## *Protective functions of coastal forests and trees against natural hazards*

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The coastal zone

- -60% of the world's population
- -population doubled the last 20 years
- -exposed to natural hazards
  - -from the land
  - -from the sea

## *HAZARD FROM THE LAND*

***1. Increased soil erosion***

*The sediment yield is largely determined by the climate, the topography and human activities, and is weakly dependent on the catchment size. (Data from Wolanski and Spagnol, 2000; Syvitski et al., 2005; Victor et al., 2005).*

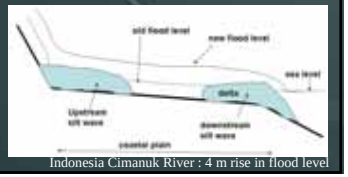
| River | Area ($10^6$ km$^2$) | Yield (tonne km$^{-2}$ year$^{-1}$) |
|---|---|---|
| **Minimal land use** | | |
| Ngerdoch (Palau) | 39 X $10^{-6}$ | 2 |
| King Sound (Australia) | 0.12 | 50 |
| **Moderate land use** | | |
| Yangtze (China) | 1.9 | 252 |
| Amazon (Brazil) | 6.1 | 190 |
| Mississippi (USA) | 3.3 | 120 |
| Mekong | 0.79 | 215 |
| **Extensive land use** | | |
| La Sa Fua (Guam) | 5 X $10^{-6}$ | 480 |
| Ganges/ Brahmaputra (India) | 1.48 | 1670 |
| Cimanuk (Java) | 0.0036 | 6350 |

Philippines

**Results**

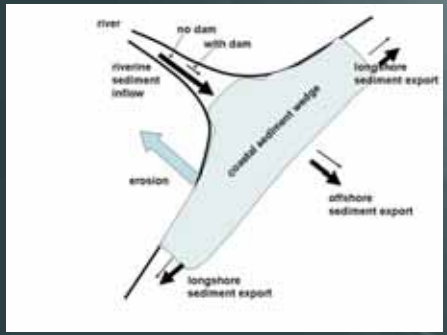
**-catastrophic mud slide**

**-siltation and more flooding**




Indonesia Cimanuk River : 4 m rise in flood level

2. Large dams: trap coarse sediment …….> coastal erosion




Lessons:

- *vegetation must be used to protect the coastal population from landslides in the mountainous areas and along the river banks*
- *large dams must be operated so as to maintain the coarse riverine sediment flow necessary to prevent coastal erosion.*

## NATURAL HAZARDS FROM THE SEA

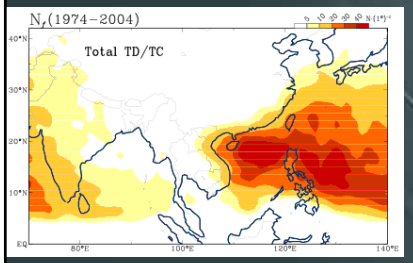
•**Storms and typhoons** generate storm surges and waves, wind and flooding rain mainly at 10 to 40º latitude. The high impact area might be 30 km wide, with extensive/lesser damage at 100 km.

•**A tsunami** is a solitary wave group generated by sudden tectonic movements and volcanoes. In shallow water its height increases to several m or even to tens of m.

•**Coastal erosion** and coastal sedimentation are natural processes. Most coasts are naturally occasionally eroded during storms. Some coasts are naturally eroding in the long-term, some are prograding.

•**Salt spray** originates from seawater droplets that evaporate; It is carried on land by offshore winds.

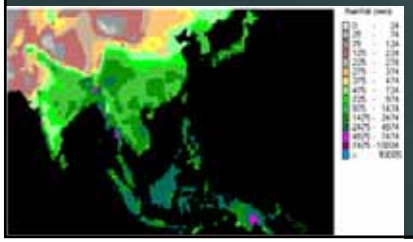
## Where do these hazards occur?




