LEBANON WATER PROJECT

WATER SECURITY ANALYSIS FOR REGIONAL WATER ESTABLISHMENTS (RWE) AND LITANI RIVER AUTHORITY (LRA)

FINAL WATER SECURITY ASSESSMENT

AUGUST 2019

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LEBANON WATER PROJECT

The Lebanon Water Project (LWP) is a five-year project funded by the United States Agency for International Development (USAID), with the objective of increasing access to clean, reliable and sustainable sources of drinking water for Lebanese citizens. LWP focuses on building Lebanon's capacity in managing water resources, improving the efficiency and sustainability of public water utilities, and addressing water-related challenges pertaining to the influx of Syrian refugees to Lebanon. The project aims to enhance the performance of the water sector in Lebanon, through the provision of technical and capital assistance to relevant stakeholders in the field. LWP also promotes improved water governance, as a means to preserve Lebanon's water resources on the long-term.

The project has the following objectives:

- Improve service delivery and resource management capacity of the five public water utilities;
- Improve civic engagement in water management and advance citizens' perception of the water utilities' role in providing a necessary and valuable service;
- Improve private sector involvement in water management.

In this context, the Climate Change and Environment Program at the Issam Fares Institute (IFI) for Public Policy and International Affairs at the American University of Beirut (AUB), aims to assist Lebanon Water Project's initiative to support Regional Water Establishments (RWE) and Litani River Authority (LRA) to conduct a Water Security Assessment (WSA)

INTRODUCTION

In recent years, the vital role of water in sustaining vibrant, productive and equitable societies, as well as the ecosystems they rely on has become indisputable (Mason and Callow, 2012). However, increasing pressures and growing demands have engendered cascading effects on global water resources, resulting in a global water crisis (UNDP, 2006; UN-Water, 2017).

The Global Water Partnership (GWP) defines water security as follows: '*water security, at any level from the household to the global, means that every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the natural environment is protected and enhanced. Water security is not only about having enough water. It involves all issues related to water. In simple terms, water security addresses the 'too little', 'too much', and 'too dirty' issues of water management. Water security is also about mitigating water-related risks, such as floods and droughts, addressing conflicts that arise from disputes over shared water resources, and resolving tensions among the various stakeholders who compete for a limited resource. […] It is critical to sustainably manage natural resources and it is embedded in all aspects of development – poverty reduction, food security, and health – and in sustaining economic growth in agriculture, industry, and energy generation. Water security has three key dimensions – social equity, environmental sustainability, and economic efficiency – also known as people, planet, and profit (the three Ps)*' (Van Beek and Lincklaen Arriens, 2014). The concept of water security has gained increasing recognition throughout the literature, and has emerged as a powerful concept which captures different and competing elements pertaining to water resource management, becoming a priority among various international frameworks and agendas (Mason and Callow, 2012; GWP, 2014; Van Beek and Licklaen Arriens, 2014). Currently, 80% of the global population is living in areas plagued with water security risks (Vörösmarty et al., 2010). Achieving water security has therefore become a pressing matter to overcome the global water crisis and achieve sustainable development.

The Middle East and North Africa (MENA) region is the most water scarce region in the world, with access to only 1.4% of global freshwater resources (El Nasser, 2009; Tabakovic, 2012; Zdanowski, 2014). Salient forms of pressures including but not limited to climate change, increasing drought frequencies, uncontrolled discharge of pollutants, and influx of significant number of refugees, have shaped the MENA region to become a prime area of high water security threat (Vörösmarty et al., 2010; Gürsoy and Jacques, 2014). Lebanon's water sector is faced with a plethora of challenges which have compromised its ability to provide water-related services, and placed its water resources under stress (UNDP and MoEW, 2014; Farajalla et al., 2015). The Beirut-Mt. Lebanon (BML) Region suffers from similar pervasive pressures, and the Beirut-Mt. Lebanon Water Establishment (BMLWE), has long struggled in providing adequate water services (MoE et al.., 2011). In this context, this study aims to assess the status of and threats to water security in BML in order to assist the BMLWE in improved decision-making, service provision and water resource management. The approach followed an inter-sector and integrative approach, based on the three pillars of sustainability – social, economic and environment Based on a holistic view of water challenges in BML, and previously established frameworks developed by the Asian Development Bank and the International Water Management Institute, six dimensions of water security were identified: (i) household, (ii) environment, (iii) economic, (iv) hazard and risk assessment, (v) water infrastructure and (vi) water governance. Indicators, populated with data pertaining to BML were chosen to express the nature of the chosen dimensions, and reflect preferred outcomes of improved water security. Established indicators across the literature were identified and were chosen to reflect to the greatest extent possible, the global definition of a water Sustainable Development Goal (SDG), and often relied on existing SDG indicators. As part of a first attempt to assess water security in Lebanon, this study offers unique insights and analysis of inherent water challenges in the region, and solidifies already established indicator-based approaches to quantifying water security.

OBJECTIVES OF THE STUDY

The overall objectives of this study are to:

- Conduct a historic overview of water-related risks in BML region through a trend analysis of hydro-climatic variabilities and anthropogenic stressors which impact water security, including an analysis of water supply and demand, and water usage per sector;
- Develop and measure a set of relevant indicators, based on identified key dimensions of water security which reflect challenges in the water sector, in order to assess the current status of water security in BML;
- Develop strategies and tools to improve water security in BML, based on status and projected trends. The strategy should be inclusive of capacity development and investment plans, that will enable BMLWE to properly deliver and ensure water service coverage in the BML region, sustainably and efficiently manage water resources, improve resilience to water-related risks, provide adequate, equitable and safe access to water for all, and restore ecological integrity to water-related ecosystems.

In this report the first section will lay out the baseline conditions in BML, explaining the status of water resources in the study area, the governance aspect relating to BMLWE, the geology and geomorphology of the region, overall water availability in the region, the impact of climate change and water conflict in the region. The second section will entail a trend analysis of variabilities affecting water resources in BML, such as rainfall, groundwater table, surface flows, population growth, urbanization, pollution rate, and water use and demand. The water security assessment, involving the development of water security dimensions and indicators, will be presented in the third section. The status of water security will be presented through an overall score derived from comparison to specific benchmarks. Projections of certain trends will then be evaluated in relation to water security in order to build scenarios and provide recommendations to the Beirut-Mt. Lebanon Water Establishment on the short, medium and long run.

BASELINE CONDITIONS

STUDY AREA

This project covers the area of BML, governed by the BMLWE. Various water bodies exist in this area; the majority of the BML rivers flow westward towards the Mediterranean an exception is the Hasbani River, which flows southward beyond the Lebanese borders to capture the Jordan Valley River system.

BEIRUT-MT. LEBANON WATER ESTABLISHMENT

The BMLWE governs the entire BML region including Chouf, Aaley, Baabda, Beirut, Metn, Kesrwen and Bint Cazas (see Figure 1). As established by Law 221/2000, the BMLWE provides water in its franchise area mostly for domestic and agricultural activities by mostly on springs and wells. In fact, 174 springs are located within BML, 10 of which, (i.e. Jeita, Afqa, Delbi) are major sources of water associated with large karstic caves (MoE et al., 2011). BMLWE is also investing in dams to store surface water flowing along some of the main rivers located in its premises. Three Dams, Chabrouh, Qaysamaneh and, Beqelaiaa with respective capacities of 9 Mm^3, 1 $Mm^3$and 0.4 Mm^3 are already in service (BMLWE, 2018). Three other dams are planned or being constructed in Bisri, Janneh, and Boqaata to add additional storages of 125 Mm^3, 37 Mm^3, and 6 Mm^3 (BMLWE, 2018).

