4.6 Vulnerability and Adaptation of Coastal Zones

The Lebanese coastal zone extends about 230 km in length and is characterized by being very narrow, representing 8% of the total Lebanese surface area in a 500 m wide corridor along the coastline (CDR, 2005). The coastal zone has a very high population density estimated at around 594 inhabitants per km^2 in 2000 and is characterized by a concentration of Lebanon's main economic activity. In fact, the largest Lebanese cities (Beirut, Saida, Tripoli, Tyre) are located along the coast, and contribute to more than 74% of Lebanon's GDP through commercial and financial activities, large industrial zones, important agricultural lands as well as fishing and tourism (UNEP-MAP, 1999). Lebanon has four main commercial ports in Beirut, Tripoli, Saida, and Tyre, and a number of small ports are scattered along the coastline, primarily used for fishing and leisure purposes. The coast is characterized by the presence of beach resorts and marinas projects for leisure and recreational activities, archaeological monuments, natural landscape (Ras Chaqaa, Enfeh, Pigeon Rock), and natural reserves (Palm Islands, Tyre Coastal Nature Reserve). Figure 4-37 shows the types of urban development along the coastline.

4.6.1 Methodology

Scope of Assessment

This section examines the current and future vulnerability of urban, industrial, commercial, touristic and agricultural agglomerations along the Lebanese coast and the shoreline to sea level rise (SLR) and sea surface temperature (SST). It assesses the likely impacts of SLR and SST on coastal and marine biodiversity, on coastal populations and on the different types of coastal activities with priority given to low-lying areas, areas under anthropogenic pressures and areas that experience saltwater intrusion. Vulnerability and impacts assessment is examined throughout the whole year and during the periods of extreme storms such as January, April and September for high wind speed and January and February for extreme high waves.

Methods of Assessment

The vulnerability and impact assessment is conducted based on the baseline socio-economic scenarios (A and B) identified under the NPMLPT and on the climate change scenario identified by PRECIS.

Development of the sector under socio-economic scenarios

Under scenario A, tourism, food production industries and commerce activities will probably be the main economic activities, which will increase shipping activities over the four main commercial ports and will threaten the coastal zone's major assets and remaining agricultural lands in Akkar plain, Damour, and south Lebanon. Population density along the coastal zone is expected to remain stable or might face a slight decrease due to low population growth, increased emigration and the planned development of inland cities which is expected to stabilize the pressure on the coast. Salt water intrusion will remain a problem or could probably decrease as coastal population density slightly declines and as agricultural areas recede to be replaced by tourism infrastructure.

Under scenario B, population density and thus concentration of settlements will increase at a high rate along the coast as a result of the high population growth. The total income from fishing will probably increase as a result of the reorganization of the agriculture sector and the investment in the fishing sector. The contribution of coastal activities (industry, agriculture, tourism, etc.) to GDP is expected to significantly increase due to an increase in Lebanon's production that will boost its competitiveness. With the increase in water demand and overpumping, the risk of seawater intrusion will highly increase despite plans (under the NPMPLT) to reduce monoculture and intensive agriculture which could potentially reduce groundwater withdrawal for irrigation.

4.6.2 Vulnerability Assessment

The coastline is sensitive to erosion due to natural factors such as strong storms, and different local, anthropogenic factors which act as pressures on coastal ecosystems. Sensitivity is higher in low-lying coastal areas such as in Tripoli, Chekka, Amchit, Jbeil, Jounieh, Damour, Jiyeh, Saida and Tyre which are more exposed to tides and have lower natural defense structures. Moreover, the improper management of agricultural activities, rural migration to coastal cities and urban sprawl is leading to the disappearance of the coastal agricultural lands which will lead to a reduction in water infiltration in the soil and therefore pose a greater risk of flooding of the lower coastal plains in the events of heavy rainfall (CDR, 2005; EC, 2006; UoB, 2006). The natural factors and anthropogenic pressures that prevail in some coastal

Figure 4-37 Land use along the Lebanese coastal zone

areas in Lebanon might result in an increased sensitivity of coastal areas and structures to climate change and its associated impacts.

