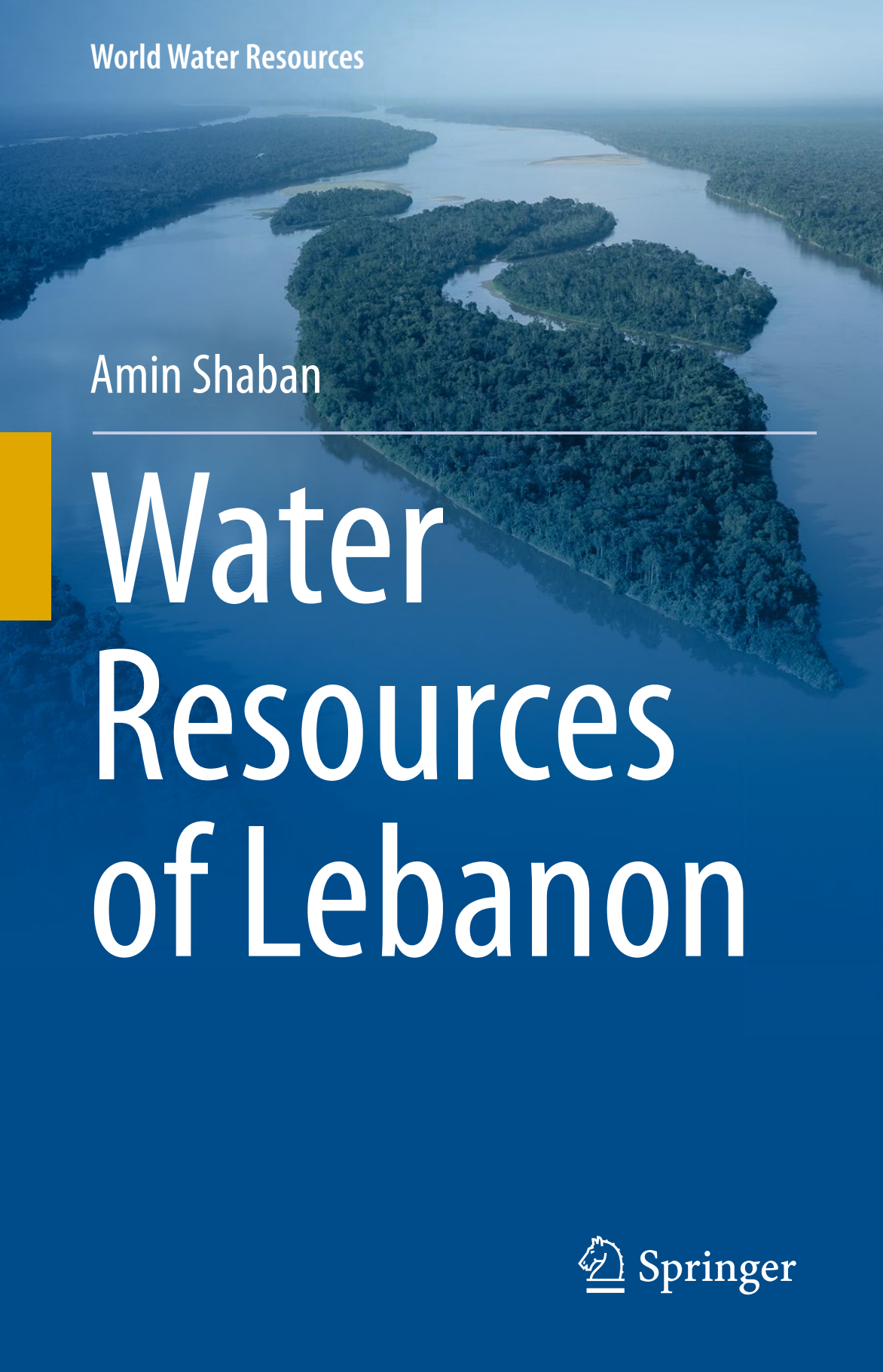
World Water Resources
Amin Shaban
Water Resources of Lebanon
Springer

World Water Resources

Volume 7

Series Editor
V.P. Singh, Department of Biological and Agricultural Engineering & Zachry Department of Civil Engineering, Texas A&M University, College Station, TX, USA

