The Coastal Vegetation Role in Protecting the Thailand Coast Against the 26th December 2004 Tsunami

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FAO Regional Technical Workshop “Coastal Protection in the Aftermath of the Indian Ocean Tsunami: What Role for Forests and Trees?”

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1. Impacts of Tsunami of 26th Dec. 2004 on Coastal Forests.

Findings of Faizal Parish & Chee Tong Yiew (Global Environment Centre) in ISME Symp. 23/8/2005, KL., Malaysia.

The main impacts of the tsunami on coastal wetlands include:

- **Loss or degradation of mangroves and seagrass beds.**
- **Silting and degrading of coral reefs & coastal ecosystem.**
- **Major changes in coastal features, intertidal flats and coastal lagoons.**
- **Sedimentation/turbidity of coastal waters leading to algal blooms.**

2.Study on Greenbelt and Tsunami

- Study by Ports and Harbour Authority/Japan Disaster Reduction Institute (2003)
- Modeled using 1998 Sissano Tsunami which killed 2000 people with 15m waves.
- A greenbelt 100m wide was simulated along the shore line in the Sissano region.
- Based on the simulation, with high density of trees (3m spacing) the maximum tsunami run-up height was reduced by 50% and power reduced by 90%.
- The test results confirmed that a greenbelt with appropriate tropical trees is applicable as a sustainable tsunami prevention method.

Classification of damage area from tsunami using satellite data.

Compute NDVI (Normalized Vegetation Difference Index) from 2 Landsat data (30 m resolution)

•before (Mar 17, 2004) &

•after tsunami (Dec 30, 2004).

NDVI

•Channel 1 (visible: 0.58 - 0.68 microns) and
•Channel 2 (near infrared: 0.725 - 1.0 microns) are used to calculate the index:

NDVI = (Ch2-Ch1)/(Ch2+Ch1)

Assumption

The abrupt NDVI reduction in cloud free areas are normally due to a decrease in vegetation cover or to the presence of water, and can be used as indicators of the potential impact of the Tsunami.

All pixels showing a negative difference were grouped into `3 classes:

❖"***high tsunami impact***" if the difference is bigger than 0.5 NDVI,

❖"***moderate tsunami impact***" if NDVI is between 0.5 and 0.1 and

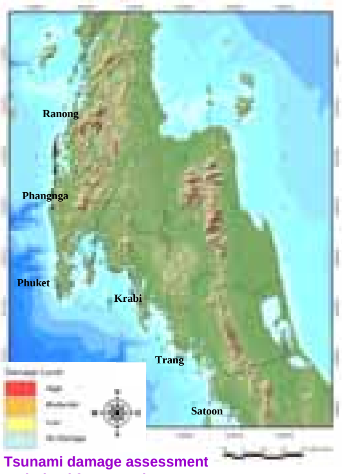
❖"***low tsunami impact***" if NDVI value between 0 and 0.1.

Our analysis indicates area affect by tsunami cover 144.15 sq. km. and classified into 3 levels.

▪***High effects*** **classified by land cover before and after tsunamis are completely change NDVI value (∆NDVI). This type of classified cover 20,265,055.18 sq. km. along the Andaman coast of Thailand.**

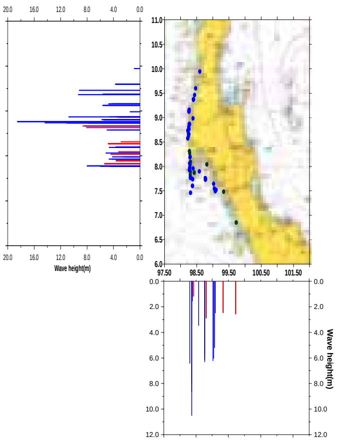
▪***Moderate effects*** **classified by different NDVI value are moderate. This type of classified cover 93,154,535.79 sq. km. along the Andaman coast.**

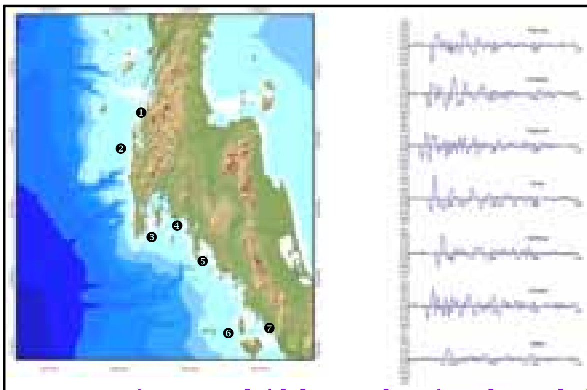
▪***Low effects*** **classified by different NDVI value are slightly different cover 30,731,055.32 sq. km. along the Andaman coast.**



Tsunami damage assessment derived from Landsat TM

Coastal ecosystem of Thailand.



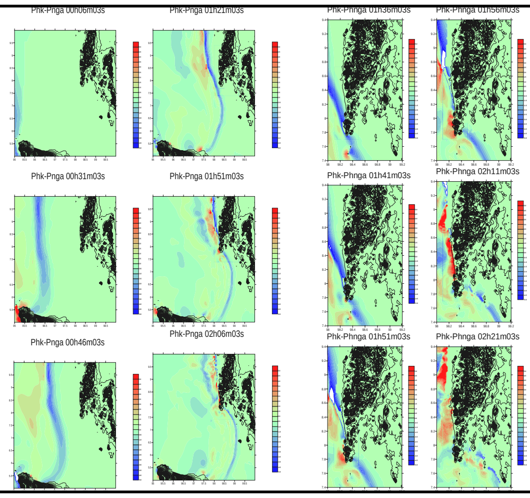


Tsunami wave and tidal gauge location along Thai Andaman Seacoast

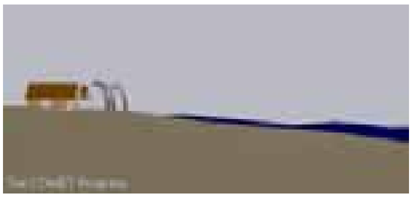
Data Source: Sea-level data from Hydrographic Department, Royal Thai Navy and Harbour Department.

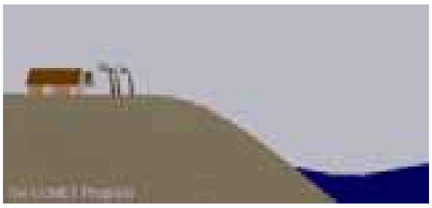
Table 1 Summary of tsunami wave arrival time at various tide-gauge stations, average period of the first 3 waves. Arrive time of the highest wave. Times in parentheses are the time after earthquake.

