Socio-economic stakes linked to climate change in Mediterranean coastlines, mitigating policies against SLR and promoting clean energy civil engineering works.

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Introduction

Conventional mitigating policies such as beach nourishment, breakwaters, polderization, shoreline retreat or comprehensive irrigation can solve the dilemma arising from moderate global warming. But when severe shore erosions, disastrous coastline submersions, inland salt water intrusions followed by droughts are dealt with, it becomes much more difficult to find solutions. Not only urban and tourism facilities will face deterioration, but essential food production of lowland crops and of lagoon fish catching will suffer, thus inducing social unrest. In view of the latter dilemma, innovative civil engineering works should be considered, securing double targets of i) coastline protection and ii) clean sustainable energy production.

We are intent in this document on presenting actual and prospective tensions linked to water hazard in the coastal areas of the Mediterranean Basin. We will take two examples focusing on the Nile and Rhône deltas. The possibility of developing hydro-wind-geo power plants at the strait of Gibraltar producing far over 1,500 Gwh of renewable energy and at the same time, regulating water level of hydraulics circulation between the Atlantic and Mediterranean for protecting lowland deltas, will be discussed.

Socio-economic stakes

According to the last GIEC report (IPCC 2014), modern technologies could help reducing the present greenhouse gas emissions by at least 50% before 2050, and lower them further at the turn of the 22nd century. Under such a scenario the global warming of earth temperature would not excess 2.6°C by 2100 and the corresponding sea level rise (SLR) would stay at a moderate 50 cm (Church et al 2013). However in the absence of relevant actions, a worst scenario of additional increase of both temperature and SLR is likely to prevail, with serious risks of water hazards in the densely populated coastal deltas of the Mediterranean Basin.

There are 23 countries or territories bordering the Mediterranean Basin which occupy 8.8 million km². They host a global population of 500 million permanent inhabitants and are divided into 13 NMC (North Mediterranean countries) in Europe, and 10 SEMC (Southern and Eastern Mediterranean countries) in Africa and Asia (see Tab.1).

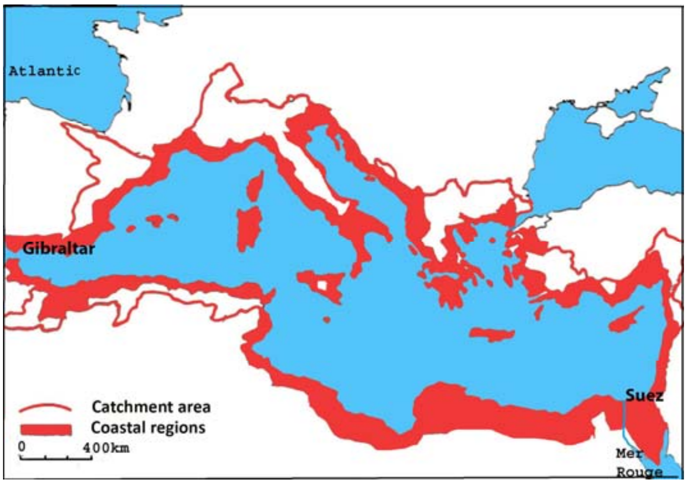

Fig 1 Mediterranean Coastal eco-regions (after Blue Plan's)

The coastal eco-regions proper (Fig.1) develop 46.000 km of shorelines but covers only 1 million km². It is divided into 300 maritime departments or governorates and host 35 per cent of the Mediterranean population on 12 per cent only of the riparian countries (Benoit and Comeau 2005).

The population of the Mediterranean countries is expected to reach 530 million by 2025 and more than 600 million in 2050. That increase will mostly occur in the coastal areas of the SEMC countries. In addition the Mediterranean will remain the first destination for seaside tourists, with international arrivals amounting to 180 million visitors by 2025.

