

# Chapter 1

## Introduction



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**Abstract** Litani River, the largest water resource in Lebanon, connects Lebanese regions with different physiographic characteristics, such as mountains and plains, and spans from the interior to the coastal zone of the country. In addition, Litani River occupies the Qaraaoun Reservoir, the largest of its type in Lebanon, with a capacity of about 220 million m<sup>3</sup>. The river is an optimal nexus of water, agriculture, and energy. However, it has lately become a geo-environmental issue with certain challenges creating a severe impact on the water quality and quantity. It is a paradox that although several studies, projects, and researches have been conducted on the river and its basin to enhance its status, deterioration was still exacerbated. Recently, a national plan for the Litani River was prepared by the Lebanese government to mitigate the existing physical and anthropogenic stresses on the river water and to reduce its harmful effects on human health. This chapter aims to highlight the principal elements concerning the river and its status. It also introduces the other chapters in this book.

### 1.1 Location of the Litani River

The territory of Lebanon is considered a regional water divide where water flows from Lebanon through three principal drainage systems, which have catchments extended as follows: (1) from the NE-SW alignment of Mount-Lebanon with a catchment area of 2500 km<sup>2</sup> toward the Mediterranean Sea; (2) from the northern Bekaa Plain, represented by the Al-Assi River, northward and comprising a major tributary of the Orontes River with a catchment area of 25,300 km<sup>2</sup>; and (3) from Hermoun Mountain, represented by the Hasbani-Wazzani River, to the south and then constituting a major tributary of the Jordan River with about 8425-km<sup>2</sup> catchment area (Shaban and Hamzé 2017). However, the catchment of Litani River

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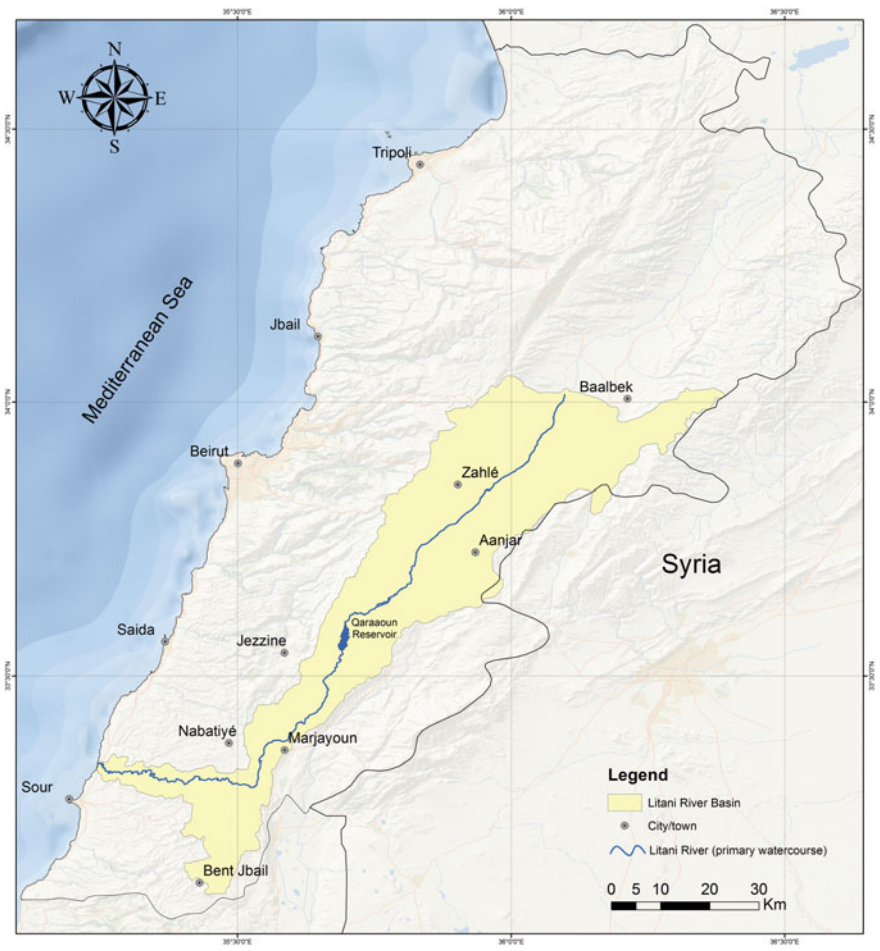
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is separated from these three drainage systems, and thus it represents the junction area for them.