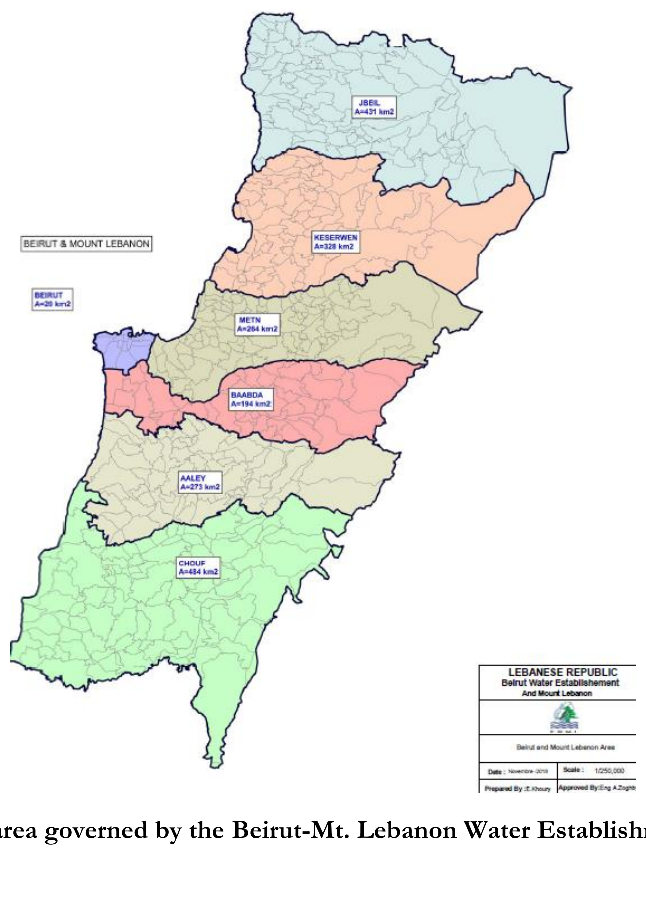

Figure 1. Map of the area governed by the Beirut-Mt. Lebanon Water Establishment (BMLWE, 2019)

WATER AVAILABILITY IN BEIRUT-MT. LEBANON

BEIRUT-MT. LEBANON GROUNDWATER BUDGET

Groundwater constitutes one of the main sources of water for the BMLWE, where the latter relies greatly on wells along with springs to supply water. The BML's groundwater budget developed for this study is based on a UNDP and MoEW (2014) study.

The groundwater budget for the BML varies between 729.1 Mm^3 for a dry year and 1389.9 Mm^3 for a wet year. The "High Central Mount Lebanon Cretaceous", the "Kesrouane Jurassic", and the "Batorun-Jounie Cretaceous" are the greatest contributors to the groundwater budget.

BEIRUT-MT. LEBANON SURFACE WATER AVAILABILITY

Five major river basins occupy the BML study area and will be considered primarily in calculating surface water availability in the region: Nahr Ibrahim, Nahr el Kalb, Nahr Beirut, Nahr el Damour, and Nahr el Awali -see Figure 2.

Nahr Beirut River Basin

Nahr Beirut once a riparian river in the city of Beirut was slowly metamorphosed along the years to a concrete canal where sewage and solid waste are continuously dumped (Frem, 2009). Based on recorded flows at the Jisr El Basha station from 1991 until 2018, the annual volumes at Nahr Beirut are calculated at 82 Mm^3.

Nahr Damour River Basin

This river is a complicated watershed comprised of several small and large tributaries. The land use surrounding the watershed includes agricultural areas, small industries, recreational activities and arable lands and forests. Based on recorded data at the seamouth gauging station, the overall average yearly flow of the Damour River from 1992 until 2018 is estimated at 175 Mm^3.

Awali River Basin

The Awali River flows at the boundary between Mount Lebanon and South Lebanon. Its upper tributary namely the Barouk River is entirely located in Mount Lebanon, in the Chouf district. Average annual flow volumes of the river are estimated at 300 Mm^3 according to Hajjar (1997) and MoE (2001). The 'Bisri dam' is planned to be constructed on this river near Jezzine, and its reservoir is expected to store around 125 Mm^3 from the river, to supply the population in the Greater Beirut area (World Bank, 2017). The impact of this dam on water availability in the South needs to be assessed in depth.

Nahr Ibrahim River Basin

Based on gauging records from 1991 until 2018, the total average flow the Ibrahim River is calculated at 310 Mm^3.

Nahr el Kalb River Basin

The average cumulative flow of Nahr el Kalb is calculated based on recording from 1991 until 2018 and amounts to 177 Mm^3.

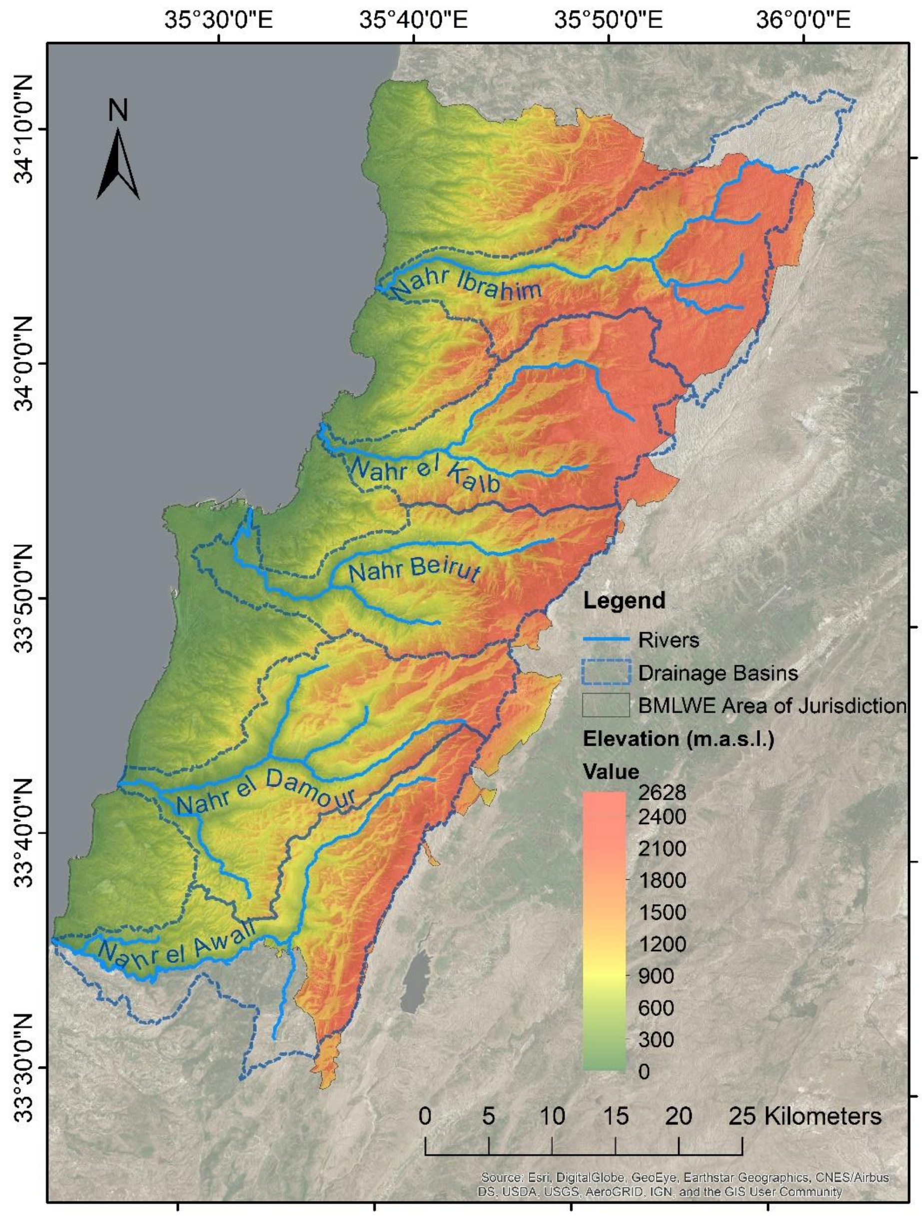

Figure 2. Beirut-Mt. Lebanon River Basins Map

TREND ANALYSIS

This section provides an overview of historic trends in BML of some parameters to better contextualize hydro-climatic and anthropogenic dynamics and their impact on water resources in the region.