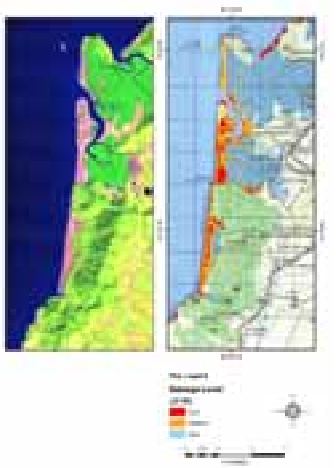
Tide gauge station	Tsunami onset time (UTC, since earthquake)	Ave. period of the 1st three waves (min)	Time of highest wave (UTC, since earthquake)	Wave height Above MSL	Sequence Of the highest wave
Ranong	4:01 (3:02)	53.3	5:20 (4:21)	0.672	First
Kuraburi	3:51 (2:52)	85.3	7:30 (6:31)	0.759	Third
Phuket	2:51 (1:52)	32.5	3:10 (2:11)	0.800	First
Krabi	3:41 (2:42)	63.3	4:50 (3:51)	1.287	First
Kantang	4:56 (3:57)	82.8	5:50 (4:51)	0.780	First
Tarutao	3:31 (2:32)	32.5	4:00 (3:01)	1.073	First
Satun	5:25 (4:26)	68.8	6:37 (5:38)	0.468	First



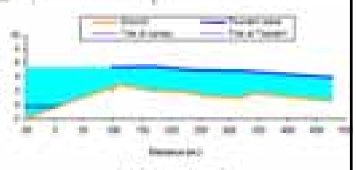
WAVES ON FLAT & STEEP BEACHES







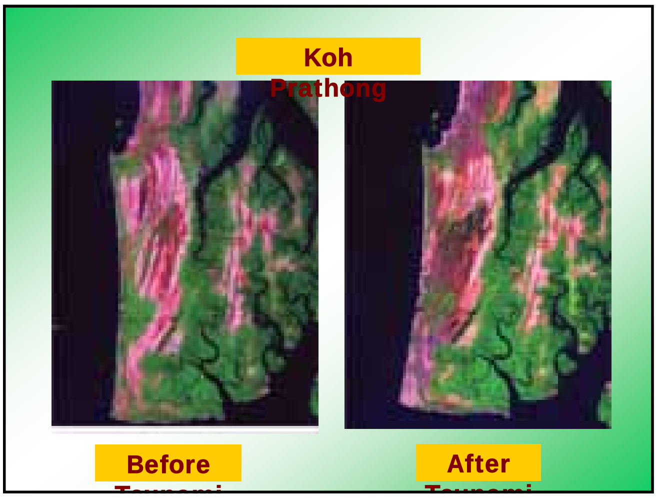
Damage assessment derived from Landsat data at Prapas Beach, Ranong province.



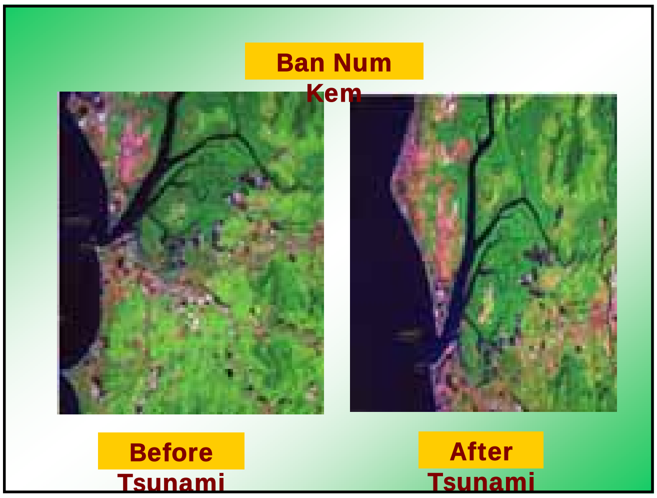
(a) Prapas Beach

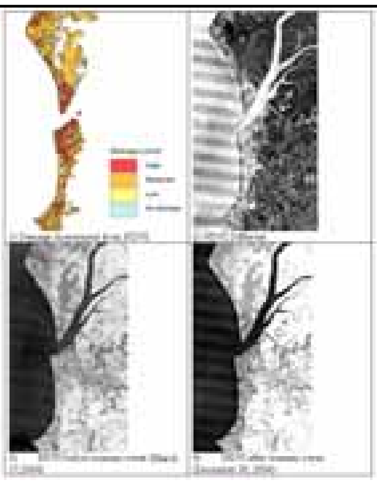
Run-up survey at Prapas Beach, Ranong province by Dr. Chugiat team.

Erosion from tsunami run-up(left) and rundown (right) at Prapas Beach, Ranong Province on 30 December 2004.



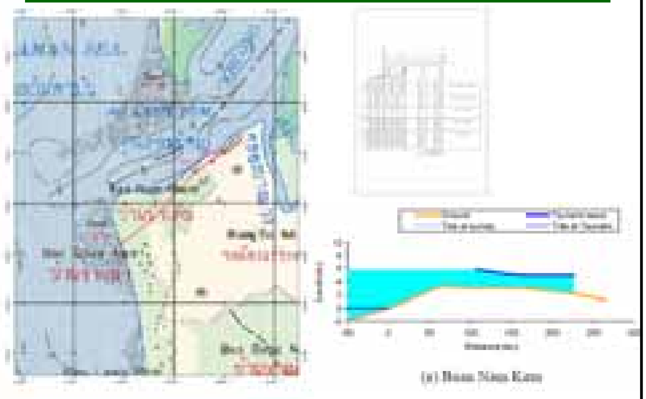
Prathong Island



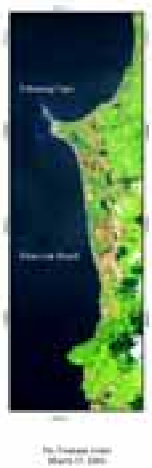


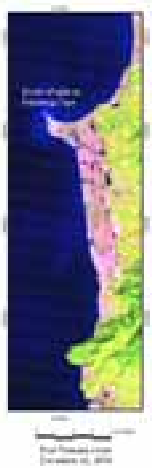
Comparison between tsunami damage assessment and Landsat NDVI Ban Num Khem and Kho Khao Islet.

Run-up survey at Ban Numkhem



Max. runup height 8.11 m, 1673.297 m from shore





Pakarang or Coral Cape, and Khao Lak Beach, Phang-nga province.

Landsat data.

Highest run-up 15.68 m. in Thailand.

Cape Coral, highest runup 15.68 m in Thailand.

Cape Coral, tsunami waves came from 3 directions.

Enlargement of inlet, Blue Village Pakarang,

Coconuts provide little protection

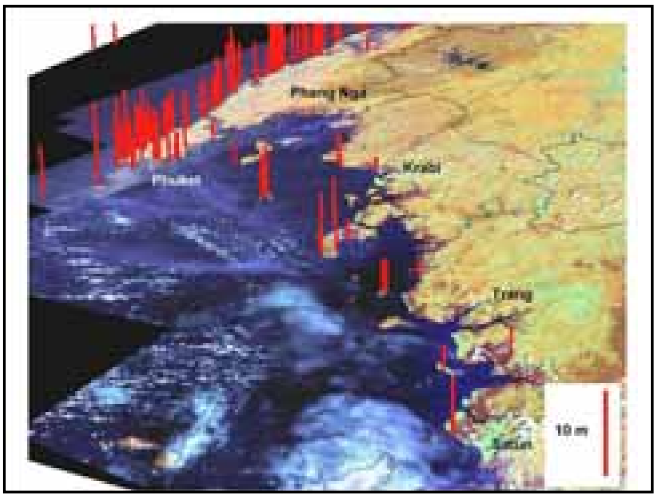
Figure 3. 33: The surveyed damage in the Khao Lak region, Phang Nga Province, Thailand. The arrows indicate locations of inundation height measurement (e.g. 10.5m@89.4m means a water height of 10.5m above mean sea level was measured a distance 89.4m from the shore).


