Conflict/Synergy and Land-Sea Interaction

Lebanon scale

Co-Evolve4BG

Analysis of Threats and Enabling Factors for Sustainable Tourism at Pilot Scale

Conflict/Synergy and Land-Sea interaction

Lebanon scale

OVERVIEW

The present document was produced in the framework of **Co-Evolve4BG** project "*Co-evolution of coastal human activities & Med natural systems for sustainable tourism & Blue Growth in the Mediterranean*" in relation to Threats and Enabling Factors for maritime and coastal tourism development on a national scale" Co-funded by ENI CBC Med Program (Grant Agreement A_B.4.4_0075).

This document constitutes the **Deliverable 3.1.4.73** (Conflict/Synergy and Land-Sea interaction – Lebanon scale) of the **Activity 3.1.4** (Threats and Enabling Factors at National Scale: Overview) under the **Output 3.1** (Integrated analysis of Threats and Enabling Factors for sustainable tourism at MED scale) of the project.

REVIEW

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I. Introduction

This document consists of deliverable 5 from phase 1 related to Conflicts/Synergies among different uses. In fact, it concerns not only land and sea but also land-sea interaction in tourist Blue Growth areas in Lebanon. Firstly, this document is going to start by assessing coastal land use impact on marine tourism (*e.g.,* coastal, and marine litter, and effect of touristic boat traffic). As a downscaling from the report "Littoralization and Urbanization - Lebanon scale"- Urban, it is going to make use of the satellite imagery and GIS to assess the impact of local human encroachment together with the overexploitation of coastal areas along the Lebanese coast. This is in order to determine the devastatingly altered areas impact both on the touristic sector and the landscape fertility.

It is also going to detect coastal degradation rates (*e.g.,* coastal erosion) as well as earthquake risks and to investigate natural resources exhaustion and abuse (*e.g.,* water resources, agricultural lands, sand, *etc.*) specifically in touristic regions.

This document will research different issues as illustrated below:

- The state of macro and microplastics' coastal sediments pollution
- Waters and biota, heavy metal concentration assessments,
- Solid wastes and wastewater risks
- Aspects of fishing through emphasising fish overexploitation and its impact on coastal biodiversity.

Apart from the above studied issues, this report is going to identify the possible occurrence of either elasmobranch or cetacean bycatch (top predators) through fishing practices (artisanal or recreational). For example, the trawling and bottom trawl are often adopted by local fishermen.

After analysing land-sea interaction, identifying human and touristic activities that have had much more effects on marine environment and vice-versa, as well as mapping marine pollution sites (hotspots) from oil spills, sewages, solid wastes, *etc*.), the document illustrates the most vulnerable and the most highly risky coastal (*e.g.,* sea level rise, earthquakes) using remote sensing and GIS techniques.

Finally, the document will end by reviewing the existing policies regarding the implementation of sustainable economic activities along the coastal area, and therefore, identifying gaps and threats for the conservation of coastal resources and marine ecosystem services.

II. The coastal and marine domain: characteristics and impacts

The Lebanese coastal area stretches over 220 km along a North South axis. It represents a narrow continental shelf with a straight coastline and few bays, cliffs, and river deltas. The Lebanese coastal line consists of rocks (80%) and sands (20%) and it is rich in archaeological sites/cultural heritage. The strongest sea waves usually occur in winter (January, February, and March) while the offshore currents take place in the North-East. In fact, as a rule the eddy currents move clockwise, leading ultimately to sand accumulation in bays and harbours (PEGASO for ICZM-IUCN Med, 2014).

The major urban agglomerations which exert the most pressure on the sea litter, and which represent the major sources of solid and liquid contaminants sources as well, are easily and clearly spotted in Beirut, Tripoli, Saida and Tyre (Figure 1).

As a part of the Middle East Region, Lebanon is characterised by a unique topography where elongated mountain chains are laying side by side to the Mediterranean Sea. These mountain ridges represent a climatic fence which makes Lebanon one of the most eminent and renowned climates among all the surrounding regions.

In fact, Lebanon topography encompasses three geomorphological blocks:

1. The uplifted mountain chain entitled Mount-Lebanon (to the west) which extends alongside the coast with its geomorphologic block is also described as the coastal zone of Lebanon,
2. The compressed mountain chain tilted eastward and was described as Anti-Lebanon.
3. A wide depression called the Bekaa Plain, which extends in between the two mountains chains. These units are headed in the NNE-SSW direction.

The coastal zone includes four geomorphological units represented mainly by the coastal plain and the adjacent mountain chain, where the geomorphology of this zone is mainly a combination of topographic surfaces and geological features with dominant mountainous nature. Therefore, the coastal zone can be divided as follows:

1. *The coastal plain* (<100 m altitude): It is a littoral ribbon, with friable sediments and loess, that extend parallel to the Mediterranean Sea (NE-EW), and it is characterised by relatively narrow width (<10 km). The average width of this plain is about 2.5 km, while it has an average slope gradient of about 20 m/km. Therefore, it seems to be totally disappearing. Besides, then rocky masses are situated directly on the shoreline:
2. In Beirut or in any other places, the plain may reach 10 km in-land, like Akkar Region, north Lebanon.

3. *Lower Slopes Plateau* (<500 m): This is the slightly elevated area which is in direct contact with the coastal plain. It has diverse extensions on the land area, which starts from the coastline to extend up to 20 km like the south Lebanon region. This geomorphological unit consists mainly of carbonate rock masses that are sculptured by valleys with gentle to moderate channel slopes. This geomorphological unit has an average slope gradient between 40 and 50 m/km.
4. *Upper Slopes Plateau* (500-1,500 m): This unit represents a transitional zone between the different littoral mountainous facies, and it extends to an altitude of 500 m with an average width of about 10-15 km. This unit is also composed mainly of carbonate, argillaceous and clastic rock masses, intersected by steep-channel valleys. This geomorphological unit has an average slope gradient of 60-65 m/km.
5. *Crests* (>1,500 m): On a regional scale, this geomorphological unit is a unique landscape, where several crests exist. The most elevated crest reaches almost 3,088 m altitude (Kornet Essawda) representing the highest crest in the Middle East. In fact, this unit, which has similar rock types as the upper slopes plateau, has also a width ranging between 5 and 15 km, while the slope gradient averages between 120 and 140 m/km.

The shoreline of the Lebanon coastal zone totals about 225 and extends between Al-Arida in the north and Ras An-Naqoura in the south. In fact, it extends between the following geographic coordinates:

- 34° 37' 58" N & 35° 58' 35" E, at Al-Arida
- 33° 05' 39" N & 35° 06' 14" E, at Ras An-Naqoura.

Lebanese shoreline general alignment is in the NNE-SSW direction, shaping the overall direction of the Mount-Lebanon ranges. A series of capes such as Ras Beirut, sandy beaches in Ras el Shaqaa, Batroun, Jbeil, Maameltein, Ramlet el Bayda, Jnah, Damour, Tyre, *etc*., intersect the coastline (Figure 1). Moreover, the coastal line is intricate by a series of cliffs such as the cliff of Ras el Chaqaa in the north and of Bayada at Naqoura, and rocky capes as well such as Ras Es-Saadiyat, Nabi-Younes and Sarafand. Three major bays are present in: Jounieh, at the Pigeon Rock in Beirut, and in Naqoura.

