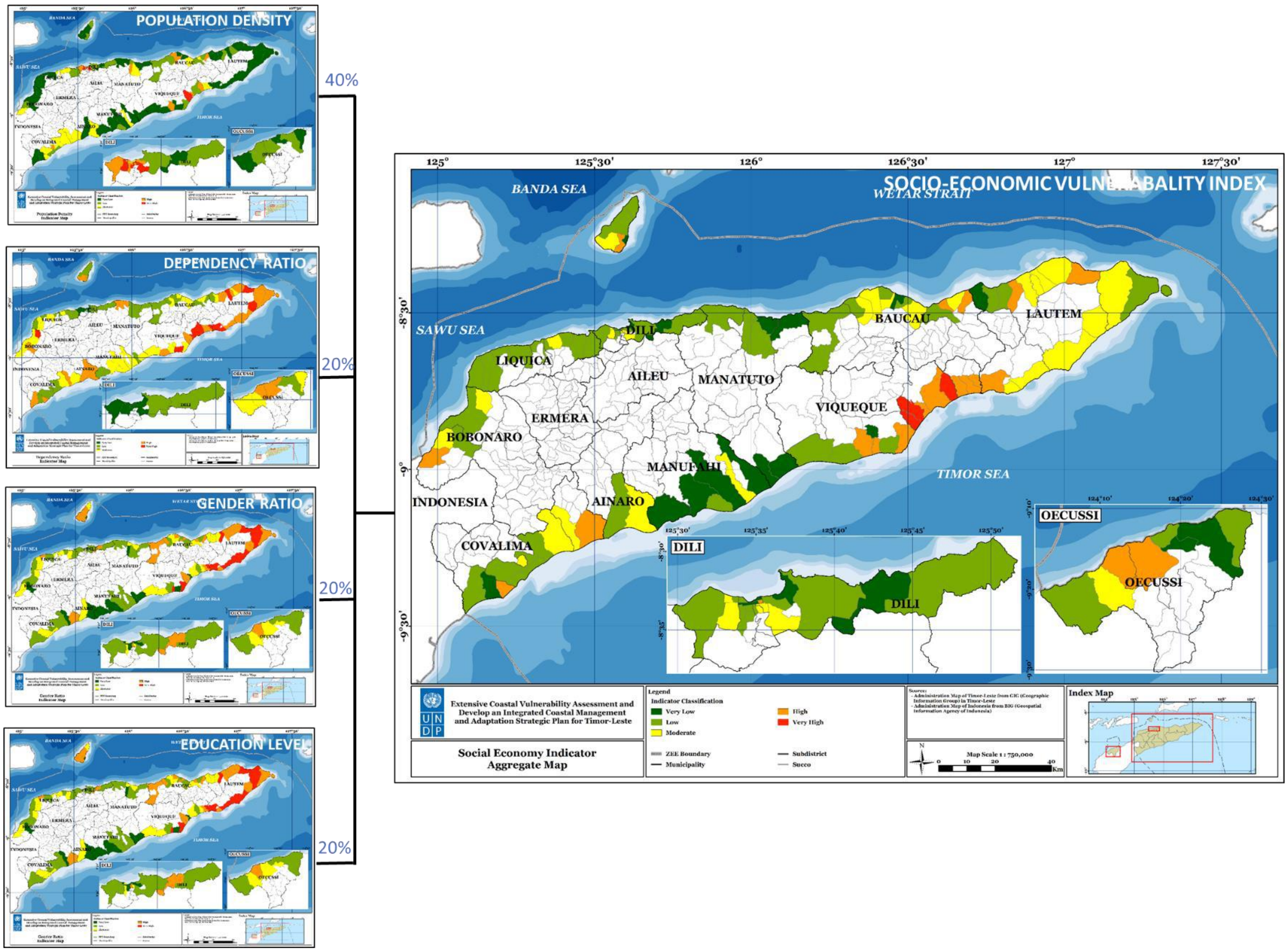


Figure 7.10 Process of Developing Socio-Economic Vulnerability Index

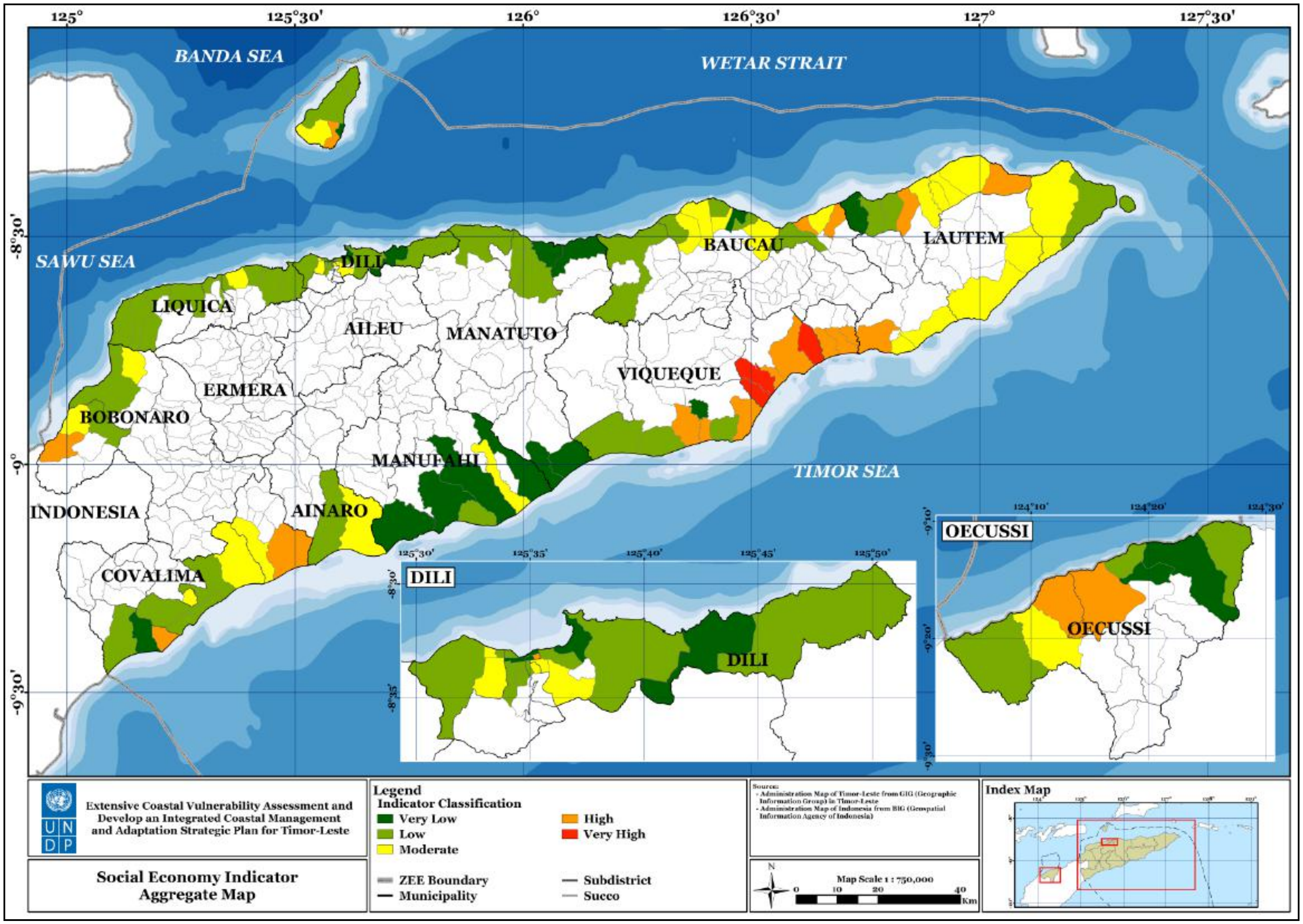


Figure 7.11 Socio-Economic Vulnerability Map

7.2.2 Analysis of Infrastructure Vulnerability

Climatic and non-climatic induced disasters have impacts on infrastructure, health and education facilities and settlements, creating significant development challenges. To further develop the country and reach the objectives of the national development plan, infrastructure development is at the core of development in Timor-Leste. One aspect to make sure that infrastructure is more resilient to climate change is the inclusion of climate proofing from the beginning. The cost of climate proofing is generally less than the cost of repairing and rebuilding infrastructure.