Table 1 List of Mediterranean countries/Territories after Blue Plan's

23 Med Countries/Territories			Coastal regions
NMC Countries	E.U.	Gibraltar	1
		Spain	12
		France	9
		Italy	57
		Greece	41
		Monaco	1
		Cyprus	6
		Malta	2
		Slovenia	1
	Eastern Adriatic	Croatia	7
		Bosnia Herzegovina	1
		Serbia Montenegro	1
		Albania	11
SEMC Countries	Asian Shores	Turkey	10
		Syria	14
		Lebanon	4
		Israel	6
		Palestinian Territories	1
	African Shores	Egypt	14
		Libya	25
		Tunisia	24
		Algeria	48
		Morocco	4
		Total	300

As 85 per cent of these new tourists arrivals will occur in the coastline regions, one can realize the peak of residents and visitors whishing to attend the coast. By 2025 strongest tourist pressure will probably occur in the East (Turkey, Lebanon, Israel, Egypt) and the North (Spain, France, Monaco, Italy, Croatia, Slovenia). The population density of Monaco for example will reach 20,000 inhabitant/km². Inevitably large concentration of roads, railways, ports, yacht harbours, marinas and airports will put these coastal areas under high pressure. For wastewater management, the scope of improvement of sewage facilities is huge since various coastal regions have only 40 per cent of connected population, and considering the expected increase of flow in SEMC by 2025 (UNEP-MAP 1999 and 2000).

Consequently over the last thirty years urban expansion and water pollution have gradually depleted the precious marine and sand dunes ecosystems that oppose the best protection against flooding and erosion. In many places precious Posidonia meadows are shrinking, and sand dunes vegetation erased. Since urban development has too often reached the point beyond the capacity of land ressources, vast projects are being developed in flood-prone areas. Winter rainfalls characterized by violent Mediterranean downpours are causing catastrophic floods, when associated to concomitant winter storms sea level rise. For these reasons any additional centimeter of SLR due to global warming is of great significance for Mediterranean coastline areas. Finally long summer droughts complicate the supply of fresh water demand for agriculture and societies as overexploitation of coastal aquifers will enhance salinity problems.

The endangered Nile river delta

The arc-shaped Nile delta is approximately 160 km from North to South, and 240 km from West to East, with two main distributaries, the Damietta and the Rosetta branches. This densely populated and fertile land is covering 3.5 millions ha, of which 2.35 million established on river silt deposits, and 0.8 M ha on new reclaimed desert-land irrigated by reused drainage wastewater. A 50 km wide strip bordering the coast of the Mediterranean sea is less than 2 m above sea level. It was so far protected by sand dunes which are now facing rapid erosion, and more acutely since the construction of the Aswan Dam where silt deposits are trapped. Erosion waves driven by the currents of the east Mediterranean gyre, swap across the shallow shelf with a speed of 1m/s. The narrow sand band separating lagoons from the Mediterranean sea is gradually disappearing. Behind these dunes there are some 200,000 ha of fresh water lakes producing one third of Egyptian fish catches (Elsharkawy et al 2009). As linear sand dunes become segmented the lakes are more open to sea intrusions and their ecosystems are being disturbed.

In addition the economic and industrial cities of Alexandria, Behaira, Damietta and Port Said established on waterfront are exposed to high risks of erosion/submersion and will be flooded permanently with only + 1m SLR (Fig 2). More generally the Northern part of the agricultural Nile delta amounting 15% of cultivated land, is under threat of SLR associated with salt water seepage into ground water. Egyptian agriculture supplies 20 per cent of the gross national product. It is anticipated that a + 1 meter SLR would impact 12 per cent of local food production.

Fig 2 Prospective of + 1 meter sea level rising (light blue) on the Nile delta coastline

Western Camargue of Languedoc

The south-west part of the Rhône delta has 60 km of fine sandy beaches encompassing 150,000 hectares of lagoons and marshes. Local economy counts 400,000 touristic hotel beds accommodating 200 millions nights/year. The coast is hosting 750 professional fishermen collecting 3,500 tonnes of catches per year and 9000 tonnes of shells (oysters and mussels). Lowand agricultural production counts 23,000 ha of rice, 6,700 ha of grapewine, 7,500 ha of fruit trees, as well as traditional bull cattle breeding in wet grassland (sources SMCG). Salt production is also developed on 30,000 ha of saltpan producing 1 million tonnes. Finally wetland ecosystems harbor rich wildlife sanctuaries for migrating birds. Future SLR is likely to disturb such an important asset as shown of Fig 3.