Located in the middle of Lebanon and joining the inner and the coastal zones, the Litani River Basin (LRB) is located between the following geographic coordinates (Fig. 1.1):

33° 06' 25"N and 34° 04' 05"N and 35° 14' 40"E and 36° 22' 44"E.

It is elaborated in the topographic maps, 1:20.000 in combination with the digital elevation model (DEM), and the hydrological concepts; however, the area of the LRB is 2110 km<sup>2</sup>, which is equivalent to about 20% of Lebanon's area, with a perimeter of about 433 km. The length of the primary watercourse of the river is 174 km.



**Fig. 1.1** Location of the Litani River and its basin boundary

Four Mohafazats (i.e., administrative governorates) extend within the border of the LRB. These (and their cazas) are as follows: Al-Bekaa (Baalbek, Zahle, Western Bekaa, and Rachaya), Mount-Lebanon (Meten, Alay, Baabda, and Esh-Shouf), Nabatie (Hasbaya, Nabatie, Marjayoun, and Bent Jbeil), and South Lebanon (Saida, Jezzine, and Sour). Within the LRB there are 246 cities, towns, and villages with >60% of them being located in the Bekaa region. These population entities occupy >370,000 people.

According to International Developing Research Center (IDRC), (National Council for Scientific Research-Lebanon) CNRS-L, Litani River Authority (LRA), and Development Studies Association (DSA) (2007), the river crosses through three microclimatic and physiographic regions, namely,

- The semi-arid flood plain including the Bekaa Plain upstream of the Qaraaoun Reservoir.
- The mountainous region between Qaraaoun and the coastal plain, which is generally in the temperate wet Mediterranean slopes subdivided into two zones: the higher slopes (500–800 m) and the lower plateau (300–500 m).
- The hot, humid coastal plain (0–300 m).

## 1.2 Previous Studies

The greatest number of applied studies and projects has been conducted on the Litani River compared with all other Lebanese rivers because it is a major source for irrigation water and spans over different lands of the country. Primarily, the river water-flow regime, hydrology, hydro-power, and irrigation were studied. Nevertheless, this was not the case after the 1990s after concerns about river water had been diverted to water-quality deterioration and volumetric regression in the discharge from the rivers and its feeding sources.

Studies focusing on the Litani River started in the early 1940s when Abd El Al published a series of documents on the river's hydrology and hydraulics, which acted as first hand-information for many consequent projects undertaken on the river and its feeding sources and tributaries. Therefore, it is not an exaggeration to say that the obtained studies by Abd El Al on the Litani River are a pioneer product on the water sector in Lebanon. They were followed by the establishment of the Qaraaoun Reservoir and its connection with the Kanan Lake and the related hydropower plants and the diverting irrigation channels over a wide portion of land in Lebanon.

However, the greatest number of the recently elaborated studies on the Litani River treat the contamination issue whether exists in the flowing water or in the Qaraaoun Reservoir. In addition, studies exist on the anthropogenic and physical challenges and stresses related to the river and its socioeconomic status.

A survey has been performed on the available studies on the Litani River and its related disciplines as shown in Table 1.1 where 60 representative studies are