Currently the government is planning to build 11 buildings in the education sector (including Agriculture Building, Engineering Building and sector 1 of UNTL Campus; Polytechnic schools in Suai, Same and Lospalos; Fishery academy in Manatuto; and Reference Schools in Lospalos, Liquiçá, Aileu, Suai) (MoF 2017).These building have the opportunity to include climate proofing for infrastructure and serve as champions buildings.

In this section, infrastructure will be looked at as the basic transportation network, including roads, air and sea transportation facilities. In addition to the transportation network, this section also comprises basic infrastructure required to support livelihoods such as health facilities and education facilities.

For the development of the infrastructure vulnerability index, infrastructure will be divided into road infrastructure and node infrastructure.

Development of the index for infrastructure vulnerability:

To improve the accuracy of road and node infrastructure vulnerability, elevation and distance from shoreline has been taken into account to reflect the level of coastal hazards that they are exposed to. For this purpose, the 20-meter elevation considered for this report has been divided into five different elevation classes ranging from 0-3 meters to 14-20 meters. Infrastructure in low elevation will have a higher vulnerability index than infrastructure in higher places. The classes were valued from 1 (very low) to 5 (very high). Matrix to help define the elevation:

Table 7.7 Road and Node Infrastructure Indicators Matrix

		Distance (m)		
		0 – 100	100 – 200	>200
Road Elevataion (m)	0-3	VH (5)	H (4)	M (3)
	3-7	H (4)	M (3)	L (2)
	7-20	M(3)	L (2)	VL (1)

		Road Class (Only for Road Infrastructure Vulnerability)				
		Others	Residential	Tertiary	Secondary	Primary
Elevation + Shoreline distance (M)	1	VL (1)	VL (1)	L (2)	L (2)	M (3)
	2	VL (1)	L (2)	L (2)	M (3)	H (4)
	3	L (2)	L (2)	M (3)	H (4)	H (4)
	4	L (2)	M (3)	H (4)	H (4)	VH (5)
	5	M (3)	H (4)	H (4)	VH (5)	VH (5)

		Elevation Class (For Node Infrastructure
Elevation (M)	14-20	VL (1)
	11-14	L (2)
	7-11	M (3)
	3-7	H (4)
	0-3	VH (5)

Infrastructure development: Importance of correct planning

Investing in creating and improving existing infrastructure is a vital approach to enable people to cope with the challenges posed by natural hazards. In this context, sound planning and implementation is very important to assure that the developed infrastructure indeed results in improving the adaptation capacity of the community and does not exacerbate the effects of natural hazards.

Negative examples:
Weak Planning and/ or implementation of newly developed infrastructure projects have increased or worsened the effects of flooding during periods of heavy rain in Costa, Oé-cusse and Fatuhada, Dili. In both communities, participants expressed the challenges faced by flooding events resulting from dead end drainage channels not able to discharge the very high levels of water during raining periods, which end up flooding the community.

Another example was given in the Community Aubeon in Manatuto, where participants identified a rather new built bridge in the northern east part of the community disrupting the river flow and causing flooding of the community.

Node Infrastructure:

The node infrastructure data is from Timor-Leste District Atlas (OCHA 2008).It indicates points of important infrastructure in Timor-Leste. Node infrastructures included in this study are airports, helicopter land zones, seaports, health facilities, education facilities and bridges. To increase accuracy of data, all the node infrastructure within elevation 0 – 20 meters is selected and then classified from value 1 (very low) to 5 (very high) based on the elevation range. Infrastructure with low elevation will have a higher vulnerability index than infrastructure in higher places. The vulnerability of the node infrastructure of a suco is calculated by adding up the values for each single node infrastructure of the suco.

Suco Node Infrastructure Vulnerability:

(Node Infrastructure1 x Elevation Class) + (Node Infrastructure2 x Elevation Class) + ……….

Education and health facilities

The country is currently facing significant pressure to improve their educational facilities and health infrastructure, as about 70% of the existing buildings in the educational sector are in precarious conditions and improvement of quality and quantity of health facilities are deemed a pressing issue. The State Budget Book 3 on Infrastructure Fund shows that, for 2017 alone, the country allocated 2.419 Million US$ and 2 Million US$ to advance the provisioning of education and health facilities, respectively to be able to meet the national priority targets (MOF 2017).

Data from the Timor-Leste Atlas shows that many health facilities and schools are located close to the coast, especially in Dili, Liquiçá, Baucau and Covalima (the rather urbanized areas in the country). Those facilities are predicted to be affected first along with other population assets. Health facilities should be located in less vulnerable areas, assuring full functioning of health facilities when disasters strike. The same applies to education facilities, considering that many school buildings are used as evacuation points in the event of a natural disaster.

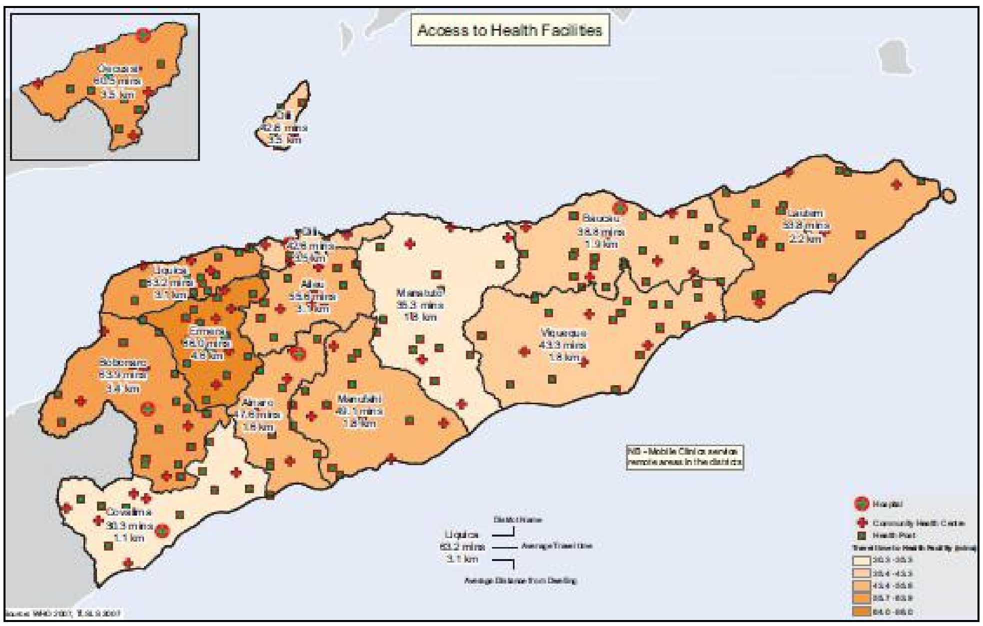


Figure 7.12 Location of Health Facilities in Timor-Leste (OCHA 2008)

Ports, Airports and Bridges

During the writing period of this report, the only infrastructure map available has been developed in 2008. An update of information is obtained from development plan reports and discussions with relevant stakeholders. Figure 7.13 below shows the location of airports and seaports in Timor-Leste.

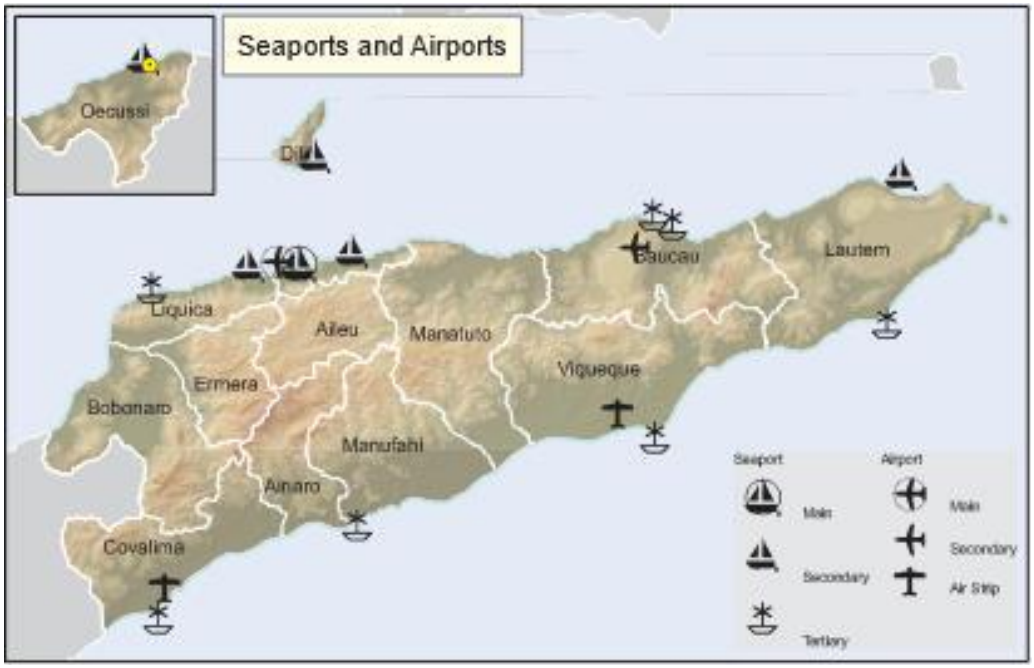


Figure 7.13 Location of Seaports and Airports in Timor-Leste (OCHA 2008)