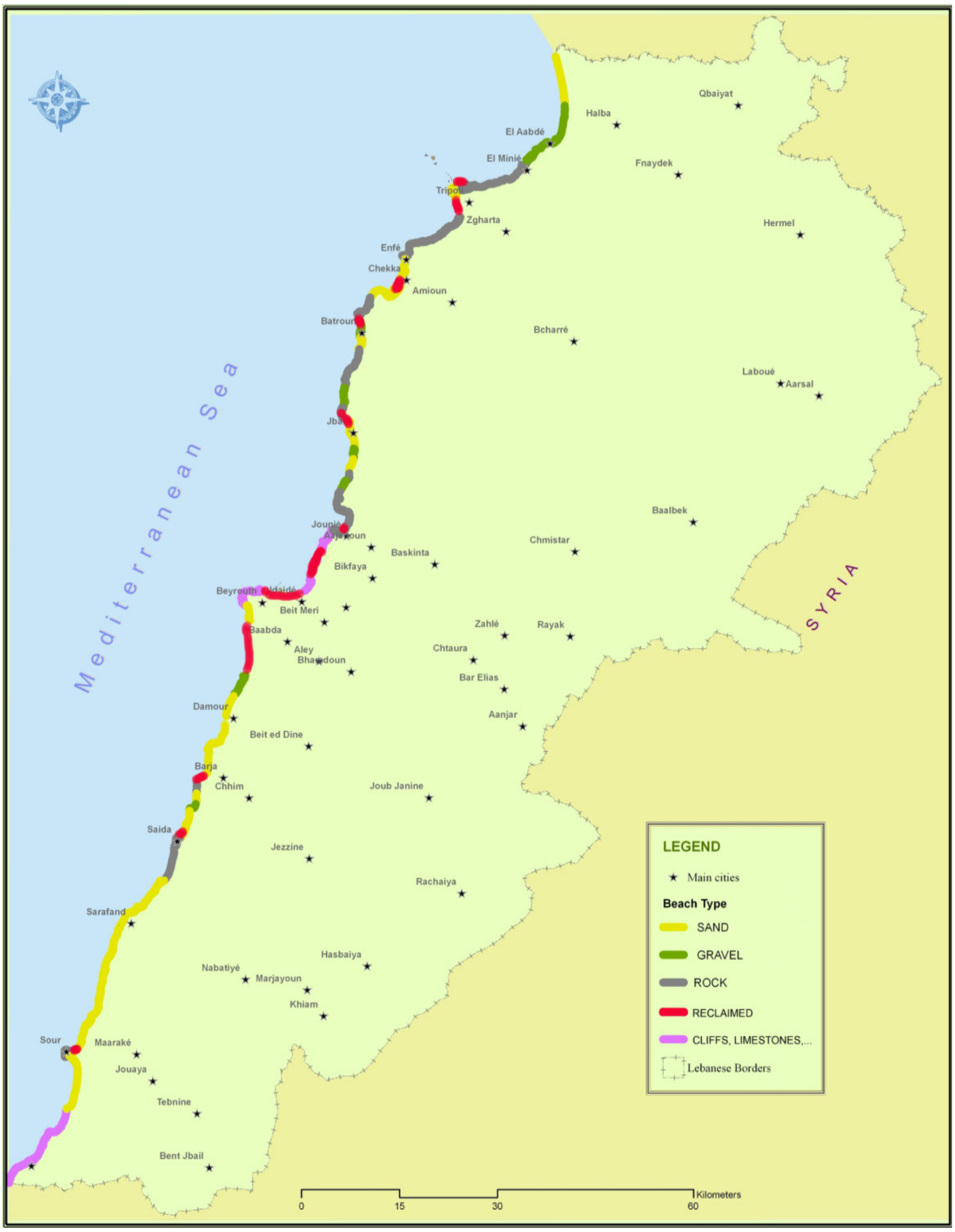


Figure 1. Types of beaches along the Lebanese coastal line (MoE/UNDP, 2011).

III. Impacts of coastal uses of the different economic sectors

A very active, deep in history, interaction between land uses and the sea is observed on the eastern shores of the Mediterranean. The long human impact is witnessed by the old water erosion caused by deforestation, leading to an intriguing process of sedimentation in lowlands, rivers and coastal waters. These sediments, emerging from the shallow mountain coastal red Mediterranean soils, have been intermixed with those sediments derived from the Nile to form different morphological units along the Lebanese coast. Human activities such as shipping, fishing, agriculture, industry, and construction, have affected the coastal line integrity and environment.

III.1. Shipping and Fishing

Lebanon has four main commercial ports in Beirut, Tripoli, Sidon (Saida), and Tyre, and several small ports along the coastline which are primarily used for fishing and leisure purposes. The Port of Beirut, one of the largest ports on the Eastern Mediterranean coastline, occupies a total area of 1.2 km^2 and has four basins, 16 quays and a newly built container terminal. The traffic at the Port of Beirut has reached around 5 million tons per year, while in Tripoli it is around 0.7 million tons per year (CDR, 2005).

Fishing ports are as traditional as the fishing sector in Lebanon which is largely artisanal. The Lebanese fishing fleet consists of 2,662 vessels operating along the coast from 44 fishing ports and landing sites (Table 1).

The marine fishing sector employs 6,500 fishermen who annually capture, on average, 3,646 tons of fish (in 2,000) and 200 tons of molluscs and crustaceans (in 1997; Majdalani, 2005). The busiest fishing ports are in Tripoli, Beirut and Saida.

Table 1. Port and Number of Fishing VESSELS on the Lebanese coast

Port	No of Vessels	%
Tripoli	957	36.0
Saida	715	26.9
Beirut	417	15.7
Tyre	231	8.7
Jounieh	184	6.9
Jbeil	125	4.7
Ras el Shaqaa	33	1.2
Total	**2,662**	**100**

III.2. Tourism

Tourism on the coast is illustrated in different forms as follows (MoE/UNDP, 2011):

- Beach resorts and marinas projects for leisure and recreational activities that both occupy 8.5% of the coastline (Assaf, 2009).
- Archaeological monuments such as in Tripoli, Jbeil, Saida and Tyre.
- Natural landscapes such as Ras Chaqaa, Enfeh, Pigeon Rock and Ras Naqoura.
- Natural reserves such as Tyre Coast Nature Reserve (TCNR) and Palm Islands Nature Reserve (PINR).
- Tyre beach is the only remaining stretch of public sandy beach located to the south of the southern city of Tyre inside TCNR. It owes its specificity to the presence of artesian springs with high flows at Ras Al Ain and the wetland at TCNR (Ramsar site). The existence of the last remaining sand dunes ecosystem in Lebanon with specific biodiversity including birds (which qualified it as an important bird and biodiversity area-IBA), and nesting sites of Sea turtles (ECODIT-IAURIF-CDR, 1997).
- The Palm Islands Nature Reserve is known for its important natural heritage. It attracts nesting, migrating and wintering bird populations of global concern. The number of bird species that were recorded at the tiny Palm Islands Nature Reserve makes 40 percent of the total national avifauna (MoE/UNDP, 2004).

III.3. Industry

The main industrial activity is in the vicinity of the coastal cities of Beirut, Tripoli, Ras el Chaqaa, Selaata, Sibline and Zouk. In fact, 65 percent of industries are situated on the coastline for a better supply of raw materials through the extensive coastal road network and faster export of products through the ports (CDR, 2005). Large industrial or commercial units occupy about 24 km of the coast, which is equal to 11 percent of its total length (Assaf, 2009).

It is worth noting that the coastal strip determined by the MoE/UNDP report as encompassing the seaward limit (the external part of the territorial sea) and the landward limit of the coastal administrative units (Figure 2), encompasses touristic resorts and ports occupying more than 50% of the narrow coastal strip (Figure 3), while urban structures occupy less than 15%, and non-built areas represent 18% of the area. For this reason, Lebanon needs further regulations and legislations to build good synergy between the land and the sea and protect the limited natural resources.