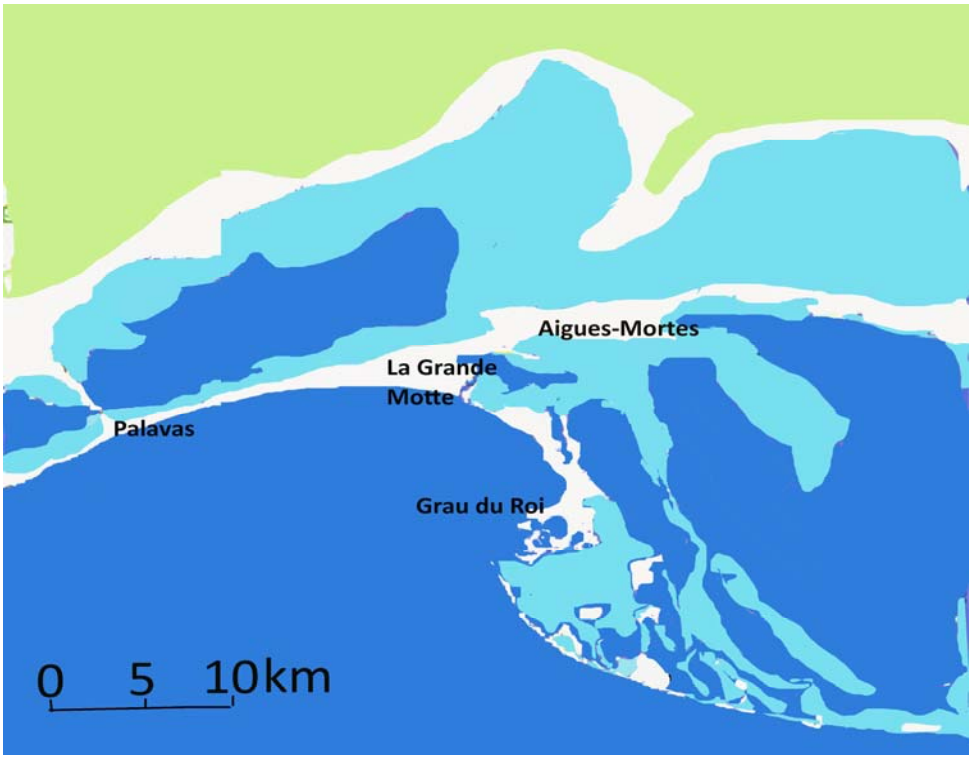

Fig 3 Prospective of + 1 meter of sea level rising (light blue) on the Western Camargue coastline

The coast of Western Camargue was built up during the Holocene on ancient deltas of the Rhône river. Today that coast is exposed to erosion by a current gyre, combined with frequent and strong south storms. At the end of the 1950s, 298 frontal and lateral breakwaters were establish between Saintes-Maries de la Mer and Sète for protecting touristic agricultural and salt industrial activities from sea intrusion (Fig 4). It was followed in the 1980s by a vast program of sand dunes rehabilitation, and more recently by marine sand replenishments (Fig 5). In 2008 1,3 million cubic meter of marine sand were extracted by suction and discharge dredging with the objective of stabilizing beaches and dunes between Grau du Roi and Palavas for the coming 20 years. But six years later this effort was annihilated by a relentless erosion.

Fig 4

Floods in low-lying resorts of the coastline of Palavas that is protected by frontal breakwaters 2003

Fig 5 Beach replenishment Carnon Petit Travers 2008

La Grande Motte an island ?

In the 1960s seaside resort which hitherto was considered in France as some kind of utopia, became common place and affordable to all. La Grande Motte in particular was developed as a new concept for accommodating 100,000 new working class tourists and residents, eager of rejuvenating body at sea and sun. The construction of this new coastal city began with a titanic dredging of Ponant lake for raising the height of ground at 2 m above sea level. For this, five million cubic meters of sand and earth were moved. The double objectives were i) securing a large river estuary to the adjacent and dangerous Vidourle river, ii) prevent the brand new seaside town from marine submersion. The chief architect Jean Balladur, whose work would span over three decades, determined and controlled the architecture of this new seaside town (Ragot 2014). He designed with great care the sea frontline for stabilizing the dunes (Fig 6) . A future + 1 meter SLR would make La Grande Motte an island city without beach(Fig 3).