HYDRO-CLIMATIC VARIABILITY

TOTAL ANNUAL RAINFALL TREND OF BEIRUT-MT. LEBANON

The aim of this analysis is to investigate temporal rainfall variations in BML. The Beirut International Airport station data along with data recorded by the AUB weather station is used to compile a rainfall time series for the period of 1874-2017 (Figure 3).

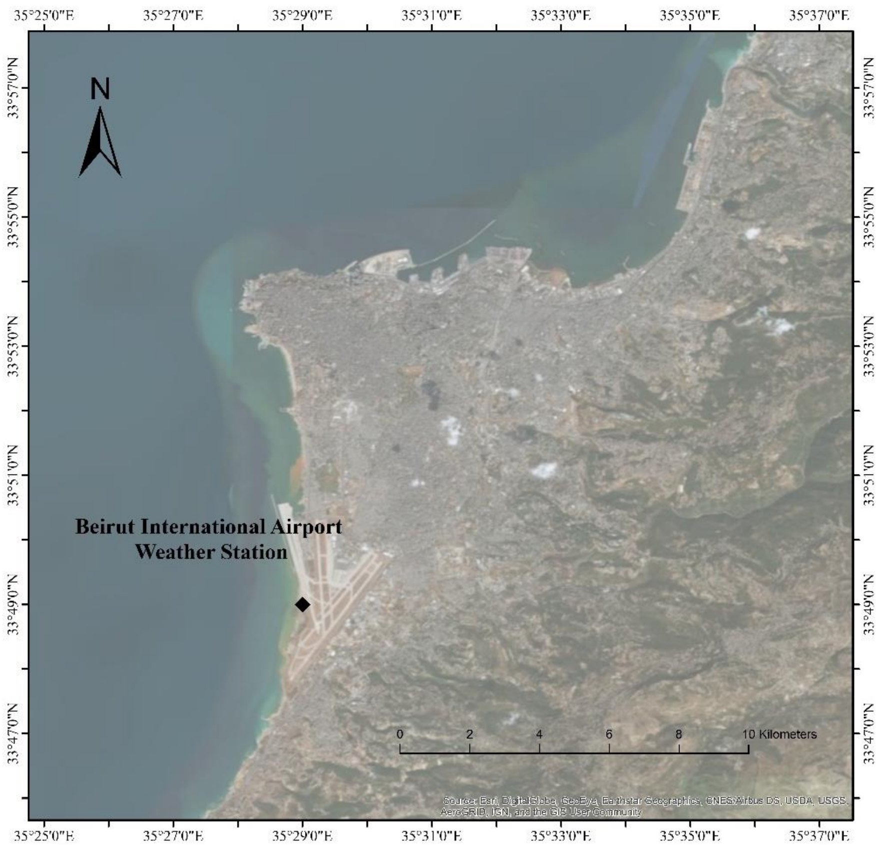

Figure 3. Geographic location of Beirut International Airport weather station used to assess rainfall variability

Normal precipitation variation was observed. A trend analysis revealed that that there is **no trend** in the precipitation of BML for the past 143 years (see Figure 4).

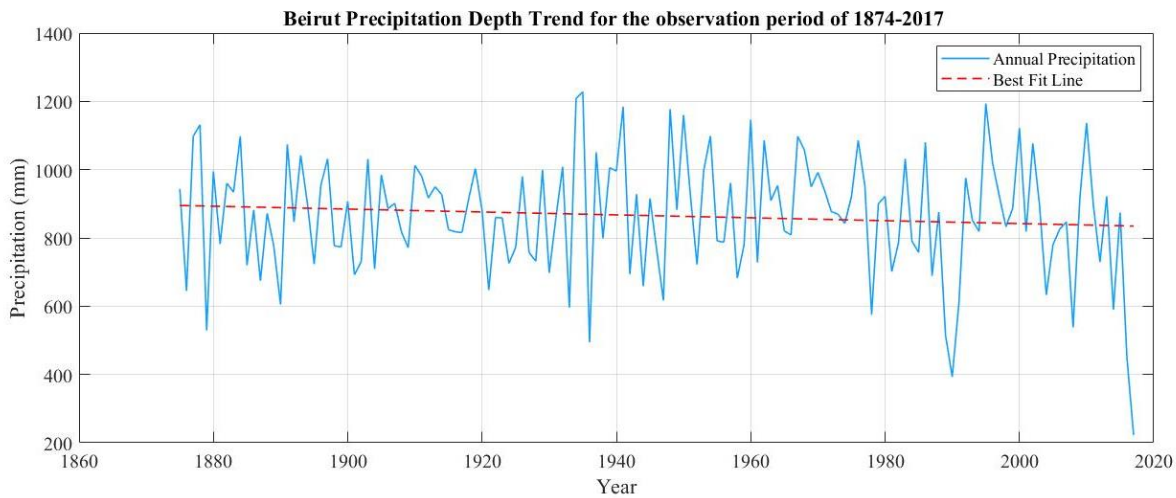

Figure 4. Total annual rainfall variation in Beirut for the observation period of 1874-2017.

SURFACE WATER LEVEL TRENDS

The main perennial rivers flowing in BML are the Awali, the Damour, the Beirut, the Kalb and the Ibrahim. These were assessed for surface flow variability.

The Awali River

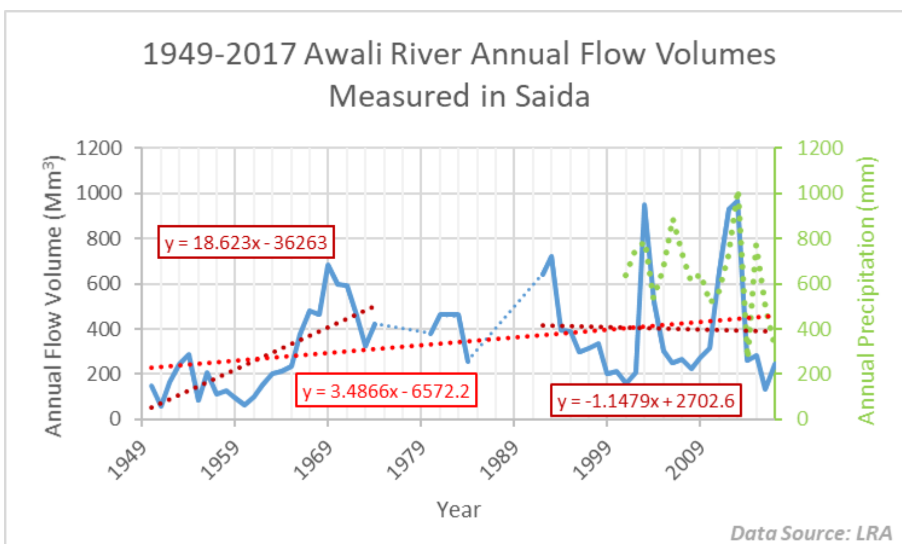

Figure 5. Awali River (Sea mouth location) hydrographs for the period of 1949-2017.