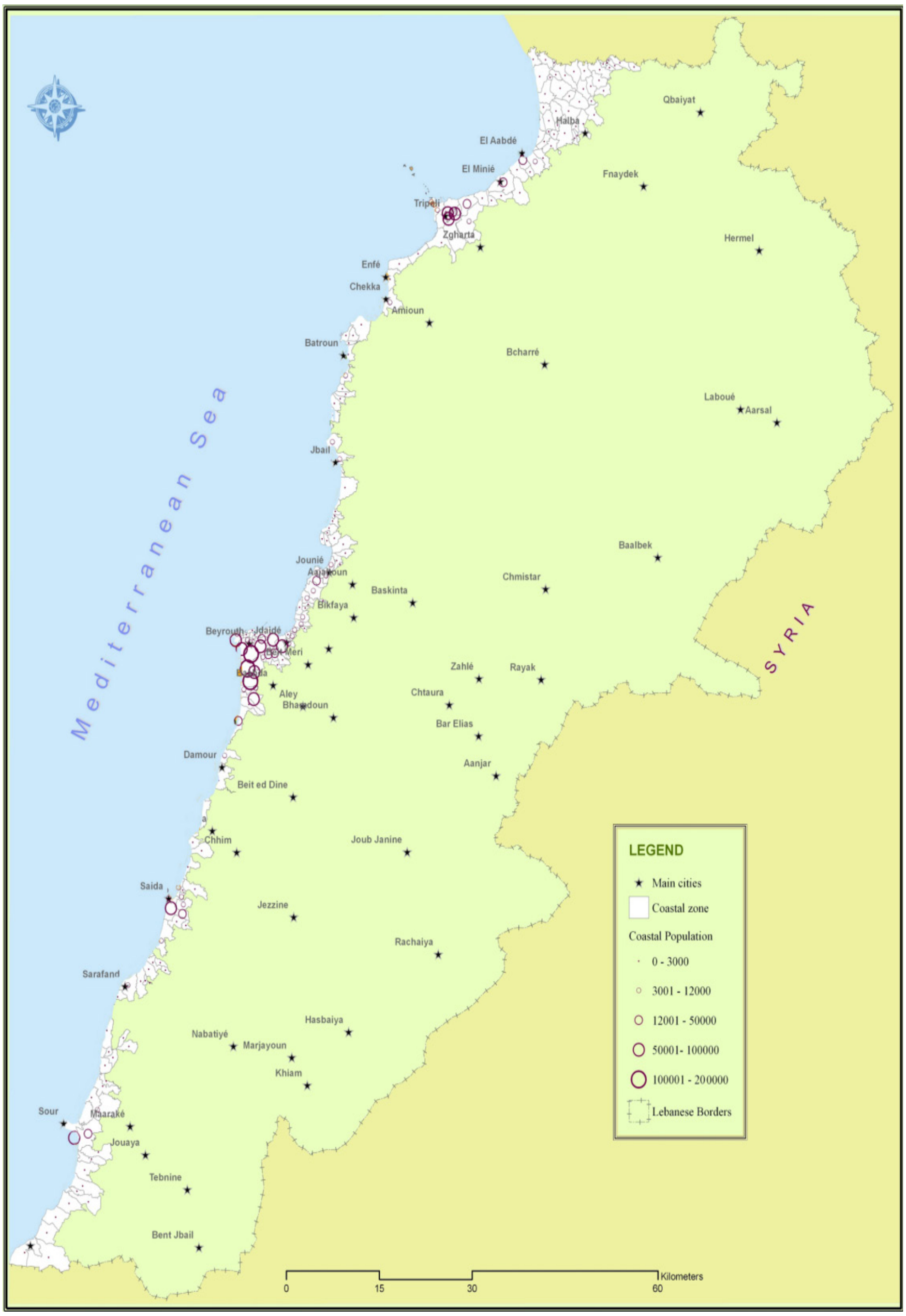


Figure 2. Distribution of the coastal area along shoreline (MoE/UNDP, 2011).

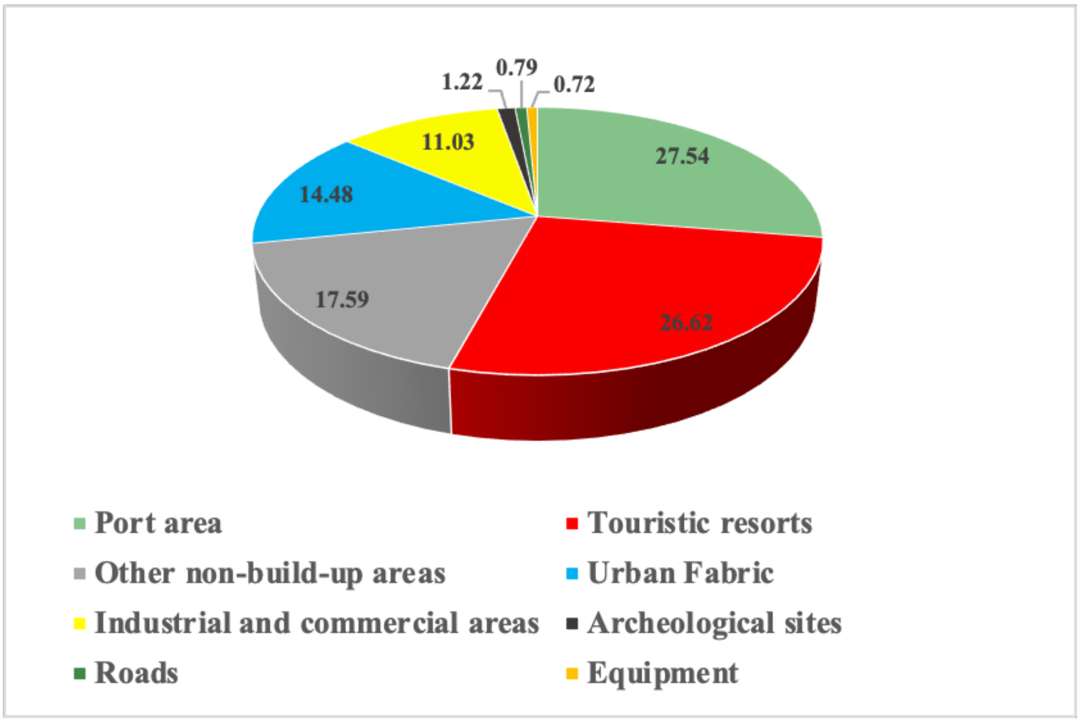


Figure 3. Land use and urban development along the coastline (Lichaa *et al.*, 2003).

IV. Impacts of coastal uses of the different economic sectors

The reported (Deliverable ID-LB-02) displayed urban expansion and industrial plants stretching on the coastal area are the following:

Three thermal stations and two cement factories. Besides, several coastal solid waste dumping sites as well as non-treated liquid waste ejected directly in the sea, together with the touristic and fishing activities under a defiant official control with the dense private car traffic and intensive agriculture as well, they all worsened the situation by exerting more pressure on both the coastal ecosystems and coastal water quality, productivity and aquatic/ marine life as well.

With a population over 5.6 million inhabitants, Lebanon generates 2.04 million tons of municipal solid waste (MSW) per year (GIZ, 2014). The principal component in Lebanon solid waste is the organic materials, derived from the rich-in-vegetable local cuisine (Figure 4). The MSW generation varies from 0.85 kg/capita/day in rural areas to around 0.95 to 1.2 kg/capita/day in urban areas, with an estimated national average of 1.05 kg/capita/day. Although nearly 100% of MSW is collected, only 15% is composted and 9% recycled. From the remaining 76%, 48% of MSW are landfilled and 29% are openly dumped.

While the industry generates annually more than 190,000 tons of solid wastes, the medical centres and hospitals generate more than 25,000 tons. Thousands of open dumping sites exist on the Lebanese territory without any safe measure or any sensible management of these areas. Thereby, burning and polluting the air of the surrounding settlements (Figure 5). The Saida waste mountain was one among the largest MSW dumpsites in Lebanon, holding 1.2 million m^3 of waste and forming a hill of around 45 m high and 150 m long with direct contact with the sea (UNDP, 2011). To reduce the impact of MSW on natural resources, the Cabinet of Ministers sent in 2012 a draft law under decree number 8003 dated 23/4/2012 to the parliament, which approved the law of integrated solid waste management under number 80 in October 2018.

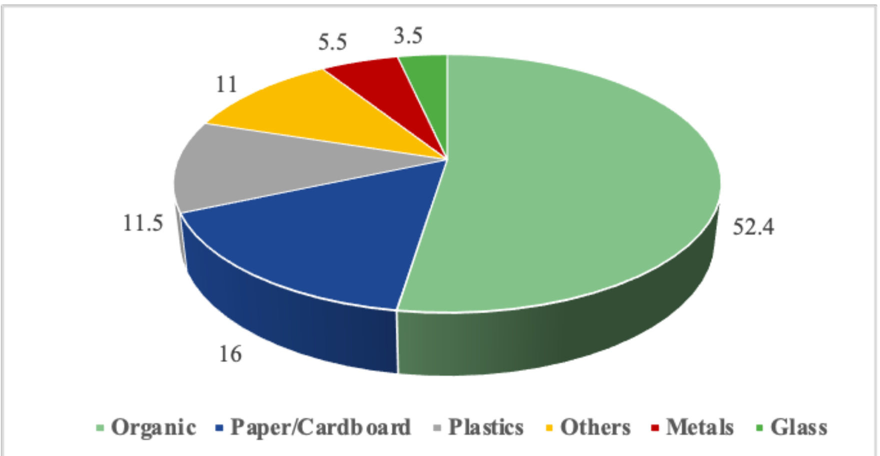


Figure 4. Composition (%) of generated solid waste in Lebanon (UNDP, 2011).

Figure 5. Mountain (Upper two photos) and Landfills of MSW in Naameh (lower photo).

Over the last years, many laws have been passed to set both the institutional framework and national strategy for hazardous and non-hazardous, integrated solid waste management, including the responsibilities and penalties as well. However, there are a few solid waste treatment plants that treat MSW of only 1.1 million people, while the rest are just landfilled, dumped or burned. As a result, an estimated 30% of all municipal solid waste (MSW) ends up in open or uncontrolled dump sites scattered around the entire country. Currently, there are 504 MSW dumps in Lebanon, with a total volume of approximately 5 million m^3 (Figure 6). Several of the dumpsites are situated in vulnerable, fragile areas with high fault and lineament density, and in proximity of rivers, streams, and springs, as well as with urban centres on the sea.

Figure 6. MSW open dumping sites over Lebanon.