**Typhoons (hurricane, tropical cyclone)**

**SE Asia & Bay of Bengal**

**(Takle et al., 2006)**

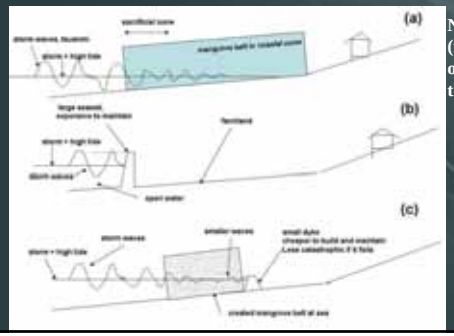


**Salt spray:**
mainly in arid areas
(rainfall less than 0. 5 m/yr)
**(Pakistan).**

For rainfall > 1 m/yr,
salt is essentially diluted
and washed out (FAO data)

•**Tsunamis can happen anywhere –**
- **the origin is mainly volcanic and tectonically active areas (eg Indonesia),**
- **the tsunami can impact coastal areas thousands of km away from the origin.**

•**Erosion can happen anywhere in storms; in the long-term some coasts are eroding and some coasts are prograding.**



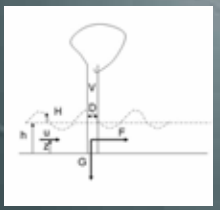

**Natural bioshield (for naturally prograding or stable coasts in the long-term)**

**Hard engineering for eroding coasts**

**Mixed bioshield - engineering structures on prograding coasts (e.g. Vietnam)**

## Protection against coastal erosion in storms/typhoons by absorption of wave energy

**Mangroves absorb energy from the water, reducing wave height and slowing down the currents**



Wave attenuation rate

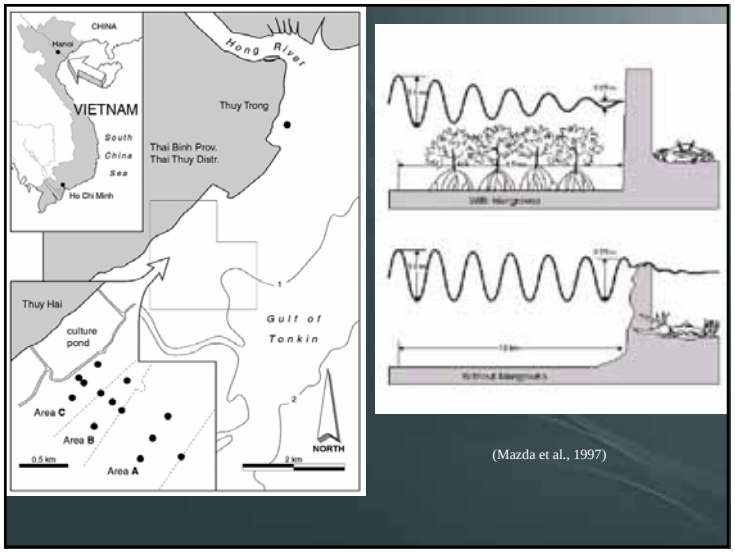
r = (wave height offshore- wave height 100 m inside mangroves)/ wave height

r (in %) per 100 m of adult mangrove plantation.

| **Mangrove species** | **Water depth (m)** | | | |
|---|---|---|---|---|
| | **0.2** | **0.4** | **0.6** | **0.8** |
| ***Kandelia candel*** | **20** | **20** | **18** | **17** |
| ***Sonneratia*** | **60** | **40** | **30** | **15-40** |

The value of r without mangroves was about 5% next to the *Kandelia candel* site and 10% next to the *Sonneratia* site.

(Data from Mazda et al., 1997 and 2006).




(Mazda et al., 1997)

India's Bhitarkanika mangroves: October 1999 super cyclone (wind 260 km $h^{-1;}$ storm surge 9 m)

Badola and Hussain (2005)

Three villages equidistant from the seashore:

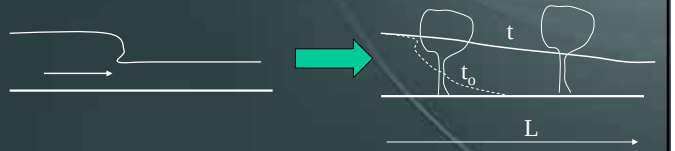
Damage included household damage by the wind, inundation of crops, loss of fingerlings, and salt intrusion.

