1.1 RESEARCH ON SUSTAINABLE MEASURES FOR TSUNAMI DAMAGE MITIGATION IN DEVELOPING COUNTRIES (1)

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Abstract:
The Indian Ocean Tsunami 2004 caused about 230,000 casualties and enormous property damage to Indian Ocean countries. This giant loss is basically due to the lack of proper preparation for tsunami disasters from national government level to local level. In order to develop sustainable measures for tsunami damage mitigation in developing countries, three main activities were carried out within the frame of this research, *i.e.* (1) investigation on the possible measures of comprehensive tsunami disaster prevention based on the potential tsunami hazard and the existing land use in the target area; (2) assessment and development of education materials on comprehensive tsunami disaster prevention and study on the potential implementation of coastal vegetation as a tsunami barrier; and (3) development of guideline for planning and design of tsunami mitigative coastal vegetation belt.
According to this research, the possible measures of comprehensive tsunami disaster prevention in target countries were proposed based on the characteristics of social conditions and topography. A textbook for comprehensive tsunami disaster prevention education as well as a Guideline for planning and design of tsunami mitigative coastal vegetation belt were developed.
Keywords：comprehensive tsunami disaster prevention, guideline, coastal vegetation

1. Introduction

The Indian Ocean Tsunami (hereafter called as IOT) on 26th December 2004 caused about 230,000 casualties and enormous property damage to Indian Ocean countries. This giant loss is basically due to the lack of proper preparation for tsunami disasters from national government level to local level. Each country has a disaster management plan and established a related organization to look after the problems; however, such a plan generally does not include tsunami disasters. People living along the coast near the epicenter of the earthquake have little knowledge of moving to higher elevations when they feel a shock of an earthquake. Tsunami warning was not issued in countries those far away from the epicenter, such as Sri Lanka and India. Structural measures are rarely in place except for some parts of the Maldives coast.

From a long experience of tsunami disasters, Japan has significantly established tsunami disaster prevention measures. In Japan, local people who live in tsunami-affected areas understand that tsunami comes after earthquakes and related legends have been taught in schools. People affected by the Meiji Sanriku Tsunami in 1896 were relocated to higher places. Structural measures such as coastal dikes, tsunami breakwaters as well as the pine tree belts on the coasts have been implemented and maintained. Tsunami warning systems were also established after the damage caused by the Chile Earthquake-induced Tsunami in 1960. Under the national plan, local tsunami prevention plans and tsunami hazard maps are recently introduced and effectively implemented in prefectures along the coast.

In order to develop sustainable measures for tsunami damage mitigation in developing countries, three main activities were carried out within the frame of this research, *i.e.* (1) investigation on the possible measures of comprehensive tsunami disaster prevention based on the potential tsunami hazard and the existing land use in the target area; (2) assessment and development of education materials on comprehensive tsunami disaster prevention for developing countries based on Japan experiences and study on the potential implementation of coastal vegetation as a tsunami barrier in the tropical countries; and (3) development of guideline for planning and design of tsunami mitigative coastal vegetation belt and an international workshop on sustainable tsunami disaster management to disseminate the research outputs.

2. Methodology

2. 1. Research flowchart

The whole research works were break downed into three steps implementation activities as is shown in Fig. 2.1.

The first step activities include data collection on casualties as well as fatalities due to Indian Ocean tsunami 2004 in the affected countries, the recent situation of tsunami disaster countermeasure in the respective countries, effects of coastal vegetation belt on tsunami damage reduction and information on the present Japan disaster management measures. Based on these data, analysis on the possible implementation of comprehensive tsunami disaster prevention in the target countries was carried out.

The second step activities consist of two group activities. The first is the assessment and development of education materials on comprehensive tsunami disaster prevention for developing countries based on Japan experiences. The second is analysis on the potential implementation of coastal vegetation as a tsunami barrier in the tropical countries.

The third step activities comprise the development of guideline for planning and design of tsunami mitigative coastal vegetation belt and conducting an international workshop on sustainable tsunami disaster management to disseminate the research outputs.