V. Interaction between land uses and the impact of users and tourism on the coastline and coastal fringes

V.1. Coastal erosion and filling

Coastal erosion is mostly obvious on sandy beaches. In North Lebanon, the assessment of coastal erosion achieved by the Integrated Management of East Mediterranean Coastlines using satellite images (IMAC project, 2014), showed significant change of coastal shape between 1962 and 2007. In fact, this region in the northern coast between Batroun and north border with Syria, witnessed an erosion of 933,000 m^2, accretion of 30,000 m^2, and filling of 1,759,000 m^2 (Figure 7). Similarly, the area between Tripoli and Qalamoun witnessed erosion at 15,000 m^2, accompanied with a large sea filling of 353,000 m^2 (Figure 8).

According to the above visuals, the satellite images showed a significant sand beach erosion in small areas stretching from Ras el Shaqaa to El Heri (less than 2 km), equivalent to 79,000 m^2 (Figure 9). The shoreline from Abdeh to Arida (~12 km length) showed a high rate of sea erosion by 150 m between 1992 and 2007 associated with the loss of 655,000 m^2 of coastal sandy beaches (Figure 10). The rock masses etching, and coastal subsidence are analysed in detail in Climate Change report.

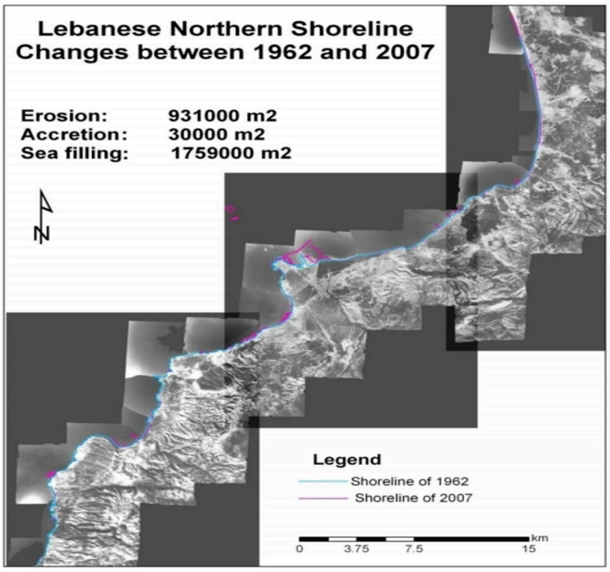


Figure 7. Sea filling and erosion along the extreme northern Lebanese coast between 1962 and 2007 (Nemr and Meghraoui, 2006).

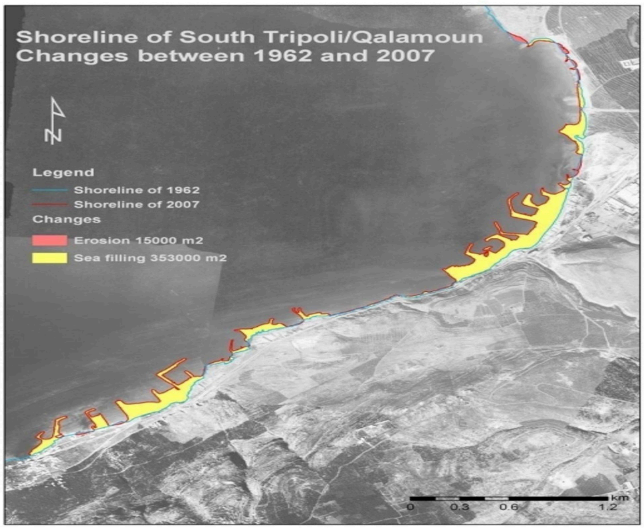


Figure 8. Sea filling and erosion along the northern Lebanese coast between Tripoli and Qalamoun (Nemr and Meghraoui, 2006).

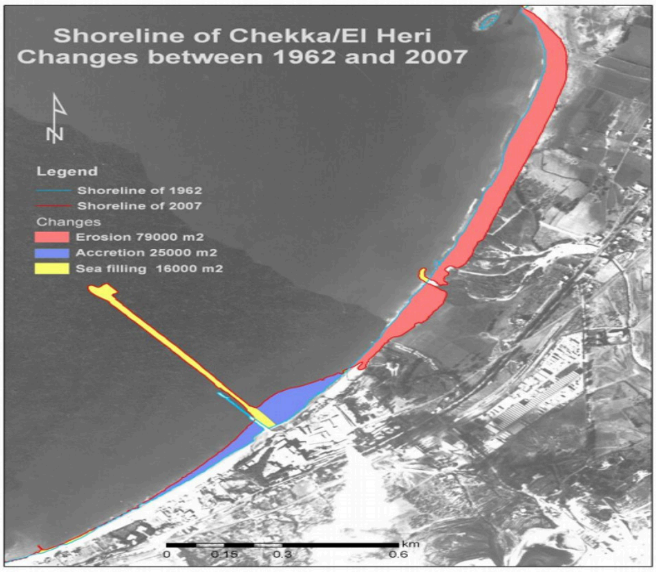
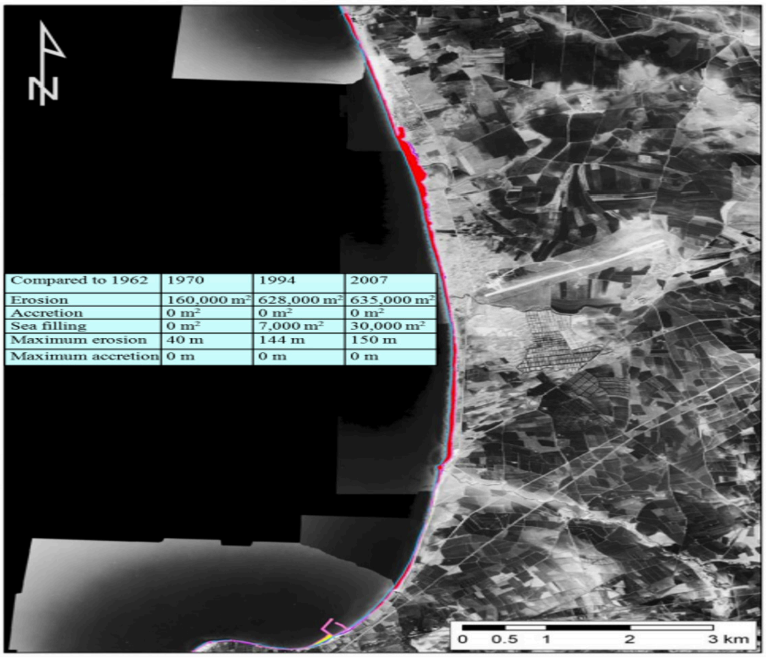


Figure 9. Erosion of northern sandy beach near El Heri, North Lebanon (Nemr and Meghraoui, 2006).



Compared to 1962	1970	1994	2007
Erosion	160,000 m^2	628,000 m^2	635,000 m^2
Accretion	0 m^2	0 m^2	0 m^2
Sea filling	0 m^2	7,000 m^2	30,000 m^2
Maximum erosion	40 m	144 m	150 m
Maximum accretion	0 m	0 m	0 m

Figure 10. Erosion of sandy coast between Arida and Abdeh, North Lebanon (Nemr and Meghraoui, 2006).

V.2. Earthquakes

The Dead Sea Transform Fault (DSTF) is the continental plate boundary between the Arabian and African plates (Figure 11). It is approximately 1,000 km long and extends along a general N-S trend from north of the Red Sea (Gulf of Aqaba) to southeast Turkey (Karasu Valley), connecting the seafloor spreading of the Red Sea to the Arabia-Eurasia collision. The structural framework of the Lebanese restraining bend (LRB) is made up of two anticlinoria separated by a synclinorium: the NNE-trending Mount Lebanon chain to the west, the NE trending Anti-Lebanon chain to the east, and the Beqaa Valley in between. The probable presence of coastal flexure (CF) and offshore monocline (OM) add to the seismicity risks along the northern coastal area. A glance at the seismicity of Lebanon and the Lebanese coast between 2006 and 2008 is highly significant in terms of the region's earthquake vulnerability (Figure 12), notably potential Tsunami that can affect low-lying lands and other coastal assets.