The losses incurred per household:
US$ 154 in the village that was not sheltered by mangroves and had a dyke that failed
US$ 44 in the village with no mangroves or dyke
US$33 in the village protected by mangroves

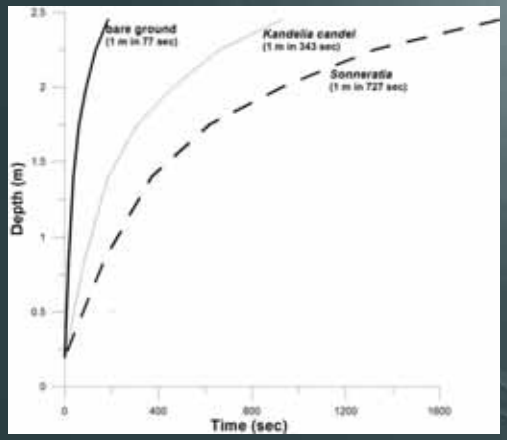
main reason: mangrove creeks drained out faster the flooded land in the shadow of mangroves

## Protection from tsunami

A tsunami is most lethal as a shock wave that carries debris that smashes people and property. The shock wave dynamics are equivalent to that of a tidal bore. Mangroves can transform it in a less lethal flood wave by increasing friction losses, over a distance L (the sacrificial zone).



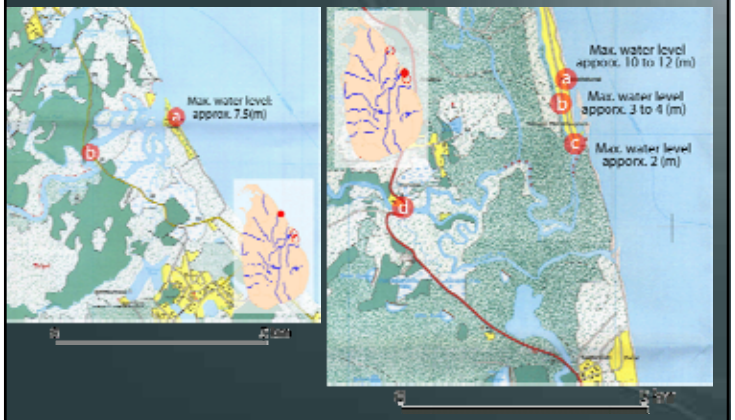
**Fluid dynamics model predictions of the rate of rise of the water surface at a point 500 m from the shore, assuming flat terrain, from a 5 m tsunami at the coast,**

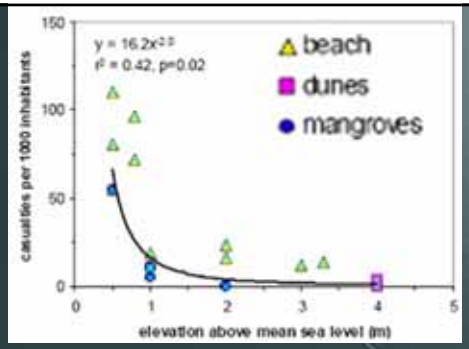



Probably nothing can stop a 10 m tsunami.

## Empirical evidence in Sri Lanka

http://river.ceri.go.jp/rpt/asiantsunami/en/survey.html

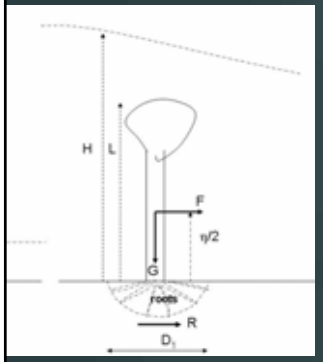



For the December 2004 Indian Ocean tsunami, mortality (lives lost per 1000) in 18 hamlets on the coast of Tamil Nadu

(Source: Vermaat and Thampanya, 2006).

## The mangrove sheltering effect stops if the tree is snapped or uprooted




**Engineering modeling and field data suggest:**

-3 m tsunami snaps 3-m tall mangrove tree
-6 m tsunami wave snaps 8-m mangrove tree
-3 m tsunami uproots an isolated 3 m tree.
However if the trees grow close together, they are more resistant due to interlocking of roots.
Thus densely vegetated mangrove forest of a height > 6 m may be able to sustain a 6 m tsunami wave.

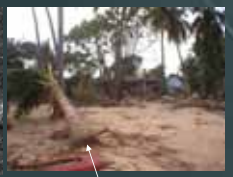
Mangrove trees can't survive a larger tsunami.

*Casuarnia* and palm trees are much weaker (< 3 m tsunami wave – no root interlock?).

