SEA LEVEL RISING: CONSEQUENT PROBLEMS ON DELTAS AND COASTAL ZONES IN MEDITERRANEAN AREAS AND OTHER PARTS OF THE WORLD

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2nd INTERNATIONAL CONFERENCE ON DELTAS AND LAGOONS
CLIMATE CHANGE EFFECTS ON COASTAL ZONES

a cura di DELTAMED
OBSERVED CHANGES. AR 5

- temperature
- sea level
- snow and ice cover
OBSERVED SEA LEVEL RISE. IPCC. AR 5
1901-2010: 19cm (17-21)
1901-2010: 1.7mm/year (1.5-1.9)
1993-2017: 3.4 mm/year (3.0-3.8)
OBSERVED AND PROJECTIONS SLR. IPCC: AR5 2014

1900-2100: ≈ 50-120 cm. CENTRAL VALUE: ≈ 80 cm
SEA LEVEL RISE. REGIONAL VARIATION
# Delta Subsidence Rate

<table>
<thead>
<tr>
<th>Natural</th>
<th>Anthropogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO</td>
<td>10 extraction of methane gas (1930-64). Average: 2.00 m</td>
</tr>
<tr>
<td>Nile</td>
<td>Maximum: 3.00-3.50 m</td>
</tr>
<tr>
<td>Ebro</td>
<td></td>
</tr>
<tr>
<td>Rhone</td>
<td></td>
</tr>
</tbody>
</table>

**Cause:**
- Estrazione del gas metano
- Bradisismo geologico
- Assettamenti locali (bonifiche)
RELATIVE SEA LEVEL RISE. RSLR

ESSENTIAL FACTORS

\[ \triangle_{\text{RSL}} = A - \triangle E - C_N - C_A \]
GLOBAL IMPACTS ON THE COASTS, ISLANDS, AND DELTAS FOR A RISE SEA LEVEL OF 1 m.

<table>
<thead>
<tr>
<th>Region</th>
<th>Land area (thousand km²)</th>
<th>Population (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td>223,000</td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>222,000</td>
<td></td>
</tr>
<tr>
<td>Asia</td>
<td>2,223,000</td>
<td>145</td>
</tr>
<tr>
<td>Global (total)</td>
<td>2,223,000</td>
<td>145</td>
</tr>
</tbody>
</table>
DELTAS VULNERABILITY

• The deltas are very fragile and very vulnerable to sea level rise, which can lead to the submersion of very sensitive parts of their current socio-economic and environmental existence.

• At present the most important risk of the deltas is the rise in sea level. Severe risk, which could affect their own existence, because they have large areas that are at levels below 50 cm, or the meter.

• This is compounded by the effect of adjacent subsidence, which makes that relative sea level rise (RSLR), would reach dangerous levels that could cause the submersion of a large part of the delta plains.
GANGES DELTA. BANGLADESH. +1.5 m

Potential impact of sea-level rise on Bangladesh

Today
- Total population: 112 Million
- Total land area: 134,000 km²

1.5 m - Impact
- Total population affected: 17 Million (15%)
- Total land area affected: 22,000 km² (16%)
MEKONG DELTA, VIETNAM
+1.0 m

1/3 DELTA AREA

12% VIETNAM POPULATION
HO CHI MINH PERIPHERAL AREAS
## Mediterranean Deltas

<table>
<thead>
<tr>
<th>Delta</th>
<th>Area (Km²)</th>
<th>Population</th>
<th>Density (Inh/ Km²)</th>
<th>Main Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nile</td>
<td>50.000</td>
<td>45 Million</td>
<td>900</td>
<td>Agriculture, Fishing</td>
</tr>
<tr>
<td>Danube</td>
<td>5.800</td>
<td>16.000</td>
<td>3</td>
<td>Nature, Agriculture, Fishing</td>
</tr>
<tr>
<td>Rhone</td>
<td>750</td>
<td>7.500</td>
<td>10</td>
<td>Nature, Tourism, Agriculture</td>
</tr>
<tr>
<td>Po</td>
<td>420</td>
<td>27.500</td>
<td>80</td>
<td>Agriculture, Fishing, Tourism, Industry</td>
</tr>
<tr>
<td>Ebro</td>
<td>320</td>
<td>15.000</td>
<td>45</td>
<td>Agriculture, Fishing, Nature</td>
</tr>
</tbody>
</table>
DELTAMED
Mediterranean Deltas Association
MEDITERRANEAN DELTAS
RELATIVE SEA LEVEL RISE (RSLR). 2050.
Δ. NILE
SEA LEVEL RISE

Potential impact of sea level rise: Nile Delta

Population: 3,800,000
Cropland (Km²): 1,800

Population: 6,100,000
Cropland (Km²): 4,500
The relative sea level rise (RSLR) is assessed for two emission scenarios (RCP4.5 and RCP8.5) between 60 cm and 90 cm, toward the end of the 21st century. In a shorter period, by the middle of this century, the RSLR would be between about 30 cm and 45 cm.