The airports are located at the coast. Future rehabilitation of these facilities, and/or even new development shall take into account the level of vulnerability in the area, particularly with regards to coastal instability and other coastal hazards. As an example, the main international airport, President Nicolau Lobato in Dili, is planned to be expanded, allowing one million passengers per year by 2020. That means the runway will be extended and a new terminal building will be constructed. The runway will be extended towards and across Comoro River to a final length of around 2,500 metres. However, the physical vulnerability assessment shows that the coast in Comoro is highly vulnerable to the impact of sea level rise and coastal instability.

Similar aspects should be taken into consideration with other crucial infrastructure, such as ports, bridges and power plants, to assure and sustain the full functioning of these infrastructures in case of disaster. If infrastructure is already developed, climate proofing action must be taken to protect these infrastructures.

The results on node infrastructure vulnerability are presented in Figure 7.14.Vulnerability with regards to node infrastructure is highest in scattered regions in the northern and southern part. The most vulnerable suco in this context is Comoro in Dili. This can be explained by a number of important facilities in low elevation such as airport and seaport, education and health facilities as well as a bridge. Other sucos which have high vulnerability due to infrastructure located close to the coast are Tequino Mata in Baucau, Aidabaleten in Bobonaro, Camenaca and Raimea in Covalima, Bairro Pite in Dili, and Costa in Oé-cusse.

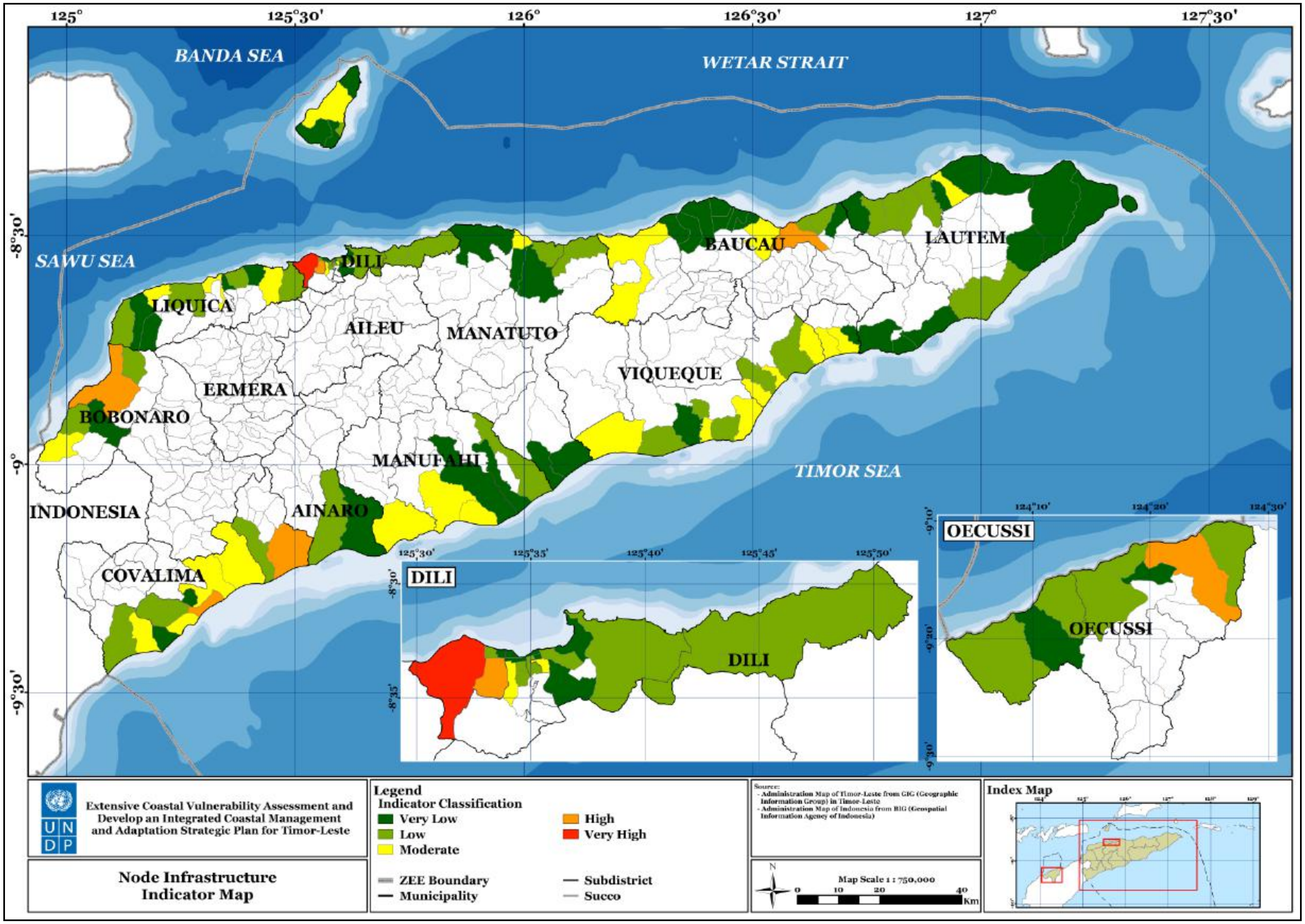


Figure 7.14 Node Infrastructure Indicator Map

Road Infrastructure:

Within the scope of this study, road is used as one additional proxy data source to determine infrastructure vulnerability. Roads are the primary means of transport and allow development as well as the delivery of resources to urban and rural areas. Existence of roads also helps to indicate the presence of infrastructure to be considered in the analysis, particularly in cases where infrastructure map/data is limited.

According to the GoTL roads are the most crucial infrastructure due to their indispensability for delivery services to other sectors such as health care, education, energy, etc. Existence of road infrastructure is essential for the development of the areas in general.

According to the country's Strategic Development Plan 2011-2030, around 90% of national roads and municipality roads are either in poor or very poor conditions, with only 10% in fair conditions. It was reported that road alignment does not meet the necessary standards and the drainage system is generally poor. During the field work, the team observed that many road segments have been improved, or are being currently renovated and even some new roads are built, e.g. the toll road from Suai. However, the team also observed that national roads are oftentimes constructed too close to the coast, and thus affected by severe coastal erosion, accelerating the deterioration process of the roads.

To assess road infrastructure vulnerability, three indicators are considered:

Table 7.8 Indicators of Road Infrastructure

Road infrastructure vulnerability Indicators	Description
Road length	The length of each single road is considered and measured in km.
Road type	All types of roads are included in the analysis: primary, secondary, tertiary, residential, and others.
Elevation	Road infrastructure selected for this assessment has an elevation between 0 and 20 meters.
Distance to Shoreline	Distance of each single road to shoreline is considered and measured in km.

Determining Road classes

Determining road classes was done based on three considerations: 1) roads closer to the shoreline are generally more vulnerable than those located in distant, 2) roads with low elevation are generally more vulnerable than those located in higher places, 3) primary roads are more important for main infrastructures than small roads and thus their vulnerability (low elevation and proximity to the coast) has a higher impact on infrastructure vulnerability.

Road classes help to determine to which extend certain road affects infrastructure vulnerability. Road classes are determined by first comparing road elevation with distance from shoreline. The results were then compared with the road types to obtain the determine road vulnerability. The result will be valued from 1 (very low) to 5 (very high).

To assess each suco´s road vulnerability, each road of the suco was given a road class, which was then multiplied with the length of the road. As a next step, all of the values for each suco road were added up.

