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Temporal Changes in the Lebanese Litani River: Hydrological Assessment and Recommended Actions to Handle with the Human and Global Change Impacts

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Authors' contributions

This work represents an output of a scientific research applied at the Lebanese University in collaboration with the National Council for Scientific Research in Lebanon. The work highlights on the largest river in Lebanon which has been subjected to severe geo-environmental problems. The decrease in the discharge of the Litani River has been lately exaggerated. The authors treated this problem and proposed the appropriate solutions as viewed from the legal aspects.

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ABSTRACT

Litani River is described as the most important river in Lebanon. Even though, high rainfall is often recorded in the Litani River basin, but several physical and anthropogenic changes in this area are affecting the hydrologic regime. This issue has been exacerbated in the last decade. This study provides the majority of the legislation which manage the water sector in Lebanon, especially in the Litani River Basin, and it presents illustrations on climatic and hydrologic trends overall Litani River Basin. It highlights the key issues of water shortage in Litani River including the existing changes and their impacts. It was established a complete figure on rainfall trend from 1994 till 2012 and

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hydrologic components trends from 1952 till 2011, which are recorded and monitored in three stations located at three parts of Litani River Basin (upper Litani Basin, middle Litani Basin and lower Litani Basin). The average annual rainfall in these three stations is shown to be increasing about to 9% along a period of 18 years. However, there is an obvious decline in the average of the river's discharge which reaches about 45% in the last four decades. This in turn reveals the negative influence of anthropogenic actions on Litani River rather than considering the climatic changes impacts. In addition, the gaps and overlaps in the existing legal framework lead to insufficient control on the major natural water sources, especially the application of the Environmental Protection Framework Law No. 444 dated 29/07/2002. However, we need urgently to start the application of the precautionary principle, principle of prevention, polluted-pays principle and environmental impact assessment in order to prevent and to be adapted to the impacts of climate change at national and international level.

Keywords: Environmental legislation; water shortage; increase in rainfall; discharge; anthropogenic impacts.

1. INTRODUCTION

Lebanon which is situated in the south-west of the continent of Asia, on the eastern coast of the Mediterranean Sea with a total area of 10 452 km^2, and it is known as one of the countries in the Mediterranean region having abundant water resources.

While Lebanon is in a favorable position in terms of rainfall and availability of water resources, the restrictions are: the very vulnerable capacity to store water and the difficulty of the imprisonment of water close to the sea, and deficiencies in the systems and the water distribution networks. The total outflow of surface water is about 735 million cubic metre/year were 160 million cubic metre/year of them goes to the sea [1].

There is difficulties to manage water sector due to the lack of data and the huge amount of losses as a result of leakages and widespread unlicensed wells where pumping is far from being monitored. This deficiency in data availability hinders possible predictions of water distribution among the three sectors: agricultural sector, domestic sector, industrial sector. However, a previous study estimates that the quota per capita from the available water is 1,324 m^3 per year. However; the consumption rate in Lebanon is estimated at 595 L/day/capita. This is distributed as: 175, 400 and 20 L/day/capita for domestic, agriculture and industry, respectively. This means that the annual needs per capita is 217 m^3/year. Therefore, the available amount of water is six times the amount of water required by each person [2]. Annually 700 million m^3 are used to produce hydroelectric power and return directly to the rivers [3]. The consumption of water for domestic purposes is estimated by 220-250 liters per person per day during the dry period and 200 liters per capita per day during the wet period [1].

The Litani River is the largest of all Lebanese rivers and the most important water resource in the country. A comprehensive watershed master plan was developed for the Litani River, which led to the construction of a major hydroelectric system in 1956 which is the Al-Qaraoun Reservoir. This led to a hydrological separation between the basin's upper reaches above Al-Qaraoun Reservoir, known as the upper Litani Basin, and the lower reaches. The return to more stable conditions encouraged the Litani River Authority to revive plans to divert substantial volumes from Al-Qaraoun Reservoir for irrigation and municipal water supply in the long neglected southern and interior parts of the country [4].

In the Upper and Middle Litani Basin, corresponding to Central and South Bekaa regions, water resources are restricted to surface and groundwater of Litani River Basin. There are no diversions of water from other basins. In the lower and coastal river basin, corresponding to South Lebanon region, only domestic and industrial water are partially fed by springs and groundwater diverting from other basins. However, water in the future shall be diverted from Litani Basin and from other southern basins for domestic and irrigation purposes. Current domestic and industrial water supply is estimated at 14 million cubic metre/year in South and 30 million cubic metre/year in Bekaa. This amount is produced mainly from springs and wells. The distribution systems suffer from big loses which is estimated at about 40% of the carried water. Supplied water volumes are under the demands needs, especially in the South. In the South, water is transmitted by networks that extend beyond the Litani River Basin. To meet

increasing demand in potable water in the region of South Lebanon, an additional amount of 20 million cubic metre will be supplied yearly from Litani Basin, via Canal 800 project, to South Lebanon. Projected domestic and industrial water demand on Litani River Basin area is shown in Tables 1 and 2 [5].

Table 1. Projected water demand for domestic supply in million cubic metre/year [5].

Year	2010	2015	2020	2025	2030
Bekaa	34.26	38.82	43.17	45.18	46.78
South	24.63	27.20	29.49	30.21	30.62
Total	58.89	66.02	72.66	75.39	77.39

Table 2. Projected water demand for industrial supply in million cubic metre/year [5]

Year	2010	2015	2020	2025	2030
Bekaa	3.61	4.05	4.57	5.14	5.74
South	1.49	1.67	1.87	2.10	2.35
Total	5.10	5.72	6.43	7.24	8.08

Due to water scarcity, the Litani River Authority (LRA) provides, for irrigation, moderate and small water volumes for several projects Table 3. Including:

1. In the southern coastal area, the Qasmiyeh (between the sea level and 100 m elevation above sea level) project, water to irrigate 4000 ha.
2. In the South Bekaa, water to irrigate 2000 ha (Phase 1 of South Bekaa Irrigation project).
3. Water to irrigate the Pilot project in Eastern Saida region (outside the Litani River Basin) (400 ha) [6].

There are many changes on Litani River Basin. These changes are either physical (natural) or anthropogenic (man-made), and both changes are acting negatively on the volume and quality of water. Besides, there are no effective water management and adaptation measures applied to preserve water and to equilibrate water demand/supply. In this respect, there are several studies on Litani River Basin, projects, proposed plans and actions done Table 3. Nevertheless, the current status of water derived from Litani River Basin remains unsolved and it is still increasing, and thus it threatens the river for the next few years; specially the changes that could be intensified lately.