This series aims to publish books, monographs and contributed volumes on water resources of the world, with particular focus per volume on water resources of a particular country or region. With the freshwater supplies becoming an increasingly important and scarce commodity, it is important to have under one cover up to date literature published on water resources and their management, e.g. lessons learnt or details from one river basin may be quite useful for other basins. Also, it is important that national and international river basins are managed, keeping each country's interest and environment in mind. The need for dialog is being heightened by climate change and global warming. It is hoped that the Series will make a contribution to this dialog. The volumes in the series ideally would follow a "Three Part" approach as outlined below: In the chapters in the first Part *Sources of Freshwater* would be covered, like water resources of river basins; water resources of lake basins, including surface water and under river flow; groundwater; desalination and snow cover/ice caps. In the second Part the chapters would include topics like: *Water Use and Consumption*, e.g. irrigation, industrial, domestic, recreational etc. In the third Part in different chapters more miscellaneous items can be covered like impacts of anthropogenic effects on water resources; impact of global warning and climate change on water resources; river basin management; river compacts and treaties; lake basin management; national development and water resources management; peace and water resources; economics of water resources development; water resources and civilization; politics and water resources; water-energy-food nexus; water security and sustainability; large water resources projects; ancient water works; and challenges for the future. Authored and edited volumes are welcomed to the series. Editor or co-editors would solicit colleagues to write chapters that make up the edited book. For an edited book, it is anticipated that there would be about 12-15 chapters in a book of about 300 pages. Books in the Series could also be authored by one person or several co-authors without inviting others to prepare separate chapters. The volumes in the Series would tend to follow the "Three Part" approach as outlined above. Topics that are of current interest can be added as well.

Readership

Readers would be university researchers, governmental agencies, NGOs, research institutes, and industry. It is also envisaged that conservation groups and those interested in water resources management would find some of the books of great interest. Comments or suggestions for future volumes are welcomed.

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Foreword

Dr. Amin Shaban, building on more than 30 years of research in the field, and working at the National Council for Scientific Research – Lebanon (CNRS-L) provides an insightful look and the first comprehensive book on water resources and its management in Lebanon.

It has been a pleasure to have witnessed, first hand, the contribution Amin Shaban has made and the evident mark he continues to create in his field of water research both nationally and regionally. Building on years of research, frequent field work and promising collaborative partnerships, Amin Shaban has contributed widely to various water-related issues with scientific knowledge, innovative analysis techniques and quality publications.

This well-illustrated 10-chapter book provides a timely endeavour to reflect on available studies, complement the research with innovative and new techniques for analysis, and provide updated and new estimations of water resources in Lebanon, which encompass various sources, including rivers, springs, snow, lakes, wetlands and groundwater rock formations, within a holistic approach that includes territorial and atmospheric variables, demand and supply consideration, as well as affecting topographic and geological features.

Located within the water-scarce region of the Middle East, Lebanon stands out with its diverse topography, encompassing various and rich water resources. Yet despite this, the challenges lie in increasing water shortages, inadequate water estimations and an increasing demand on a limited water supply.

Building on the rich data provided in his book, the author's later chapters help highlight existing challenges that exasperate the stress on surface water and groundwater resources in Lebanon. With both natural and anthropogenic challenges, that is, topography, climate, hydrology and shared water resources, exasperated by human interference, that is, population growth, water quality deterioration and unwise use of a limited resource, the author declares that ''Water in Lebanon is in jeopardy''.

But the book doesn't end there. It continues to provide, based on a scientific approach, outlines for active solutions built on expertise, observations and a scientific outline for further actions within a study that encompasses aspects of surface

water harvesting, technologies of artificial groundwater recharge, tapping ground water discharges into the sea, reducing water contamination, proposed economic policies to enhance the water sector, ethics and moral behaviour, as well as mainstreaming the applicability of Sustainable Development Goals in water (particularly SDG-6).

It is my conviction that the data and analyses provided by Amin Shaban will be extremely beneficial to decision makers, stakeholders and beneficiaries, providing a strong scientific footing for mitigation policies and sustainable development of the water sector in Lebanon, whilst also providing a comprehensive case study with various dimensions for further regional and international applicability.

Secretary General
National Council for Scientific Research
Beirut
Lebanon

Mouïn Hamzé

Preface

Water shortage remains the most crucial geoenvironmental issue in many regions of the world, especially where annual precipitation is very low. Recently, this issue has been addressed aggressively due to existing challenges. Moreover, water resources are under serious threat because of increase in water demand. Therefore, water has become a valuable commodity and also results in geopolitical conflicts between neighbouring nations. In Lebanon, there is a severe water crisis and demand for water has been exacerbated. However, no improvement has been observed in the water sector since 1990.

The climate of Lebanon is relatively wet, even though some spells of dryness occur. This is well evidenced by the green cover that spreads over more than 80% of the Lebanese territory.