Tap Lamu, Naval Base.
Max. runup height 5.71 m,
50 m from shore.
A battleship was tossed on to the shore. In front of a naval base at Tap La-mu Pier in Phang-Nga


Beach forest protect from tsunami.


Lumpee HadtaiMuang National Park: thick beach forest, not much damage.
Buildings did not much damage behind.
Thin forest, damage.


Sirinart National Park, near Phu-ket airport. Thin beach forest & canal caused more damages.


Phang Nga
Phuket
Krabi
Trang
Satun
10 m

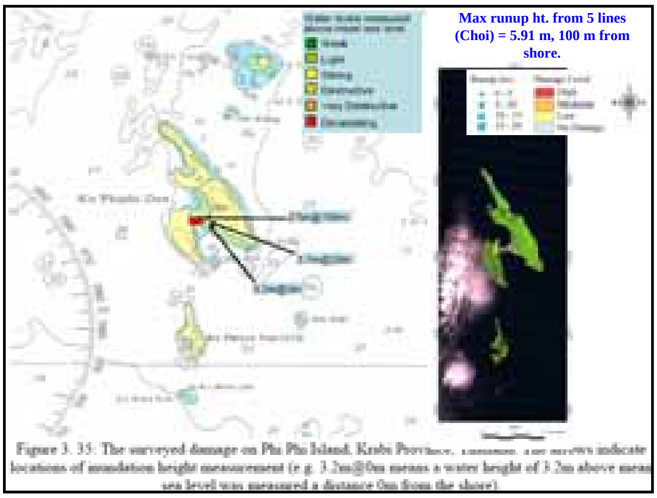
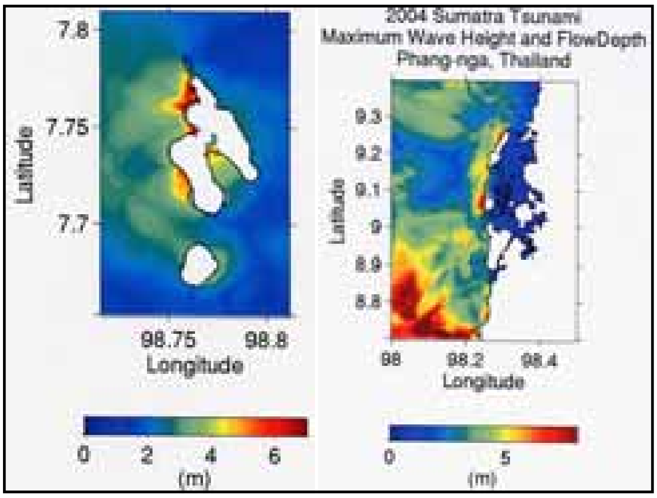

Max runup ht. from 5 lines (Choi) = 5.91 m, 100 m from shore.
Figure 3. 35: The surveyed damage on Phi Phi Island, Krabi Province,
locations of inundation height measurement (e.g. 3.2m@0m means a water height of 3.2m above mean
sea level was measured a distance 0m from the shore).


Figure 3. 16: Aerial views of Phi Phi Island and Ton Sai Bay: (a) The arrows indicate how the tsunami
was refracted around the western granite cliff and hit the narrow land strip (tombolo) from both the
North and South directions. (b) Ton Sai Bay four days after the tsunami.


2004 Sumatra Tsunami
Maximum Wave Height and FlowDepth
Phang-nga, Thailand
7.8
7.75
7.7
Latitude
98.75
98.8
Longitude
0
2
4
6
(m)
9.3
9.2
9.1
9
8.9
8.8
Latitude
98
98.2
98.4
Longitude
0
5
(m)

Situations where forests provided less protection

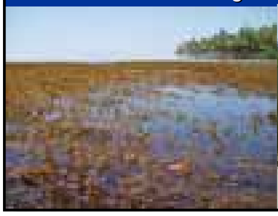
- Close to epicentre (eg west coast of aceh)
- Where landforms led to extremely high waves
- Less protection from riverine vs coastal fringe
- Where forests had been degraded or cleared
- Where vegetation cover did not give much resistance to waves – eg coconut trees

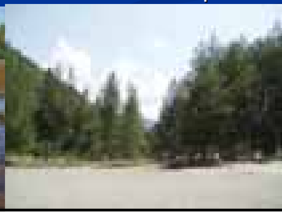
Peatlands protected inland areas and provide water source

- Coastline washed out

Coastal peatlands intact and provide freshwater source

South west aceh – seagrass and coastal forest protect shore





Criteria of Damage by Tsunami Flow Velocity and Height.

Tsunami Reduction Due to Coastal Greenbelts

According to Dr. Tetsuya Hiraishi
Port and Airport Research Institute (PARI), Japan.
Seminar on Tsunami Disaster Prevention/Reduction in 2006.
2 August 2006.

Coastal Damage

Damage Level (by Matsutomi, Shuto, 1994)

3. Heavy (Completely washed-out or Recovery impossible)

2. Medium (Column remained but Wall broken)

1. Light (Window broken, Wall slightly damaged)

Facility

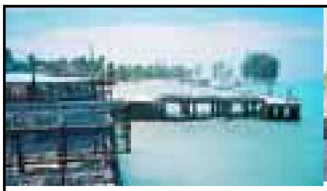
A : Reinforced Concrete House and Building

B : Concrete and Blocks

C : Wooden House

S : Sea Wall

P : Pier, Jetty



Thailand, S (Seawall), level 1

Facility A, Damage 2

C, 3

Banda Aceh, S (Seawall), level 3

Observed Damage Level

No.		R(m)	SW	Structure D(m)	A	B	C	S	P
					Damage Level (Heavy=3)				
1	Bang Nam Kem Harbor	5.4	Y		2	3	3	1	2
2	Khao Lak resort	8.8	N	2.5	2	3	3		
3	Cape Pakarang	9.8	N	1.1	3	3	3	3	
4	Kamala (Phuket)	6.0	Y	1.3	1	3	3	1	
5	Patong (Phuket)	3.4	Y	1.0	2	3	3	2	
6	Banda Ache	10	Y	4	3	3	3	3	

D: Scoring Depth
R: Tsunami Run Up Height
SW: Seawall, Y:existance N: no

Structure Strength : Seawall > Pier = Reinforced Concrete > Block > Wood

Criteria of Shuto, Matsutomi

- Heavy Damage
- Reinforced Concrete Building: u>7m/s
- Concrete Blocks : u=7m/s
- Wooden house : u=4.2