Since the last nineties, major of studies have focused on the pollution of Litani River while few studies have addressed on the hydrological cycle. All of these studies identify the problem facing the Litani River Basin which is due to the short period of rain, difficulties to store water and mismanagement of water sector in Lebanon. Also, the effect of climate change on water resources is considered when there are combined change in temperature and precipitation [7]. On another hand, they highlight the remedial measures which they are necessary to improve water quality.

This study shows a comprehensive view on the problematic aspects of Litani River Basin, including surface water. The study discusses the elements of the physical and anthropogenic changes. It relies on diagnosing the general status of the available data and information from previous records.

This paper presents a water quantity assessment of the upper Litani River Basin, Al-Qaraoun Reservoir and lower Litani River Basin. It differs from many other applied studies on Litani River in Lebanon because discussed all the problematic issues that Litani River's discharge facing. The impacts are grouped according to their origin, and this work represents an inventory that highlights the key issues on Litani River Basin in Lebanon. According to the synthesis obtained in this study and in previous ones, is needed to find rapid solutions, and implement them, to facing the existing changes on Litani River Basin [8]. This in turn will help the introduction of first-hand information for better water resources management in Lebanon.

2. AREA OF STUDY

Litani River which has a length of 177 kilometres and area of about 2180km^2. It constitutes 25% of the total area of Lebanon where it occupies four Mohafazats (administrative governess). These are Bekaa, Nabatiye, Mount Lebanon and South Lebanon. It comprises 263 villages that are part of 12 Cazas. The population growth in the basin was studied. The number of people in 2010 was about 376000 and it is predicted in 2020 to reach 470000 [5].

The Litani River (Fig. 1), which originates from the middle part of the Bekaa plain forming the upper Litani Basin, discharges primarily in the Qaraoun Reservoir, then it continues southward as lower Litani Basin where it is meandered near Al-Khardali region and then extends westward to the Qasmiye where it outlets finally into the sea [9].

Table 3. The planned and ongoing LRA Irrigation projects

South Lebanon	**Canal 800**	**To irrigate 14700 ha, between the 800 and 500 m above sea level**
	Canal 600	To irrigate 3500 ha.
	Saida- Jezzine (phase 2)	To irrigate 1220 ha.
	Khardale Dam Project	To irrigate 15000 ha.
	Bissri Dam project	To provide drinking water for the city of Beirut.
	Massa -Yahfoufa Dam project	To store an amount of water close to 800 million of cubic metre.
	Kfarsir Dam project	To store an amount of water close to 15 million of cubic metre on the bottom of the basin of the Litani River.
	Qasmieh-Ras El Ain	To irrigate 2000 ha.

The current study treats the entire Litani River including the located station upstream and downstream (Fig. 1). This work focuses on the upper Litani Basin, lower Litani Basin and Al-Qaraoun Reservoir (Fig. 1), where we find 3 stations to measure the overall rainfall that recharge the watershed located at:

a) Der El-Ahmar at an altitude of 1280 m, in the upper Litani River Basin.
b) Sour located at an altitude of 10 m, in the lower Litani River Basin.
c) Zahle located at an altitude of 952 m, in the middle Litani River Basin (near to Al-Qaraoun Reservoir).

At the other hand, the 3 other stations which record the discharge and the volume flow of the river since 1944 till 2010 are located in (Fig. 1):

a) Berdaouni on El-Berdaouni river (upper Litani River Basin) at an altitude of 866 m, in the upper Litani River Basin.
b) Qasmiye on El-Qasmiyeh River (lower Litani River Basin, mouth of the river) at an altitude of 3 m, in the lower Litani River Basin.
c) Khrayzat after the El-Khrayzat spring (near to Al-Qaraoun Reservoir) at an altitude of 967 m in middle Litani River Basin (near to Al-Qaraoun Reservoir).

3. MATERIALS AND METHODS

3.1 Data Availability

In this study, the majority of data availability was dependent on records and measures from Litani River Authority (LRA), National Council for Scientific Research (CNRS) and Ministry of Power and Water (MoPW). The foremost obligation of LRA and CNRS to the project was to provide, in a comprehensive approach, information related to Litani Basin characteristics. It also undertook to provide information about the current water management practices and perceived needs.

Supplementary data were needed from the institutes which are not primarily concerned with water resources, but are concerned with disciplines and issues that are directly related to water, but also sometimes apply measurements on water. In Lebanon, these can be: Ministry of Agriculture (MoA) and the related scientific institutes, such as the Lebanese Agricultural Research Institute (LARI), Ministry of Environment (MoE) and General Directorate of Civil Aviation (DGAC).

Nevertheless, these series have a number of gaps where data is lacking due to several technical reasons, and certainly much more gaps in the river's discharge from 1976 to 1990. The lack of information is due to the following reasons:

a) The management of the Litani River Basin was not from the responsibility of a unique institution: Data related to the Litani River Basin is spread between many institutions or sporadic studies (especially environmental studies).
b) The wars (1975-1990 and 2006) and security conditions that has perturbed the regularity of data collection.
c) Technical problems.

3.2 Legal Approach

Most of laws in Lebanon were formulated by the Ottoman Empire and modified and used by the French Mandate, who introduced the first water laws in Lebanon in 1925 and 1926. A large number of concessions and water committees have been created in the few decades before and after the end of the French Mandate over Lebanon. Since 1951 the government of Lebanon issued some 22 decrees dealing with