Statistical analysis reveals the presence of an increasing trend for the entire period of 1949-2017, measured at Saida. Due to gaps within the dataset between 1974 and 1991, the periods 1949-1974 and 1991-2017 were analyzed separately. Investigation for monotonic trends in the Awali River's historical flows measured at the sea mouth show an **increasing trend** during the period of 1949-1974 and **no trend** during the period of 1991-2017 (Figure 5**Error! Reference source not found.**).

Figure 6. Comparison of flows in the Awali at Saida and Marj Bisri.

The increasing trend of the 1949-1974 is further contemplated at different segments of the Awali River and the flows at the sea mouth are further analyzed for step trends. Step trend statistical analysis for the annual Awali river flows indicates an increasing step in the flow values at the sea mouth in year 1965. This abrupt increase is associated with the annual diversion of nearly 236 Mm^3 of water from the Litani to the Awali through the Markabi Tunnel (Amery, 1993).

The Damour River

Statistical trend analysis for the Damour River at three locations for the periods of 1948-1974 and 1991-2018 show **no trends** in annual flow volumes in this river for these periods separately. Yet a decrease is observed when the entire period of 1948-2018 is considered.

The Beirut River

Statistical trend analysis for the Beirut River annual flows, measured at three localities, for the periods of 1958-1973 and 1992-2018, show **no trends** in the annual flow volumes. An exception is for the Ras el Matn Bridge station when considering its readings covering the period of 1965-2018 with a gap between 1975 and 2006. Over this period a decrease is noticed.

The Kalb River

The annual flow volumes of the Kalb River are measured at three localities of which the sea-mouth is the most representative of the total volumes, the most extensive and the most complete. Statistical trend analysis for the Kalb River annual flows, measured at sea-mouth, for the periods of 1949-1972 and 1991-2018, show **no trends** in the annual flow volumes over these separate periods. However, when considering the entire period of 1949 – 2018, the test yields a decreasing trend.

The Ibrahim River

Statistical trend analysis for the Ibahim River at three locations for the periods of 1991-2018 show **no trends** in annual flow volumes in this river.

TEMPERATURE TRENDS FOR BEIRUT-MT. LEBANON

Temperature is an important parameter in assessing water availability, as it plays a factor in human and crop water demand, as well as the maintenance of snow cover in high altitude areas. This section addresses the trends in average annual minimum and maximum temperatures for the observation period of 1874-2017 from the Beirut International Airport weather station. The results are summarized in Table 1 and

Figure 7.

Table 1. Minimum and Maximum Temperature Trend for Beirut

Station	Minimum temperature Trend	Maximum Temperature Trend
Beirut	Increasing Trend	Increasing Trend

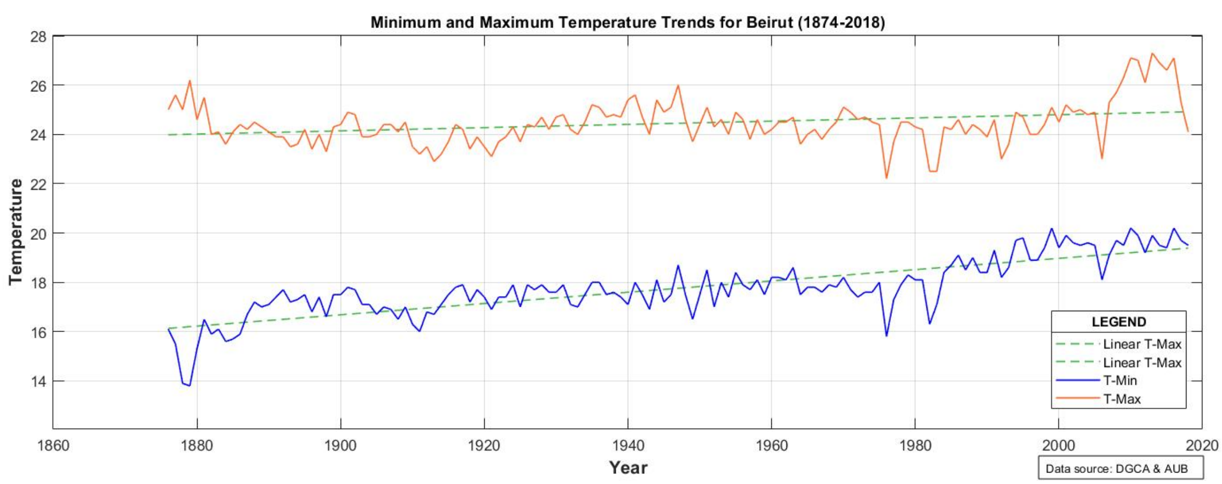

Figure 7. Minimum temperatures measured at Beirut

Statistical analysis reveals increasing trends in the minimum and maximum temperatures in Beirut. The increase is minimum temperature appears to be more pronounced. The results reveal an apparent warming of Beirut, which is probably caused by climate change in addition to anthropogenic activities.

GROUNDWATER LEVEL

A study conducted by UNDP and MoEW (2014) shows that between 1970 and 2013 groundwater levels of the coastal/near coastal areas dropped between 2m and 8m.

NORMALIZED DIFFERENCE VEGETATION INDEX

Normalized Difference Vegetation Index (NDVI) is an indicator that uses remotely sensed data to determine the presence of vegetation in an area by evaluating the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). In general, NDVI ranges from -1 to +1. For instance, negative values suggest that the observed area is likely water. On the other hand, NDVI values close to +1 shows a high possibility of the area containing dense green leaves. Urban areas typically have an NDVI value that is close to zero. Generally, NDVI is a standardized way to measure healthy vegetation (Brown et al., 2006). Therefore, higher NDVI values depict healthy vegetation while low NDVI values portray low or no vegetation. NDVI is considered a good indicator of drought by monitoring plant health affected by water stress. For this report, a time-series dataset from February 2000 to April 2018, at 250 m spatial resolution, was downloaded from the EOS NASA Land Processes Distributed Active Archive Center (NASA, 2018). The data was processed to determine mean monthly NDVI values for the study area, namely Beirut-Mt. Lebanon.

The mean monthly NDVI values for BML were found to be moderate and ranged between 0.27 and 0.50. In the drought years of 2007-2008 and 2013-2014, NDVI values were lower than the average. Thus, reduced precipitation which resulted in water shortage and resulted in the drought affected the vegetation health (Figure 8) and hence the lower NDVI value.