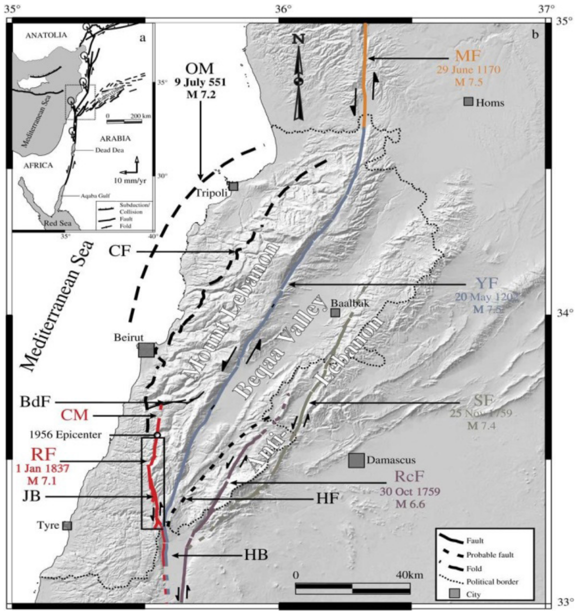


Figure 11. The left-lateral Dead Sea Transform Fault extending from the Gulf of Aqaba to southeast Turkey (Nemr and Meghraoui, 2006).

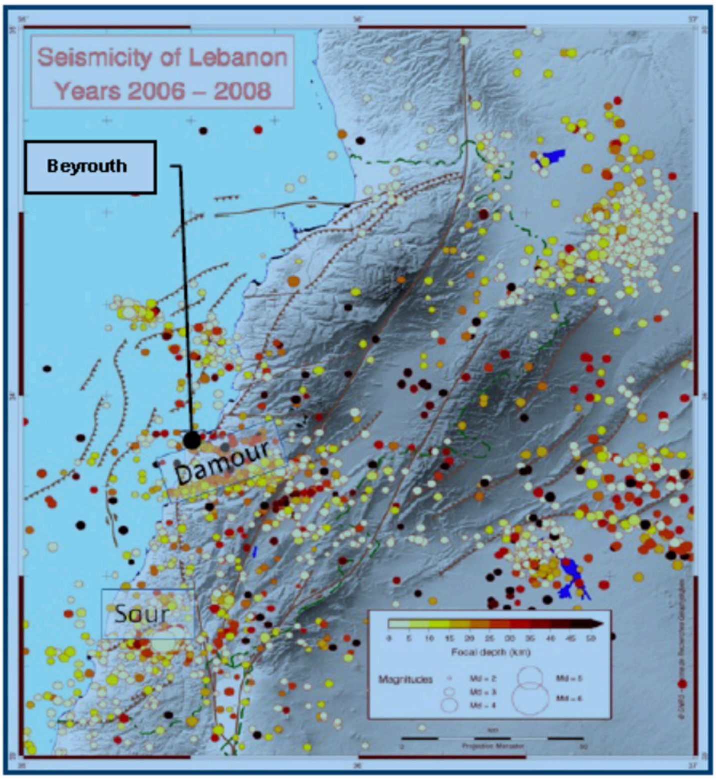


Figure 12. Lebanon seismicity between 2006 and 2008 (Lacave *et al.*, 2012).

V.3. Critical zones along the coastal area

The land-use distribution of the coastal zone stretching over 500 m from the sea, the dominance of economic activities over 80% of the coastline seems to be highly important, while the natural areas represent less than one-fifth of the total coastal landscape (CDR, 2005). Such a misbalanced setting multiplies the vulnerability of coastal ecosystems and affects their services. Based on human activities and urban encroachment, the vulnerable areas along the coast were identified by MoE/UNDP (2011), the same as the major agricultural and touristic areas in the North, Center, and the South, surrounding marine ports and cultural heritage sites (MoE/UNDP, 2011; Figure 13).

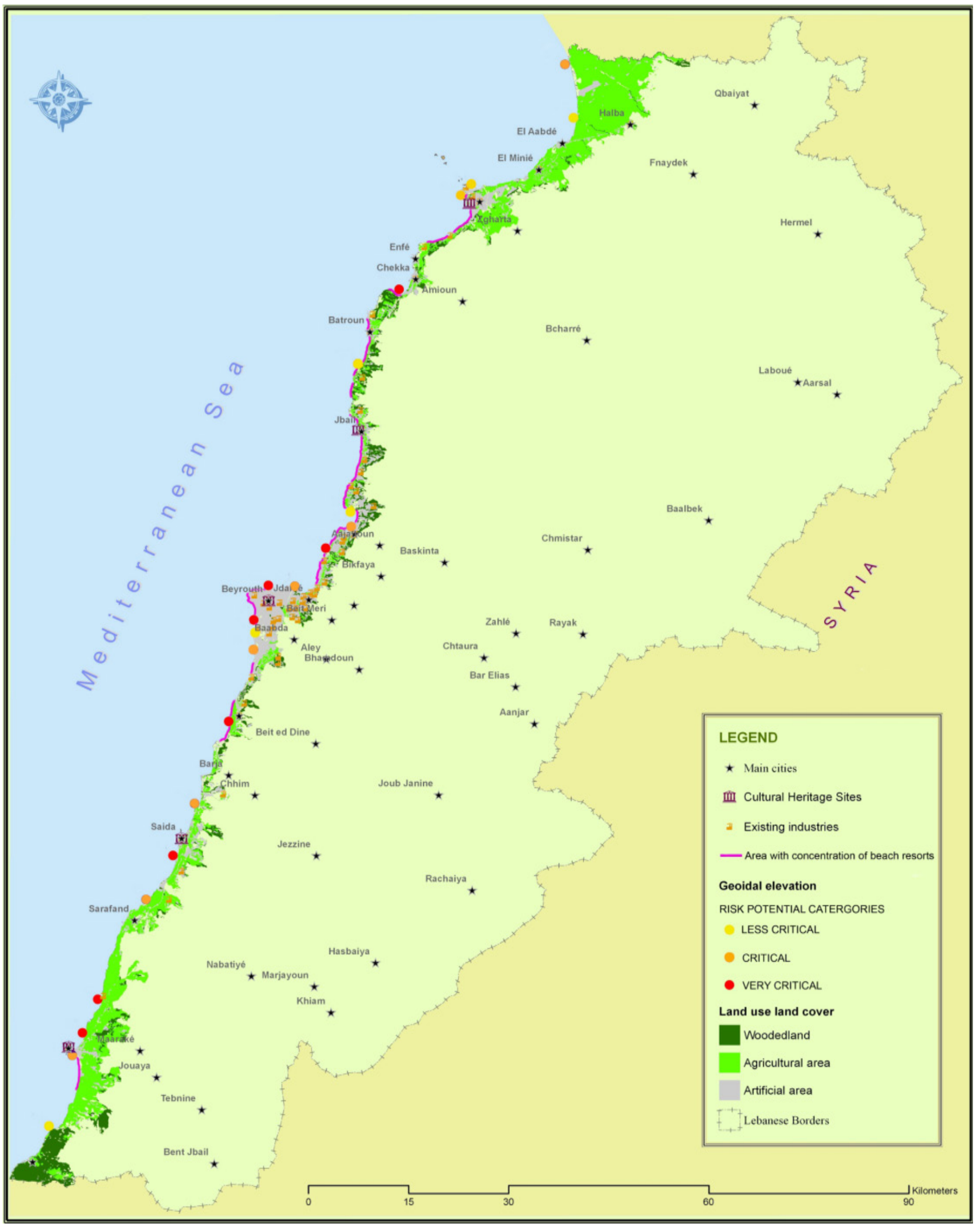


Figure 13. Critical zones along the Lebanese coast.

VI. Land-sea interaction for sustainable blue economy

At its 69th plenary meeting on 1st March 2019, the United Nations General Assembly proclaimed 2021–2030 as the Decade of Ecosystem Restoration aiming at restoring 350 million ha of degraded lands. Thereby, realising up to USD $9 trillion in net benefits and alleviating poverty in many rural communities (UN, 2019). Restoring these lands can be possible through the implementation of land stewardship to protect the healthy soils, and the restoration of degraded landscapes from erosion, salinity, and chaotic urban expansion, deterioration of physical and physio-chemical properties. In fact, all these calamities were the outcome of the following factors: irresponsible human practices, the nutrient imbalance, wildfires, compaction, acidification, and alkalization, as well as land abandonment.

VI.1. Green cover reduction

For the period span between 2000 and 2010, land-use went through large changes in the area of annual and perennial crops, both on country and local levels (FAO, 2012). Affected by the governmental subsidy policy on wheat, the national area of cultivated and irrigated field crops showed an increase from 1,486 km^2 in 2000 to 1,670 km^2 in 2010, *i.e.,* corresponding to 184 km^2 increases (Figure 14; Table 3).

In general, the area of national arable land and all lands under cultivation derived from remote sensing was 308,600 ha in 2000, which decreased in 2010 until 301,900 ha. At the national level, both the permanent crops and intensive agriculture areas decreased from 1,544 km^2 to 1,307 km^2 (by 237 km^2) and from 56 km^2 to 42 km^2 (by 14 km^2) respectively.