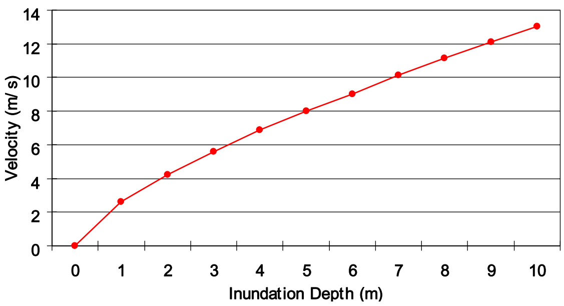
$u=2.6h_f^{0.7}$

$$\frac{u}{\sqrt{gR}} = \sqrt{\frac{2C_v^2 F_r^2}{F_r^2 + 2C_v^2}} \sqrt{\frac{h_f}{R}}$$

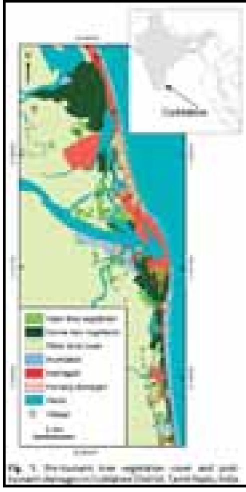
$$F_r = 1$$

$$u \approx \sqrt{\frac{2}{3} gR}$$

U~a√gR



Field observation of Inundation Damage in front and behind of Greenbelt



SCIENCE F. Danielsen et al., 2005

Dense Tree Vegetation

Damaged Village

Matsutomi(2005) : ***R 4.9 →4.6m***

Study on Effect of Greenbelt to reduce Tsunami Force (2001)

Variation of Pressure by Greenbelt

$$WF = \frac{1}{2} C_D \rho A_0 u|u| + C_M \rho \frac{V_0}{V} \frac{\partial u}{\partial t}$$

C_D : Drag Coefficient

C_M : Inertia Coefficient

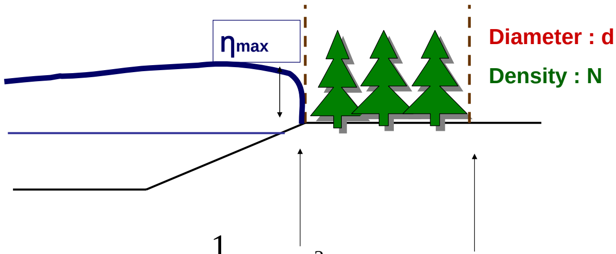
u : Tsunami flow velocity

A_0 : Projection area of Vegetation

V_0 : Volume of vegetation

V : Total volume under water

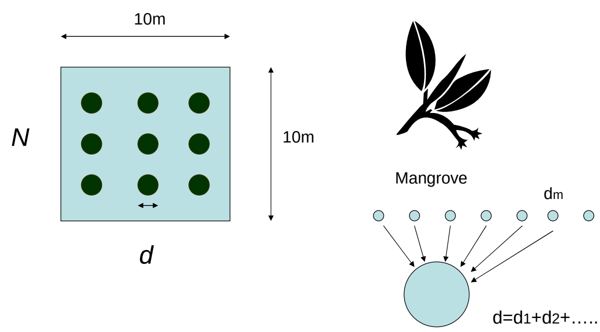
Simple Evaluation



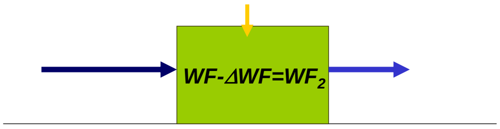
$$P_{front}(N/m) = \frac{1}{2} \rho C_D u^2 \eta$$

$$P_{back}(N/m) = \frac{1}{2} \rho C_D u_2{}^2 \eta_2$$

Definition of Greenbelt Intensity



Effect of Greenbelt



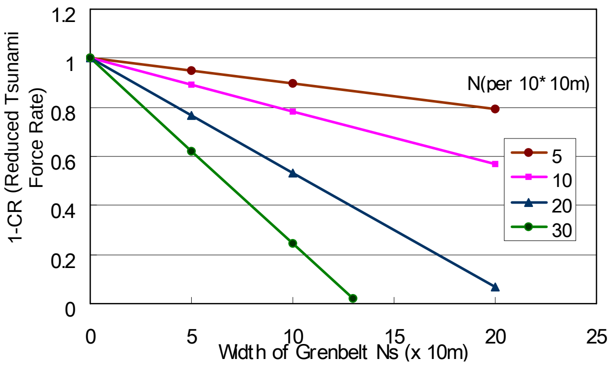
$WF=\rho\eta u_1^2\Delta x\Delta y/2$ $WF_2=\rho\eta u_2^2\Delta x\Delta y/2$

$\Delta WF=\rho u_1^2 C_D' A_1/(\Delta x\Delta y)\Delta x\Delta y N_S/2$

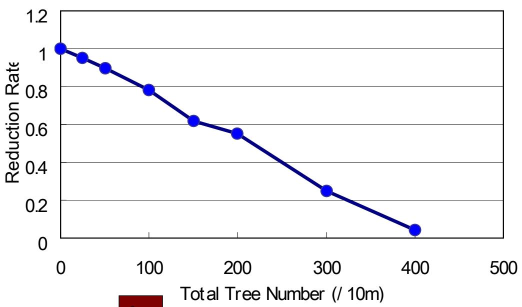
$C_D'=(8.4\pi d_1^2(N/100)/4+0.66)$ $A_1=\eta(d_1(N/100)\Delta x\Delta y)$

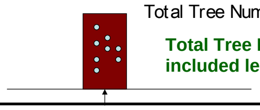
Drag Term Resistance ***Effective Projection Area***

$1-C_R(C_R=\Delta WF/WF)$
Reduction Rate



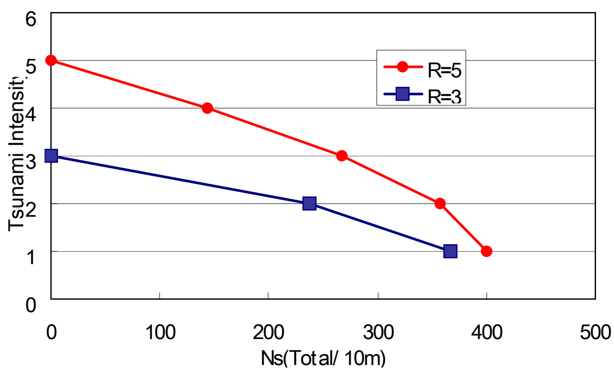
Averaged Reduction Rate



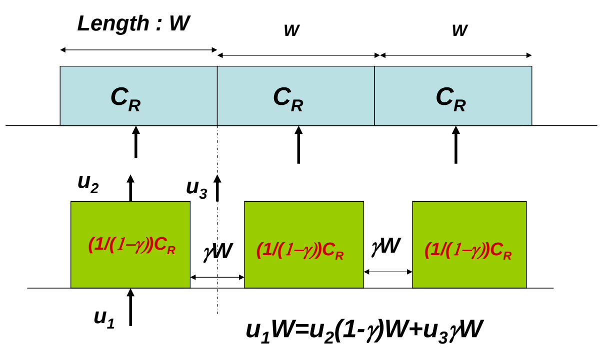


d_1=30cm

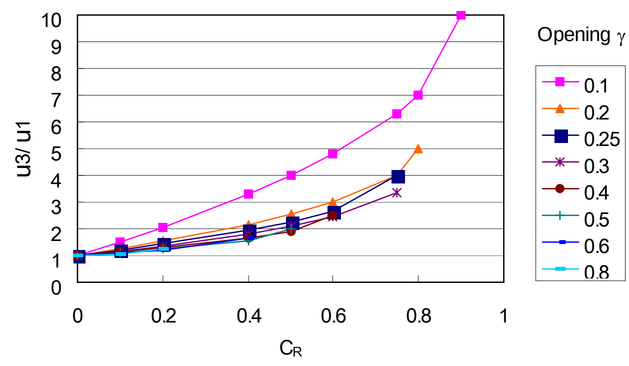
Demanded Greenbelt Density
R: Run-up Height