The adaptive capacity of coastal communities is low, due to the concentration of activities and the mix of livelihood resources on the coast. The sensitivity and adaptive capacity are undermined by the urban sprawl and privatization of the coastline; marine pollution from solid waste disposal and wastewater discharge in the sea; beach quarrying and sand extraction; salt water intrusion; and coastal setbacks.

The absence of proper land use planning, high population density along the Lebanese coast, industrial and commercial activity, lack of legislation, and weak enforcement capacity increase the vulnerability of the Lebanese coast to climatic factors. The vulnerability of some coastal hotspots such as marginalized urban settlements and coastal slums, small and medium coastal enterprises, natural areas and coastal agricultural plains is higher with the exposure to sea level rise, storm surges, coastal inundation and flooding, and increased rainfall intensity. Indeed, small beach resorts and small fishing harbors are potentially vulnerable to coastal flooding and inundation from sea level rise combined with likely extreme storm events. Sandy beaches, which represent 20% of the shoreline, and corresponding habitats, are extremely vulnerable to shoreline erosion or the permanent loss of sand and gravel caused by high water level, wind-driven waves, and past sand and gravel dredging practices. Furthermore, the presence of the five large-scale dumps, namely Normandy, Bourj Hammoud, Tripoli, Tyre and Saida on the coast exacerbates coastal degradation and causes significant pollution of marine waters. As for agricultural plains, Akkar, Damour, Saida and Tyre are vulnerable to coastal flooding and inundation, especially under Scenario B with high population growth and high urbanization rate. The vulnerability of coastal zones to climate change in both scenarios could be low to moderate if steps to initiate investment in adaptation and internalize future risks from climatic variability are taken.

4.6.3 Impact assessment

The impacts of climate change on coastal zones are:

- Coastal flooding and inundation during high sea level conditions (e.g. storms), which degrades coastal ecosystem services, limits coastal use and damages infrastructures especially in heavily populated areas and agricultural plains (Georgas, 2003; Micallef, 2009);
- Sea water intrusion and salinization of coastal aquifers, especially that groundwater aquifers are over-utilized. The coastal area of Choueifat-Rmeileh region is one of many districts in Lebanon that are threatened by the penetration of seawater into the aquifers (El Moujabber and Bou Samra, 2002; El Moujabber et al., 2004);
- Coastal erosion due to an increase in the frequency and intensity of episodic weather events, sea level rise or an alteration of coastal circulation patterns. Studies have shown that between 1963 and 2003 erosion of the Lebanese coast was the highest in sandy and pebble sand (Abi Rizk, 2005);
- Losses in coastal and marine economic activities such as tourism, agriculture, fisheries, transportation and other essential services. Coastal communities relying on ecosystem services, such as fishing for livelihoods will bear the impacts of increases in sea water temperature as the marine fish stock might decrease and marine biodiversity might change or decline. However, other thermophilic species might become more abundant such as Sardina (MoE et al., 1999). The combination of higher water temperatures, overfishing and sewage discharge will cause a predominance of jellyfish and algal blooms in coastal waters (FAO, 2009c).

4.6.4 Adaptation measures

The purpose of coastal zone adaptation is to reduce the net cost of climate change impacts, whether those costs apply to an economic sector, an ecosystem, or a country. The vulnerability of the coastal zone is not only determined by the degree of climate change but also by the current social, economic and environmental conditions as well as existing management practices. Three generic options (Figure 4-38) should be adopted and the choice of the suitable option depends on the pattern of relative sea level change, geomorphologic setting, sediment availability and erosions as well as social, economic and political factors:

- **Planned retreat adaptation measures:** they consist of pulling back human activities from the coast through the creation of buffer zones on a minimum width of 100 m of the shore band and the creation of a network of coastal marine reserves through

the rehabilitation and preservation of the 30 remarkable sites defined by the NPMLT (CDR, 2005). This measure will strengthen the ability of coastal habitats and species to adapt on their own.