**Table 1.1** Representative studies obtained on the Litani River

No.	Title	Date	Type	Author(s)	Major topic
1	Series of hydrological studies	1943	Project	Abd-El-Al, I.	Hydraulics and hydrology
2	Possibility of using the hydro-power in Lebanon: application to Litani River	1944	Conference	LCE	Hydro-power
3	Hydrogeologie de la region Litani-Awali	1974	Report	LRA, FAO, UNDP	Hydrogeology
4	The Litani River of Lebanon	1992	Research	Amery, H.	Political
5	Actual irrigation plans of Litani River	1993	Conference	Owaydah, K.	Irrigation
6	The Litani River: geologic and hydrologic study	1993	Conference	Khair et al.	Hydrogeology
7	Field report on the pollution of the Litani waters	1994	Report	Mansour, H.	pollution
8	Pollution of the Litani River and Qaraaoun Lake	1994	Report	Jaafar et al.	Pollution
9	Water quality of Qaraaoun Lake	1995	Report	Jurdi et al.	Pollution
10	Preliminary considerations on the pollution of the Litani River	1995	Report	Abou-Ziad, H.	Pollution
11	Water management plan for the Litani River and Qaraaoun Reservoir	1998	Research	Srou, S.	Management and pollution
12	Modeling of the Litani River water quality in time and space	1999	Thesis	Dandan, A.	Pollution
13	Environmental Master plan for Litani River and Qaraaoun Lake catchment area	2000	Project	MVM konsult AB, MOE	Management and pollution
14	Water quality monitoring of the Litani River	2001	Article	Haddad, N.	Pollution
15	Evaluation of water quality of the Qaraaoun Reservoir, Lebanon: suitability for multi-purposes usage	2002	Article	Jurdi et al.	Pollution
16	Water quality assessment of the Upper Litani River Basin and Lake Qaraaoun	2003	Project	DIA, WESS	Pollution

(continued)

**Table 1.1** (continued)

No.	Title	Date	Type	Author(s)	Major topic
17	Water quality in the Litani River and the Qaraaoun Lake. Forwarded program: integrated water and coastal resources	2003	Project	Bureau for Asia and near east	Pollution
18	Identifying sources of pollution in the Qaraaoun Lake	2004	Thesis	Ghoul, Z.	Pollution
19	Use of hydrochemistry and environmental isotopes to evaluate water quality, Litani River, Lebanon	2005	Article	Saadeh et al.	Management and hydrology
20	Restructuring water sector in Lebanon: Litani River authority facing the challenges of good water governance	2005	Conference	Catafago, S.	Management
21	Litani water quality management	2005	Project	USAID/AUB	Pollution
22	Sources and transport mechanism of pollutants in the Qaraaoun Lake	2007	Article	Shaban and Nassif	Pollution
23	Towards an ecosystem approach to the sustainable management of the Litani watershed	2007	Project	CNRS, LRA, DSA, Cadham Hayes	Pollution and ecosystem management
24	Post-conflict assessment (2006) of the Litani River	2007	Report	CNRS	Post-conflict assessment
25	Assessing water quality management options in the Upper Litani Basin, Lebanon, using an integrated GIS-based decision support system	2008	Article	Assaf et al.	Management and pollution
26	Optimal water resources management: case of Lower Litani River, Lebanon	2009	Article	Doummar et al.	Management and pollution
27	Geostatistical assessment of groundwater nitrate contamination with reflection on DRASTIC vulnerability assessment: the case of the Upper Litani Basin, Lebanon	2009	Article	Assaf et al.	Management and pollution

(continued)

**Table 1.1** (continued)

No.	Title	Date	Type	Author(s)	Major topic
28	Investigation on macrophyte development in Litani River (Lebanon) subjected to human disturbances	2009	Article	Ismail et al.	Pollution
29	Chemical and environmental isotope investigation on hydrodynamics of a monomictic lake: a case study on Qaraaoun dam, Lebanon	2009	Article	Saadeh et al.	Management and hydrology
30	Litani River flood field survey report	2010	Report	USAID	Flood risk management
31	Water balance report	2010	Report	USAID	Management
32	Wet season water quality survey of the Litani River Basin Project	2011	Project	AUB	Pollution
33	Business plan for combating pollution of the Qaraaoun Lake	2011	Project	ELARD/ UNDP	Pollution
34	Physicochemical evaluation of the Upper Litani River Watershed, Lebanon	2012	Article	Saadeh et al.	Pollution
35	An economic assessment of water use and water pollution in the Litani River Basin	2012	Report	USAID	Consumption and Pollution
36	Climate effects on the Litani Basin Watershed in Lebanon	2012	Thesis	Ramadan, H.	Management and hydrology
37	Preliminary assessment of macrophytic community in Qaraaoun Reservoir, Lebanon	2012	Article	Abou-Hamdan et al.	Pollution
38	Sensitivity analysis of climate change impact on the hydrology of the Litani Basin in Lebanon	2013	Article	Ramadan et al.	Hydrology
39	Qaraaoun Reservoir bathymetric survey	2013	Report	USAID	Hydraulics
40	Fault-controlled analysis for dam construction along the Lower Litani River	2013	Report	Shaban, A.	Risk management