In Lebanon, several observations point to abundant water resources, spanning from watercourses on terrain surface to a large number of springs and wetlands. In addition, snow remains on the Lebanese mountains for a few months and may extend from one year to another. Moreover, groundwater potentiality is feasible in large part of the Lebanese territory. It is, therefore, a paradox that the country with abundant water supply is facing water shortage, and the public water supply fulfils only 35% of water demand. Besides, there are many studies, projects and initiatives done to assure water supply, but still there is a water shortage. It is also surprising enough that the funding by the Lebanese government does not exceed 10% of financial resources to conduct studies and assess water resources, and this might be the case for the halted projects. This, in turn, raises several questions about the management approaches and about the concern of the Lebanese government in securing water, a vital element, for its inhabitants.

Several initiative scan be taken to rescue water resources and to provide pure and sufficient quantity of water for inhabitants. For example, but not limited to, if shared water resources of Lebanon are well managed, 80% of water demand can be met. Also, if rainwater harvesting is implemented, even on individual basis by building small check dams, approximately more than 3 million m^3 of surface water can be conserved. Moreover, if simplified methods like rooftop harvesting is adopted, there

will be an increase of about 18 m^3/capita/year. Therefore, solutions exist, but proper execution is still lacking.

Several research are being conducted out to assess water resources in Lebanon, and most of these studies aim to detect the reasons behind water stress in the country. It is frustrating to find that many studies attribute the failure in the water sector in Lebanon to physical challenges, with special emphasis on climate change, but overlook the poor water management.

In conclusion, "Water in Lebanon is in jeopardy". Hence, practical actions should be taken, and the government must dedicate much concern to the water sector by employing experts in water resources and from related disciplines to carry out creditable studies.

If we envision the future of water in Lebanon, all scenarios seem pessimistic. This emergency has been declared even by decision-makers and people who manage the water sector. Therefore, there is no more time to waste and rapid action is required.

As the author of this book, I could build a vision on current and future trends in water sector. My experience and knowledge on water resources in Lebanon, including in-depth investigation, research and field measures accompanied with the use of advanced techniques, were useful to produce this comprehensive book.

This book describes all aspects of water resources in Lebanon, the surface and subsurface ones, with detailed discussion on new estimations. This book discusses all physical and anthropogenic factors that influence water resources. It also underpins comprehensive discussion on rivers, springs, snow, lakes, reservoirs, wetlands and groundwater. It, eventually, presents the existing challenges and proposes possible solutions to overcome them. Therefore, this book would be a helpful tool for different-level stakeholders, starting from individuals to high-level decision-makers.

The National Council for Scientific Research of Lebanon (CNRS-L) has shown concern to water resources studies. Therefore, CNRS-L always cooperates with and helps researchers to perform various water studies, especially those using advanced techniques for analysis. Considering the important objectives and scientific relevance of water studies, CNRS-L introduces facilities and logistics to me to author this book.

Beirut, Lebanon Amin Shaban

Contents

Acronyms

CDR	Council of Development and Reconstruction
CESBIO	Centre d'Etudes Spatiales de la Biosphère
CNRS–L	National Council for Scientific Research–Lebanon
COMEST	World Commission on the Ethics of Science and Technology
CPA	Consumer Protection Association
CS	Council for South
FAO	Food and Agriculture Organization
GDEM	Global Digital Elevation Model
GIS	Geographic Information System
IETC	International Environmental Technology Centre
IHP	International Hydrology Programme
IRD	Institut de Recherche pour le Développement – France
IWMI	International Water Management Institute
LARI	Lebanese Agronomical Research Institute
LRA	Litani River Authority
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water
MoFA	Ministry of Foreign Affairs
NWSS	National Water Sector Strategy
OECD	Organization for Economic Cooperation and Development
SDGs	Sustainable Development Goals
SNC	Second National Communication for Lebanon
UNDP	UN Development Programme
UNEP	United Nations Environmental Program
UN-HABITAT	The United Nations Human Settlements Programme
UNHCR	UN High Commissioner for Refugees
UNIECF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development
WB	World Bank
WE	Water Establishments
WEF	World Economic Forum

Chapter 1
Introduction

Abstract Water resources in the Middle East Region, where they are scarce, is a matter of utmost significance. However, it must be made clear that Lebanon has a diverse topography that makes it with different physical setting from the surrounding regions in the Middle East. Even though, Lebanon has a small area (10,452 km^2), yet it encompasses different aspects of water resources whether on surface including rivers, springs, snow and lakes; and sub-surface where a number of aquiferous rock formations and karstic conduits exist with considerable amounts of water. Nevertheless, there is still complain about water supply/demand. The country becomes under water stress and suffering from water shortage. Meanwhile, creditable estimations on water resources are still inadequate. Recently, challenges on water resources have been exacerbated including the population growth and the increased water demand, plus the changing climatic conditions. The existing management approaches done by the governmental sector are few enough to adapt water sector to these challenges. Thus, managing the demand of water in Lebanon is substantially adopted by the individuals rather than the public sector itself. This chapter will introduce an overview on the Lebanon's territory, then it will illustrate different measurements on water resources including mainly water availability, demand and supply. In addition, an inventory on the previous obtained studies will be mentioned.