Suco Road Vulnerability:

$$\frac{(\sum Road\ Class\ 1\ x\ \sum Road\ Lenght\ 1) + (\sum Road\ Class\ 2\ x\ \sum Road\ Lenght\ 2) + (\dots.)}{\sum Road\ Length}$$

Figure 7.15 depicts the types of road networks within the assessment boundary (within 20 metres of elevation). As presented in Figure 7.16, several suco in each municipality have highest road vulnerability such as Suco Atauro Vila/Maumeta, Beloi, Bidau Santana, Meti Aut in Dili Municipality, Suco Nunira, Samalari, Soba, in Baucau Municipality, Suco Batugade in Bobonaro Municipality, Suco Euquisi in Lautem Municipality, Umacaduac in Manatuto Municipality, Suco Motaulun in Liquica Municipality, and Suco Uma Uain Leten and Babulo in Viqueque Municipality. This is reflected in the vulnerability map for road density below.

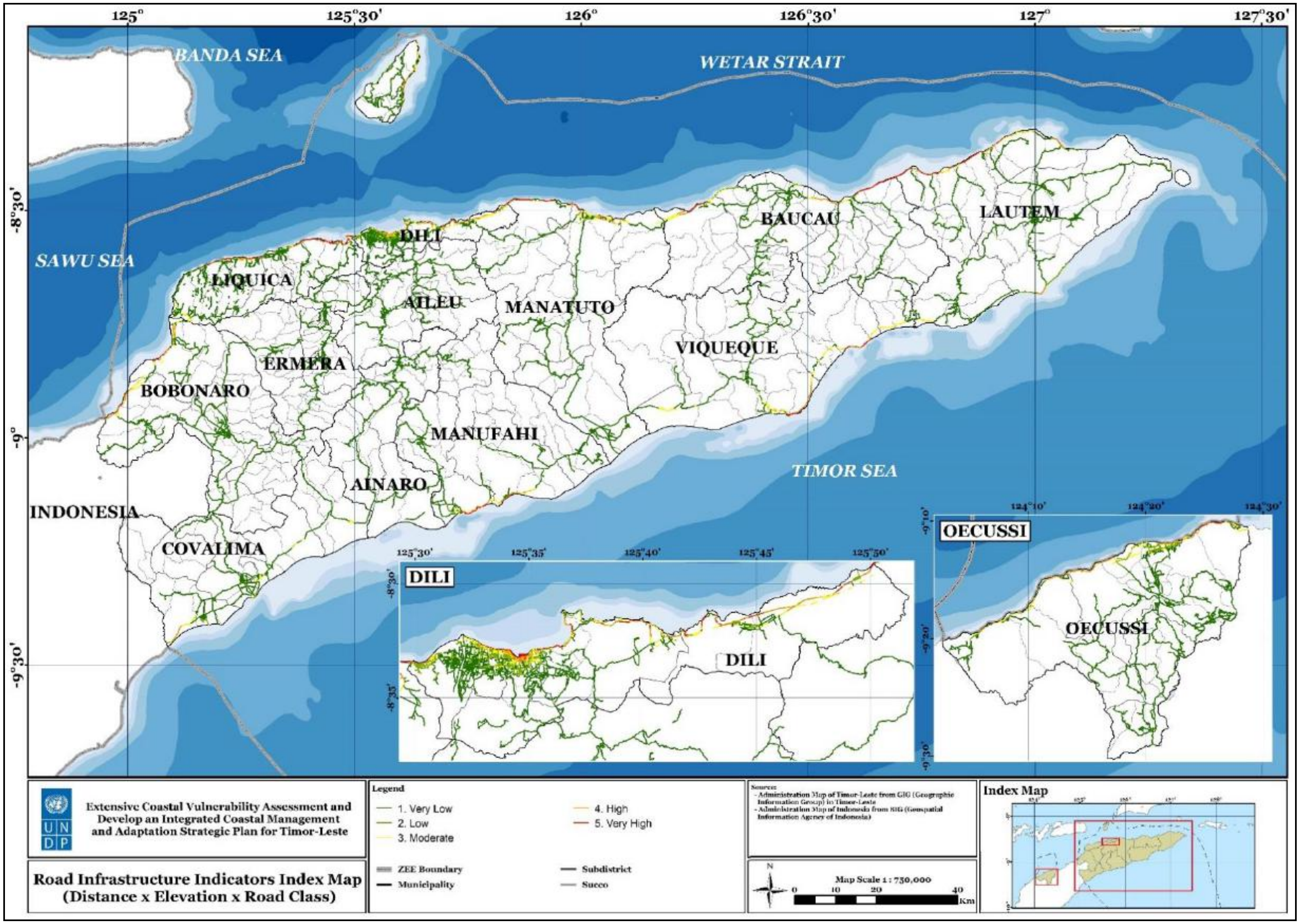


Figure 7.15 Road Classes and Network in Timor-Leste within 20 metres of elevation.

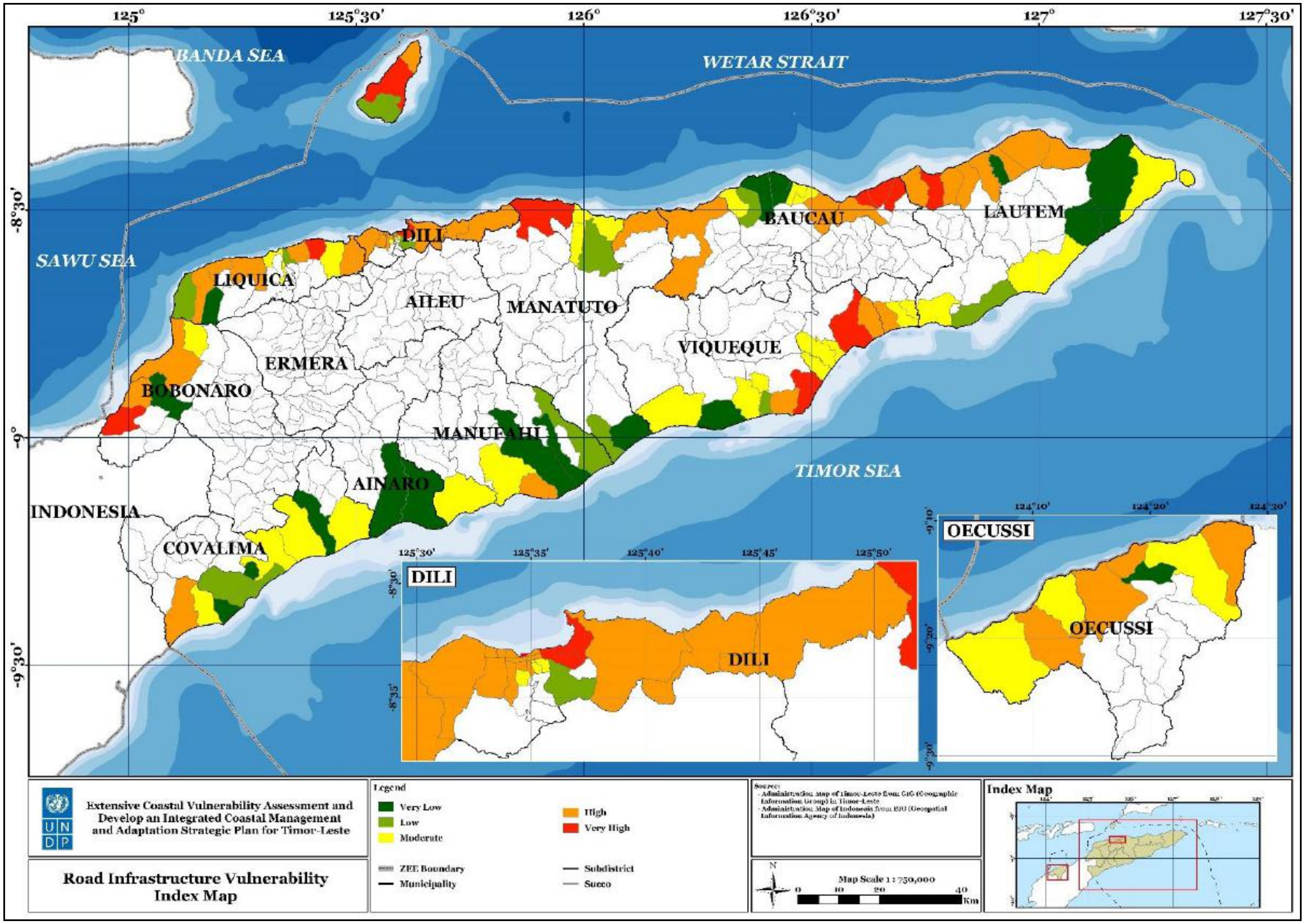


Figure 7.16 Road Network Infrastructure Indicator Map

Infrastructure vulnerability index

The infrastructure vulnerability index has been developed merging the results of the road infrastructure and node infrastructure. The result has been reclassified into different vulnerability levels from very low to very high. The overall result for the infrastructure vulnerability index is shown in Figure 7.17 below.