(continued)

**Table 1.1** (continued)

No.	Title	Date	Type	Author(s)	Major topic
41	Hydrologic assessment of Qaraaoun Reservoir in the view of climate change: recommendations and Legislations	2013	Thesis	Kchour, H.	Hydrology and legislations
42	Groundwater modeling within the upper Litani Basin report	2013	Report	USAID	Groundwater
43	Global warming as a driving factor for cyanobacterial blooms in Lake Qaraaoun, Lebanon	2014	Article	Slim et al.	Pollution
44	Physico-chemical functioning and development of phytoplankton in Qaraaoun Reservoir (Lebanon): application of a hydrodynamic-ecological model	2014	Thesis	Fadel, A.	Management, hydrology and pollution
45	Temporal changes in the Lebanese Litani River: hydrological assessment and recommended actions to handle with the human and global change impacts	2014	Article	Nassif et al.	Hydrological Assessment
46	Monitoring the trophic state and phycocyanin pigment of Qaraaoun Reservoir, Lebanon	2014	Article	Fadel et al.	Pollution
47	Analysis of long-term fluctuations in stream flow time series: an application to Litani River, Lebanon	2014	Article	Shaban et al.	Hydrology
48	First assessment of the ecological status of Qaraaoun Reservoir, Lebanon	2014	Article	Fadel et al.	Pollution
49	The distribution of heavy metals in the Lower River Basin, Lebanon	2014	Article	Nehme et al.	Pollution
50	Évaluation de la qualité de l'eau du bassin inférieur de la rivière du Litani, Liban: approche environnementale	2014	Thesis	Nehme, N.	Pollution

(continued)

**Table 1.1** (continued)

No.	Title	Date	Type	Author(s)	Major topic
51	Évaluation de la qualité de l'eau du bassin supérieur de la rivière du Litani, Liban: approche hydrogéochimique	2014	Thesis	Haidar, C.	Pollution
52	Sources and levels of metals in the Upper Litani Basin Soils: Lebanon	2014	Article	Korfali et al.	Pollution
53	Study of physicochemical properties of colloidal sediments of Litani River in Lebanon	2014	Article	Diab et al.	Pollution
54	Spatial-temporal characterization of water quality indicators of the open irrigation canal 900 of Qaraaoun Reservoir, Lebanon	2015	Article	Amasha et al.	Pollution
55	Implantation des échantillonneurs passifs pour le suivi des pesticides dans les milieux aquatiques libanais	2015	Thesis	Al Ashi, A.	Pollution
56	Environmental factors associated with phytoplankton succession in a Mediterranean reservoir with a highly fluctuating water level	2015	Article	Fadel et al.	Pollution
57	Hydrologic Assessment of Litani River Basin in the view of climatic change	2015	Thesis	Daher, M.	Hydrology and climate
58	Spatial and temporal assessment of metal pollution in the sediments of the Qaraaoun Reservoir, Lebanon	2016	Article	Wazne et al.	Pollution
59	Assessment of the trophic state and chlorophyll-a concentrations using Landsat OLI in Qaraaoun Reservoir, Lebanon	2016	Article	Fadel et al.	Pollution
60	Sustainable land management in the Qaraaoun catchment	On-going	Project	UNDP, GEF, MoE	Land management



identified. The table shows that about 80% of the studies were conducted after 2000, and about two thirds of these studies focus on the issue of pollution and whether it is in the river water or in the Qaraaoun Reservoir. In addition, there is an obvious concern from academics on the Litani River, and hence, two thirds of the surveyed studies have also been elaborated upon by researchers and students (e.g., publications, master's theses, and doctoral dissertations, etc.). Moreover, the greatest number of applied research projects were carried out/or supported by international agencies.