Keywords Water stress · Mountainous region · River flow · Contamination · Eastern Mediterranean

1.1 Lebanon in the Regional View

Lebanon, the Middle East country along the Eastern Mediterranean Sea, is was ranked as the 162nd country worldwide, and the 19th Arab country in terms of the geographic area. Lebanon is mainly a mountainous region where a number of elevated areas occur and represent a chain of mountains extending parallel to the

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Mediterranean. The country occupies the highest crest in the entire Middle East Region, where a 3088 m altitude is.

Lebanon has a relatively small area (10,452 km^2) with a maximum coastal length of 220 km and 85 km width. Even though Lebanon has limited geographic area, yet it encompasses diverse physiography which is remarkably different from the surrounding regions. Thus, three major geomorphological features exist. They are the Mount-Lebanon, Bekaa Plain and the Anti-Lebanon. These features, with their exposed rock bodies, form a climatic barrier that captures wet air masses blown by wind from the Mediterranean to the east, and this is the main reason why Lebanon is characterized by relatively high precipitation rate including rainfall and snow.

The entire territory of Lebanon is considered as a regional water junction where surface water flows from Lebanese territory into three regional drainage systems. These systems are: (1) the occidental Lebanon drainage system which comprises a number of relatively short rivers and streams, and thus provides water into the Mediterranean Sea, (2) the northern Bekaa Plain which is represented by the Al-Assi River as a major tributary of the Orontes River that spans to Syria and then Turkey, and (3) the Hermoun Mountain which is represented by the Hasbani-Wazzani River a major tributary of the Jordan River (Shaban and Hamzé 2017).

The geographic location of Lebanon implies the following geographic coordinates:

33° 03′ 14″ N and 34° 41′ 32″N &
35° 06′ 14″ E and 36° 37′ 25″E

Lebanon is almost situated in a semi-arid region, but its morphology characterized it by relatively wet climate. Even though, higher temperatures are noticed as a regional climatic phenomenon, yet a recent study depended on advanced statistical analysis shows that Lebanon is a located in a sub-humid-climatic zone (Shaban and Houhou 2015).

The geographic location of Lebanon, which is almost adjacent to the borders of three continents (Africa, Asia and Europe), often put it within diverse regional geographical nomenclatures. Thus, Lebanon belongs to the regions of: Middle East (ME), Middle East-North Africa (MENA), Arab Region (AR), and ESCWA Region.

Due to its remarkable nature and setting, Lebanon is always viewed as a distinguished place, and thus it was named by several descriptions, such as: the Swiss of the Levant, Water Tower of the Middle East, Cedars Land, etc.

1.2 Historical Overview

Even though it has a small geographic area, yet Lebanon is one of rare countries which encompass the entire elements of the water cycle (e.g. snow cover, water-bearing conduits, renewable groundwater, sub-marine springs, etc.). In this view, and since the ancient time periods, Lebanon is known by abundant water resources, and the remarkable thing is that these resources have diverse aspects whether on

surface or the sub-surface. This made Lebanon a country with distinguished historical water-related constructions, such as water collecting ponds, man-made cannels, terraces, watermills, caves and stone bridges (Fig. 1.1).

In this regards, many appreciations and poems celebrated Lebanon's landscape throughout ancient history, and water was the main element of the charming nature. This includes snow cover, running water in rivers and springs, water-bearing grottos. These aspects of water resources result colourful fertile lands.

Fig. 2.1 Old bridge on Naher El-Kaleb. Photo taken in 1810 by Sami Toubia (Maïla-Ateihe 2009)

The history of water in Lebanon has been come to light since the Ottoman Empire (1516–1919). During this period, the empire undertook a number of reforms on the basic services including mainly the drinking water and land. Therefore, several regulations and diligences have been put on water and land management, such as: *amirié land*, *tariffs, firman*, etc. (Mallat 2003).

In this respect, the most significant established regulation was the bring water from Naher El-Kalb to Beirut and provide running water to the city (OEB 1996). This affected many agricultural lands, notably where irrigation canals and watermills exist. Thus the issue arose of recognizing the water rights acquired by dignitaries and monasteries. Thus, the concession changed the distribution of water access by bringing together various social groups outside of the established framework based on the confessional system.