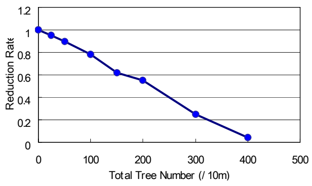
Effect of Greenbelt Arrangement

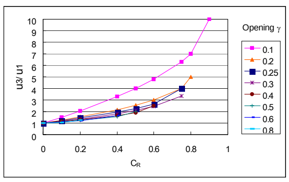


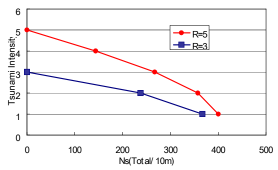
Increasing of Flow Velocity at Opening



Design of Greenbelt







Design Tsunami Height R

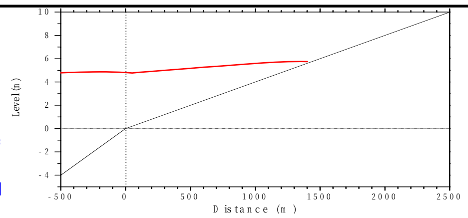
↓

Target Tsunami Intensity behind Greenbelt

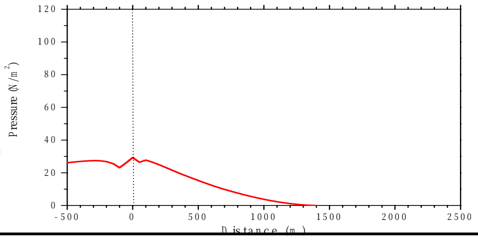
↓

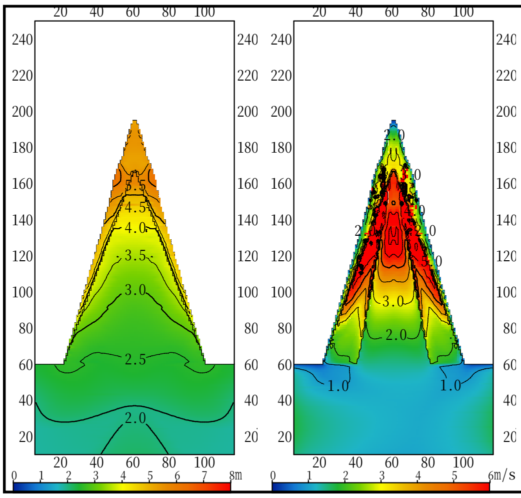
Determination of N, B, W and Opening(if necessary)

Variation of Maximum Water Level



Variation of Maximum Tsunami Force





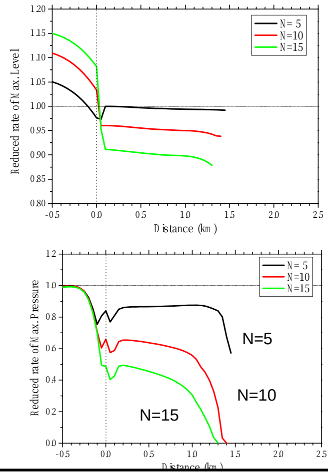
Tsunami W.L. and F.V.

In **V-Shape**

Bay

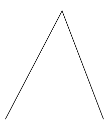
Straight Beach

B=100m

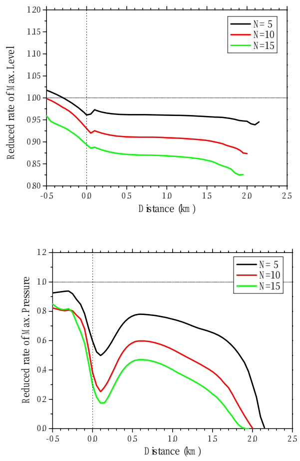


Reduction Rate of Water Level

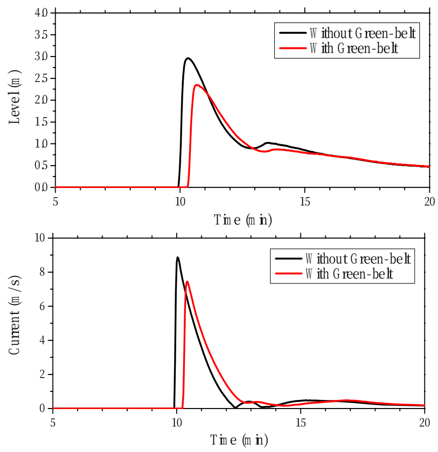
Reduction Rate of Tsunami Force



V-shape Bay

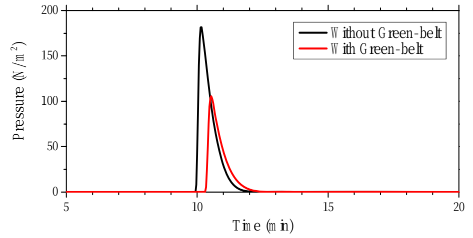


Tsunami Force is Increased at Center



Greenbelt reduce Tsunami Inundation Depth + Velocity

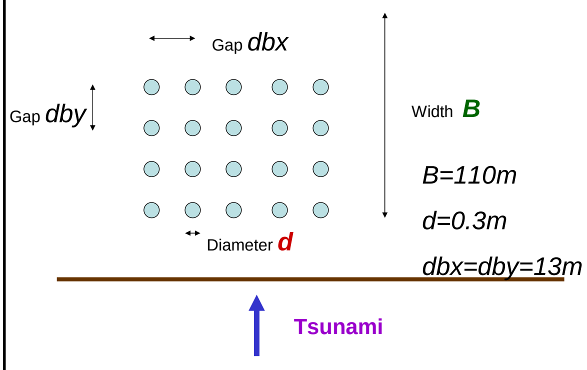
- Effective Evacuation Time
- Safety of House