The map displays twenty three sucos that are vulnerable (one with very high vulnerability and twenty two with high vulnerability). These twenty three sucos also show high vulnerability in road infrastructure, meaning that they have important roads in low elevation and near coastal areas. In addition, the one suco that scored as very high vulnerable show a high node infrastructure vulnerability is Suco Comoro in Dili Municipality.

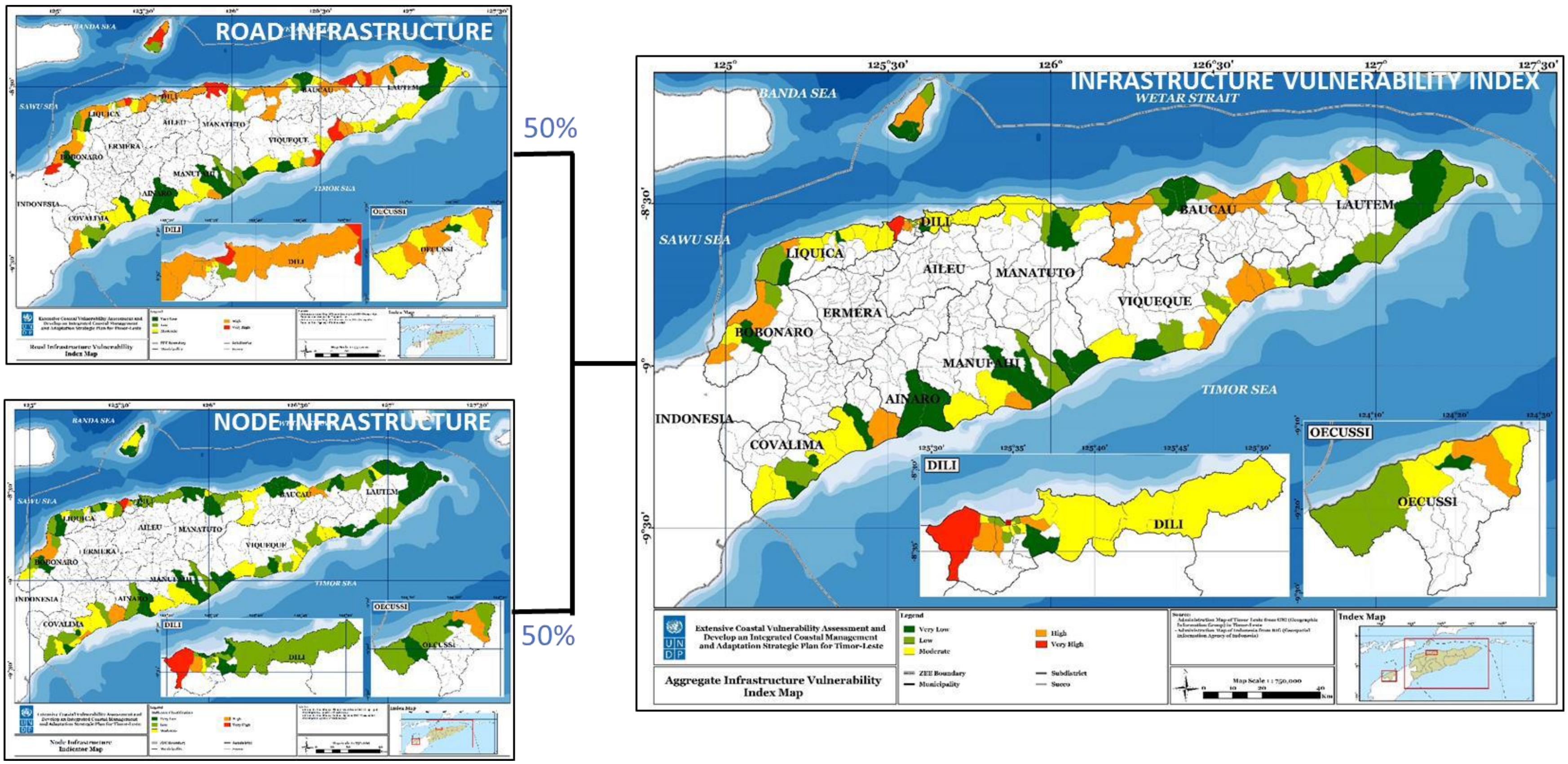


Figure 7.17 Process of Developing Infrastructure Vulnerability Index

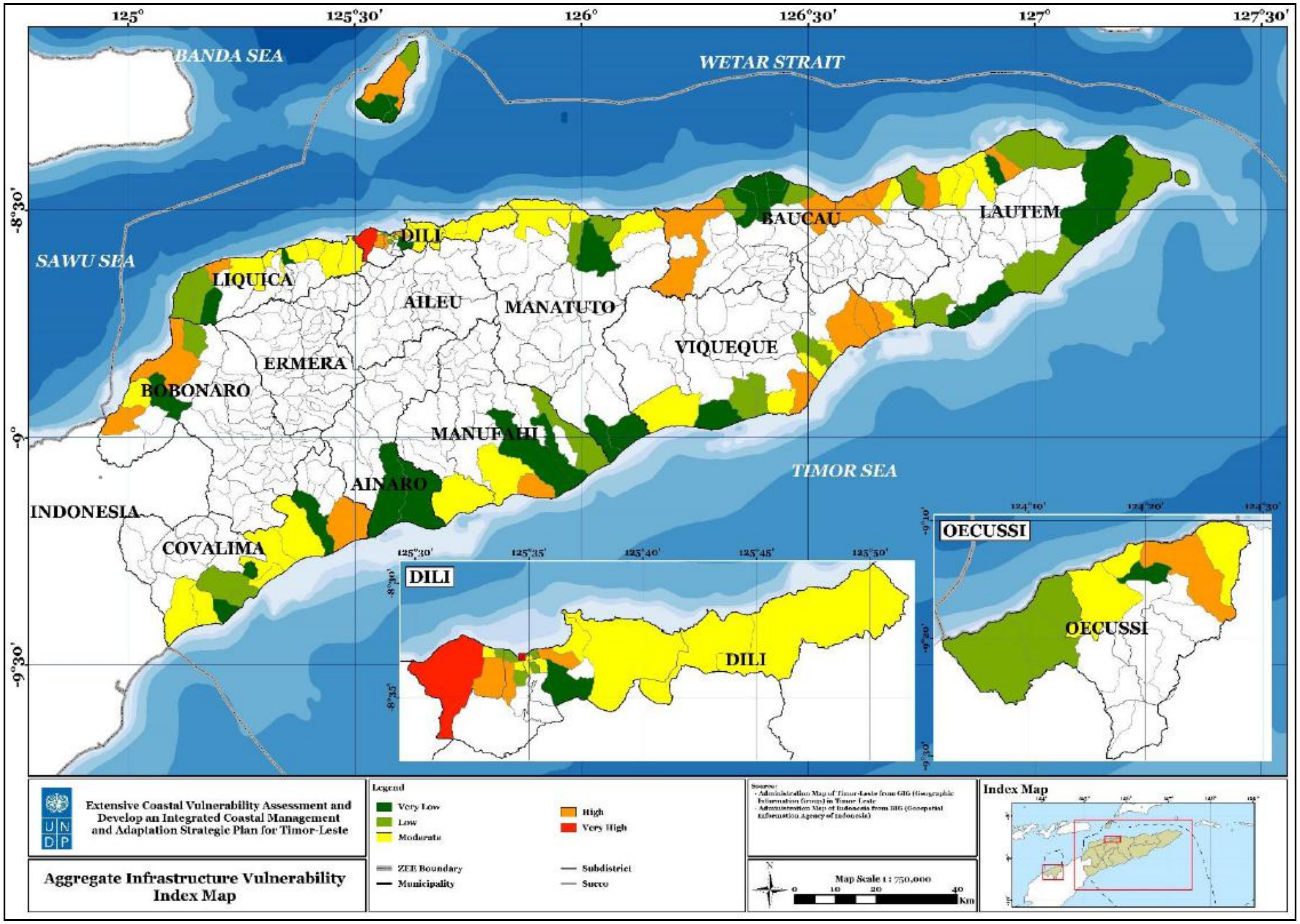


Figure 7.18 Infrastructure Vulnerability Map

7.2.3 Analysis of Ecosystem Vulnerability

Coastal ecosystems such as mangrove forests protect the coastline from erosion. However, in light of their scattered geographical distribution as well as their poor condition, in Timor-Leste this is not the case. Mangrove forests in Timor-Leste are rather exposed to coastal hazards and degradation. Degradation results mainly from sedimentation and human activity. For this reason, mangroves are considered vulnerable ecosystems which need to be restored and protected. As a consequence, in this analysis ecosystem vulnerability is represented by the proportion of land area covered by mangrove forest in coastal areas.