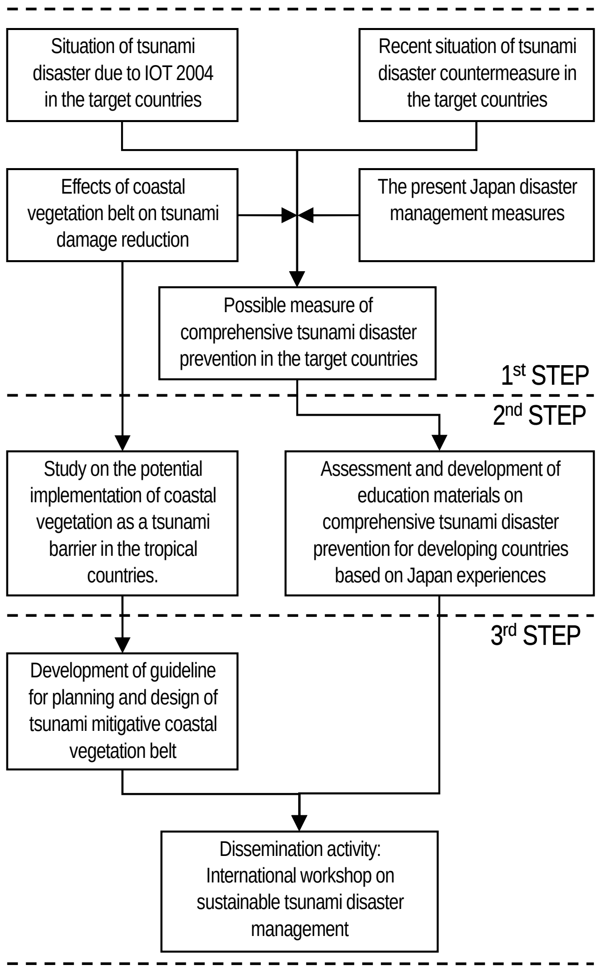


Figure 2.1 Flow chart of research activities

2. 2. Target countries

Figure 3.1 illustrates propagation of 2004 IOT wave from its generation source at offshore Banda Aceh, Indonesia towards countries surrounding Indian Ocean. The redline marks coastlines in the target countries hit by tsunami.

Six countries with the highest fatalities due the 2004 Indian Ocean Tsunami disaster were selected as the investigated target area. They are

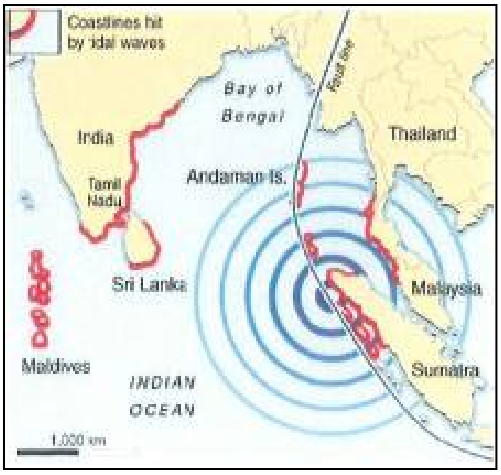


Figure 3.1 Propagation of 2004 IOT wave from its generation source at offshore Banda Aceh, Indonesia towards countries surrounding Indian Ocean; the redline marks coastlines hit by tsunami. [Hiraishi *et al.*, 2005]

including India, Indonesia, Malaysia, the Maldives, Sri Lanka and Thailand.

2. 3. Data collection

Data on tsunami disaster situation as well as tsunami mitigation measures in the countries affected by Indian Ocean Tsunami 2004 are collected through available literatures, such as reports, news, conference proceeding, journal articles, *etc.* Field surveys were also carried out in Sri Lanka to do sample verification and collect additional data.

In this investigation the characteristic of investigated area were classified based on two conditions, *i.e.* social condition (urban, tourism area, fishery village and agricultural village) and topography condition. The appropriate countermeasures were discussed based on each respective characteristic classification. The potential tsunami disaster characteristics of each classification are described as follow.

2.3.1. Potential tsunami disaster characteristics based on social condition

1) Urban area:
   - Coastal area was developed as a populated city with various important infrastructures.
   - High dense populated area that widely lay on the flood plain cause high vulnerability against tsunami disaster.
   - Devastation of public facilities after the disaster (government office, lifeline facilities, hospital, etc.) will cause life difficulties for the survivors.
2) Tourism area:
   - Coastal area is fully developed as a resort beach.
   - Many hotels, restaurants, souvenir shops, rental shop, etc. on the plain beach as well as huge numbers of tourist who play in the seashore and around the beach as well are highly under vulnerable condition.
3) Fishery and/ or agricultural village:
   - Fishery or agricultural (industry) area is widely spread over the coastal area.
   - Usually these villages are located over beach sand banks or around beach lagoon that make it highly vulnerable against tsunami overtopping flow.