This episode of Ottoman reforms had a major influence on the water sector. The identification of legal problems linked to this concession and the solutions adopted

Fig. 1.1 Location of Lebanon

strongly influenced the Ottoman Civil Code which is assigned a "Mecelle" (Ghiotti and Riachi 2013).

The civil war (1975–1990) occurred in Lebanon was one of the most hindered factors in the development of the water sector. Therefore, new water projects and supply implementations have been proposed to form a new era in the water policy of Lebanon.

Yet, Lebanon has only two large dams (i.e. Qaraaoun and Shabrouh) while the country encompasses more than 40 major watercourses that run water for a couple of months per year. This reflects the shortage in applying proper and required water measures for better water resources management.

Nowadays, it can be tedious to match the reality with the history of natural resources in Lebanon, notably when it comes to water. Therefore, access to water became a geo-environmental issue, and the majority of consumers only have access to water for few days per month. Hence, water provided by the public water sector is very limited, and therefore, consumers depend on themselves to access water for different purposes. This in turn led to uncontrolled behaviours to reach water resources, such as digging chaotic boreholes, direct pumping from rivers and springs, etc.

Recently, water has become a commodity for trading in Lebanon. There is the bottled water for more than 40 trademarks, water tankers and tractor are commonly seen, in addition boreholes are widespread, notably the illegal ones. For example, there are over 30.000 illegal groundwater wells dug in the Greater Beirut and the adjacent mountainous region. In the same time, water contamination became a daily issue for discussion, but no solutions have been reached yet. In conclusion, water resources in Lebanon are in jeopardy.

1.3 General Water Measurements

Usually, Lebanon is described as the country with plenty water resources, and perhaps this is because water can be seen everywhere on the Lebanese territory. However, the supply/demand reflects a contradictory figure, and the overall figure on water reserves and the mechanism of water retention is still obscure.

Therefore, the condensed cold air masses from the Mediterranean result considerable precipitation if compared with the precipitation in the neighboring Middle East countries. Hence, general estimates reveal that the average annual rainfall rate in Lebanon ranges between 700 mm and 1500 mm, and snow covers annually more 2000–2500 km^2. Moreover, Lebanon occupies 14 perennial watercourses (i.e. rivers) and more than 1500–2000 springs with permanent flow. In addition, there are a number of aquiferous formations and karstic conduits which store considerable volume of groundwater.

There are many estimates on the renewable water resources in Lebanon, which have been plotted by many sources, such as: UNDP and FAO 1983, Jaber 1995, Bou Zeid and El-Fadel 2002, Fawaz 2007, and the National Council for Scientific Research (CNRS-L) 2015. However, renewable water resources in Lebanon have

been subjected to abrupt fluctuations from one year to another as a result of climatic variability. As an example, a recent wet storm hit Lebanon in the beginning of 2019 for a couple of days; therefore, this storm added about 1.5 billion m^3 of water which is equivalent to the amount of stored groundwater in Lebanon.

The average volume of the precipitated water in Lebanon is about 9.5 billion m^3/year, and after subtracting the evapotranspiration, which is about 4.85 billion m^3/year, or equivalent to 51% of the precipitated water, the rest will be 4.65 billion m^3/year. However, some studies stated that the renewable water resources in Lebanon is averaging about 4.1 billion m^3/year (CESFB 2018).

1.4 Water Availability

In general, water resources are considered as plenty since they can be observed everywhere in Lebanon, notably the surface resources. In addition, the tangible wet climate over couple of months (including the snow cover and rainfall) brings good sense towards water availability. This optimistic figure has been assured since water availability exceeds the threshold of the standard water-poverty which is determined at 1000 m^3/capita/year, even though the supply and demand are still imbalanced. Hence, several estimates done to calculate the water quota for inhabitants in Lebanon.

Lonergan and Brooks (1994), for example, calculated water availability per capita in Lebanon at 950 m^3/year. While, Shahin (1996) estimated much higher value of approximately 3750 m^3/year. However, recent estimations were done by Shaban (2011) where detailed socioeconomic survey has been applied to different regions in Lebanon including the estimation of water availability and even the consumption rates. In the obtained survey, Shaban considered all available resources, virtual water, climatic variability and oscillations as well as diversity of water use in different regions. Thus, the resulted estimation was at 1350 m^3/capita/year.