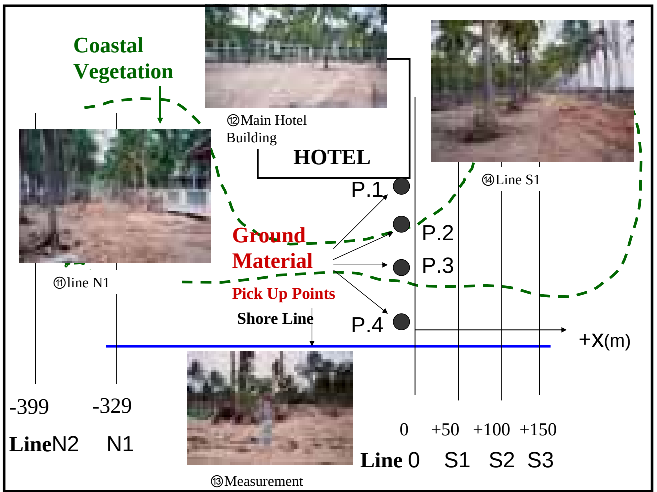


Conclusion

1. Some Greenbelt Reduced the Damage in Coastal Village due to 2004 Tsunami
2. Greenbelt Intensity is Evaluated in Density N and Width B
3. Effect of Greenbelt varies according to the coastal topography
4. Evacuation Time : Increase, Tsunami Force : Decrease

Coastal Vegetation (Greenbelt)



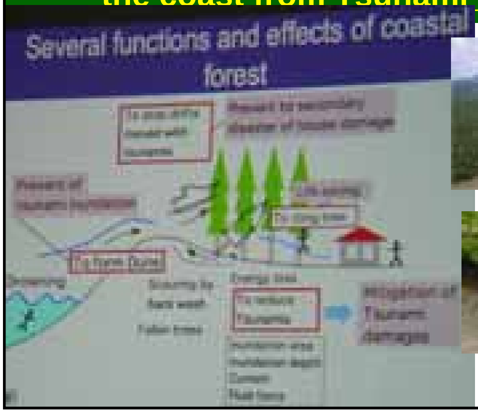


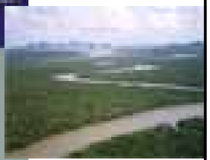
Possibility of Greenbelt to Prevent Land Scouring and Beach Erosion

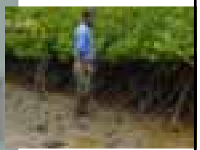
Point 1

Next Step !!!!!!

3. Role of Coastal Vegetation to protect the coast from Tsunami Disaster.



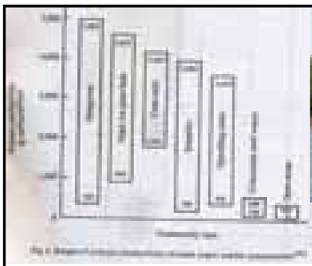


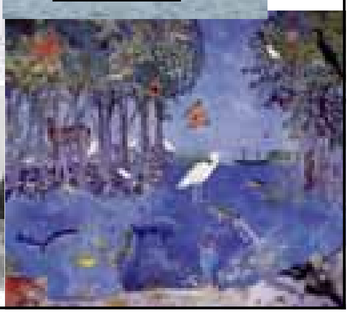


Imamura.

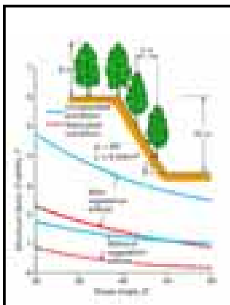
Mangrove's Role in Preventing Natural Disaster

- shock absorbers for the types of flooding and the tsunami
- where there were dense mangroves, there was substantially less damage
- They form a protective buffer, stabilize sediments, reduce shoreline and riverbank erosion, regulate flooding, and recycle nutrients.





BIO SHIELDS Typical Cross section of the coast with Mangroves



Mangrove forests are **natural coastal protection** and where they are removed, for whatever reason, **erosion** is the price to be paid for sure

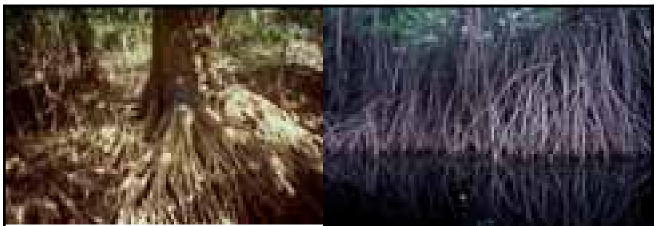
MANGROVES

Mangroves are essentially the root systems of trees and shrubs which thrive in the shallows of salt Water areas. They provide an excellent safe habitat for small marine creatures.

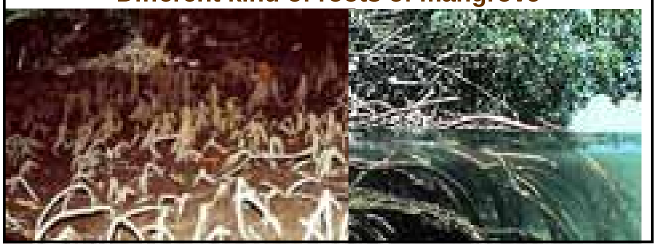
By reducing current speed and trapping sediments, the tangled roots, and trunks of the mangroves help to reduce siltation.

Compared to other **tropical forests**, **mangrove floras** are of low diversity.

Mangrove roots form powerful limbs in open water.

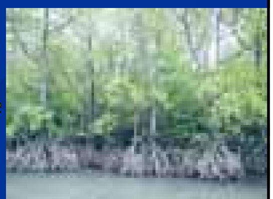


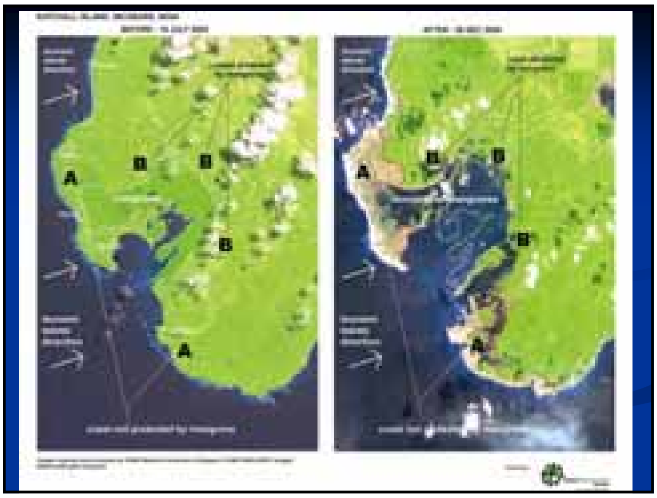
Different kind of roots of mangrove



Did Coastal mangroves protect shorelines?