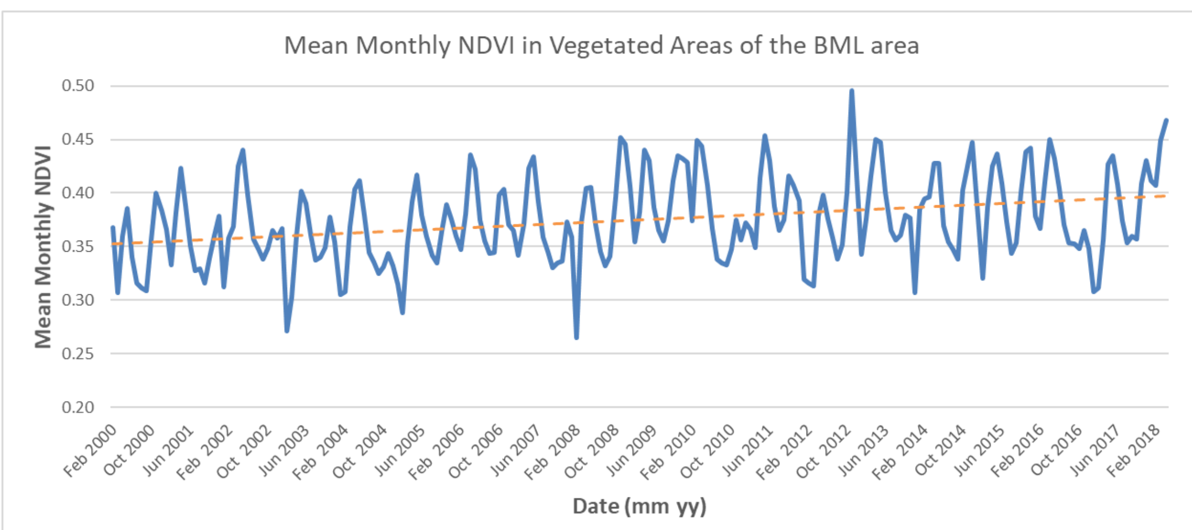

Figure 8. Mean Monthly NDVI in Vegetated Areas in BML

Statistical trend analysis for the NDVI of BML indicate that there is **no trend** over the period of 2000-2018.

ANTHROPOGENIC STRESSORS

POPULATION GROWTH

Prior to the influx of Syrian refugees from Syria in 2010, the BML's population showed a decrease between 1997 and 2007 from 1,910,896 to 1,845,840. Population started to increase between 2007 and 2010 back to 1,901,212 (**Figure 9**). As of mid-2010, a divergence in the population graph is observed that is associated with the inflow of Syrian refugees to BML. This influx has caused an approximately 15% increase in population to 2,268,014 by 2017 compared to the local population of 2017, estimated at 1,969,429 persons (MoPH, 2017).

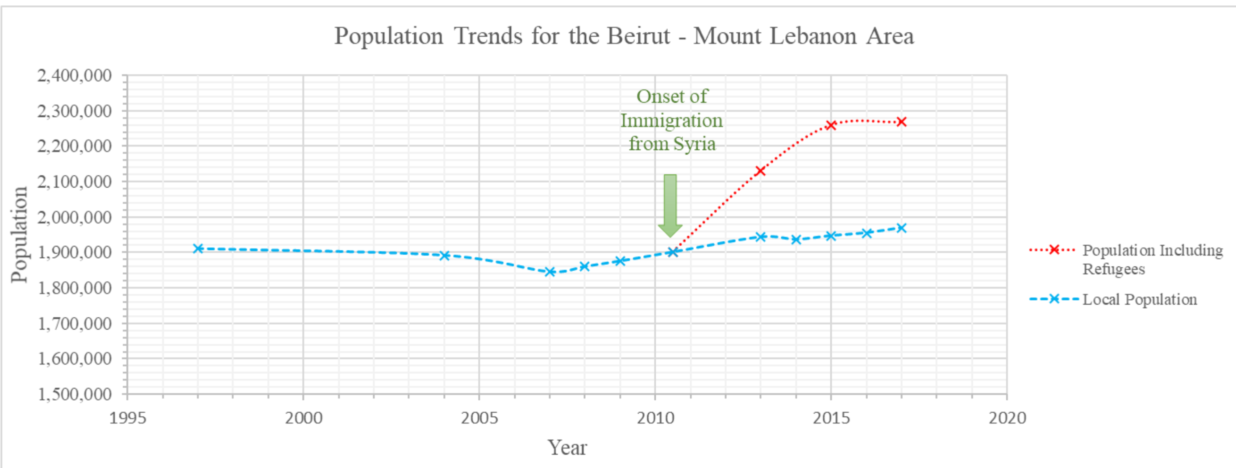

Figure 9. Beirut-Mt. Lebanon population trends between 1997 and 2017

URBAN AREAS GROWTH IN BEIRUT-MT. LEBANON

Coastal urban centers were well established before 1987 in BML. In the post 1987 period, coastal urban zones expanded eastward new built-up surfaces started appearing in the mountainous region of Mt. Lebanon. Figure 10 clearly illustrates this phenomenon. Accordingly, arable pervious lands are being gradually converted to impervious urban surfaces. This has impacts on both agriculture and water infiltration to recharge aquifers.