Figure 7.19 shows the areas covered by mangrove forest in the country and thus considered as highly vulnerable. The sucos Beco in Covalima; Duyung (Sereia) and Sabuli in Dili; Clacuc in Manufahi; and Uaitame in Viqueque are considered particularly vulnerable due to the exceptionally large size of the mangroves.

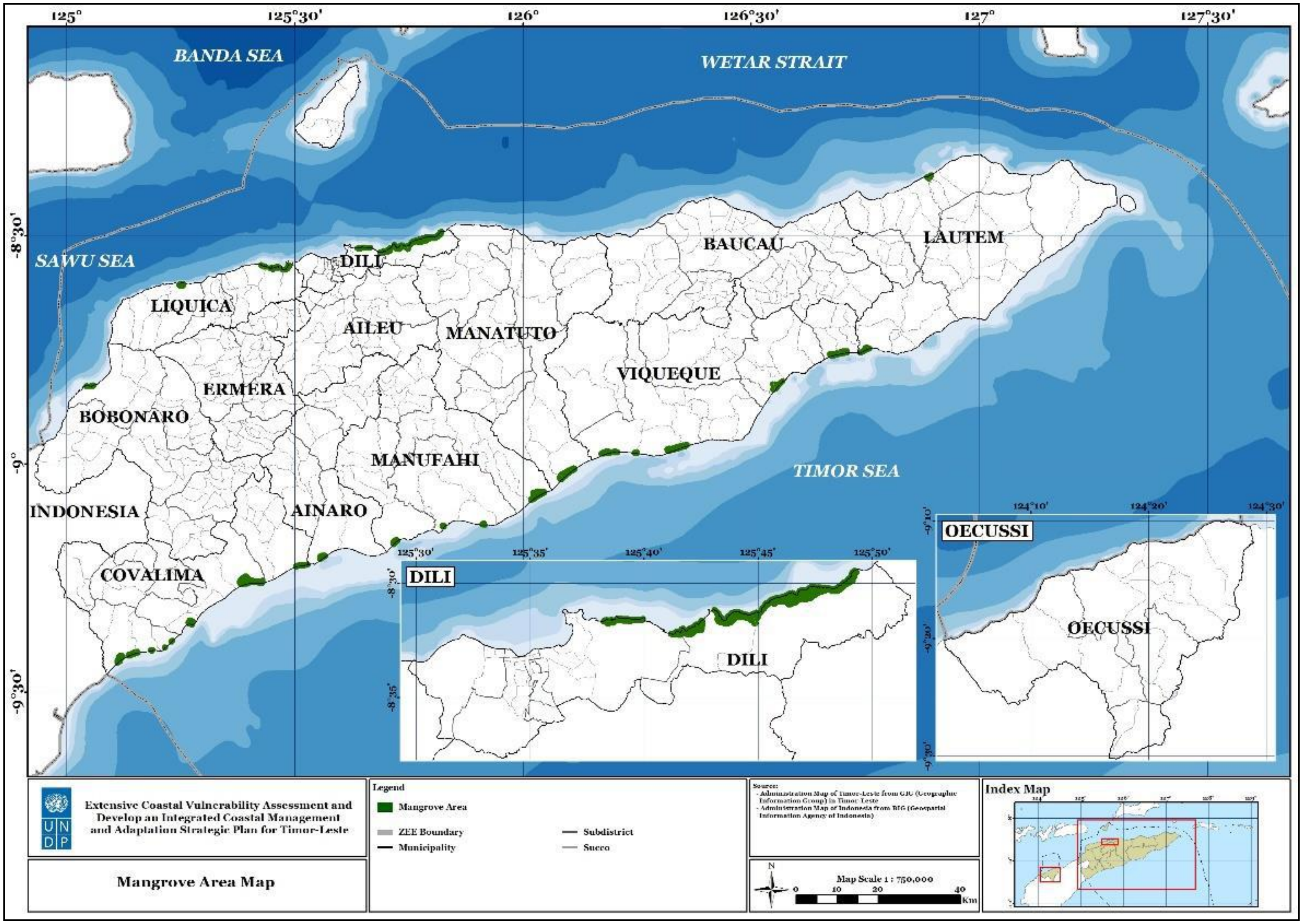


Figure 7.19 Mangrove Area Map

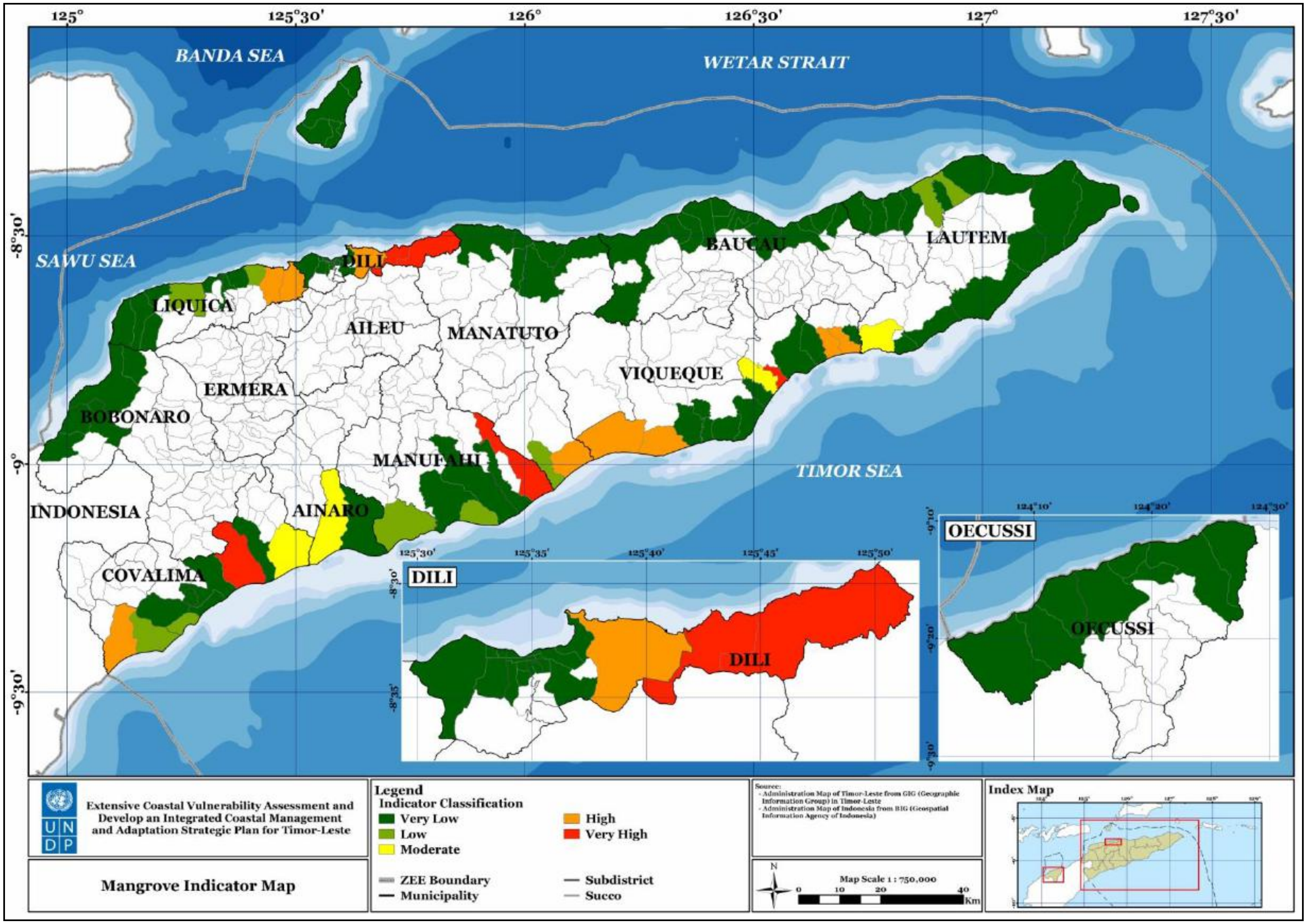


Figure 7.20 Ecosystem Vulnerability Map

7.3 Results of the Vulnerability Index Assessment

The final vulnerability index is the result of merging the input of the different factors: the infrastructure vulnerability, the socio-economic vulnerability, and the ecosystem vulnerability. The results are shown in Figure 7.21.