2.3.2. Potential tsunami disaster characteristics based on topography condition

1) Island:
   - Small island with diameter about 2 to 3 kms; tsunamis are easily inundate inland from any parts of the island; e.g. Male Island at the Maldives, Phiphi Island at Thailand.
2) River flood plain:
   - The area lay on sand banks beside the river or nearby river mouth, which are easily inundated by flood from the river and the seashore as well; very vulnerable against flood disaster.
3) Head of a bay:
   - U or V shapes of the bay cause the tsunami flow energy are concentrated into the area around the bay head, causes high tsunami runup and increase disaster vulnerability.
4) Low and flat area:
   - The low and flat land over wide area without disturbance is enable high speed and dangerous flow of tsunami.
5) Harbor and fishery port:
   - Many ships, boats and other port equipments are possibly drifted inland by tsunami, destroyed buildings and may cause

fires, etc.

3. Possible Comprehensive Tsunami Disaster Prevention Measures in the Target Countries

3. 1. Classification of investigated area

Table 3.1 shows the classification of the investigated area according to the previously described characteristics.

Table 3.1
Classification of investigated area according to social condition and topography characteristics

	Urban area	Tourism area	Fishery or agricultural village
Island	Male Island of the Maldives	Phiphi Island of Thailand	
River flood plain	Galle of Sri Lanka		
Head of a bay	Hanbantota of Sri Lanka	Phuket beach and Phaton beach of Thailand	
Low and flat area	Banda Aceh of Indonesia		MGR Titto Village of India
Harbor and fishery port	Galle and Hikkaduwa of Sri Lanka		

3. 2. Suggestion on possible comprehensive countermeasure

The possible measures of comprehensive tsunami disaster prevention for the combination cases of the above mentioned characteristics is given based on the analysis of the available case study.

3.2.1 Case#1: Island – urban area

Cause of casulaties and fatalities:

- Very low level of island let tsunami penetrate easily into the land

Possible countermeasure:

- Evacuation tower will help much to reduce the victim
- Coastal vegetations are potential (e.g. pandanus odoratissimus) to reduce tsunami flow which eventually reducing tsunami force and damage
- Considering vulnerability distribution along the beach, building retrofitting and relocation as well as construction of escape building are necessary.
- Information, warning, and alert regarding the disaster situation as well as evacuation prosedur
- Encourgae the local community related to tourism industry lead the evacuation drill regularly

3.2.2 Case#2: Island – tourism area

Cause of casulaties and fatalities:

- Sea water recede about 100m toward offshore; many tourist go to the offshore direction; 3 to5 minutes later the first wave came and captured tourist;
- Hotels on the beach shore were destroyed by high speed tsunami inundation onshore flow, caused big damages;
- Tsunami height were amplifed at U-sahpe Tonsai ahrbor and Rodarom harbor;

Possible countemeasures:

- Rearrangement and replantation of hard trunk trees surrounding hotels nearby the beach to prevent damage
- Considering vulnerability distribution along the beach, building retrofitting and relocation as well as construction of escape building are necessary.
- Information, warning, and alert regarding the disaster situation as well as evacuation prosedur
- Encourgae the local community related to tourism industry lead the evacuation drill regularly

3.2.3 Case#3: River flood plain – urban area

Cause of casulaties and fatalities:

- The central city area were trapped by wave collition coming from the beach and from the river mouth
- Tsunami runup through the river mouth reach one km upstream and inundated flood plain area.
- Tsunami inland flow speed from the beach was very fast since no barrier along the flow.

Possible countermeasure:

- Enlarge the flood plain araea of the river to reduce inundation level
- Combination of coastal vegetation belt to reduce flow speed and embankment to reduce inundation volume along the beach and river mouth.
- Buildings and factory along the river should be structurally strengthened against tsunami force. Coastal vegetation surrounding building will help to prevent direct crash with drifted materials.
- Development of tsunami early warning and evacuation system as well as tsunami hazard mapping are very urgent.

3.2.4 Case#4: Head of a bay – urban area

Cause of casulaties and fatalities:

- The city is located at the end of a U-shape bay, which is subjected to amplified wave attack.
- The city is located in a low land between coastaline and swampy wetland area

Possible countermeasure:

- A protective structure like breakwater is necessary to reduce wave energy.
- To avoid human victim as many as possible, tsunami early warning and evacuation system should well installed and implemented.
- To reduce tsunami flow, 50 to 200m thickness of coastal vegetation belt is suggested in combination with 1-2m heith of embankment along the coastline.

Case#5: Head of a bay – tourism area

Cause of casulaties and fatalities:

- The location is directly face to incoming wave direction from the andaman Island.
- Waves were directly attack the port and resort beach.