A Landsat-based assessment of land-use change in the whole coastal city of Tripoli between 1984 and 2004 (Figure 15) showed 300% increase of settlements against the 35-75% reduction of orchards (Table 3).

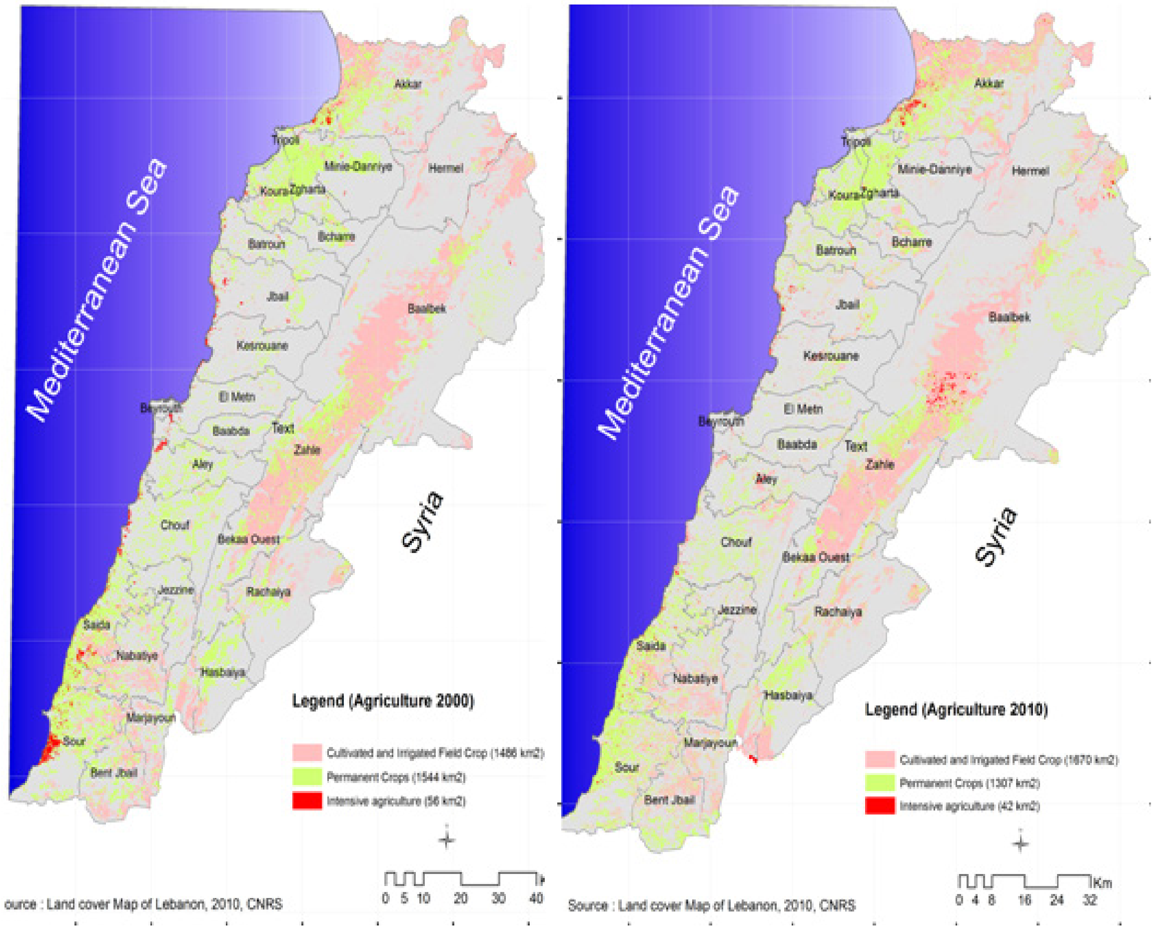


Figure 14. Land-use change in Lebanon between 2000 and 2010 (CNRS, 2010).

Table 2. Recent land-use changes in Lebanon (km^2).

Crop	Lebanon		
	2000	2010	±
Cultivated and irrigated field crops	1,486	1,670	+184
Permanent crops	1,544	1,307	-237
Intensive agriculture	56	42	-14
Total area of cultivated lands	3,086	3,019	-67

Table 3. Monitoring of land-use change in Tripoli-Mina, Ras Maska and Baddaoui area.

Year	Urban		Forest		Gardens		Fruit trees		Olive		Citrus	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
1964	333	100	66.6	100	0.89	100	2,220	100	1,324	100	896	100
2001	999	300	16	24.5	5.14	577	1,105	50	868	65	230	25.5

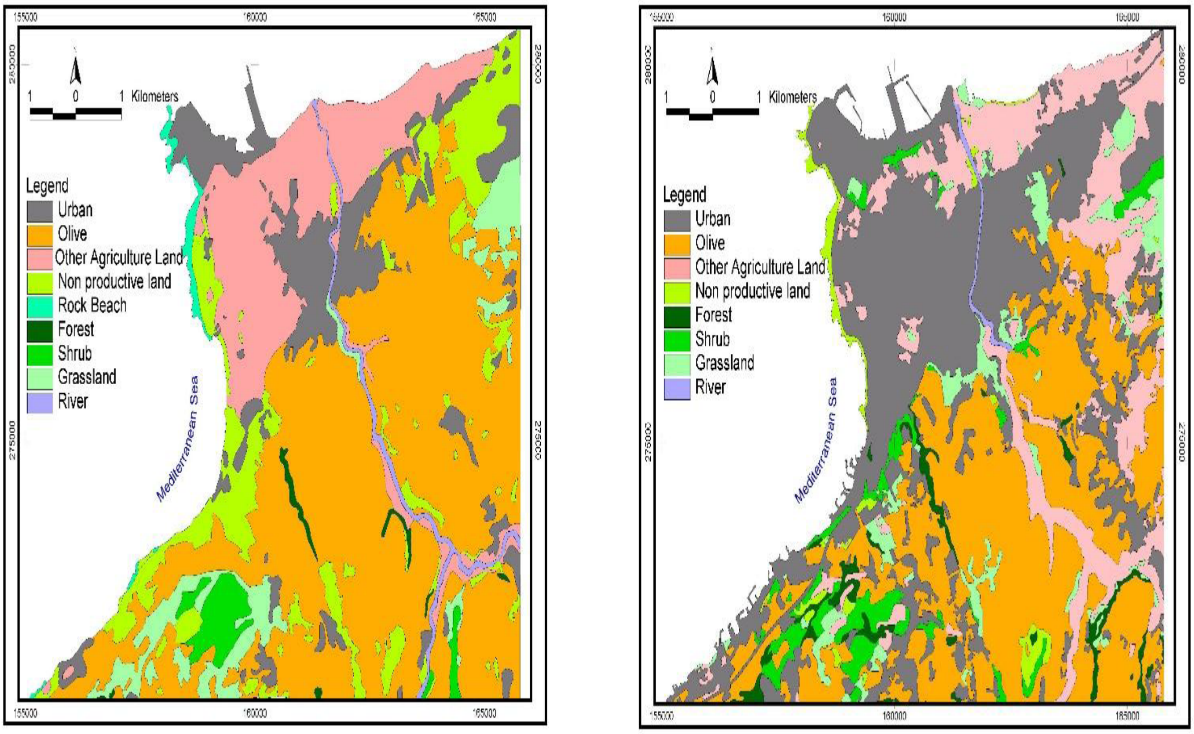


Figure 15. Land-use change in the coastal city of Tripoli between 1964 and 2000 (Kazour *et al.,* 2019b).

Indeed, Tripoli coastal urban development was one of the most dynamic in Lebanon. The assessment of urban expansion between 1912, 1921, 1938, 1965 and 2001 showed an expansion from 65.32 ha to 66.30 ha, 145.92 ha, 332.69 ha and 999.15 ha, corresponding to a relative increase equivalent to 101.5%, 223.4%, 509.3% and 1,529.6% compared to 1912 respectively.

This trend was associated with the loss of prime arable lands, classified based on soil type, geomorphology, and soil physio-chemical properties, from most productive (class 1) to least productive (class 4), which were unfairly converted into concrete for households and industry (Table 4). The actual urban expansion on prime lands was 79% resulting in the misuse of 30% of productive lands. Needless to mention that the urban planning good sense might have proposed to set the industry on less productive soils.

Table 4. Loss of soil resources in Tripoli in view of planned land-use (Kazour *et al.,* 2019b).