Figure 7.22 shows the results of the Vulnerability Index. In total, there are 13 sucos which are very highly vulnerable, namely Beco and Raimea in Covalima, Matahoi, Irabin de Baixo Macadique, Uaitame, Uma Uain Leten, Uani Uma, Babulo, Vessoru in Viqueque Municipality, Soba in Baucau Municipality, Batugade in Bobonaro Municipality and Pairara in Lautem Municipality. And 35 sucos that are highly vulnerable, namely, Tirilolo, Com, Suni-Ufe, Irabin de Cima, Maluro, Uma Quic, Acadiruhun, Samalari, Sanirin, Lalawa, Culuhun, Hera, Fatuhada, Duyung (Sereia), Sabuli, Baduro, Serelau, Lauhata, Tibar, Ulmera, Taiboco, Luca, Seical, Nunira, Tequino Mata, Vemase, Aidabaleten, Beloi, Bidau Santana, Bairro Pite, Vila Verde, Euquisi, Vaviquinia, Uma Berloic, Comoro.

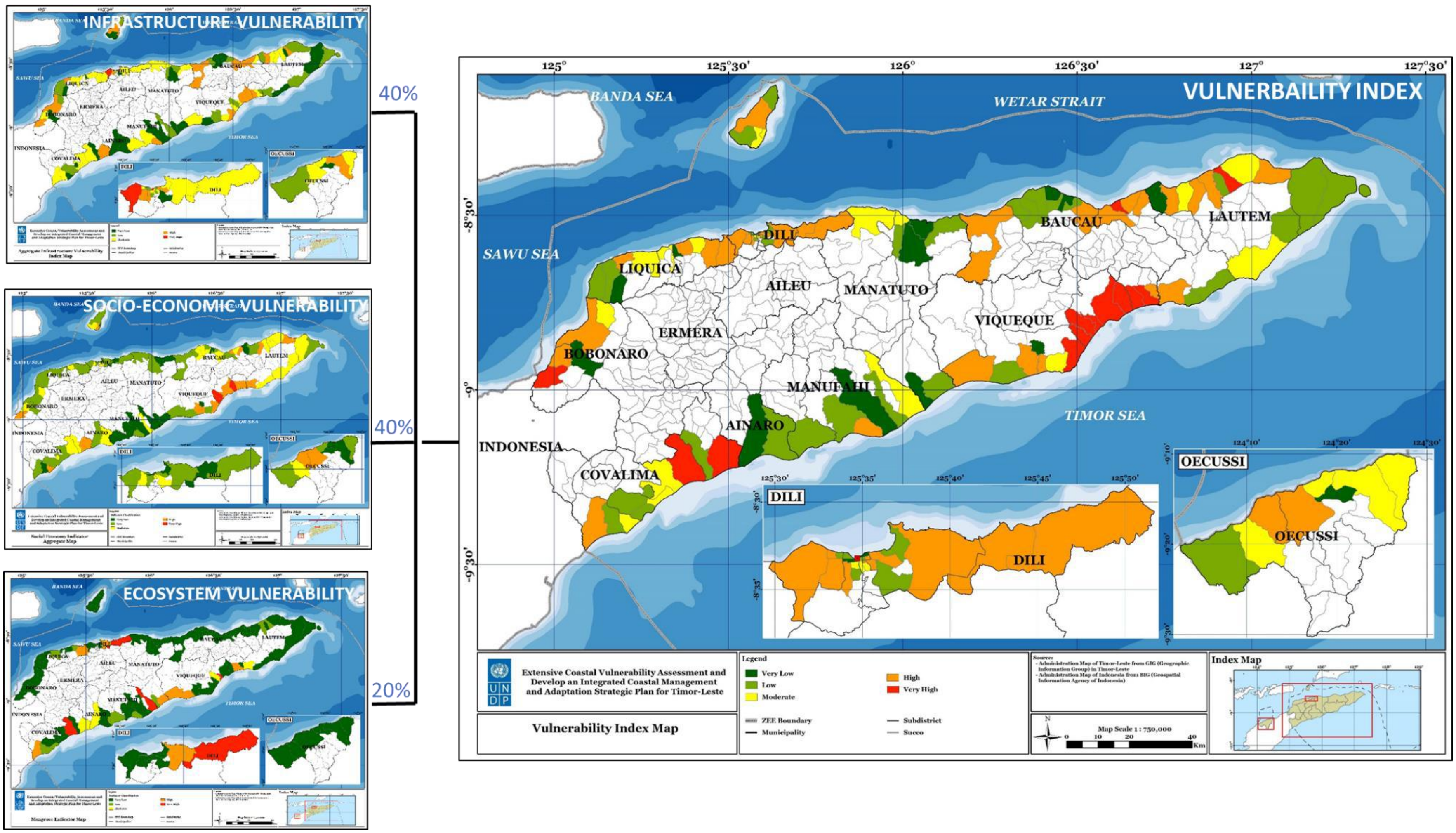


Figure 7.21 Process of Developing Vulnerability Index

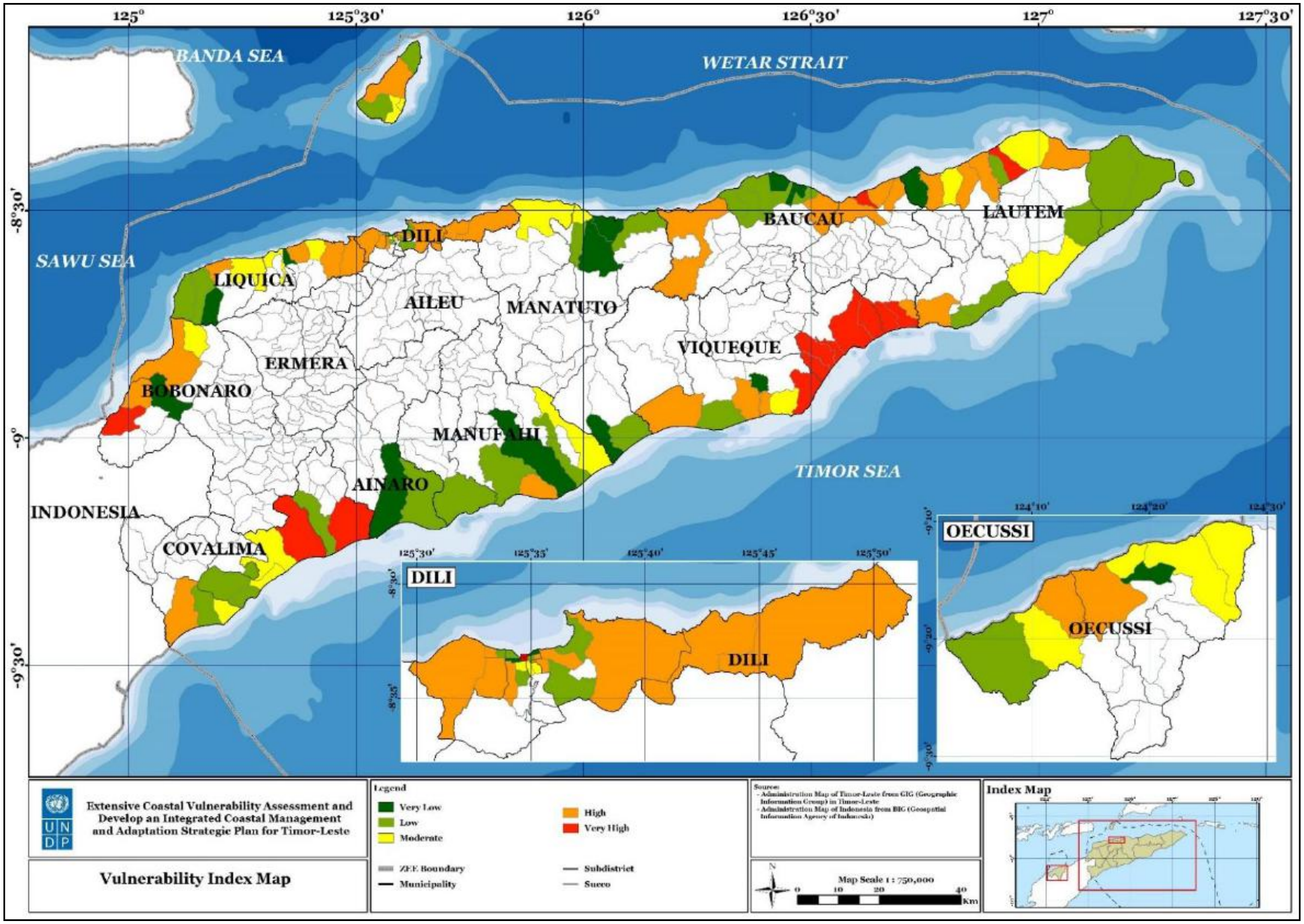


Figure 7.22 Vulnerability Index Map

7.4 Results of Modified CVI

The modified CVI represents perceived hazards (CVI results) and vulnerability indicators. The weight of each component is 1: 1 and the results are classified into five classes (from very low to very high). The five classes are represented in the following matrix.