- **From previous observations and earlier studies, the function of coastal forests in tsunami disaster reduction are:**
  1. **to reflect and resist tsunami energy, reduce inundation depth, inundation area, tsunami current.**
  2. **to stop driftwood and other materials moved by tsunamis, and to prevent the secondary damage by driftwood impact.**
  3. **to prevent people being washed out to sea.**
  4. **to reduce erosion of beaches and dunes which also act as**



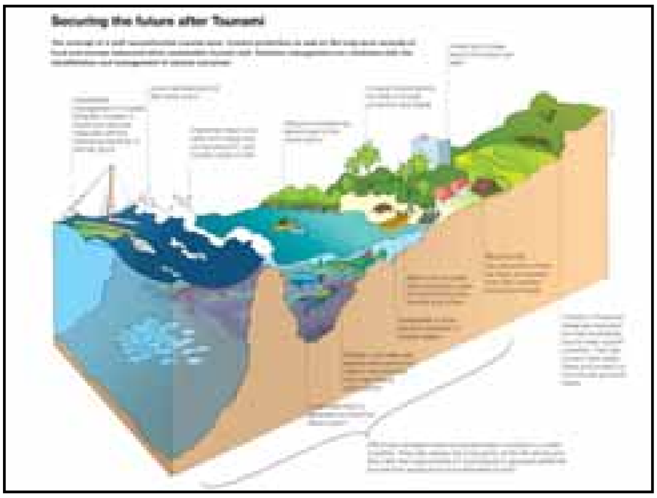


4. Coastline Rehabilitation and Protection.

The six affected provinces of Thailand:

Ranong, Phang-nga, Phuket, Krabi, Trang & Satun.

1.6% (306 ha) of mangrove areas were badly damaged. Value 7.5 M.US$ or 294 M . Baht.



COMPREHENSIVE TSUNAMI HAZARD MITIGATION IN INDONESIA

STRUCTURAL COUNTER MEASURE

❑ **SOFT STRUCTURE**

(Mangrove, sand dune, coastal forest).

❑ **HARD STRUCTURE**

- **breakwater, Seawall**
- **Retrofitting : building reinforcement :**
  - **perpendicular to coast line**
  - **Shear wall dan lateral bracing**
  - **open wall for 1st floor**
  - **Hidrodynamics roof**
- **Shelter**
- **Evacuation route**
- **Relocation**

NON STRUCTURAL COUNTER MEASURE :

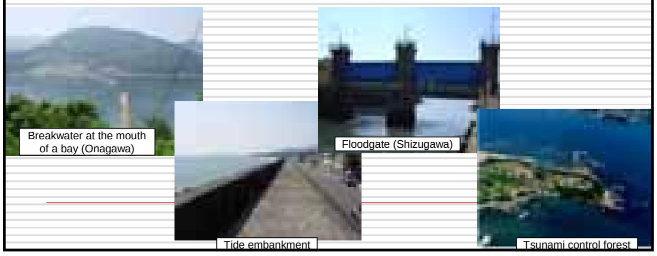
- **Tsunami Zoning map**
- **Tsunami Hazard map**
- **Land use planning**
- **Education and training**
- **Law and regulation**
- **TEWS**
- **Public awareness**
- **Building Code**
- **Poverty alleviation**
- **ICZM**

By Dr.Subandono Diposaptono

REDUCING IMPACTS OF TSUNAMI DISASTER

Provision of facilities after the Chile Tsunami (1960)

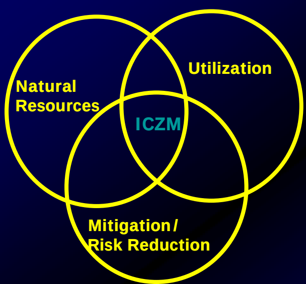
- Construction of breakwaters at the mouths of bays, and tide embankments
- Provision of floodgates at river mouths
- Tree planting for tsunami control forests behind tide embankments



Tsunami defense at Miyako City.

Takata Matsubana Coast.

INTEGRATED COASTAL ZONE MANAGMENT



ICZM must address natural resources, utilization and disaster mitigation

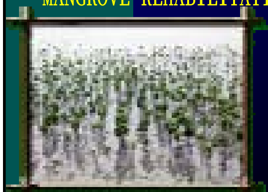
ICZM program has built-in components to address risk reduction

ICZM process starts with the identification of issues, goals and objectives (strategic plan), establishment of zonation plan, formulation of management plan, and establishment of action plan

Integrated Coastal Zone Management (ICZM) is a process that unites government and the community, terrestrial and marine ecosystem, science and management, sectoral and public interests in preparing and implementing an integrated plan for the protection and development of coastal ecosystems and resources.

SOFT STRUCTURE

MANGROVE REHABILITATION FOR COASTAL HAZARD MITIGATION



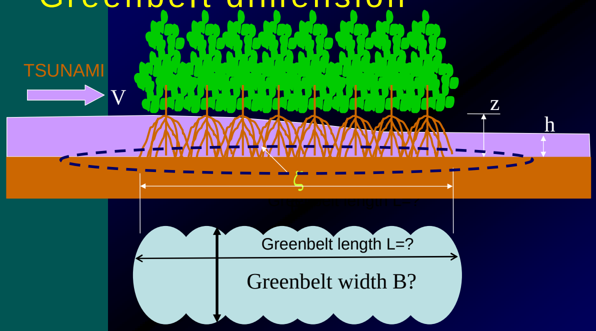
OBJECTIVE

To rehabilitate the coast, with suitable technical interventions and direct communinity involvment in design and implementation of the activities for coastal hazard mitigation

OUTPUT

- Wave attenuation devices installed to protect young mangrove against strong wave action
- Mangrove seedlings planted in the fish pond closest to the shore and behind the wave attenuation devices at selected location
- Monitoring data on the eefect of wave attenuation devices on wave energy and sediment transport.
- A mangrove nursery
- Tambak farmers trained in record keeping, site monitoring, data collection.
- Public awareness materials on coasal rehabilitation which can be used for coastal disaster mitigation.

Greenbelt dimension



The replanting of mangroves is not an easy task, as various factors have to be considered. For example, a plantation-style approach to mangrove rehabilitation programme could result in damage to the coastal ecosystem if done without sufficient preparation. Existing mangrove plants cannot be removed to put in new saplings and mangroves cannot be planted in all intertidal areas .

In Aceh, pollution of waste takes place in the coastal areas due to the waste of ruins of building, waste of things and materials owned by the community, sea materials, decaying human corpses, animal carcasses, and mud from the tsunami. In some places, the content of heavy metals of Cd, Cu, and Pb in the mud of tsunami has exceeded the set limit.

nizam@ugm.ac.id

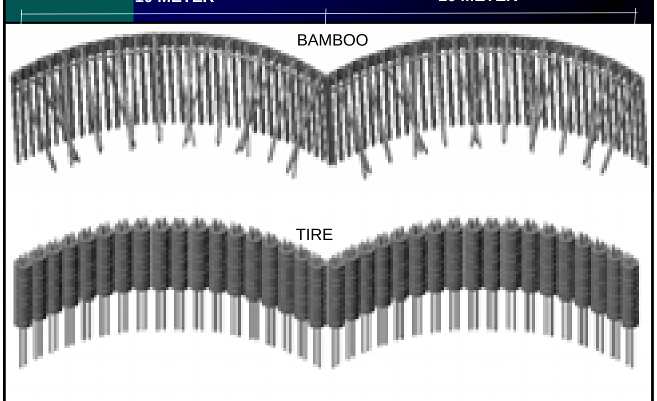
COMPARISON OF MANGROVE GREENBELT THICKNESS