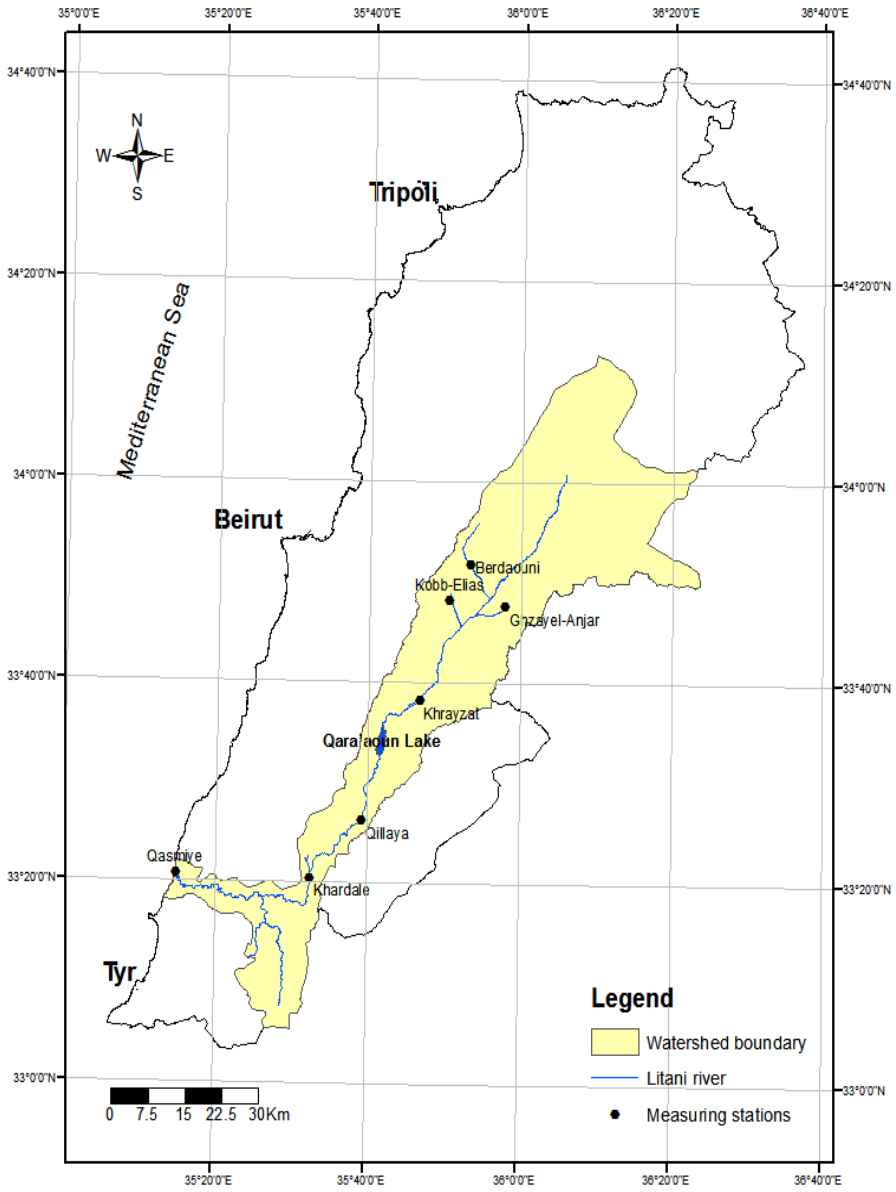

Fig. 1. Hydrological sub-catchments of the Litani River Basin

the creation of water authorities in the country [10].

Unfortunately, our laws moves so slowly towards development and to be applicable by all country not just like words on paper. On other hand, the MoE has no authority to resolve all issues relating to the crossing roles between different ministries. Working within the agenda of an evolving legal and regulatory framework, government agencies at national and local levels are becoming more aware of the need to consider the environmental impacts of their policies and actions, and are gradually building their capacity to manage the environment.

According to the legal framework, which is the base of the water sector, there is no clear stipulated authority for the Ministry of Energy and Water or any agency or a public institution for the formulation and development of policies. The absence of a clear government policy which operates and regulates the water sector lead to freeze this sector for decades. To this day, there

is only an initiative, limited so far, to define a clear policy for the water sector supported by legislation and regulation, the law 221/2000 and its amending's (Law 241/2000 and Law 337/2001). This law defines the institutional foundation that the sector must proceed from but its impact is not yet significant for the following reasons:

a) The authority of planning and implementation is not incorporated into the Water Corporation. Instead, it remains the prerogatives of the Ministry of Energy and Water and from the Council for Development and Reconstruction.
b) The local irrigation committees remain responsible for the management of irrigation systems.
c) The implementation of projects remains within the functions of the Ministry of Energy and Water and from the Council of Development and Reconstruction (CDR), from the Council of the South, from the Fund for the Displaced and from the National Interest of the Litani River.
d) Water institutions are still not equipped as it should be and still lacks an integrated team who would carry out the coordination of new projects when they are implemented.
e) The regulatory framework that would impose standards and technical standards and environmental taxes is either not existing or is ineffective. For example, extraction of water that is not subjected to any regulation continues uncontrollably, and stills the behaviour of household waste disposal and industrial rampant intensively in the country.

Globally, the Law 444/2002 of the protection of the environment needs 30-45 application decrees to achieve full implementation and it is not promulgated till now. This is mandatory to apply environmental law and this is to the most important legal gap in the environmental Lebanese Law. Law 444/2002 has two very important decrees: decree 8157, promulgated in 2012, related to the formation of the National Council for the Environment, were defined its functions and organization, and the decree 8633, also promulgated in 2012, about the assets of EIA (Environmental Impact Assessment)."

The legislation relating to environmental issues, publish recently, responds to more than one target, and decide more than one demand or need. This youngest of law is not really valid at a time of changes and where the mentality of the citizen changed, like the nature of land and ways of life, especially with the technological development and its different effects on environment. Also, the scattering, plentiful and complexity of environmental texts, without being collected in front of a basic title, to be able to develop a uniform vision of environmental law and determine environmental policies, applied to protect the environment and plan the way intended by the legislature, made arise conflicting or heterogeneous texts, to some extent, disrupts the role and effectiveness of the law.

3.3 Tools for Data Acquisition

3.3.1 Ordinary tools and method

a) The main source of information was the archive of Litani River Authority (LRA), Ministry of Energy and Water (MOEW), Ministry of Environment (MOE) and from the Council for Development and Reconstruction (CDR).
b) Field investigation to the study area allowed collecting information through the register of the landscape by photos.
c) Available topographic maps in Lebanon were generated from aerial photographs. Even though, the overall land cover components have been changed; however, they still include the principal elements for terrain analysis and geomorphologic and hydrologic measures. Thus, topographic maps (scale 1:20000) were primarily used as base maps where drainage systems were extracted from. There are extended within twenty five Map Sheets to cover the whole Lebanon. The maps involve Geographic and Grid Coordinate Systems.

3.3.2 Advanced techniques

These techniques depend mainly on methods to measure the amount of surface water, satellites technology and advanced software and programs that can integrate data to obtain specific results and present them in the way that helps the researcher to reach his objectives. From these techniques, the following was used:

a) Moulinet: An electronic device used to measure the flow velocity profile.
b) Stations: They was based on limnigraph records to measure the water flow, flow intensity and water level, or the adoption of a weekly measurement process which

device (Different types: OTT, SEBA-Germany, SIAP-Italy) was placed in an iron box into the course of the river, attached by pipes.

c) Software: to give the final results of measurements of surface water through the program HYDATA and the HYDRAS.

d) GIS (Geographic Information System) was mainly used in this project to delineate the borders of Al-Litani River Basin.

e) Satellite Images Analysis: In this study, data provided from satellite images were used to obtain some measurements and characteristics of the river basin (water course length, gradient slope, basin feature, among others parameters) and to fill gaps in ground records especially in the case of rainfall records. Therefore, interpolation was applied to link several data series.