Snapped mangroves protected the mangroves inland = sacrificial mangroves

Snapped mangroves

Overturned mangroves



Catastrophic failure and debris flow

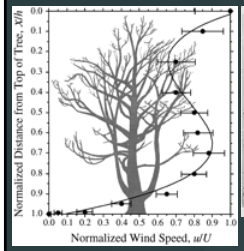
Overturned palm tree

Overturned casuarina

Sources: Muntadhar et al., V. Selvam, the Internet, the author.

## Protection of the coast against wind and salt spray

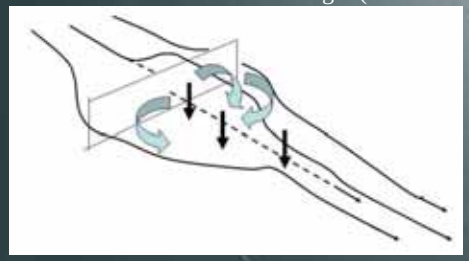
**Flow around and through a tree canopy = porous barrier**
**-Sheltering effect**
**-deposition of salt particles in suspension**





Niklas et al. (2000), Takle et al. (2006)

This sheltering/deposition effect is magnified by 3-D wake effects of flow around an obstacle if the obstacle is made larger (a tree shelterbelt)



This effect disappears if the tree is defoliated or overturned by the wind

Source: USGS Florida

Manage it as a sacrificial buffer zone! (100m?)

## Ecological services provided by mangroves

1. **Enhancement of estuarine and coastal fisheries**

   *Typically 1 ha of mangrove forests support 100-1000 kg/yr of marine fish and shrimp catch; for the Mekong this catch is about 450 kg/yr.* *(Manson et al., 2005)*

2. **Trapping sediment and sheltering seagrass/coral reefs/fisheries**
   - *A mangrove area = 5% of the catchment area traps 50% of riverine mud flux*
   - *Mangroves facing the sea trap 1,000 tonnes/km$^2$/year*

3. **Providing self-scoured, deep, navigable channels**

## Socio-economic services provided by coastal forests and mangroves

1. **Food (eg honey, crabs, shrimp, fish), fodder, wood, medicine, ….**

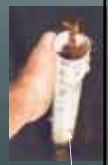
Restoring mangroves + creating new mangroves = soft technology, local knowledge, local conditions. Does not work in naturally eroding coasts.

**Problems = acidic soils + stagnant water (shrimp ponds) + waves**

Stagnant water kills seedlings (Thailand)

New mangrove forest offshore where they did not exist before (Eritrea) (sandy soil enriched by manure)

Failure in wave-dominated areas (upper Gulf of Thailand) – hard structures are still needed



Riley enclosed method, one of several to protect seedlings from wave erosion.

**In steep slopes, wind-driven shallow water waves and boat wakes undercut mangroves at low tide**

## *The width of bioshields* *(empirical evidence)*

**•typhoon winds:**

- **•mangroves: 100-300 m**
- **•coastal forests: 1-2 km**

**•typhoon waves:**

- **•500 – 1000 m of mangroves to protect small coastal dykes**

**This will fail if the coast is naturally eroding.**

**•storm surge:**

- **•200 m of coastal forest and mangrove to produce weak currents;**
- **•will not change much the storm surge height;**
- **•mangroves will speed up draining out the flooded area after the surge.**

**•tsunami:**

- **•>500 m of mangroves for a tsunami < 4 m**
- **•2000 m of mangroves will reduce the tsunami to a small wave less than 1 m.**
- **•mangroves will not be helpful against a larger tsunami at which times other measures (such as advance warning systems, evacuation plans, and shelters) are necessary**

**•Salt spray:**

- **•long shelterbelt several km long, several rows 100 m apart**

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## Take-home message

***•coastal bioshields cannot provide complete protection;***
***•they must be part of regional plan to reduce the risk of loss of life, property and infrastructure to an acceptable level.***
***•a sacrificial zone within this bioshield must be incorporated in the management plan.***
***•the choice of vegetation depends on the severity of the natural hazards, the bathymetry, the climate, the local land use, and the available options to survive extreme events.***
***•the solution must involve the whole river catchment.***
***•vegetation to protect from erosion***
***•in the mountainous areas***
***•along the river banks***
***•large dams must be operated so as prevent coastal erosion.***