Countermeasure:

- A protective structure like breakwater is necessary to reduce wave energy.
- To avoid human victim as many as possible, tsunami early warning and evacuation system should well installed and implemented.

Case#6: Low and flat area – urban area

Cause of casulaties and fatalities:

- The city is located in a triangle shape low land flat area.
- Tsunami flew over pond and swampy area to directly attack the city.
- Less knowledge about tsunami and limited time of evacuation after the earthquake (10 to 15 minutes)

Possible countermeasure:

- Development of new land use management, including designation of evacuation building etc.
- Tsunami early warning and evacuation system
- Construction of evacuation tower, evacuation hill
- Tsunami breakwater to protect important ports.
- Coastal vegetation/mangrove plantation over sampy coastal area and along the river floodplain.

Case#7: Low and flat area – fishery/agricultural vilage

Cause of casulaties and fatalities:

- The land is located between prot and water canal.
- With no any vegetation along coastline and canal, the wave propagate up to one km inland the village.

Possible countermeasure:

- To avoid direct attack of tsunami flow, alll fisheriy facilities shoul be relocated to the safer area.
- Evacuation buidling for temporary evacuation ar quite important
- Plantation of mangrove along the water canal to reduce tsunami inundation flow.
- Tsunami early warning and evacuation system should be developed.

Case#8: Harbor and fishery port – urban area

Cause of casulaties and fatalities:

- Wave energy were concentrated into the prot , many ship and boat were drifted inland, causing damage to building and living thing
- The existence of road behind the harbor reduce tsunami inundation into the land behind.

Possible countermeasure:

- Since this port is very important, a tsunami protective structure like breakwater is necessary to reduce direct atteck of tsunami.

- On the coastline, combination of coastal vegetation belt and 1-2m embankment will worth to reduce the hazard level.
- The available buildings, port and factory should be retrofit againt stnami force.
- Development and implementation of tsunami early warning and evacuation system should be taking urgent.

4. Assessment and Development of Textbook on Comprehensive Tsunami Disaster Prevention for Developing Countries

4. 1. Objective

The objective of this activity is to provide education materials towards development of human resources who can contribute to comprehensive tsunami disaster mitigation, including structural measures, tsunami early warning systems, and local disaster management plans in developing countries.

Specifically, the developed materials were used in the Comprehensive Tsunami Disaster Prevention Training Course, which was jointly conducted by ICHARM, JICA and UNISDR from June 2nd to July 11th, 2008 at ICHARM, Tsukuba, Japan.

4. 2. Framework of the textbook development

The textbook was developed through consolidation of up-to-date and the most appropriate teaching materials and tsunami textbooks available in Japan, which was tailored to fulfill the actual situation and requirement of developing countries.

The "Guidebook to Enhance Tsunami Countermeasures in Local Disaster Management Planning" published in 1998, which explains the process of tsunami disaster mitigation planning and its basic concepts for administrative organizations for disaster risk management to enhance tsunami countermeasures particularly for coastal areas, is used as the main source. In addition several Local Disaster Management Plan developed by Cities or Municipalities in Japan were also used as main references.

4. 3. Contents of the developed Textbook

Content of the developed textbook is shown in Table 4.1 under the title of "Tsunami Disaster Management Based on Local Disaster Management Plan".

Table 4.1
Contents of the Textbook

1. Key concepts for tsunami countermeasures in Japan
2. Basic laws and plan related to disasters in Japan
   2.1 Disaster Countermeasures Basic Act
   2.2 Basic Disaster Management Plan
   2.3 Local Disaster Management Plan
3. Tsunami countermeasures in Japan
4. Building capacity and disaster education for tsunami
   4.1 Transfer of knowledge and experiences in disaster mitigation —
   4.2 Training materials for workshop
   4.3 Disaster mitigation education for local residents

5. Study on the potential implementation of coastal vegetation as a tsunami barrier in the tropical countries.

5. 1. Objective

To synthesize the available knowledge on the control functions of coastal vegetation belt against tsunami and to propose a best practicable and optimal solution based on a comparative study among available results and recommendations.

5. 2. Activities

The overall activities include reviews on previously produced numerical and experimental results and comparison with field observation and analysis on the relationship between the degree of damage reduction and associated parameters (especially width, size and density of coastal vegetation). Field surveys were also conducted to provide additional vegetation data for breaking moment capacity as well as allometry correlation analysis.