4. RESULTS AND DISCUSSION

4.1 Climatic Data

Influenced by the Mediterranean Sea, as well as by the Syrian Desert to the north, a variety of microclimates occur within the Bekaa plain with contrasting temperatures and rainfall distribution.

4.1.1 Rainfall

The data used to illustrate rainfall trends in this study is almost adapted from records taken from the Litani River Authority. Three stations are located in the area of study which are Der El-Ahmar station (upper Litani River Basin), Zahle station (near to Al-Qaraoun Reservoir) and Sour station (lower Litani River Basin). The obtained rainfall rates are continuous from 1994 till 2011 in Der El-Ahmar, from 1998 till 2012 in Sour (gaps from 1994 till 1997 are due to technical problems) and from 1994 till 2010 in Zahle.

The rainfall data recorded along a period extending from 1994 to 2011 were analyzed and the average rainfall rate values were calculated and used to generate a general trend of rainfall in the region of interest. These values, together with the general trend of rainfall are shown in the following graphs. We can notice, by analyzing these graphs, that linear average trend in Der El-Ahmar increases from about 400 mm at 1995 to reach 500 mm at 2011, an increase in rainfall of 100 mm which is equivalent to 20% along a period of 16 years (Fig. 2). Whereas linear average trend in Zahle increases weakly from about 620 mm at 1994 to reach 650 mm at 2010, an increase in rainfall of 30 mm which is equivalent to 4.6% along a period of 16 years (Fig. 3). Also, linear average trend in Sour increases weakly from about 550 mm at 1998 to reach 570 mm at 2012, an increase in rainfall of 20 mm which is equivalent to 3.5% along a period of 14 years (Fig. 4). The average of annual trend in these 3 stations is about to 9.36%.

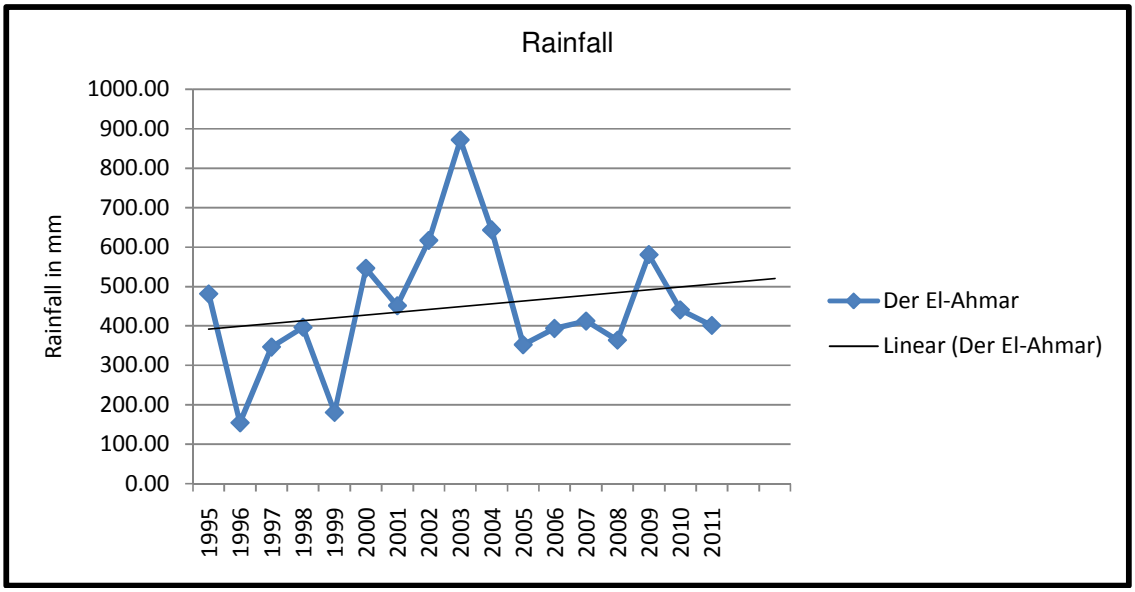

Fig. 2. Rainfall recorded in Der El-Ahmar (upper Litani River Basin) station from 1995 till 2011

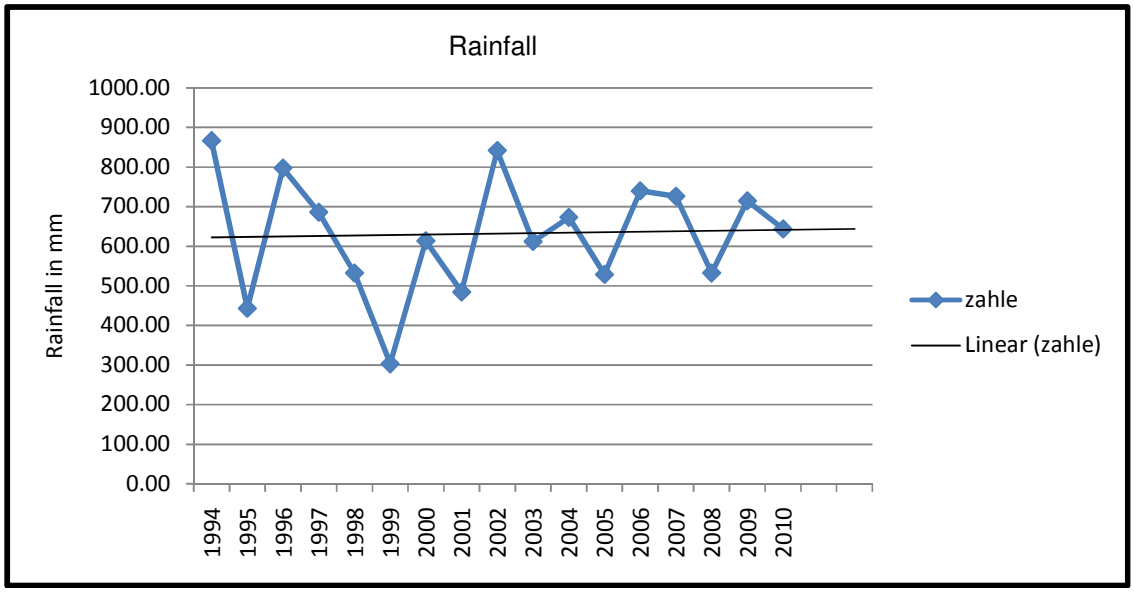

Fig. 3. Rainfall recorded in Zahle (middle Litani River Basin) station from 1994 till 2010