Land Capability class	Area	Planned land-use according to Law N0. 1915 of 14/09/1971 (ha)				Actual urban expansion	Loss of land
	ha	Historical	Tourism	Industry	Urban	ha	%
1	2,209.96	91.52	32.12	46.68	230.88	530.8	24.02
2	538.41	0.84	-	50.60	73.12	292.0	54.23
3	695.6	12.40	-	10.92	-	219.68	31.78
4	200.49	0.52	-	9.28	35.36	43.08	21.49

VI.2. Hazards from pollution

Coastal and marine pollution caused by irresponsible and random human activities has always not only badly affected the ecosystem functions, but it has as well threatened the organisms, notably those consumed by animals and human beings. The food chain is intertwined, and different sources of contamination emitting liquid and solid waste, eventually reach the air, soil and water resources and end up in the living organisms and biota. These sources are mainly as illustrated earlier: wastewaters, solid wastes, oil spills, industrial emissions, energy generation, consumption, and mining. Trace metals and hydrocarbons represent a subject of many studies in the East Mediterranean region. However, little attention has been so far attributed to plastic contamination.

VI.2.1. Macro and microplastics' pollution

Microplastic, as a source of hazards to marine habitats and biota, is a relatively new domain of concern that is the outcome of today's civilization and modernization. A new review about studies on microplastics' threats on marine biota proved that only 44 countries or 22.9% of the 199 countries of the world have carried out research on microplastics with the focus on fish in 38% of studies (Ajith *et al.,* 2020). With only 1% of worldwide studies targeting turtles, this highly affected organism by macro and micro plastics, is still not sufficiently researched and documented.

As one of the semi-closed and most populated seas, the Mediterranean Sea is subject to human overexploitation as well as to the threats of micro plastic (MP) accumulation in the coastal waters. This is highly obvious in small and large aquatic organisms. A recent study succeeded in identifying the primary source of MPs generated from the coastal solid waste landfills, as well as by the coastal sewage water treatment plants (Kazour *et al.,* 2019a; Figure 16).

Figure 16. Coastal landfills are the primary source of plastics found in the sea.

To specify the risks of MPs to seawater and seafood contamination, the European anchovy, *Engraulis encrasicolus*, together with the spiny oysters *Spondylus spinosus*, as well as the water and sea sediments. They were all collected from three different sea sites (Figure 17) from the Lebanese littoral of Tripoli, Beirut, and Sidon (Kazour *et al.*, 2019b). Then, they were analysed to point out that water samples from Sidon were the most highly contaminated in MPs (6.7 MPs/m^3) exceeding the values of the norms of the average abundance of 1.16 items/m^3 ± 0.83 reported in the water samples of Tunisia (Hobeika and Youness, 2020).

The analysis of sediments showed the highest MPs content to be found in Tripoli coast (4.68 MPs/g). The occurrence of MPs in the most largely consumed Lebanese population was high (83.4% and 86.3% in anchovies and spiny oysters, respectively). The highest ingested MPs/individual in anchovies and oysters collected from the Beirut region had 2.9 ± 1.9 and 8.3 ± 4.4 MPs/individual, respectively.

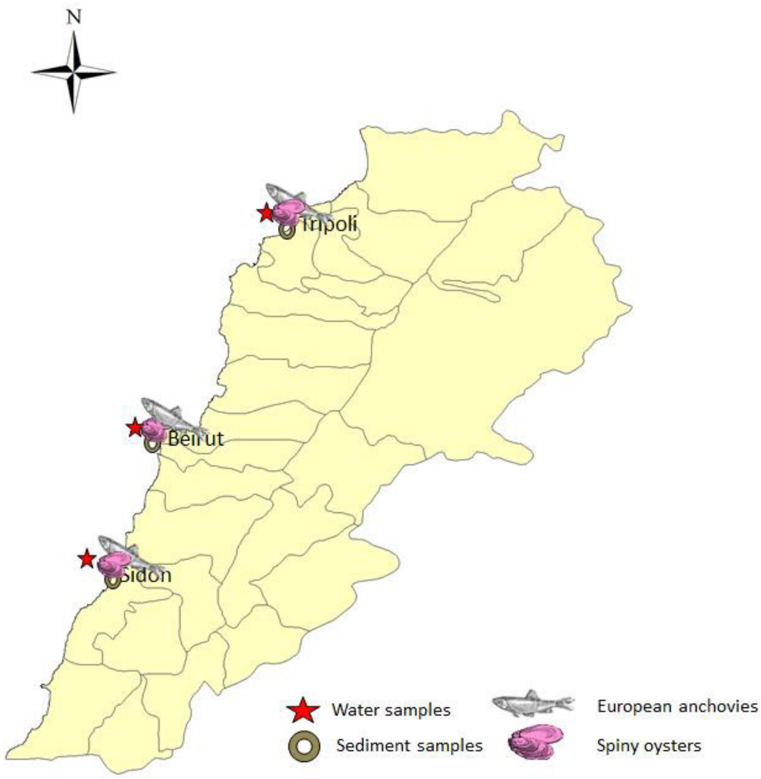


Figure 17. Location of samples to assess the impact of microplastics on marine environment and biota (Abi-Ghanem *et al.,* 2015).

It is recommended to carry out additional studies on the state of plastic contamination in the Lebanese coastal environment and estuaries. It should be conducted in order to establish national standards for water microplastic contamination and sediment and to elaborate a set of national strategies to contain such contaminations. Perhaps, the recent initiatives to reduce and decrease the use of plastic bags should be encouraged as well as innovative alternatives to plastics using degradable natural sources of packaging must be promoted. A trial on the use of the sensitive-to-microplastic contamination juvenile flounders' fish (7-9 cm) as indicator of contaminated waters was carried in caught wild and in cage fish demonstrated the presence of microplastics in their track, varying between 58% and 75% of samples respectively (Kazour *et al.,* 2018).

VI.2.2. Heavy metal concentration in coastal waters and sediments

The concentration of lead, cadmium and copper on the superficial sediments collected from Beirut army naval port and Tripoli fishing port in Lebanon, showed relatively high concentrations of Pb (181.4-518.9 $\mu g.g^{-1}$), Cd (1.33-6.7$\mu g.g^{-1}$), and Cu (141-246.8 $\mu g.g^{-1}$) in Beirut, with higher Cu concentrations (up to 524.5 $\mu g.g^{-1}$) in the Tripoli port (Abi-Ghanem *et al.,* 2015). Compared to background levels (6.21 $\mu g.g^{-1}$ for Pb, 0.19 $\mu g.g^{-1}$ for Cd, 11 $\mu g.g^{-1}$ for Cu), and based on the geo-accumulation assessment and extractability by EDTA and $CaCl_2$ showing high mobility for Pb in Beirut and Cu in

Tripoli, these values are high. In fact, they represented high risks of transfer on the fish and human food chains. These concentrations proved to be almost the same or sometimes exceeded the upper limits detected in sediments of other Mediterranean harbours under the impact of the discharge of untreated wastewater, the presence of solid waste, and cities and harbours' activities.

Lebanese population exposure to mercury from the consumption of imported Mediterranean canned tuna fish, varying between 124.5 ± 106 µg/kg, was assessed and defined that the consumption of one can of about 200 g per day is not harmful (Kouyoumjian *et al.,* 2001). A recent assessment of the quality of the deep sediments (60 m) on the Jounieh Bay, showed significant content of proteins and carbohydrates, and high concentrations of lipid which might be linked to the presence of leisure ports, boats, human wastes or due to the association with hydrophobic organic micropollutants (Fakhri *et al.,* 2018). The authors concluded that despite the continuous load of nutrients from sewage outfall, leachates from industry, fertilisers, and leisure boats, notably at its middle and southern parts, the Bay of Jounieh is still able to adapt and provide minimal conditions for primary productivity of benthic organisms.

The accumulation of trace elements (Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Ag, Cd, Sn, Sb, Ba, Hg, Pb, and U) was detected mainly in the liver and less in the mussels of two demersal fish species (*Siganus rivulatus* and *Lithognathus mormyrus*) and one pelagic species (*Etrumeus teres)* from the Lebanese coast with the highest levels in herbivorous species (*S. rivulatus),* and the lowest levels in carnivorous species (*L. mormyrus;*) (Ghosn *et al.,* 2020). The authors indicated higher values in the wet seasons with 2-3-time higher levels of most trace metals in livers than those detected in other Mediterranean regions. Fortunately, the levels of Cd, Pb, and Hg in fish muscle, which were found below the maximum levels set by the European Commission, can indicate no health risks from the consumption of these fish species with more risk to the population from frequent or excess fish consumption.

VII. Fishing and impacts on the marine environment

The CIHEAM PESCA-Libano project collected data from 65 different sites along the Lebanon coast and at depths ranging from 10 to 600 m just to assess the abundance of cartilaginous species (Lteif *et al.*, 2014; Figure 18). In fact, fishermen were hired to collect information from their catch at 100-600 m depth, and field visits to fish markets were undertaken to register the present species. A total of 225 specimens of cartilaginous fish were sampled and included 25 cartilaginous fish species, 11 shark species and 14 batoid species. Most of the sharks sampled were *Centrophorus granulosus, Galeus melastomus, Squalus blainvillei, Mustelus mustelus* and *Carcharhinus obscurus*.