5. 3. Summary of the result

5.3.1. Roles of coastal vegetation belt in tsunami damage reduction

Coastal vegetation belt performs several roles in tsunami disaster mitigation depending on the scale of tsunami and characteristics of vegetation. Shuto [1987] and Tanaka [2007]) identified that the roles of coastal forest in tsunami disaster mitigation may include

(i) trapping effect, *i.e.* stop driftwood (fallen trees, *etc.*), debris (destroyed houses, *etc.*) and other floatages (*e.g.* boat);

(ii) energy dissipation effect, *i.e.* reduces water flow velocity, flow pressures and inundation water depth;

(iii) soft-landing effect, *i.e.* provide a life-saving means by catching persons carried-off by tsunamis and enable them landed on tree branches; and

(iv) escaping effect, *i.e.* provide "a way" of escape by climbing trees.

(v) Additionally, in coastal area with high supply of sandy sediment materials, the existence of coastal forest may collects wind-blown sands and raises dunes, which eventually will act as natural barrier against tsunami [Shuto, 1987].

5.3.2. Factors involved in the interaction of tsunami and coastal vegetation belt

In many analysis, tsunami inundation depth is considered as the main external force working onto coastal forest (*e.g.* [Shuto, 1991], [Harada and Imamura, 2000], [Tanaka, 2008]), whereas forest resistance capacity depends on the single tree capacity as well as the capacity of the whole unit of forest. Factors involved in the tsunami and coastal forest interaction are summarized in Table 5.1.

Resistance effectiveness of a coastal forest increases along with the increase of survived tree numbers, *e.g.* [Shuto, 1987], [Tanaka *et al.*, 2007, 2008]. The survivability of a single tree depends on its capacity to stand against tsunami forces. The capacity of a single tree to stand against tsunami force is dependent on its breaking limit under tsunami flow. Trunk diameter is considered to be the representative variable related to the breaking capacity of a tree. In this relation, type of vegetation has important effect [Tanaka *et al.*, 2006]. However, ground soil capacity against scouring or against moment force working on the ground has significant effect too on the capacity of a single tree. Shuto [1987] and Tanaka *et al.* [2007] found several cases of collapsed trees along the front-fringe of the forest due to ground soil scouring or erosion by tsunami.

Table 5.1
Factors in the tsunami and coastal forest interaction

TSUNAMI CHARACTERISTICS	FOREST CHARACTERISTICS
▪ Wave height ➔ Inundation depth ▪ Period/wave length ▪ Wave direction	▪ Single tree capacity: ➔ Type of vegetation ➔ Breaking moment ▪ Soil strength
	Unit forest: ➔ Forest width (or length) ➔ Tree arrangement ➔ Forest density o Trees number o Trunk diameter o Vertical structure ▪ Tree height ▪ Root-trunk-canopy composition
	Ground slope/topography

Tsunami flow reduction rate by a coastal forest is influenced by forest density and width (or length) of forest in the tsunami direction. Numbers of tree, trunk diameter, vertical structure composition (portion of roots, trunk and canopy) and horizontal arrangement are the main variables that influence forest density. In this regard, Shuto [1987] proposed "summed diameter", *dn* (product of trunk diameter d in cm by numbers of tree n), as an important variable representing forest density. In more integral definition, Tanaka *et al.* [2007] proposed "vegetation thickness", *dN*all, to represent the effect of forest density. Here, *dN*all is a product of diameter of a tree at breast height bref by total drag coefficient of a whole tree body $C_{D\text{all}}$ by total tree numbers within the forest width γ'). Although forest density effect is very significant in reducing tsunami flow, Harada and Kawata [2004] numerically simulated that change in forest width gives greater significant effect to the flow reduction. Therefore, the maximum forest width should be designed for coastal protection against tsunami.

5.3.3. The capacity limit of coastal forest in

preventing tsunami disaster

Table 5.2 summarizes the maximum capacity of coastal forest in reducing tsunami flow based on numerical simulation results of Tanaka *et al.* [2009]. Reduction rate (R) is defined according to the following equation:

$$R = (1 - a/a') \times 100\% \quad (1)$$

where a is value of the variables with coastal forest and a' is their related value without coastal forest.