- **Accommodation adaptation measures:** they consist of reactive measures to minimize human impacts through reducing or moving sources of urban, industrial and agriculture pollution and introducing effective early warning systems along the coast for coastal hazards.

- **Protection adaptation measures:** consist of proactive measures that consist of developing a defense strategy to control sea level rise through soft or hard engineering. Hard engineering techniques are coastal structures such as sea walls, dykes, and embankments against high water and sea storms. However, they do not stop beach erosion and can contribute negatively to coastal water quality. They are usually adopted on active economic environments that cannot be moved as well as on highly urbanized areas to protect expensive properties or infrastructures. Soft engineering techniques include beach nourishment by feeding a beach periodically with material brought from elsewhere to remedy erosion, and sand dune stabilization by planting vegetation such as beach grass that retains sand and creates natural habitats for animals and plants (Parry et al., 2009; Ozhan, 2002).

An overarching adaptation and management option to relieve pressures on the coastal zones can be the adoption of integrated coastal zone management that includes preservation of coastal ecosystems and preventing and reducing the effects of natural hazards. Additional adaptation measures are presented in Table 4-10.

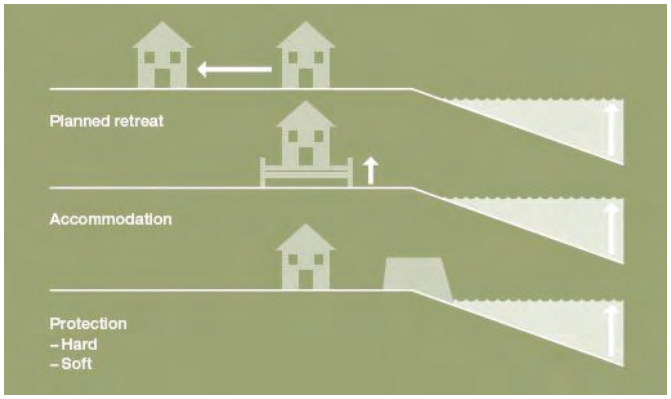

Figure 4-38 Illustration of the possible adaptation responses to sea-level rise. Source: Parry et al., 2009

4.7 Vulnerability and Adaptation of the Forestry Sector

Lebanon is a highly mountainous country with extreme variability in climatic conditions, soils and socio-economic status. Forests in Lebanon are very particular in their variation and characteristics as they represent a unique feature in the arid environment of the Eastern Mediterranean. Natural ecosystems in Lebanon and particularly forests are under various pressures most of which are landscape and habitat fragmentation, changes in land use, unorganized urban sprawl, forest fires and pest outbreaks. Many species have either disappeared or are endangered because of the different threats on their habitats (Asmar, 2005; AFDC, 2007). In view of this existing pressure on natural ecosystems, future expected climate change will mainly exacerbate their consequences.

4.7.1 Methodology

Scope of Assessment

The assessment focuses only on the forestry sector, particularly forest types that are most sensitive to climate change as identified by stakeholders during the scoping phase. The temporal scope of the assessment extends over the entire year, since forest vulnerability depends on both temperature increase (summer) and precipitation (winter). The year 2004 is taken as a baseline year, and projections are made until 2030, i.e., over a time frame of around 25 years.

Climatic factors

Temperature increase is an important factor affecting forest growth and survival. In addition, water availability which results from rainfall, snowfall in mountains and the soil's capacity to store water are considered as the most relevant parameters to the forestry sector, especially during critical phases such as spring and early autumn.

Mediterranean vegetation and specifically Mediterranean forests have adapted to prevailing climatic constraints and are typically represented by clear altitudinal leveling: the vegetation levels. In Lebanon, vegetation levels have been described and illustrated in the phyto-association map published by Abi Saleh & Safi (1988), in which 10 vegetation levels can be clearly distinguished with respect to altitude (Figure 4-39). These vegetation levels derive from the "Quotient pluviothermique" of Emberger (Quezel,1976), which reflect the tolerance of species within a range of precipitation, mean maximum