The Ebro delta is a very flat plain with maximum levels of around 1m, and most of its surface (about 50%) is at levels lower than 50cm.
EBRO DELTA. RELATIVE SEA LEVEL RISE
EBRO DELTA. SEA LEVEL RISE +0,40 m.

Ebro Delta Natural Park
EBRO DELTA. SEA LEVEL RISE. + 0,5 m. + 1 m.

Today

+0,5 m

+1 m
EBRO DELTA. SEA LEVEL RISE . + 2ºC
RISK MAPS

NATURAL SYSTEMS

HUMAN SYSTEMS AND POPULATION
DELTAS. ACTIONS AND MEASURES FOR ADAPTATION TO SEA LEVEL RISE. ALTERNATIVES

- **Renaturalization** of the deltas. Conversion of the delta to earlier, more primitive states

- **Artificial accretion**. Sediment supply to the delta plain

- **Removal of cultivation areas** and other activities in the lower parts of the deltas and their **transformation into wetlands**

- **Non-intervention.** Progressive abandonment of environmentally rich areas and urban and agricultural areas

- **Combination of structural actions**
COMBINATION OF STRUCTURAL ACTIONS

• One of the possible, viable and effective actions to reduce the vulnerability of the deltas and increase their resilience to climate change are structural solutions.

• Combining and coordinating traditional structural types (gray infrastructure) with more natural structures (green infrastructure). Working with nature.
In November 1966, Italy suffered a major storm which caused severe flooding, producing about 120 fatalities and extensive damage.

The floods in Florence, the highest tide recorded in the Venetian lagoon, with “aqua alte” reaching +2 m, and the destruction of the coastal defences of the Po delta.

After these floods, the current, sea dikes and river dikes of the Po delta were constructed. Completed in 1980.
Dall'ultima alluvione da mare del 1966 sono stati realizzati argini di prima e seconda linea di difesa a mare.
The dikes: earth type, with a protection of rockfill up to level + 1 m. The top level is + 4.00 m above sea level, and the length of its base is about 50 m.

In the north of the main branch of the Po, these levees divide the agricultural territory from the fishing valleys (fish farms).
**COASTAL DUNES**
On the coast there are, in some areas, some coastal dunes. Its crest level is variable between +1.00 m and +2.00 m above sea level.

**DELTA PO. ZONES**

-1. Open delta. Area between the coastal dunes and the first line of defence. Connected directly to the sea through the mouths in the dunes.

-2. Closed delta. Area between the first and second line of defense. Separated from the sea by the first line of dikes.
- In the Po river there are also dikes of defense against the fluvial floods, that channel the river through dikes. Dikes crest levels varying between +4.00 m and +14.00 m.

- In general the river flows very high above the deltaic plain. Hanging waterway.
After the severe floods of 1856 Napoleon III made the decision to build new dykes in the river, and also to defend the delta sea front for the protection of the deltaic territory.
A dike for the sea defence ("Digue à la mer") was constructed, designed to prevent the effects of storms.

Length of about 25 km along the coast of the Camargue, south of the lagoon of Vaccarès in the National Reserve of the Camargue. Crest level +1m
The two active branches of the river Rhône, Great Rhone and Little Rhone, were channelled by dikes in their totality. Thus, as early as the nineteenth Century the Camargue was artificially closed in its entirety, by sea defence dikes and river dikes.
1.- Perimeter **dike** for the protection of the inland delta plain (**red line**)

2.- Heightening the coastlines **arrows** (**yellow line**)

3.- Coastal **front protection** (**green line**)
1.- Perimeter **dike** (**red line**).
Earth type. Length of about 50 km. Crest: level, + 1.50 m to +2.0 m, width 4-5 m.

2.- **Heightening the coastlines arrows** (**yellow line**)
Artificial supply of sands up to +1 m to +2 m, to be progressively coupled to the RSLR, and to maintain, in general, its current coastal structure and dynamics.

3.- **Coastal front protection** (**green line**)
Dunes and coastal artificial islands, with various configurations: exempt or low coronation, to partially dissipate the energy of the incident external waves.
• Two lines of defence: the first active and dynamic (yellow and green lines) located on the coastline, the second (red line) with a perimeter dike to avoid submersion and flooding of the inland part of the delta plain.

• Initial assessment of the cost: about 170 M€
PERIMETER DIKE CONSTRUCTION
IMPACTS OF CLIMATE CHANGE IN THE DELTAS

• Submersion of the deltas, due to sea level rise
• Changes and losses in lagoons and wetlands
• Increase of regression and other morphological changes of the coastline
• Changes in river floods and sea storms
• Increase of salt water intrusion. More saline environments
• Increase in penetration and permanence of the salt wedge
• Affection to the drainage network. Increase of drainage pumping.
• Changes in the availability of water resources
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