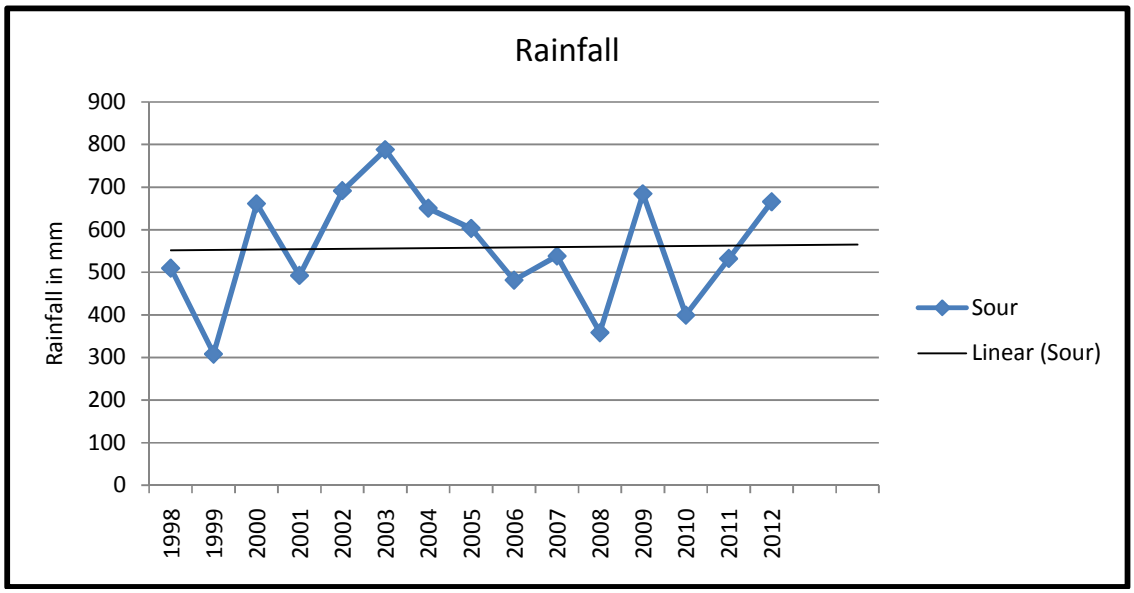

Fig. 4. Rainfall recorded in sour station sour (lower LitaniRiver Basin) from 1998 till 2011

The analysis of this 3 graphs shows that the general trend of rainfall along the last decade is shown to be increasing which is the main source of nourishing Al-Litani River either by direct runoff caught by the watershed of the river or by indirect way by feeding the underground reservoirs. So the winter system is changing but the amount of rainfall is fixed, which prevents the torrential rainfall from leaking into groundwater, as a consequence, the water completes its way, unfortunately, to poor into the sea by runoff.

The huge mass of Mount Lebanon is an effective barrier to winds or cold fronts coming from the Mediterranean. Thus, there is an increase in rain from the coast to the crests, an altitude-related phenomenon, and then decreases gradually towards the east. Because of that the rainfall in Sour, which is costal region, are more important than that one in Der-El Ahmar and Zahle, which are located in Bekaa region, into the east of the country.

Most of the rainfall which is recorded in Der El-Ahmar, Sour and Zahle station, takes place during the period extending from October to April (period responsible for the largest amount of rainfalls with a maximum in January). While dryness takes over again from May to September. Figs. 5, 6 and 7 shows the distribution of annual rainfall respectively in Der El-Ahmar, Zahle and Sour along the last decades.

4.1.2 Temperature

The temperature at the Northern and Southern inland parts, it is around 17°C, and increases at the central inland part to 22°C. In the central Mount Lebanon, mean annual temperature is around 15°C at 1000 m, and decreases to 9°C at 2000 m. In the coastal strip, the temperature ranges from 19°C to 23°C, enhancing the formation of soils corresponding to the normal climatic types of the Mediterranean regions, sometimes with subtropical tendencies [5].

4.2 Data on Water Resources

4.2.1 River's discharge

4.2.1.1 Annual river's discharge

The general trend of the annual discharge was generated, with the collected data, as seen in the following graphs in Figs. 8, 9 and 10. These values cover several decades (1952-2011), but it express a main gap where data are missing due to the Lebanese war (1976-1990) and other gaps are due to technical problems. It is clear that the general trend of annual discharge is decreasing along the period from 1952 to 2011 in Berdaouni, from 40 million cubic metre/year to 35 million cubic metre/year, which is equivalent to 12.5%. While, the general trend of annual discharge in Khrayzat is decreasing from 10 million cubic metre/year to 5.5 million cubic metre/year which is equivalent to 45%. Whereas, the river's discharge of Qasmiyeh decreases from 470 million cubic metre/year to 100 million cubic metre/year, which is equivalent to 78.72%.

4.2.1.2 Monthly river's discharge

The Litani River historical records of the monthly river's discharge were examined in the mentioned three stations. These records date back to 2000; and they are dotted with many gaps reflecting the long years of neglect and civil strife. Litani river authority has kept a steady record of Monthly River's discharge. The important discharge is in Berdaouni (upper Litani River Basin) and Qasmiyeh (lower Litani River Basin) from November to June from 2000 till 2011. For the other months, it is either extremely small or nil. Whereas, the greatest discharge is in February and March, because the snow melts, this is an important source of nourishing the Litani River.

In contrast, the overall annual river discharge is in accordance to the records of Khrayzat station, which due to the presence of this station, near to Al-Qaraoun Reservoir is the place where the water is stored.

5. CONCLUSION AND CONSIDERATIONS

The Litani River and Al-Qaraoun Reservoir are the most important freshwater source in Lebanon. This river seems to be a very important natural resource that can be helpful in different active Lebanese sectors and life quality, starting from domestic usage, agricultural, industrial water use and hydroelectric production.

After the data analysis and their trend studies of the overall rainfall in the Litani River Basin and its discharge, we note that the rainfall in coastal region are most important than that one in Bekaa region (upper and middle Litani River Basin) which is explained by the topography of Lebanon and effects of altitude on rainfall. In addition the general trend of rainfall along the last decades is shown to be increasing about to 9.36% along a period of 18 years; this means an increased volume of rainfall. Increasing in rainfall volume is the main source of nourishing Al-Litani River either by direct runoff caught by the watershed of the river or by indirect way by feeding the underground Reservoirs.

Contradictory, the general trend of the river's discharge is shown to be decreasing about to 45.40% along a period of 59 years. If this has a physical meaning, probably is an exterior factor able to affect the water balance of the Litani River. From the data collected in this study seems that the winter rainfall are changing which could prevents the torrential rainfall to leaking into groundwater, as consequence, the water completes its way by runoff, unfortunately, into the sea.