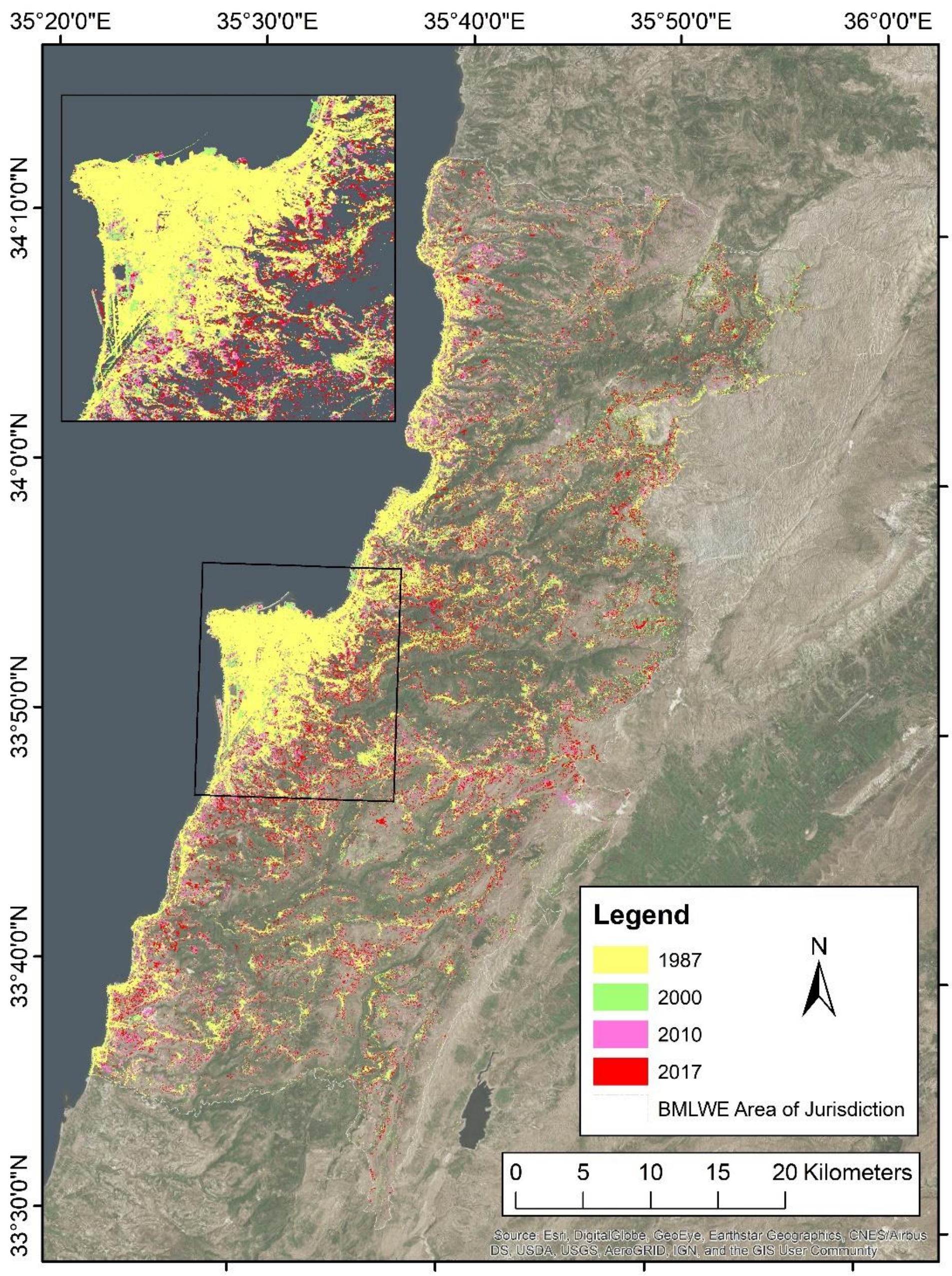

Figure 10. Built-up surfaces in BML for 1987, 2000, 2010 and 2017. The inset map zoom into Beirut.

There is a clear increasing trend of overall urban areas in BML as indicated in **Figure 11**. In 1987, urbanized surface areas accounted for 16,000 Ha, and increased to 23,000 Ha in 2000, remained at 23,000 Ha till 2010, where a new increase to 32,000 Ha is observed by 2017.

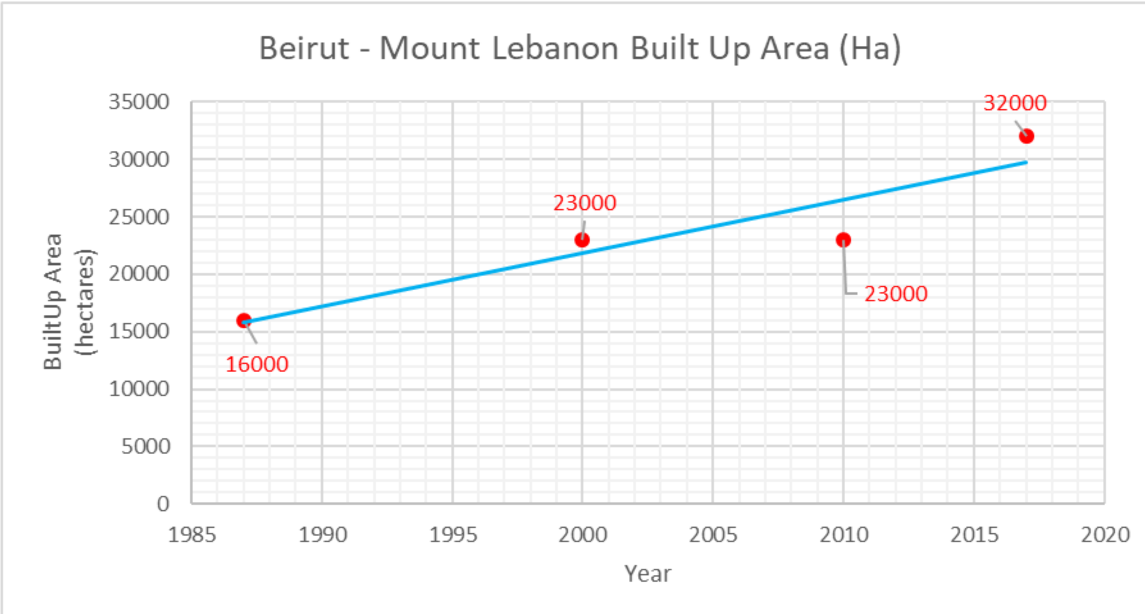

Figure 11. Increase in the surface areas of urban zones in BML between 1987 and 2017

WATER USAGE AND DEMAND PER SECTOR

Water use in BML (Table 2 and Figure 12) is predominantly dedicated to domestic purposes, representing 61% of total water use, followed by the agricultural activities with 25% and finally the industrial sector, which constitutes 14% of water use.

Table 2. Water Use per Sector in BML

DOMESTIC USE (Mm^3)	INDUSTRIAL USE (Mm^3)	IRRIGATION (Mm^3)	TOTAL (Mm^3)	Source
67.61	5.75	133.6	206.96	JICA (2003)
38	9	159	206	Comair (2006)
113	34	108	255	MoEW (2010)
72.87	**16.25**	**133.5**	**222.62**	Average

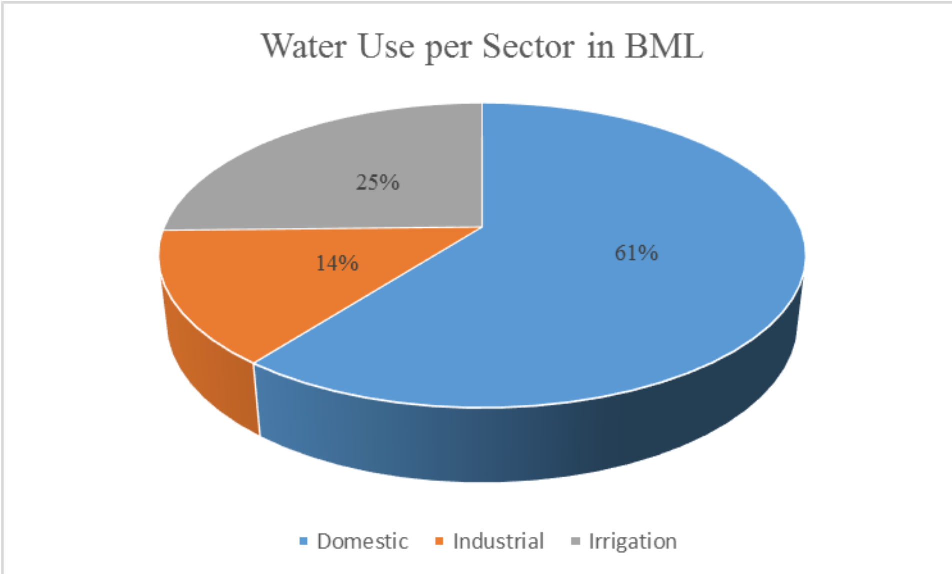

Figure 12. Water Use per Sector in BML

SYNTHESIS

The analysis of different trends pertaining to hydro-climatic variabilities and anthropogenic stressors in Beirut and Mount Lebanon revealed the following:

- Rainfall variability was assessed for the Beirut International Airport station because of its extensive data covering an observation period of 143 years from 1874 until 2017. Statistical analysis revealed **the absence of any statistically significant trends for total annual precipitation**. The unavailability of daily data precluded the analysis and assessment of any statistically significant change in number of rainy days for this station.

- Surface water flows were evaluated in major rivers in Beirut and Mount Lebanon such as the Awali, the Damour and the Beirut Rivers. Analysis reveals a disparity of results for each river presented below:

    - Statistical results confirm the presence of a statistically significant **increasing trend for the Awali River**. This sudden increase in volume which occurred around 1974 could be attributed to the construction of the Litani-Awali and Markabi tunnels at that time, which are used from trans-basin water diversion from the Litani to the Awali for hydroelectric production. Indeed 236 Mm^3 are annually diverted to the Awali through the Markabi Tunnel.

    - Statistical results reveal a **decreasing trend recorded at the Jisr el Qadi station for the period 1948-2018 over time.** This could be contributed to overexploitation of the resource or, this decrease might be due to a possible change in the location of the gauging station, however further investigation is warranted to confirm such hypotheses.