Table 7.9 Relation of Vulnerability and Hazard to Develop Modified CVI

		Hazard				
		Very Low	**Low**	**Moderate**	**High**	**Very High**
Vulnerability	**Very Low**	VL	VL	L	L	M
	Low	VL	L	L	M	H
	Moderate	L	L	M	H	H
	High	L	M	H	H	VH
	Very High	M	H	H	VH	VH

The results of the modified CVI are presented in Figure 7.23. In a nutshell, the conclusions that can be drawn from all the analysis are:

- In total, there are 16 sucos that have a very high class and 40 sucos have high class for modified CVI.
- While each municipality has at least one high or very high risk suco based on results of modified CVI index, sucos with the highest modified CVI index are located in Bobonaro, Covalima, Manufahi, Lautem, and Viqueque.

The result for of each suco modified CVI index is shown in Table 7.10 below.

Table 7.10 Results of Modified CVI

No	Rank	Municipality	Suco
1	Very Low	Baucau	Trilolo
		Bobonaro	Rairobo, Leolima
		Covalima	Matai, Debos
		Dili	Macadade, Becora, Bemori, Santa Cruz, Caicoli, Macarenhas
		Lautem	Ililai, Maina I, Muapitine, Mehara, Tutuala
		Liquiçá	Gugleur, Guico, Vatuboro
		Manatuto	Ailili, Aiteas
		Oé-cusse	Lalisuc
		Viqueque	Uma Uain Craic
2	Low	Baucau	Bahu, Bucoli, Buruma, Triloca, Caibada I, Caibada II
		Dili	Beloi, Biceli, Maquili, Culu Hun, Meti Aut, Bairro Pite, Kampung Alor, Bidau Lecidere, Motael, Gricenfor, Colmera, Vila Verde
		Lautem	Iliomar I, Iliomar iI, Com, Daudaere, Euquisi,
		Liquiçá	Maumeta
		Manatuto	Umacaduac, Lifau, Ma'abat
		Oé-cusse	Bene-Ufe
		Viqueque	Irabin de Cima
3	Moderate	Ainaro	Leolima
		Baucau	Seical, Tequino Mata, Vemase
		Dili	Comoro
		Lautem	Parlamento, Lore I, Serelau
		Liquiçá	Dato
		Manatuto	Uma Boco, Sau
		Manufahi	Dotic
		Oé-cusse	Lifau
4	High	Ainaro	Foho Ai Lico,
		Baucau	Samalari, Nunira, Soba
		Bobonaro	Aidabaleten, Sanirin
		Covalima	Camenaca, Labarai, Casabauc, Maudemo, Tashilin, Suai Loro, Acadiru Hun
		Dili	Hera, Duyung (Sereia), Sabuli, Atauro Vila/Maumeta, Fatuhada, Bidau Santana
		Lautem	Baduro, Pairara, Lauhata, Motaulun, Tibar, Vatuvou, Vaviquinia
		Liquiçá	Ulmera
		Manatuto	Aubeon, Mahaquidan, Betano
		Oé-cusse	Suni-Ufe, Usi-Taco, Costa, Nipani, Taiboco, Uaitame
		Manufahi	Caicasa, Clacuc
		Viqueque	Watu Dere, Bibileo
5	Very High	Bobonaro	Batugade
		Covalima	Beco, Lalawa, Raimea
		Lautem	Trilolo
		Manufahi	Uma Berloic
		Viqueque	Irabin de Baixo, Uani Uma, Luca, Maluro, Uma Uain Leten, Babulo, Macadique, Matahoi, Vessoru, Uma Quic

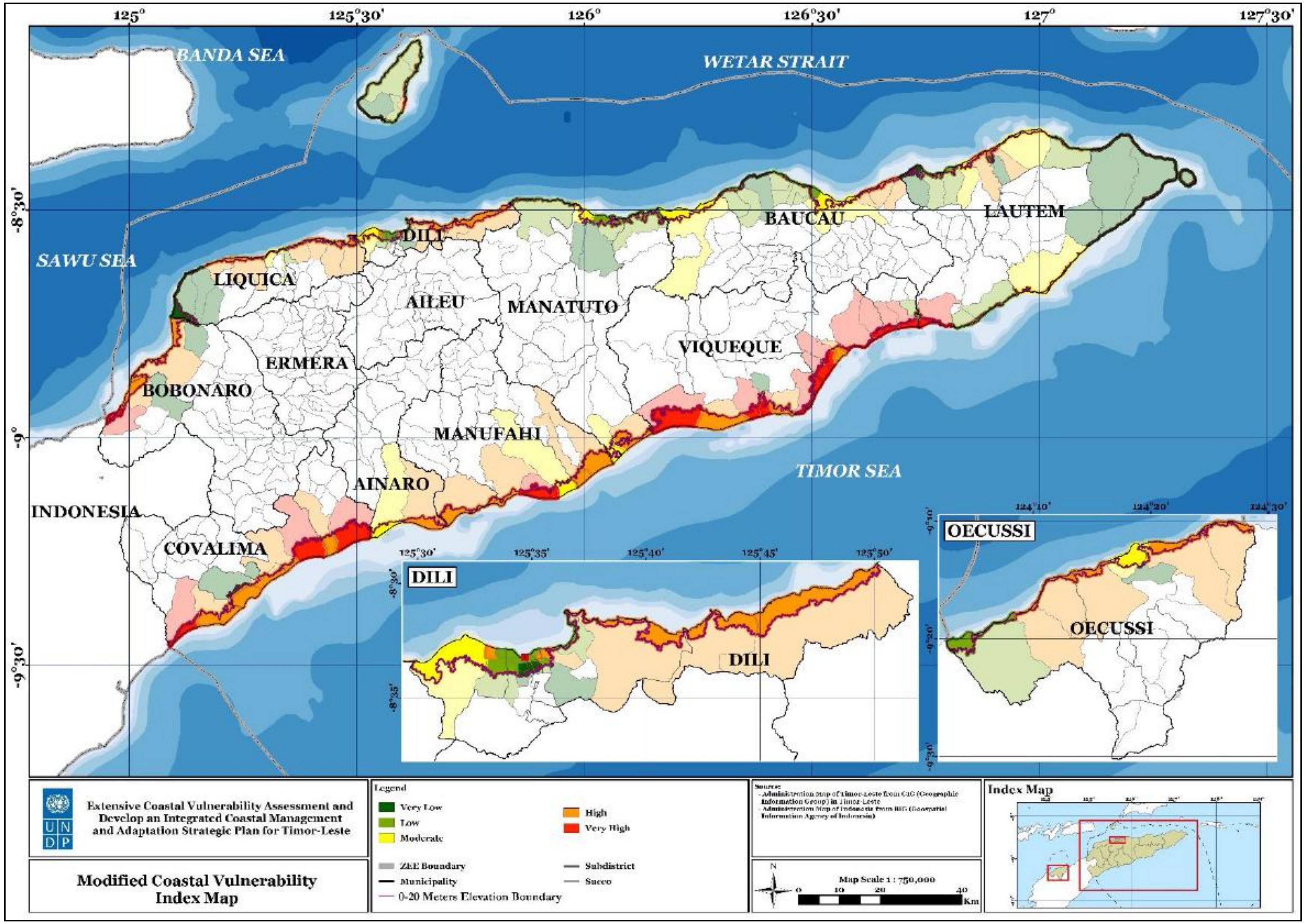


Figure 7.23 Modified CVI Map

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