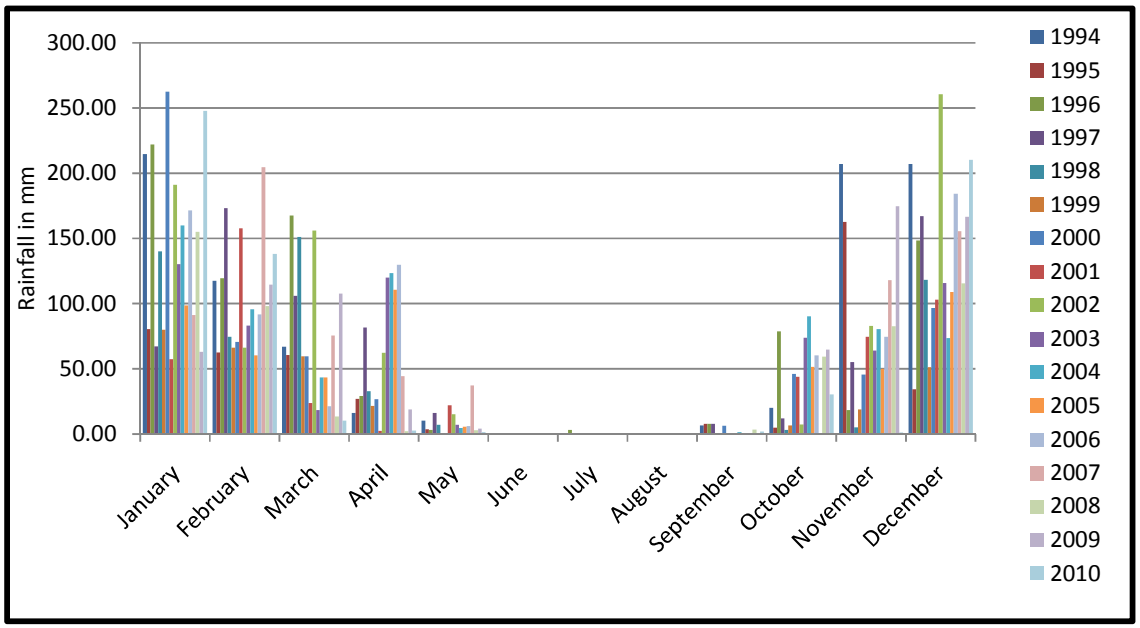

Fig. 5. Distribution of annual rainfall in Der El-Ahmar (upper Litani River Basin) from 1995 till 2011

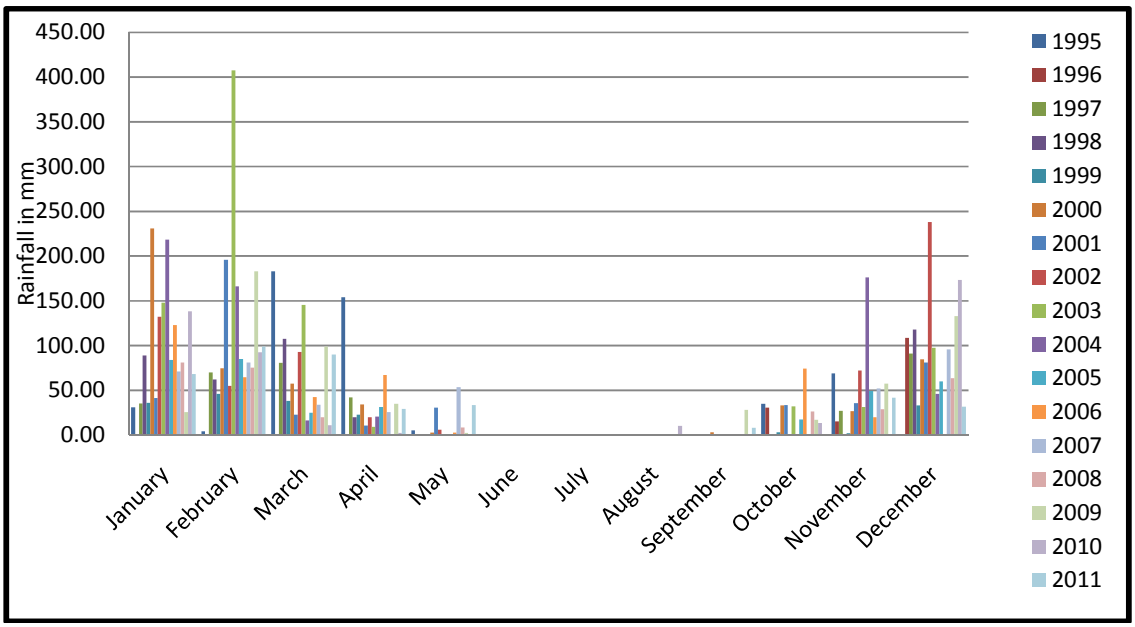

Fig. 6. Distribution of annual rainfall in Zahle (near Al-Qaraoun Reservoir) from 1994 till 2010

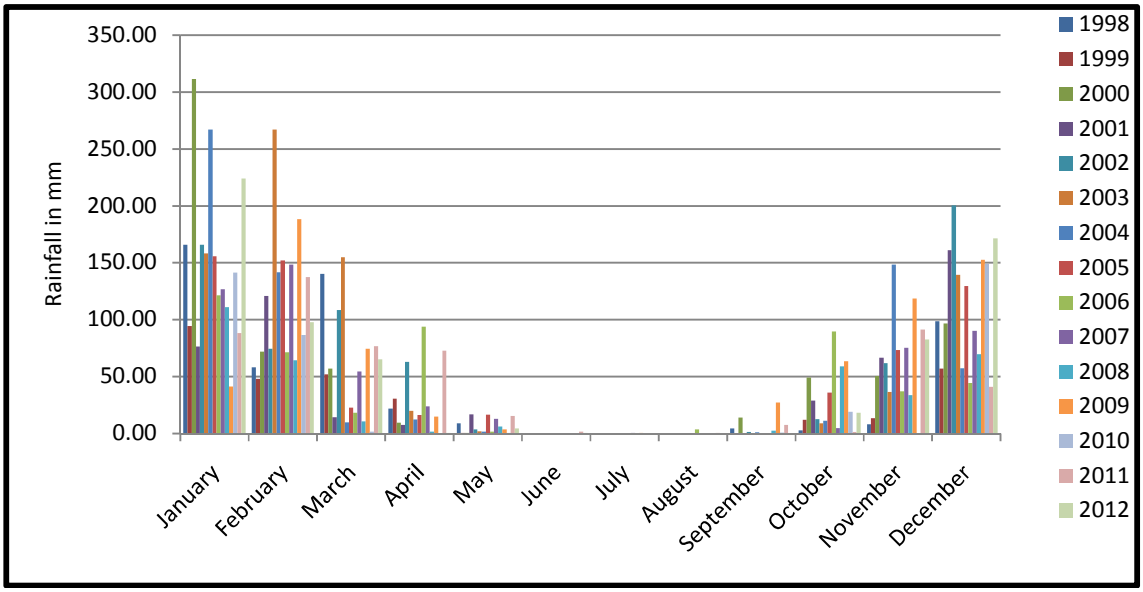

Fig. 7. Distribution of annual rainfall in sour (lower Litani River Basin) from 1998 till 2012