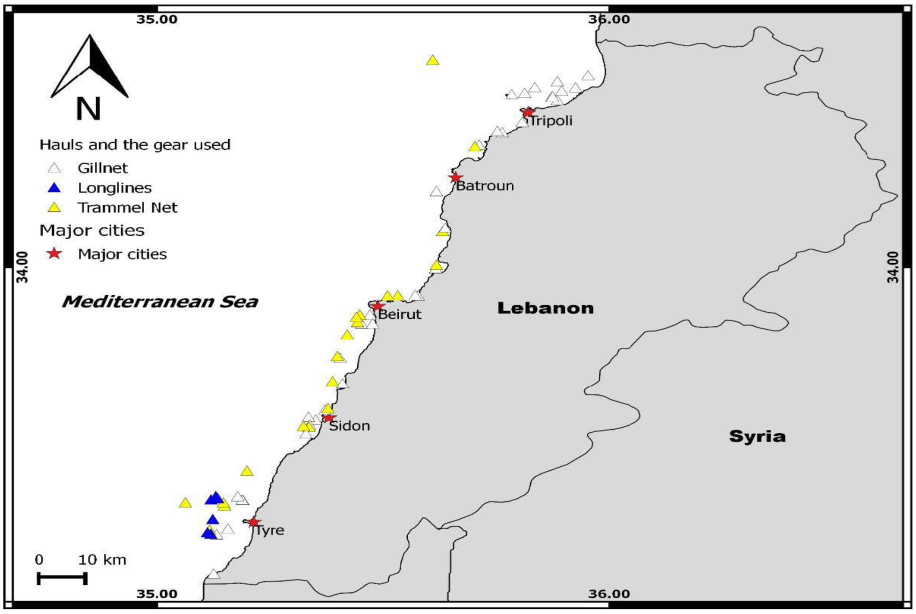


Figure 18. Location of the hauls surveyed by the CIHEAM PESCA-Libano campaign and the type of gear (MoA, 2010)

The majority of the batoids sampled were *Rhinobatos rhinobatos, Rhinobatos cemiculus, Torpedo marmorata, Torpedo nobiliana, Raja miraletus* and *Raja clavata*. The majority of caught species (66.7%) were observed at depths of less than 150 m, whereas 18.2% and 10.6% were observed at depths ranging from 150 to 400 m and 450 m to 600 m respectively. In addition, demersal species such as, *Raja clavata*¸ *Raja miraletus, Torpedo marmorata*¸ and *Torpedo nobiliana* were principally caught by trammel nets, whereas *Rhinobatos rhinobatos* and *Rhinobatos cemiculus* were only caught by longlines, and species such as *Squatina oculata, Squatina aculeata, Mustelus mustelus*, and Isurus oxyrhincus were only caught by gillnets. It is worth noting that, the batoid species *Rhinobatos rhinobatos* (common guitarfish) and *Rhinobatos cemiculus* (blackchin guitarfish), the shark species *Hexanchus griseus*, and sharks from the Carcharhinidae family, revealed high commercial value in Tripoli (North Lebanon) and in Sidon (South

Lebanon). As an indicator of species richness, this study showed that more species were caught in the southern and central regions. However, Sharks showed a high number of species in a confined area in the central and northern regions only. Compared to sharks, the batoids dataset displayed a higher specific richness.

Overfishing and the use of fishing illegal tools can be identified as the main factor affecting the productivity of the Lebanese coastal waters. The use of small size nets and trawling/bottom trawl fishing, affect young fish generation and negatively reflect on the sustainability of this old traditional activity. Besides, further reports revealed top predator invasions passing through the Red Sea specifically through the Suez Canal, like elasmobranchs that can compete for local feed and habitat and can destroy the existing sensitive balance.

Cetacean bycatch events have been organised for sharks, which are sold and consumed without direct intervention from the municipalities or government. The Lebanese coast is among 35 sites in the Mediterranean basin of high importance for the survival and regeneration of 19 species of Mammalia (Pavone, 2019). It is vital for "conserving the components of biological diversity in the Mediterranean", and/or "contain ecosystems specific to the Mediterranean area or the habitats of endangered species".

To compensate for the overfishing and the decrease rates in catch, the Lebanese Ministry of Agriculture (MoA) has introduced aquaculture since the late 1990s in Batroun. The MoA had one experimental marine aquaculture pilot station run by the Department of Fisheries and Wildlife (DFW-MoA) within the facilities of the Oceanographic & Fisheries Institute in Batroun. The 3-ha site consisted of marine research laboratories, an administration/accommodation block, an aquarium/museum, a mariculture hatchery and grow-out facility, and finally a workshop (FAO, 2005). Considerable parts of the buildings were vandalised and damaged during the 17 years of civil war. However, a mariculture hatchery and grow-out pilot project facility were constructed in 2000.

To become properly functional, the facility required slight modifications and additions to the water supply and aeration. The hatchery and raceways were under one greenhouse (1,000 m^2), which consisted of a spawning and maturation room, algae room, larvae room, nursery room, and raceways.

However, to rehabilitate and disseminate the marine aquaculture in Lebanon, the MoA prepared in 2010 a 5-year, 10 million USD project "Programme of Modernization, Rehabilitation and Development of Marine Fisheries and Aquaculture in Lebanon". It aimed at strengthening the fishery and aquaculture sectors which possessed 2,662 vessels, producing less than 6,000 tons, and imported more than 19,000 tons of fish (MoA, 2010). The project was supposed to enhance the rehabilitation and the modernization of the fishing techniques, aquaculture, as well as fisheries research, equipped with laboratories and equipment in the following locations: Batroun (Institute of Oceanography and Fisheries), Chouaifat, South of Beirut (Aquaculture Centre), Anjar-Central Bekaa (Fish Farming Centre), Hermel-North Bekaa (Fish Farming Centre) and South Lebanon (Marine Fisheries & Aquaculture Centre).

Fish Consumption in Lebanon was expected to reach 35,000 ton/year before 2020. Local production contributed less than 27% of local consumption. Meanwhile, aquaculture (limited, in 2010, to Rainbow Trout and some shrimps and tilapia) used to contribute about 17 % of local production and 4% of local fish consumption. In such conditions, aquaculture seemed to be the most feasible means to bridge this gap. Aquaculture Projects for e.g., Shrimp, Trout, Tilapia, Sea Bass and Sea Bream were expected to be feasible and highly profitable. In 1999-2000, the DFW had introduced and established the infrastructure for marine aquaculture pilot projects in Batroun. However, while it succeeded with freshwater fish production, aquaculture failed in the marine sector due to the lack of local experts in this field. In fact, such experts could carry out research and trials to help disseminate the knowledge and to establish local commercial projects. Another reason for the failure of marine aquaculture in Lebanon was the absence of supporting legislation regulating private marine aquaculture. Even the planned Aquarium and Fish Museum in Batroun, were not finalised.

VIII. Conclusions

The major obstacles encountering the sustainable management of natural resources in Lebanon and the preservation of its coastal area is mainly related to the frail national and local land-use policies. Even though the construction law (Decree-law no. 148, issued on September 16th, 1983) states that planned buildings need to comply with the zoning and building regulations, and that illegally constructed buildings must be destroyed, the reality is different notably in non-ranked territories. These measures can be applied not only to housing, but also to industrial plants built in vulnerable areas. Due to several administrative and property rights concerns, many illegally built buildings could not be registered officially in the real estate registry. Thereby, remaining outside the market arena. Updating national information on land-use change contributes to classifying the national and coastal lands as densely urbanised areas. Scattered urban areas with mixed green fields, forests, shrub lands, grasslands, ports and roads at local scale, represent the prerequisite factors to redefine land capacity and land-use requirements. Underdeveloped national and local districts should be prioritised to establish funding development programs to eradicate poverty and reduce rural exodus. It seems highly truthful to admit that in order to promote economic and social development without exhausting the rest of the land is a crucial strategy to save Lebanon ecology. Adopting such principles and strategies can reduce the impact on coastal ecosystems' functions. Besides, implementing regenerative activities can protect and develop harmony between human activities and footprint (urban, economic, and social) together with the coastal and aquatic life. It can as well promote sustainable land/sea interactions. Supporting aquaculture and changing the governmental attitude towards more funding to develop as well as expanding the marine fishery research and producing with capacity building of local stakeholders, all could contribute to food security based on local fish production.

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