In fact, funds provided by the Lebanese water sectors to conduct these studies and projects on the Litani River are few and can be considered negligible when compared with those introduced by the international agencies, especially the World Bank, USAID.

Although the elaborated studies highlight the problems of proposed solutions to enhance the river's status, there has been no remarkable improvement in the river and its basin. This can be attributed to the lack of coordination between the different institutes and stakeholders concerned with the water resources in Lebanon as well as the lack of government's attention to these studies.

### 1.3 Significance of the Litani River

Due to its geographic location, notably, its extent from the interior to the coastal region and then crossing over diverse topographic surfaces with a miscellany of human settlements, the Litani River has always been considered a principal component in the socioeconomic development of Lebanon. The significance of the Litani River is not limited to the basin where it flows into but rather where it extends outbound of its catchment area. Therefore, the Litani River provides water in channels over several hundreds of kilometers in and out of its basin where it irrigates large agricultural lands. The river is also a major source of energy where electricity generation from the river covers a large part of the Lebanese territory, especially when demand for energy becomes competitive. Therefore, the Litani River, which occupies about 9% of the Lebanese population, plays a major role in the development of Lebanon. This can be summarized as follows:

1. The river contributes to the irrigation system for thousands of hectares of farmland. It is also believed that the river contributes to the water needs of close to a million people and also secures wetlands, a major reservoir, and the watershed ecosystem including its soil and forests (IDRC, CNRS, LRA, and DSA 2007). This is well-reflected on food security and the conservation of the natural resources of the country.
2. The agricultural sector in the LRB is mainly governed by the Litani water, and thus 31% of the income within the basin comes from agriculture where 6% (of the 370,000 inhabitants) work in the agricultural sector. This contributes to the majority of income.

3. The running water in the river is connected to three electricity plants: the Qaraaoun, Markaba, and Al-Awali stations. They generate electrical energy averaging about 190 megawatts, which is equivalent to 10–12% of Lebanon's electricity needs.
4. The volume of water discharged from the basin is equivalent to 24% of the net rainfall received by the entire Lebanese territories. This quantity represents >40% of the total amount of running water in the internal rivers (LRA 2014).
5. Many distinguished and water-related features belong to the LRB. This includes the mountain crests, which are covered by snow for several months over the year. In addition, the river basin occupies the largest artificial lake in Lebanon, the Qaraaoun Reservoir, which has a capacity of about 220 million m<sup>3</sup>. In addition, wetlands of different dimension exist in the LRB with the two most well-known ones being Ammiq and Kfar Zabad.

## 1.4 Challenges on the Litani River

It is not an exaggeration to say that the Litani River is subjected to one of the most severe geo-environmental problems not only on a national level but also on an international level. The volume of water is affected badly and its quality even more severely. Hence, encroachments on the river are everywhere including its tributaries and flood plains, the Qaraaoun Reservoir, as well as the groundwater, the water body that feeds and is fed from the river.

The existing challenges on the Litani River have been exacerbating since the last two decades as a chaotic distribution of human activities take place in the context of total lack of any control and legislation to mitigate or even reduce the unfavorable impact. Therefore, the challenges on the Litani River compose a typical example for those on the entire Lebanon country where all water resources are under stress.

Several complaints about the reasons behind the unfavorable status in the water sector in Lebanon. Due to a lack of knowledge and misunderstanding, many people attribute this to the physical conditions with a special emphasis on the changing climatic conditions and negligence related to human interference and mismanagement of the water sector.

Several alarming challenges occur on the water resources of Lebanon. These are either physical (natural) or anthropogenic (man-made) in nature. Both aspects of the challenges negatively influence the volume and quality of the Litani River system. Combined with these challenges, water management is also at a weak level regarding stabilisation of the current situation in the water sector. This is attributed to many political issues acting on Lebanon and the region as a whole. In addition, adaptation measures to conserve water and to equilibrate water demand/supply are still inefficient.