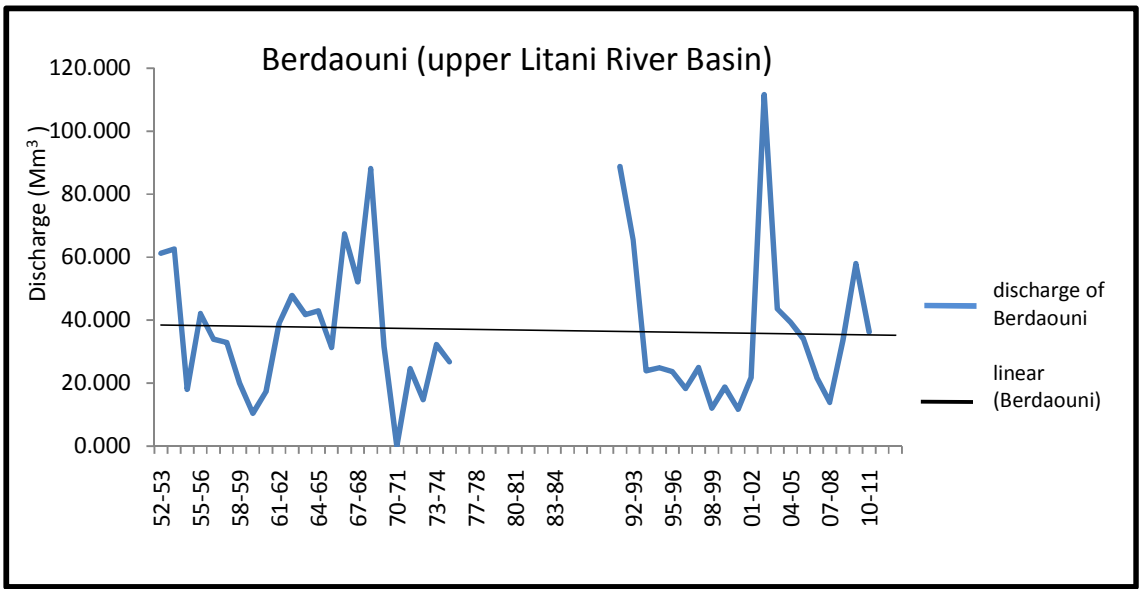

Fig. 8. Graph showing the annual discharge volume of Al-Litani River at Berdaouni station from 1952 till 2011 [11]

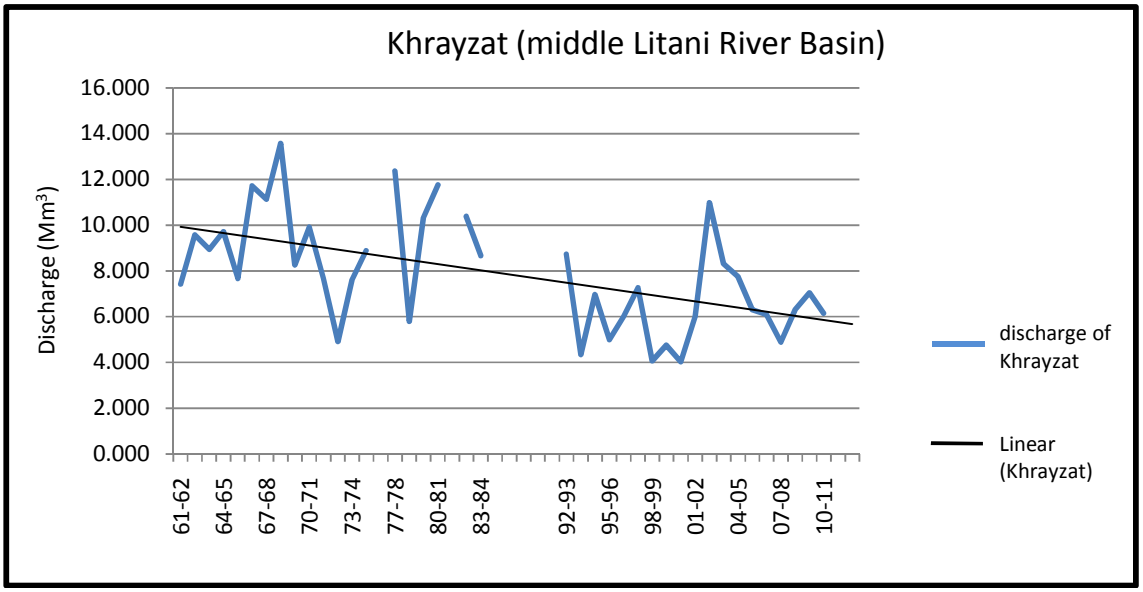

Fig. 9. Graph showing the annual discharge volume of Al-Litani River at Khrayzat station from 1961 till 2011 [11]