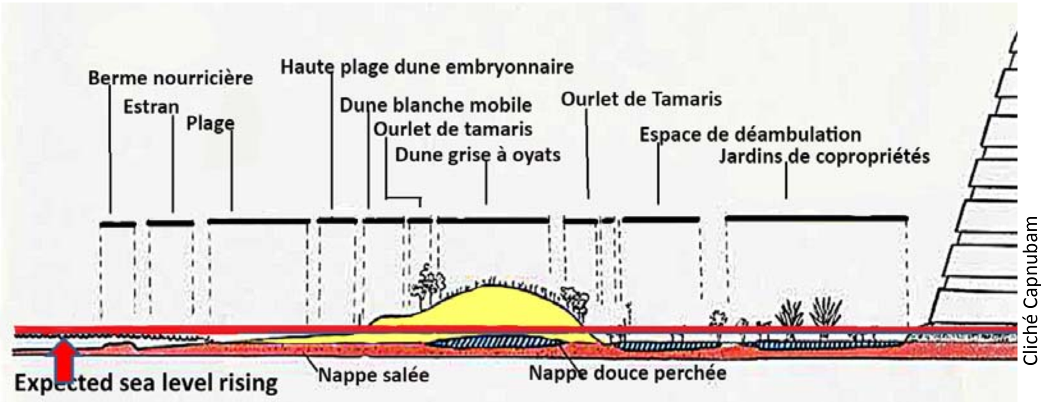

Fig 6 Cross section of urban seafront line of La Grande Motte

As a whole, the numerous touristic agricultural and fishery activities will be impacted by SLR. For instance all the new mobile home villages real estate being presently established below 1 meter above sea level will have to be raised at 2 m above sea level. On the other hand coastal cities are already facing difficult problems for the management of underground networks of drinking water supply as well sewage electricity and telecommunication networks. Salt industry will become probably no longer competitive, as dyke protections established 50 years ago will have to be rebuilt on retreat shorelines.

Coastal agricultures have been developed on reclaimed areas. This conquest was difficult and they are of great value. But now they are threatened by salinity and the sprawl of urban areas. Swamp rice production will need more and more precious fresh water to remove salinity. Fruit (stone fruits, citrus) and grapevine productions are already experiencing lower crops due to gradual increase in salinity as the salt wedge is moving further inland.

The need for clean sustainable energy

Over the coming years, the driving force of Mediterranean energy demand will remain population and economic developments. For the NMC and SEMC countries, the energy needs will rise from 12,700 TWh in 2010 to 17,500 TWh in 2025. Among the demands for fossil sources, oil will increase from 4650 TWh to 6400 TWh in 2025, considering that only four Mediterranean countries are hydrocarbon exporting (Algeria, Egypt, Libya and Syria), all others being importers. Finally 87 per cent of the energy demand will come from fossil sources (coal,oil,gas) with a growing share to gas. By 2025 renewable energies are projected to provide no more than 4 per cent of total energy sources (OME 2002), and only NMC countries will remain endowed with nuclear sources for electricity supply.

Clearly there is a crucial need for SEMC countries to get access to advanced energy parks combining GW hydro-power, wind power, marine power, solar power and deep geo-thermal cogeneration (GEOCOGEN).

Hydro-wind-geo power plants at the strait of Gibraltar

The Mediterranean sea has a negative hydrological balance since evaporation exceeds the total runoff and precipitation reaching the Basin. Buoyancy losses of around 0.7m/year, produce 25 x 10^{12} m^3 / year of salty water that flows out of the Strait of Gibraltar as a mighty river discharging at 800,000 m3/s^{-1} and compensated by an upper layer opposite flow slightly greater which fills up water losses. This exchange takes place through the very constraining topography of the Camarinal sill where tides move back and forth a volume of water five times greater than the mean exchange and generating a train of internal waves that travel eastward at 1.5-2ms^{-1}. The use of these flows for hydro energy, will need complex multi-disciplinary studies especially if a partial closure of the Strait is targeted for a significant impact on the Mediterranean SLR.