1. Physical challenges: These are related to the natural setting from which water is demanded. If this setting is not favorable for the water regime or for storage, a physical challenge on water occurs (Shaban 2014). In the LRB, the existing physical challenges can be summarized as follows:
  - The existing climatic variability with a special focus on the torrential rainfall regime and the resulting low infiltration rate. In addition, the increased temperature by about 1.8 °C created an increased water demand, notably for irrigation purposes (Shaban 2011). This accelerates the melting rate of the snow, which has doubled lately due to the increased temperature and sun-light radiation resulting in faster stream flow (Shaban et al. 2014).
  - The geomorphology of the LRB, as an elongated catchment, makes it lack water-flow uniformity from the upstream to the confluences and then the outlet, which often reduces the infiltration rate and enhances flooding.
  - A very gentle slope occurs in the Bekaa Plain, comprising the Upper Litani Sub-basin, resulting in slow stream-flow energy. This in turn buys time for evaporation processes as well as for sediments and pollutants to settle.
  - The existence of karstification often results in groundwater loss in deep/undefined rock stratum, as in the case of Mount-Lebanon and Anti-Lebanon chains, which confine the largest part of the Litani River. Moreover, the considerable number of karstic springs results in fast water discharge from these springs, which is accompanied by less exploitation of these resources.
  - The existence of fault systems with several sets and aspects adds a negative role to water loss through these faults, and the resulting water seeps into undefined and very deep aquifers.
2. Anthropogenic challenges: These represent the negative impact of human interference on water resources compared with the physical challenges. In addition, the anthropogenic challenges can be controlled or regulated, which is not always the case for the physical challenges.

In the LRB, the challenges on water resources are tremendous, which severely influence the general status of the river. In addition, these challenges are being dramatically exacerbated without any concurrent mitigation. They can be summarized as follows:

- Pollution is the major problem in the LRB. This includes the river water, water in the Qaraaoun Reservoir, and groundwater. In this respect, three chapters in this book discuss these aspects of pollution. However, the microbiological and chemical analyses of the river water (surface and sub-surface), which was performed several years ago, show that contamination is doubly exceeding the normal standards. Results on the water analysis from the river tributary of the reservoir of Qaraaoun and from the groundwater are discussed in Chaps. 4-6 in this book. Hence, the reason behind this severe condition is the lack of control and the increased aspects of violations, notably, in delivering sewages, including liquid and solid wastes disposal, into the river course. Moreover, the uncontrolled

use of fertilizers in agriculture negatively affects the water quality, especially that of the groundwater (Darwich et al. 2011; Baydoun et al. 2015).

- Increased population is well pronounced in Lebanon and adds to the challenges regarding the different socioeconomic elements including the water sector. This also affects water supply and demand as well as food security in the LRB. Hence, the annual population increase in Lebanon fluctuates between 0.20% and 4.18% and stands at 1.70% (UN 2012). The greatest population increase is often reported in the rural areas, like that of the LRB, which can be estimated at 2.6%. In this case, an annual increase of 9000 people in the LRB can be estimated. If the annual water demand (220 m<sup>3</sup>/capita/y) is considered, then it amounts to 2 million m<sup>3</sup> water that is additionally needed every year. This is not the only aspect of increased water demand. There are also the increased new requirements for water, which have become a new aspect of water consumption including water not accounted for water as well as virtual water.
- Waste disposal is a major problem faced by Lebanon. This is attributed to many factors with politics being a major one. Therefore, the lack of favorable sites to dispose of wastes results in a chaotic distribution of waste disposal (liquid and solid) and landfills of different dimensions. This status affects water resources where these disposals are dumped, and they reach the groundwater reservoirs as well.
- Lack of legal controls and environmental legislations to govern several water-related issues whether on the exploitation or conservation aspects. Therefore, several controls should be applied such as monitoring borehole drilling, fixing water meters, and applying tariffs and other economic policies.

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