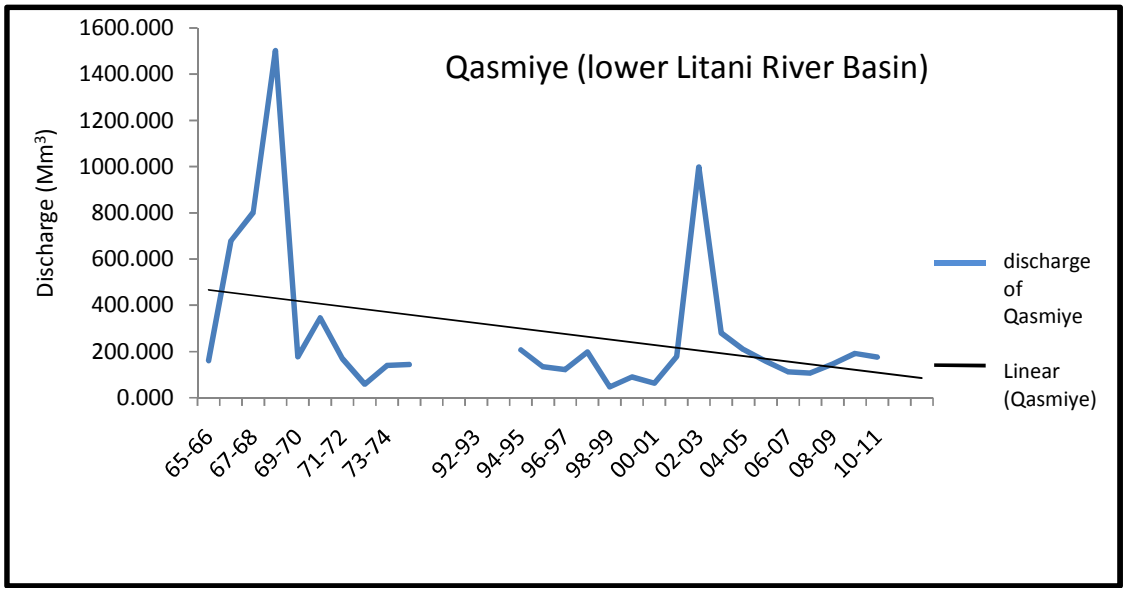

Fig. 10. Graph showing the annual discharge volume of Al-Litani River at Qasmiye station from 1965 till 2011 [11]

The environmental impacts on Litani River are directly linked to the anthropogenic activities which influence the hydrologic regime, and thus, disturbing the river waters volume and even its quality. It is a typical example of the negative human interference on water resources.

The main aspects of uncontrolled water on Litani River are:

a) The large number of villages that benefit from potable water, dragged from the Litani River and distributed by a vast network.
b) Unlicensed wells in the river's basin.
c) Irrigation systems with poor maintenance, management control and facilities, which permit the waste of a large amount of water during flood irrigation.

d) Deforestation and urbanization which causes increased run-off, so rain water reaches rivers faster and flooding becomes more frequent.
e) Excavation of snow, to be collected in site, melting and increased their demand due to human uses, such as for car washing stations, touristic resorts, swimming pools, among others.

Others factors also could be attributed to the non-management of the Litani River Basin, such as:

a) The lack of adequate and updated hydrologic and climatic information and data.
b) Lack of appropriate financial resources devoted for the water sector and projects.
c) Fragmental responsibility and weak institutional cooperation.
d) Lack of confidence between the consumers and water suppliers, especially due to the absence of legislation and governmental control.

The political conflict and war in the country retards any progress in developing water plans or strategies

The absence of legal control on water supply in Lebanon and the failure to apply the environmental laws are due to the political conflicts and social instability and this has several negative effects on the Lebanese water management, like the existence of a satisfactory control on the major natural water sources.

There are several reasons behind the mismanagement in Lebanon, like, for example, the feasible legal framework. The gaps in the existing legal framework are:

a) Most of the laws can be described as outdated, unenforceable, overlapping and inconsistent. Certain legal texts have become obsolete and require updating to current scientific and technological advances.
b) The existing laws require updating and integration within a well-articulated environmental policy framework.
c) Most standards are a copy from the international standards without any reflection on their applicability on Lebanon or relevance to the local political and socio-economic context.
d) The discrepancies between the structure and organization of ministries and public institutions described in the Lebanese legislation and those found on the field, resulting from understaffing.
e) The absence of application of the decrees from the law 444/2002, and limited financial resources to apply them.
f) Some laws awaiting ratification from neighbouring countries to implement them.
g) The overlap in the mandates of ministries and public institutions, especially with respect to planning, specifying standards and criteria, and wastewater management.
h) No sanctions are applied to the ones that fail to comply with the law.
i) The principles of the environmental law 444/2002 (prevention, precaution, polluted/payor, among others) are not applied.

In Lebanon, there is no complete solution applied for any aspect of the existing challenges for water management or treatment of water. This makes the problem of water demand and regional development, markedly out of control. Water shortage in Lebanon; therefore, is exacerbated since water supply could not reach water demand [12]. Consequently, outline the best solution of each challenge/threaten for water supply in Lebanon must be identified. The water quantity and quality of Al-Litani River are very important, especially for agriculture and domestic uses. The water demand from this river, due to the huge water supply needed in villages of the region, obliges the responsible authorities and industries to find strategies for the management of the river and to capitalize each drop of water rather than ending in the sea. For that, the following recommendations are highlighted:

a) Accelerating the creation of a High Council of Water (previously previewed by the Lebanese Government), which will be the responsible for Integrated water resources management at national level including the Litani River Basin.
b) Improving distribution pipelines and provides maintenance of the water supply networks to avoid leakages.
c) Strategies must include the register, monitoring and control of the unlicensed wells that leads to an excessive water exploitation, negatively affecting the water balance of the Litani River Basin.
d) Monitor infractions in the river after defining their borders.

e) Evaluate the designs of the river bridges and the international road designs that constitute barriers to the runoff, in order to caging the rain excess.
f) Request to the authorities, especially the municipalities, to ensure the prevention of the use of the riverbed as a place of waste disposal.
h) Building walls to consolidate the river's borders.
i) Implementation of the national decennial strategic plan for the water sector (2000-2010) created by the ministry of energy and water.
j) Application of the environmental principles in the laws, such as, the prevention principle, the pollutant/payer, among others.
k) Promulgation of decrees for managing the Litani River and reduce their water pollution.
l) Adoption of drip irrigation system rather than the flood irrigation.
m) Ensure that the process of reform of the water sector in Lebanon is undertaken in a coherent and integrated way, based on realistic objectives within the socio-economic and political contexts.
n) Construction of dams with small earth barriers and concrete storage to save the river's water since it provides the storage of the water excess in winter (which are lost in the sea without any benefit to use it during dry months of summer) where the discharge of the Litani River is the lowest, and does not stand for the real needs of water in the region.
o) Management of the water resources, involving legal and institutional tools, should be suitable for all water sectors (drinking, irrigation, sanitary, flood mitigation and reuse). The application should be made with the involvement of scientific, technical, economic and financial instruments which are properly adapted for the social and cultural Lebanese environment. The specific management of each application of water should be efficient, harmonious and systematically balanced involving a vast number of both public and private partners. The broad objectives of this water management shall cover the utilization and development of water resources in an efficient, environmentally sound, equitable and reasonable manner in order to satisfy the social water demand, water-related goods and services, as well as to safeguard the ecological functions of ecosystems. It aims providing at all users the sufficient amount of water, to guarantee the efficiency of water use by maintaining the balance between supply and demand and by sustainable development.
p) After participating in international conferences, Lebanon should ratifies international conventions and apply them.
q) Climate change problems in Lebanon needs the implementation of mitigation and adaptation measures, and we should start thinking on solutions now and act now, not later. The application of mitigation and adaptation measures should concern all Lebanon, not only the Litani River Basin.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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