Table 5.2
The maximum capacity of coastal forest in reducing tsunami flow with dN_{all} equal to 1000 based on the numerical simulation results of Tanaka *et al.* [2009][1]

Flow reduction function	Beach land slope			
	1/100	1/200	1/500	1/1000
Run-up reduction	11%	18%	22%	23%
Time propagation reduction	57sec.	40sec.	34sec.	32sec.
Inundation-depth reduction	-	-	50%[2]	20%[3]
Flow force reduction	58%	56%	55%	54%

[1] *vegetations of P.odoratissimus; A.occidentale; C.equisetifolia; R.mucronata; inundation depth 3 to7m*
[2] *according toHarada & Kawata [2004]; Jap. pine tree; inundation depth 3m*
[3] *according toYanagisawa et al. [2008]; R.apiculata-type; inundation depth 3m*

Reduction rates shown in Table 5.2 are under assumption that all trees effectively stand against tsunami force. Thus, determination of appropriate trunk diameter is quite significant. Further, since the reduction rate in Table 5.2 were calculated through ideal condition of numerical simulation, the actual rate may be smaller due to *e.g.* difficulties to reach the expected forest density, *etc.*

It should be kept in mind that all post-tsunami disaster investigation results have shown that coastal forest posed none mitigation effects for tsunami inundation greater than 5m, *e.g.* [Shuto, 1987], [Tanaka *et al.*, 2006,2007]. Thus, for area with tsunami hazard potential of inundation depth greater than 5m, coastal forest would provide no protection at all. In such cases coastal forest may be utilized as a supplement to the main protection structure such as seawall *etc.*

It should be emphasized too that even for tsunami inundation less than 5m coastal forest never provide a hundred percent protection *e.g.* [Harada and Imamura, 2000], [Harada and Kawata, 2004], [Yanagisawa *et al.* ,2008]. Therefore, depends on the necessity, combination with other type of mitigation measures is quite important to ensure higher level of disaster risk reduction.

5.3.4. Potential application of coastal forest under constraint of coastal morphology, space and vegetation-type

1) Constraint due to the limited availability of space

The available land space along the coastline for coastal vegetation plantation should be clearly confirmed since a tsunami-protective coastal forest needs considerable width to work effectively. However, existing coastal morphology and land use may hamper the fulfillment of even the minimum requirement. Most coastal areas in the countries around Indian Ocean are plain with mild slope in average [Bird, E.C.F. and Ongkosongo, S.R., 1980]. Many of the tsunami vulnerable coastal areas are occupied for the settlements and have been developing for various purposes (industry, urban and residential development, tourism and recreation, transport, fisheries and agriculture) which left only limited space remained between the land and the sea. For example, in coastal area where economically reliable for aqua farming, coastal forest design that accommodates both functions of short term economic benefit and long term tsunami disaster mitigation will be highly demanded. Converting all aqua farm area to be coastal forest will face strong resistance from those who are benefited by the farm. But, if coastal forest is considered significant to support tsunami disaster countermeasure in the concerned area, smart combination of coastal forest and aqua farm should be considered.

Resettlement policy is usually unsuccessful without serious persuasion efforts and good planning and management of resettlement. For example, 65% of the four million Indonesian fisherfolks are unwilling to resettle due to the general inconvenience reason [Takayama, 1997]. Even if they are forced to live on higher land, they will eventually return to their previous homes despite the tsunami threat.

In case of limited space, a smart combination with other types of structural protection must be elaborated. One of possibility is by including tsunami protection design in the coastal area infrastructure development plan. Functioning coastal rural road as tsunami flow breaker in combination with coastal forest is a possible alternative to reduce tsunami propagation time to provide relative longer time for evacuation to the higher ground behind.