- Statistical analysis reveals that the flow of the Beirut River is **decreasing over time**, as recorded at the Ras El Metn station for the period 1965-2018**.** This decreasing flow is likely attributed to increased anthropogenic activities and over abstraction in the region.

- Temperature data was analyzed for the city of Beirut over an extensive time period of 144 years from 1874-2018. Statistical analysis reveal that **minimal and maximal temperatures are increasing in Beirut**. These trends confirm observations highlighted in section 3.4, and results might reflect increased temperature due to climate change impacts which have started to become apparent.

- **NDVI results do not reveal a statistically significant trend**, despite the presence of a visual increase over the observation period.

- Demographic analyses reveal a **high increase in population growth** in Beirut and Mount Lebanon, starting 2004 at a rate of around 15821 person/year. Yet drastic immigration activities to the area post the 2010 onset of the Syrian war **accelerated this rate and lead to around 15%** increase in the area's population compared to the expected normal growth. This has definite repercussions on the water sector and its security;

- **Sectoral use of water** in Beirut and Mount Lebanon is partially skewed towards **domestic purposes with a share of 61%,** followed by the **domestic sector with 33%** and finally the **industrial with 7%**. Tradeoffs in the water sector favor the agricultural sector, followed by the domestic sector.

Thus, the trend analysis reveals significant present and past impacts on all aspects of physical water security, making it imperative to undertake a holistic WSA, and evaluate Beirut and Mount Lebanon's current water security status. The baseline conditions highlighted in section 3 were further analyzed in the trend section, revealing significant threats on water resources. The next section provides a snapshot of water security in Beirut and Mount Lebanon through an indicator-based approach. Variables measured in this trend analysis will be further evaluated in the next section, and compared to benchmarks of water security, to be given an overall score.

WATER SECURITY ASSESSMENT

METHODOLOGY

In this study, water security was determined according to a framework derived from, in the most part, approaches developed by the ADB and IWMI and from input from an exhaustive literature review of current works on water security. The water security assessment (WSA) in this study adopts an inter-sectoral and integrative approach to water security, founded upon the three pillars of sustainability: economic, social, and environmental. Indeed, the framework aims to harness the productive potential of water, minimize its damaging impacts while ensuring social equity through a holistic view of water management challenges (Grey and Sadoff, 2007). The resulting framework is an amalgam of six key dimensions each composed of sets of indicators as represented in Figure 13.

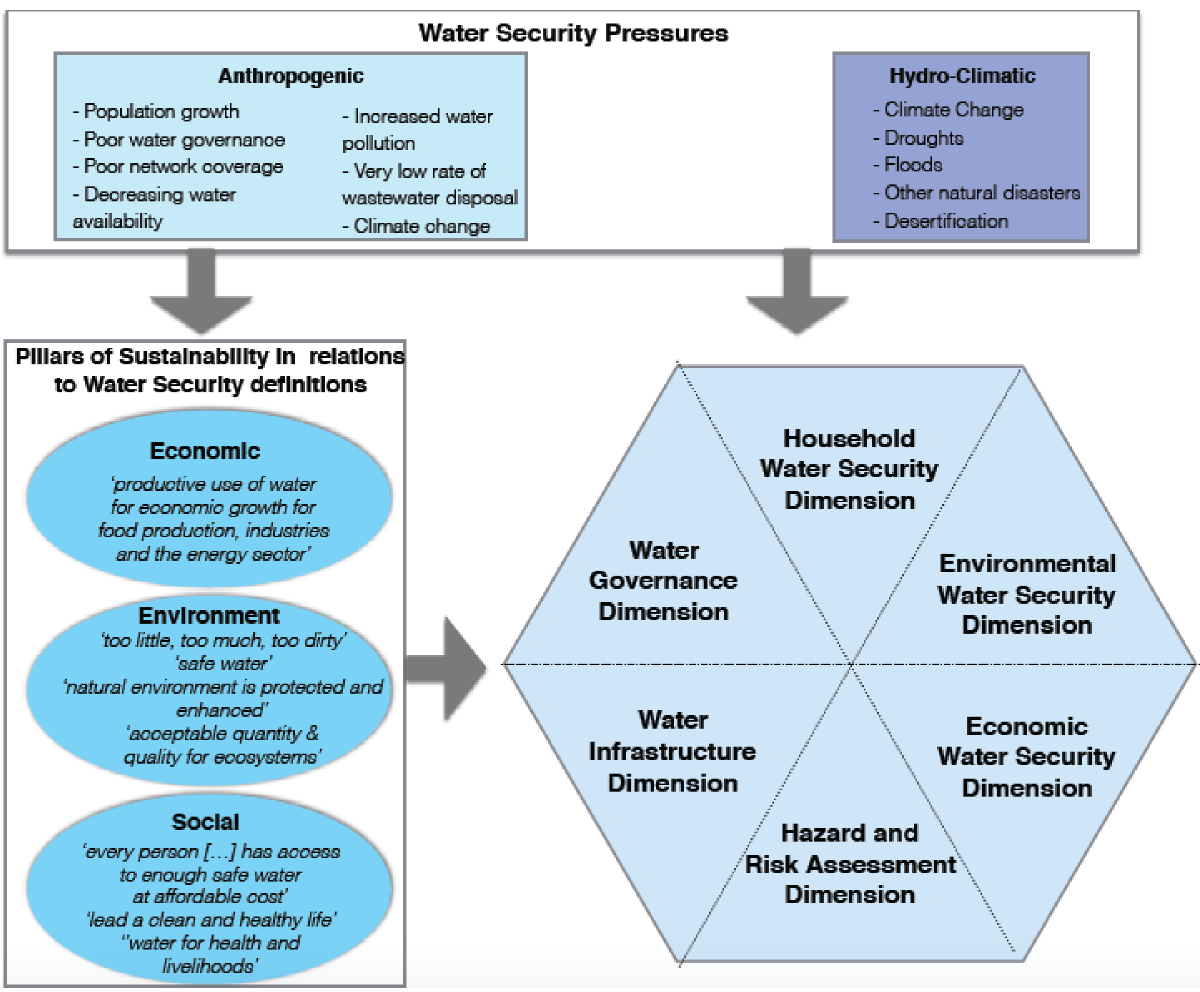

Figure 13. Conceptual Framework of the Water Security Assessment in BML

An analysis of pertinent issues in BML was conducted based on available data, complemented with an analysis guided by water security definitions as related to the pillars of sustainability. A more detailed description of identified dimensions of water security is presented in the following sections.

1. **Household Water Security:** This dimension aims to evaluate the access to water in BML, in terms of water availability, affordability and level of access in households. It also tackles the sanitation and safety aspect of water, by evaluating the community's access to sanitation, as well as the incidence of water borne diseases in the region, which stem from the exposure to contaminated water resources. Indeed, an optimal state of water security means that every individual has access to safe drinking water and improved sanitation, at an affordable cost, while being protected from water-related diseases.

2. **Environmental Water Security:** This dimension seeks to assess the status of and risks to water-related ecosystems, in terms of quality and quantity, focusing primarily on major rivers, peripheral springs, as well as public wells within the BMLWE jurisdiction. This dimension also evaluates hydro-climatic and anthropogenic factors, which affect water availability and quality, primarily rainfall variability and pollution caused by untreated wastewater in Beirut-Mt. Lebanon. The rationale for this dimension is that in a water secure world, the intrinsic value of water and water-related ecosystems is respected, and environmental protection is enhanced.