Keeping the level of Mediterranean Sea constant

Johnson (1997) proposed the construction of a dam at Gibraltar for regulating Mediterranean inflow and outflow waters by separate gates (Fig 7). On the other hand preliminary studies of water circulation at the strait of Gibraltar were undertaken by Smaoui and Ouahsine with a model grid of uniform horizontal and vertical spacing of 500 metres (2006). The model was run for a complete fortnigthly period, with harmonic analysis to compare computed results with observed data of marine circulation. A more detailed numerical modeling of three-dimensional stratified tidal flow over Caraminal sill was proposed by Sanchez et al (2011). Recently Ha-Phong Nguyen (2014) simulated the set up of a dam 500 metres wide, 27 kilometres long, with a central gate. He suggested that a 90% closure of the strait would keep the Mediterranean sea level constant, in the advent of a global SLR. The balance cost/benefit of such a dam will have to be compared with that of countless dyke constructions aiming to prevent endangered Mediterranean lowland deltas.

The issue of developing a plant securing sustainable clean energy production together with SLR protection, will obviously need innovations of devices and technical solutions. Furthermore ecological and socio-economic constraints are now far beyond those met by Herman Sörgel (1932) when he launched his utopian Atlantopia project of keeping the Mediterranean Sea 120 meters lower.

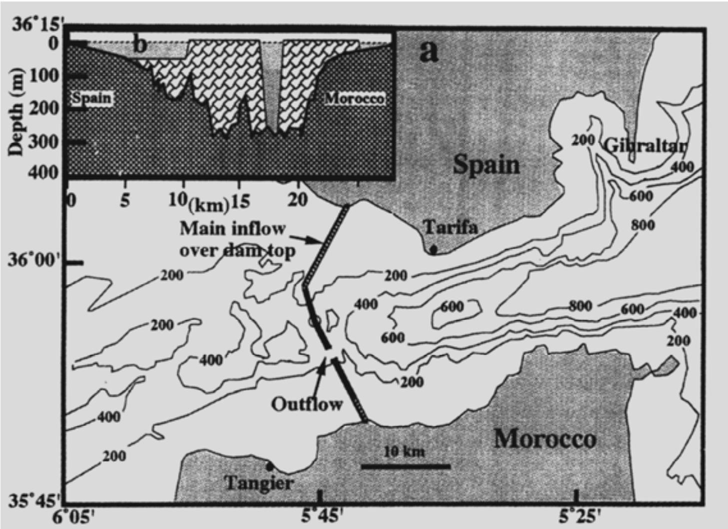

Fig 7 Gibraltar dam with a) Map showing inflow openings and the outflow gate at Camarinal sill b) Transect of the dam (after Johnson 1997)

The Medshild project

The MEDSHILD project aims to develop a multi-purpose dam producing 15,000Gwh to 20,000GWh of renewable energy, besides regulating hydraulic circulation between the Atlantic and Mediterranean following the Ha-Phong Nguyen scheme. This project Medshild is being developed under the umbrella of environmental and marine experts from United Nations bodies like the World Meteorological Organization (WMO), the IPCC, the United Nation Environmental Program (UNEP), the International Marine Organization (IMO), and NGOs like the International Union for the Conservation of Nature (IUNC), the International Hydropower Association (IHA), the World Commission on Dams (WCD), the World Wind Energy Association (WWEA) and the International Sustainable Energy Organizatiotion (ISEO). A sister project called Redshild Locks has also been set up for Red Sea level regulation into the Mediterranean. The objectives are to coordinate all involved partners and avoid imbalance between shipping routes of Gibraltar and Suez. A Consortium treaty will be concluded between all parties.

Conclusion

Group around a commonly shared sea, the coastal provinces are the cornerstone of economic activities for the Mediterranean Basin, especially the rich lowland deltas exposed to the risks of sea level rising. The innovative and ambitious sustainable project of Gibraltar dam, could offer new types of fostering partnerships among the Mediterranean. The cost and the magnitude of the task might delay the decision until climate deterioration becomes a reality. Besides the scarcity of petroleum supply in the future will inevitably lead to political and military conflicts thus increasing the difficulty of the broad internal effort needed to carry out the project.

Acronyms

GIEC: Group intergouvernemental d'experts sur l'évolution du climat
IPCC: Intergovernmental Panel on Climate Change
OME: Observatoire méditerranéen de l'énergie
SMCG: Syndicat mixte pour la protection et la gestion de la Camargue Gardoise

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