GREENBELT	ADVANTAGES	DISADVANTAGES	NOTES
THICK	SUITABLE FOR TSUNAMI PROTECTION	NOT PROVIDE ENOUGH SPACE FOR AQUACULTURE	INFORMATION ABOUT MAXIMUM GREENBELT THICKNESS
I D E A L	*O P T I M U M*	*M I N I M U M*	*GUIDELINES* *RESEARCH IS NEEDED*
THIN	PROVIDE ENOUGH SPACE FOR AQUACULTURE	VULNERABLE FOR TSUNAMI	INFORMATION ABOUT MINIMUM GREENBELT THICKNESS

Ikonos 2002

MAPPING OF THE SIDE

10 METER 10 METER

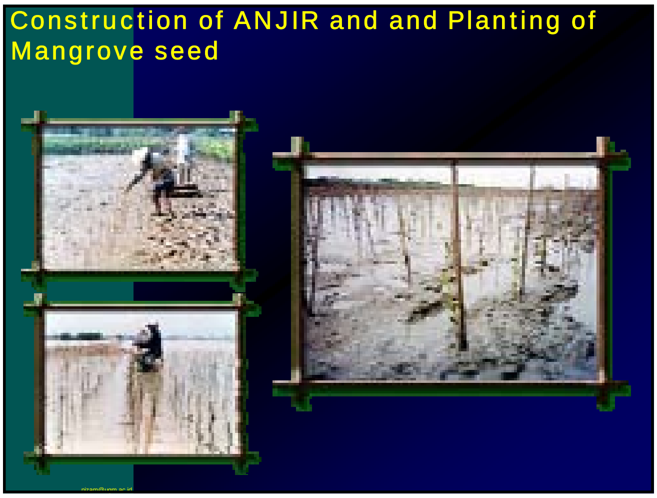


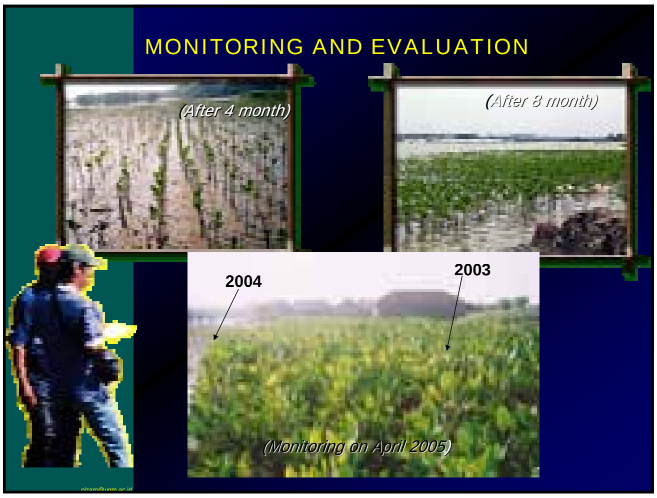
SCHEMATIC OF CONVEX WAVE ATTENUATION DEVICE TO PROTECT MANGROVE SEEDLINGS FROM WAVE ATTACK


Samutprakarn, Ban Laem Sing, THAILAND.
Reforestation by Metropolitan Electricity Authority (MEA).


WAD
INSTALLED CONVEX WAVE ATTENUATION DEVICE FROM BAMBOO MATERIALS TO PROTECT MANGROVE SEEDLINGS


Selection of propagule, Mangrove seedling and preparation of ANJIR (young mangrove supporting device)


Construction of ANJIR and and Planting of Mangrove seed



- Multi-disciplinary survey in the disaster areas
- Recovering by planting the right species in the right places or making the right places for the right species
- Promote ecosystem management to local communities.

Recovery programs in Thailand

(1) Cleaning up all areas including coral reefs seagrass and mangroves and beach nourishment
(2) Monitoring sediment supply along the shoreline and its salinity that contaminated inland
(3) Setting up coastal resources
(4) Maintaining the remain beach trees which uproots and grow on more salty soils
(5) Replanting the deteriorated coastal forests and increasing green zones
(6) Residential areas should longer distance from seashores
(7) Warning systems should be set in all communities and tourist areas.

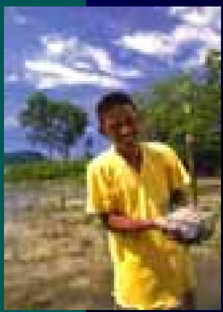
Metropolitan Electricity Authority (MEA)

5. Conclusions

- Coastal forests provided significant protection where there was a sufficient width of intact forest
- Degraded forest or widely spaced trees provided little protection
- Situation varies significantly between sites influenced by different factors
- Strong justification for protection of remaining coastal forests

- Strong justification for immediate support for rehabilitation
- Sufficient experience available in the region for rehabilitation techniques – but information is scattered and not available to many affected communities

Results

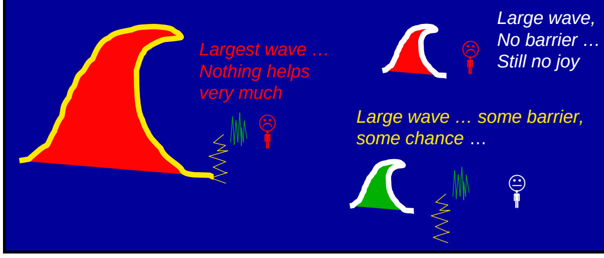


- **Accumulation of sediment behind straight wave attenuation.**
- **Mangrove seedlings growing up healthy.**
- **Increasing awareness of the community on mangrove ecosystems**

The full statement should say "fringing coral reefs and a sand berm of 5-6 m did not protect Banda Aceh from a tsunami wave height of 15-30 m"

In Sri Lanka and Thailand, reef and mangrove protection HAVE been reported, where the wave height was 5-10 m …

Thus natural ecosystems *under XX conditions DID* provide protection but under *YY conditions they DID NOT* …



Tsunami and Coastal Wetlands (selected) Recommendations for Action (Feb 05)

- Prioritise the enhancement of natural coastal defenses through greenbelt/ development.
- Develop predictive guidelines on the value and appropriate positioning, structure and composition of natural greenbelts to provide protection to coastal communities from severe storms/tsunamis
- Establish and enforce "no construction zones" in vulnerable areas and manage them to enable sustainable use by local communities as well as ecosystem recovery.
- Develop community led approaches for protection and restoration of affected and other wetlands, drawing on traditional knowledge and practices and with provision of incentives for sustainable livelihood development.

Ideas for Regional Cooperation for Successful Coastal Forest Restoration (MAP)

- **Establish clearing house for linking local restoration needs with technical restoration agencies and donors**
- **Establish successful restoration models as demonstration sites**
- **Insure community participation in restoration process for sustainability (communities are involved in protection and monitoring)**
- **Coordination & networking amongst NGOs and practitioners to document "Best Practices" of Ecological Mangrove Restoration**

The future – the choice is ours

We dedicated our works to the dead and alive victims of tsunamis.

This tragedy should not happen again in the future.

We'll prepare and cooperate.