2) Constraint due to coastal morphology and vegetation-type

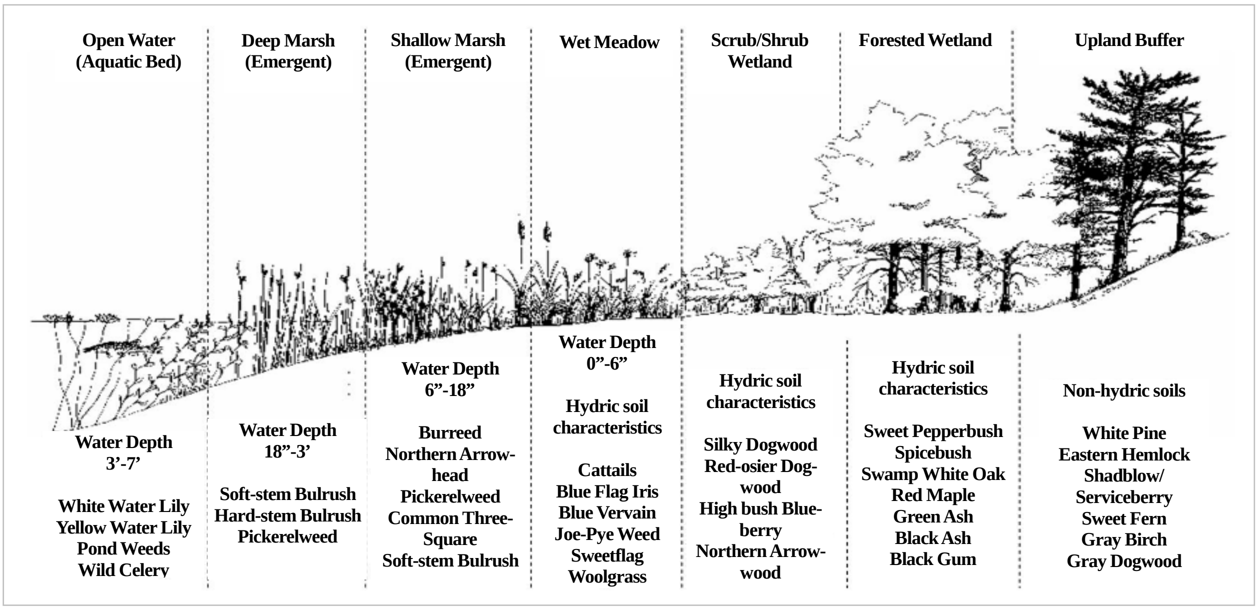
Data on coastal morphology and its relevant vegetation is indispensible at the initial steps of planning and design of tsunami protective coastal forest. These data will also give initial picture on the possible mitigation by coastal forest at the concerned area.

Type of vegetation is usually specific to local coastal morphology. Mangroves-type vegetations are specifically dominant in wetland areas, whereas in sandy beach area various hard trunk types of vegetations exist in combination. Very few descriptions are available now regarding their performance in terms of tsunami protection.

Typically, the composition of vegetation in estuarine wetland cross section is more or less similar to the illustration in Fig.5.1. This ideal cross-section normally exists in the area with mild sea-wave climate. However, mismanagement of coastal zone land use may cause the destruction of vegetations even far until the beach shore. In the coastal area with severe wave climate, the beach cross-section usually left only sandy-beach in which coastal vegetation like Pandanus odoratissimus or hard trunk tree like pine trees exist. The developed sand dunes provide natural protection to the coastal area against severe storm, but in many tropical areas sand dunes usually do not exist.

5.3.5. Law enforcement and disaster awareness education for coastal forest sustainability

Sustainability of coastal forest is very important to ensure its continuous mitigation function against tsunami disaster. Forest maintenance is a challenging matter, especially in many developing countries where coastal forest



[*Source: http://www.newp.com/wetland cross section.htm*]

Figure 5.1 Typical wetland cross-section (with typical plant for each zone) resources are highly demanded to support the daily life of local people.

In this relation, community based coastal forest development in combination with incentive scheme can be carried out to solve this problem. This scheme includes the selection of vegetation types that fulfill both tsunami mitigation function and economic demand. The authorization and rules on the responsibility of the forest maintenance and cultivation should be clearly described.

Many countries that were affected by Indian Ocean tsunami disaster 2004 have now prepared coastal area development plan, which includes land use and development zonation by considering tsunami disaster risk reduction principles. However, implementation of that development plan is in many cases are not easy due to the strong objection by fisherfolks who insist to live back in their original coastal homeland.

Along with the strong enforcement and good governance of well planned land use regulation, public education should be continuously conducted to increase public understanding and awareness on tsunami danger as well as tsunami disaster risk reduction. Without correct understanding and proper awareness, any disaster risk reduction based development plan will face long term objection in its actual implementation.

6. Development of Guideline for Planning and Design of Tsunami Mitigative Coastal Vegetation Belt.

6. 1. Contents of guideline

The contents include description of the general roles and limitations of coastal vegetations in tsunami disaster mitigation, description of basic steps in planning and design, data requirement and collection, design parameters and calculation procedure, and example of calculation processes as well.

Notes on the requirement of combination with other structures and the importance of good governance for the sustainability of tsunami-protective coastal forest are also described.

6. 2. Objective and limitation

The guideline is intended to give general guidance and provides a simple tool for planning and design of coastal vegetation belt for tsunami disaster mitigation according to the present available knowledge.

However, the fact that research results on this theme are limited and the available graphs and diagrams, *e.g.* Shuto [1987], Tanaka and Sasaki [2007], Tanaka *et al.* [2006] that are potentially used in the design steps were dependent a lot on empirical data, collection of many additional field data, especially related to vegetation characteristics are indispensible to enhance the applicability of the Guideline.