Nevertheless, the rate of water availability has been declined and it was believed that the changing climate is the main reason behind, but this understanding was no longer convince when the demographic control was involved after the year 2015 due to the displacement of large number of people (estimated at 2 million people) from the surrounding countries as a result of political conflicts in the Middle East Region. Therefore, it was lately estimated at 921 m^3/capita/year (Shaban 2016). This means that water availability in Lebanon has been decreased at about 429 m^3/capita/year (i.e. equivalent to 32%) between 2011 and 2016.

1.5 Water Demand

Water demand in Lebanon is still undefined, because no creditable measures have been applied, and if these measures exist, they are found with obvious contradictory. In all cases, the largest part of the Lebanese territory is under water shortage and the demand for water is a national problem that remains unsolved since long time.

Added to water shortage and the intermittent water supply, there is also water pollution which becomes a widespread geo-environmental problem, and it reached both the surface and sub-surface water resources in the entire country. Hence, the current unfavorable situation on water resources in Lebanon creates conflicts between the supplier and the consumer. The inadequate supply, in some instances, results irresponsible and unethical behavior from consumers in different water uses, and thus consumers believe that they should manage their water needs and they cannot depend on the governmental sector to provide them with their water needs.

Recently, demand for water has been diverted by the consumers into chaotic exploitation manners, and they started utilizing water resources with no control and without any regulated methods. Therefore, direct water pumping from surface water sources (e.g. rivers, lakes, etc.) becomes a common phenomenon; even though small pools are dug near snowpack to collect the melting water and deliver it for long distances for agricultural and domestic purposes. In addition, groundwater exploitation has been chaotically increased and the number of private water wells are being in dramatic increase, notably in regions where groundwater is shallow and can be tapped easily with cheap cost such as the case in the Bekaa Plain where hundreds of water wells are dug every month. Most of these private wells have low discharge rate and they sometime become dry.

The recent estimates showed that there is a decline in the surface water resources between 55% and 60% over the last four decades (Shaban 2011). This also accompanied with an abrupt lowering (i.e. several tens of meters) in the water table for the major aquifers in Lebanon. The obvious decrease in the volume of surface and groundwater affected the nexus between water and the related sectors, thus it is reflected on the agriculture, energy, food security and it extended to the socioeconomic sector as well.

In Lebanon, the majority of water demand goes to irrigation purposes and many contradictory estimates have been illustrated for water allocation. For example: Jaber (1997) and Comair (1998) allocated water consumption in Lebanon as 12–32%, 8–18%, and 60–70% for domestic, industrial and irrigation purposes; respectively. Besides, World Bank (2003), illustrated 30.5%, 10.5% and 59% for domestic, industrial and irrigation; respectively.

The common estimates for irrigation range between 62% and 80%, and sometimes 85%.However, the recent applied survey showed that 72% is found the most convenient ratio even though this ratio is always oscillating from one year to another depending on the rainfall rate as well as on the demand for water for domestic and industrial purposes.

For the domestic and industrial sectors, they almost consume 26% and 6%; respectively (Shaban and Hamzé 2017). These ratio are also controlled by many factors (e.g. volume of water supply, partitioning period, etc.) and then they are found to be changed but with less percentage if compared with that of irrigation.

Water demand projections have been also applied to figure out future water requirements in Lebanon. According to SOER (2010), a projection for the years 2010–2035 have been done. It resulted that the demand for water in 2030 will be as: 583, 156 and 1050 million m^3 for domestic, industrial and irrigation uses; respectively (Fig. 1.2).

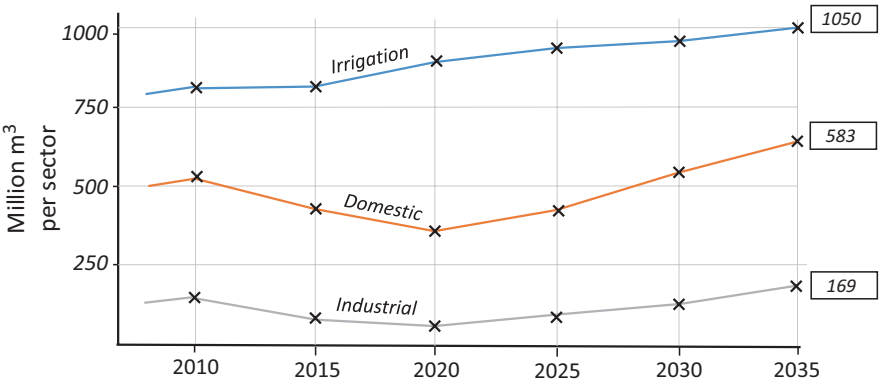

Fig. 1.2 Annual water demand by sector (2010–2035). (Adapted after SOER 2010)

Table 1.1 Water demand per capita in Lebanon as adopted from different sources

Year[a]	Consumption (m^3/capita/year)	Source
1966	243	Jaber (1997), Comair (1998)
1966	236	Fawaz (2007)
1990	437	Jaber (1997), Comair (1998)
1990	297	Jaber (1997), Comair (1998)
1996	367	Fawaz (2007)
2000	592	El-Fadel et al. (2001)
2001	442	MoE (2011)
2010	307	MoEW (2010)
2011	220	Shaban (2011)
2015	526	Jaber (1997), Comair (1998)
2015	489	MoE (2011)

[a]Year of estimation

Water demand per capita in Lebanon has been recently estimated at about 217 m^3/capita/year. In this regards, there are many estimates obtained by many researchers and the resulted values were totally different (Table 1.1). The following estimates show an example of the calculated water consumption per capita in Lebanon:

The discrepancy in water allocation also occurs between different regions in Lebanon. Therefore, it is always understood that water consumption in urban areas are greater than that in the rural ones. Nevertheless, recently the applied socioeconomic survey in selected regions revealed that rural areas demand amount of water larger than that in the urban ones. Therefore, the resulted survey showed that domestic water consumption are: 190 *l*/day/capita and 157 *l*/day/capita in the rural and urban areas; respectively.

1.6 Water Supply

Water supply is usually considered as the amount of water received from the public water sector, but when this amount becomes insufficient to cope with the consumer demand, alternative supply sources are adopted. In Lebanon, water supply has many aspects and it is dependent on miscellany of sources; however, it varies between rural, urban and densely urbanized rural regions (Fig. 1.3). The majority of water supply includes water from the obtained pipes by the public water sector, from groundwater boreholes, bottled water, water trading and harvested water (Shaban 2016).

Drilling water wells is a common phenomenon in Lebanon to compensate water shortage. These wells, which are mostly private ones, can contribute to a considerable range which is in average equal to 1/3 of water needs. These wells are widespread in the urban/or densely rural areas, such as in Beirut and Zahle (Fig. 1.3).

Bottled water, as an aspect of water supply, is only for domestic uses (e.g. drinking, cooking, etc.) and the highest percentage of bottled water distribution is in Beirut and its suburbs where sufficient/or pure water is lacking. The number of bottled water companies which are permitted by the Ministry of Public Health (MoPH) is 42 ones. They are 10, 15, 11 and 6 distributed in Mohafazat North, Mount-Lebanon, Bekaa and South; respectively (MoPH 2019).

Water trading has also a major contribution in water supply, and it is usually extracted either from boreholes in major cities like in Beirut area, or from the harvested water in the rural areas. In this respect, water trading is continuously increasing and different prices were noticed. However, the average price in Beirut rages between 100 and 125 LL/*l* and be between 50 and 75 LL/*l* in rural areas.

Stored water is another source of water supply in Lebanon. The largest part of this water is collected in wet season and then used in summer time and mainly for irrigation purposes. This aspect of water is usually harvested from rainfall or from the melting snow, notably in the mountainous rural areas where hill lakes and Earth reservoirs are established to store, in some instance, 1/3 of the water needs. However,

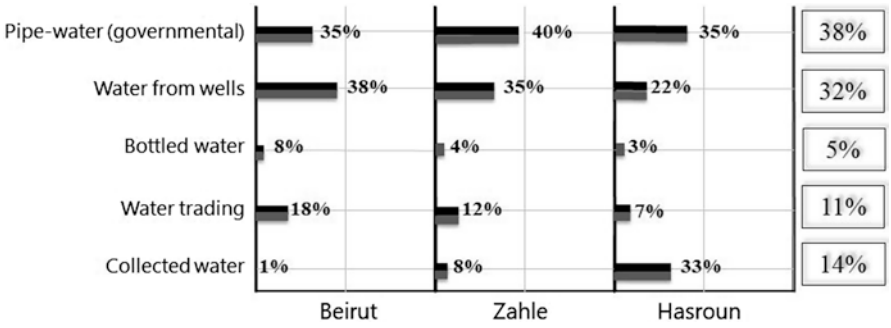

Fig. 1.3 Aspects of water supply in representative regions from Lebanon. (Adapted after Shaban 2016)