6. 3. Guideline enhancement requirements

The followings are requirements for the Guideline enhancement.

1) Pre-calculation results of tsunami flow reduction for more various coastal vegetation species.
2) Pre-calculation results of tsunami flow reduction for various vegetation age.
3) Allometry relations of each vegetation species to calculate potential vegetation density and drag coefficient.
4) Data on breaking moment capacity of more various species of vegetations.
5) Simple graphs for design purposes instead of numerical calculation running.

7. Dissemination Activity: Workshop on Sustainable Tsunami Disaster Mitigation

7. 1. Workshop objectives

The overall objective is to improve the capacity of sustainable tsunami disaster management through the development of tsunami disaster awareness and preparedness by using tsunami hazard map and coastal forest implementation.

7. 2. Workshop participants

The participants were selected among local government officials or community leaders whose work is directly related to disaster management. Among the 30 invited participants, five participants were invited from the Indian Ocean region countries, *i.e.* one participant from India, Indonesia, Malaysia, Sri Lanka and Thailand, respectively. The rest of participants came from relevant institutions as well as several tsunami-prone coastal cities in Indonesia.

7. 3. Workshop Programme and Contents

The Workshop was carried out as a two-and-a half day-programme that covers following topics: development of awareness and preparedness; the roles and limitations of coastal forest in tsunami mitigation; planning and design of coastal forest for tsunami mitigation; planning, design and utilization of tsunami hazard map; discussion and group presentation for the enhancement of guideline for tsunami hazard mapping as well as planning and design of coastal forest for tsunami mitigation; discussion and group presentation on the role of Tsunami Hazard Map in awareness raising; coastal disaster management plan; field orientation and a tour to tsunami historical places in Banda Aceh City.

Figure 7.1 shows a group of participants in a discussion during group discussion session.

7. 4. Workshop Conclusion

According to the group discussion results, conclusions were drawn as follows:

1) Tsunami disaster cause huge casualties because of lack of awareness and protection.
2) Lack of awareness maybe caused by unreliable information and little knowledge and understanding about the risk
3) Tsunami hazard maps shall be used to communicate reliable information and develop knowledge and understanding about the risk
4) Integration of tsunami hazard mapping into entire development program enables effective and sustainable tsunami disaster mitigation
5) Assuming their development integrates elements such as, environmental sustainability, coastal disaster countermeasures, and local community livelihood, implementation of coastal vegetation belt will contribute to sustainable tsunami disaster mitigation.

Further necessary activities:

1) Enhancement of guidelines for planning and design of coastal vegetation belt for tsunami mitigation to be more simple and implementable. Translation of the guidelines into other languages should be provided if necessary.
2) It is requested and expected that participants inform the progress of coastal forest development in their locality.

Figure 7.1 A group of participants in a discussion during group discussion session

8. Conclusion

Well understanding on the limitation of coastal forest capacity in reducing tsunami damage and people awareness on the importance of forest sustainability are among key aspects for the successful application of coastal forest in tsunami disaster mitigation. The other important aspects are law enforcement and governance on land use management.

Assuming their development integrates elements such as, environmental sustainability, coastal disaster countermeasures, and local community livelihood; implementation of tsunami hazard map and coastal vegetation belt protection will contribute to long-term preparedness and awareness of the community against tsunami disaster.

A Guideline for planning and design of tsunami mitigative coastal vegetation belt have been developed by ICHARM and provide general guidance and simple tools for planning and design of coastal vegetation belt for tsunami disaster mitigation according to the present available knowledge.

A textbook on comprehensive tsunami disaster prevention under the title of "Tsunami Disaster Management Based on Local Disaster Management Plan" was developed.

A workshop on sustainable tsunami disaster mitigation was successfully carried out with a conclusion of the importance of awareness and preparedness development towards sustainable tsunami disaster mitigation.

Reference

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1.1 発展途上国における持続的な津波対策に関する研究（１）

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【要旨】
2004 年に発生したインド洋大津波は、沿岸国に 23 万人を超える死者を出した。これは、各国における国家レベルから各家庭レベルに至る各段階での、津波に対する適切な準備不足によるところが大きい。本研究では、(1) インド洋沿岸の対象国における潜在的な津波ハザードと既存の土地利用に基づいた総合的な津波減災策の調査 、(2) 総合的な津波防災の教育資料の調査と開発、(3) 津波防御策としての海岸植生の利用可能性の研究、(4) 海岸植生を用いた津波減災ガイドラインの作成と普及　を行った。

キーワード：総合津波防災、ガイドライン、海岸植生