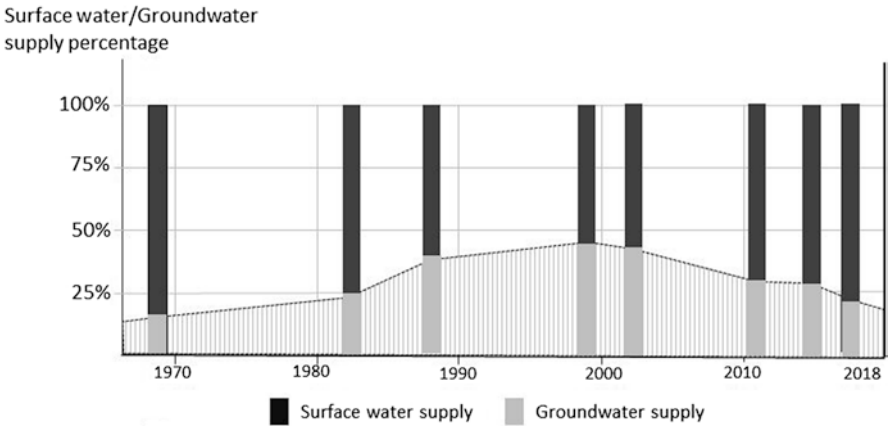

Fig. 1.4 Water supply from surface water and groundwater in Lebanon (1970–2018)

in urban areas like in Beirut, water collection is done in ponds and plastic tanks, and it is collected from the water supplied by pipes.

In generally, the current status in water supply is not satisfied. Thus, then water public sector is applying water partitioning, and it almost follows 2 days per week, and in many regions water sometimes do not reach consumers for a couple of weeks, notably in summer season or when maintenance is required for water networks. This indicates the poor supply and the urgent need for alternative management approaches.

It is clear that water supply form the public water sector does not exceed the 35% of the total water demand in all regions in Lebanon where the supply pipes are not well maintained and leakage from these pipes exceeds 40% in some cases. This unfavorable situation created new implementations; in particular, the increased number of illegal wells and water trading without quality controls.

In early 1970s, water from surface resources (notably from rivers) exceeded 85% of the total water supply in Lebanon, and the rest 15% was from groundwater pumping. Therefore, many changes have been developed and groundwater contribution reached about 45% of water supply in the year 2000. Lately, the adopted groundwater pumping regulations taken by the Ministry of Power and Water (MoPW) in Lebanon controlled the number of dug boreholes and then the pumping rate and this in turn created a new figure for water supply from surface water and groundwater resources (Fig. 1.4).

1.7 Previous Studies

Many studies on water resources in Lebanon have been produced, but they are mostly integrated with other themes (e.g. geology, agriculture, energy, political conflicts, etc.). From the geological point of view, they have been started since early 1830s when concerns on the geology of Lebanon has been raised. This was

pioneered by the French geologists who worked in the region (Botta 1833; Blanche 1847). Further on, with the beginning of 1930s, another French geologist worked in the entire region of Lebanon and Syria; Louis Dubertret (*Father of Lebanon's geology*) started the geological mapping of the region at different scale including Lebanon (Dubertret 1933, 1953, 1955, 1963, 1966).

Since the early 1950s water studies were substantially raised in Lebanon. These studies belonged to different institutes concerned with water resources. Thus, the majority of these studies implies research papers, thesis dissertations, technical and assessment reports, projects, books. There are many of topics selected on these studies; in particular on hydrogeology such as:

(e.g. Yondanov 1962; water economics El-Qareh 1967; Majdalani 1977; Shaban 1987 and Khadra 2003); hydrology (e.g. Abd EL-Al 1953; Ghattas 1975; Daher 2015); karst hydrogeology (e.g. Hakim 1985; Edgell 1997 and Hamdan 2018); water quality (e.g. Abbud and Aker 1986; Peltikian 1980; Darwich et al. 2011); environmental hydrology (e.g. Khair et al. 1994; Jurdi et al. 2002; Fadel et al. 2015); water economics and policy (Fawaz 1969, 2007; Jaber 1995; Na'ameh 1995; Khawlie 2000b; CNRS-L 2015 and Shaban 2016); impact of climate change on water (e.g. Khawlie 2000a; Bou Zeid and El-Fadel 2002; Karam 2009; Shaban 2011 and Shaban et al. 2019); use of new techniques in water resources assessment (e.g. Shaban 2003 and Shaban et al. 2005).

Chapter Highlights

- Lebanon constitutes a climatic barrier that captures wet air masses blown by wind from the Mediterranean Sea.
- The entire Lebanese territory represents a water junction where three regional surface water systems exist.
- Water demand for is estimated at 1350 m^3/capita/year, and it has been decreased at by about 32% due to the geo-political conflicts and the displacement from neighboring regions.
- Water supply form the public water sector does not exceed the 35% of the total water demand.
- Except this book, there is no comprehensive study, including all aspects of water resources, has been elaborated for the entire Lebanon.

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