3. **Economic Water Security:** This dimension assesses the productive use of water resources to sustain economic growth in the agricultural, industrial and energy sector. The rationale is that water security is achieved in part by contributing to food and energy security in a cost-effective and cost-efficient fashion. In turn, the enhanced efficiency and productivity of water use in these respective sectors will ensure that the economic potentials of these sectors are achieved with minimal pressure on water resources.

4. **Hazard and Risk Assessment:** This dimension evaluates prominent risks emanating from droughts and floods, and the impacts they might have on the BMLWE, the economic sectors, and the community in the BML. This dimension accordingly assesses these risks by evaluating hazards, vulnerabilities, and coping capacities. Indeed, water security means that every individual is protected from water-related disasters, including but not limited to the ones mentioned.

5. **Water Infrastructure:** This dimension seeks to assess the current status of water-related infrastructure in BML in terms of network coverage, storage capacity, and network conditions, in terms of aging and losses. A well-designed and functioning water system ensures a complete and efficient coverage of water-services, warranting equal access to water and sanitation and enabling BMLWE to have an appropriate infrastructure to meet all water-related needs, thus enhancing overall water security.

6. **Water Governance**: The ability of a government or institution to properly manage its interaction with water resources can be a defining factor in achieving water security. From over extraction to equitable access, the governance of water resources has a direct effect on the ecosystem and society. A country rich in water resources may still be far from water security, it is the quality of water governance that will determine the level in which communities can utilize as well as protect this valuable resource. This dimension also includes the financial sustainability of water supply services given the importance of this aspect in making available water resources to the above-mentioned productive sectors.

Assessment of each dimension along with their associated indicators, sub-indicators and scores (1 being very poor and 5 being optimal) is presented in the following sections.

HOUSEHOLD WATER SECURITY ANALYSIS

INDICATOR CONCEPTUAL FRAMEWORK

Two main indices make up this dimension: Access to Water and Safe Water and Sanitation. These entail sub-indicators which reflect key elements of water security, such as piped water supply to households, hours of service, water availability and affordability as well as access to improved sanitation and incidence of water borne diseases. Figure 14 details the conceptual framework for the indices and their sub-indicators and their role in determining the dimension's over all water security score.

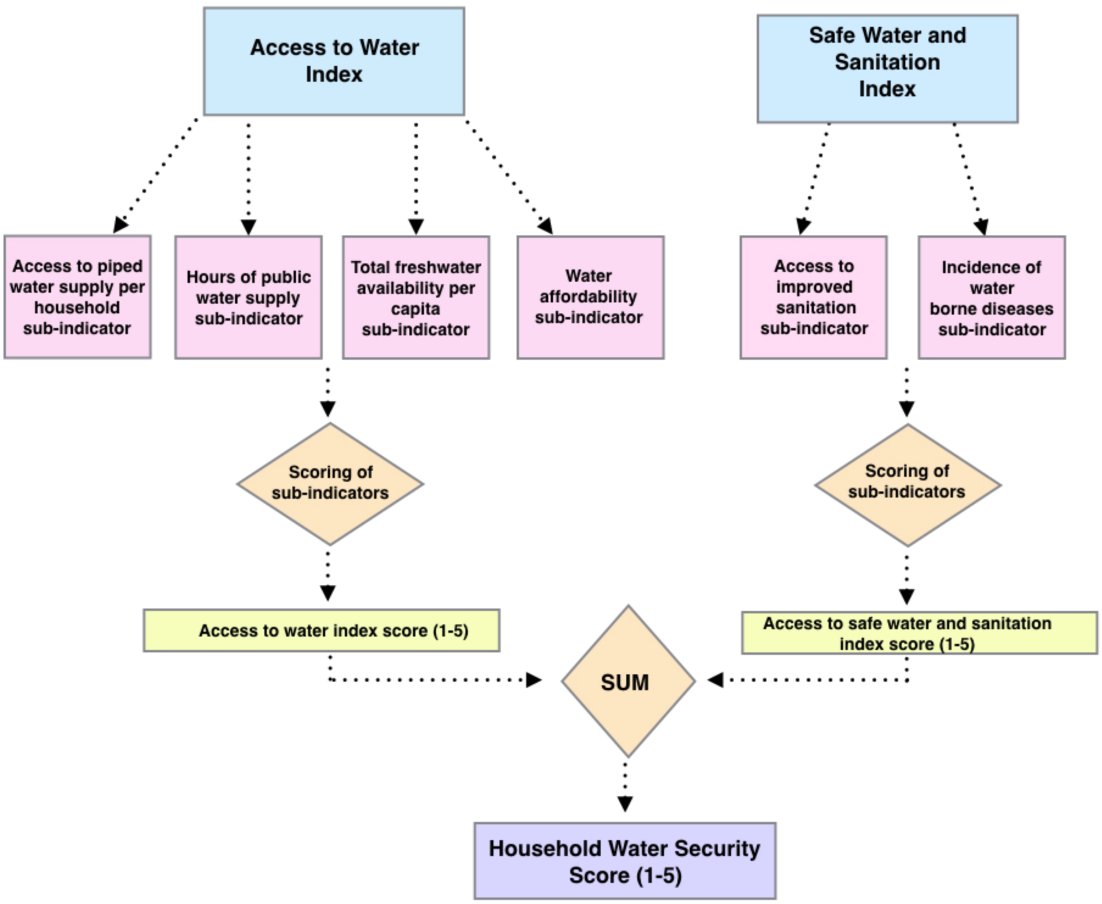

Figure 14. Conceptual Framework for the Household Water Security Dimension

DIMENSION SCORE

Sub-Indicator	Method of Calculation	Source for Data and Calculations	Value Calculated for BML	Score (1 low to 5 high)
Access to piped water supply per household	Percentage household connected to the water network	BMLWE (2018)	70.1%	3
Hours of public water supply	Average number of hours for summer and winter	MoE et al., 2011	6.5	1
Total renewable water resources per capita (m^3/capita/year)	Total availability divided by population in BML	UNDP & MoEW (2014); Hajjar (1997); MoE (2001); LRA (2018)	953	2
Water Affordability	Expenditure on water service as a percentage of average income	Household survey in Beirut and Mount Lebanon	4.2%	3
Access to Water Index		**2.25**		
Access to improved and shared sanitation	Percentage of households connected to the sewage network	World Bank and CDR (2018)	74%	3
Water borne diseases	Annual incidence of water borne diseases per 100,000 inhabitants	MoPH (2018)	12 per 100,000	4
Safe Water and Sanitation Index		**3.5**		
Household Water Security Dimension		**2.8**		

Household Water Security scored 2.8/5. Access to piped water in Beirut and Mount Lebanon is generally average, with 70.1% of households connected to the network. However, supply is very highly intermittent, with an average of 6.5 hours of water supply and BML is in a general state of water scarcity, revealing a poor score for the access to water index, despite the fair score for water affordability. The safe water and sanitation index receives an average score, with a fair coverage for the wastewater network and a generally good score for water borne diseases. Overall the dimension receives a poor score despite being close to average.

ENVIRONMENT WATER SECURITY ANALYSIS

INDICATOR CONCEPTUAL FRAMEWORK

This dimension is assessed through four indices: rainfall variability, groundwater health, surface water health and percentage of wastewater safely treated. Groundwater and surface health indices are each further described by sub-indicators related to stress and quality for the former, and flow and quality for the latter. Figure 15 layouts the framework leading to the overall score of the dimension.

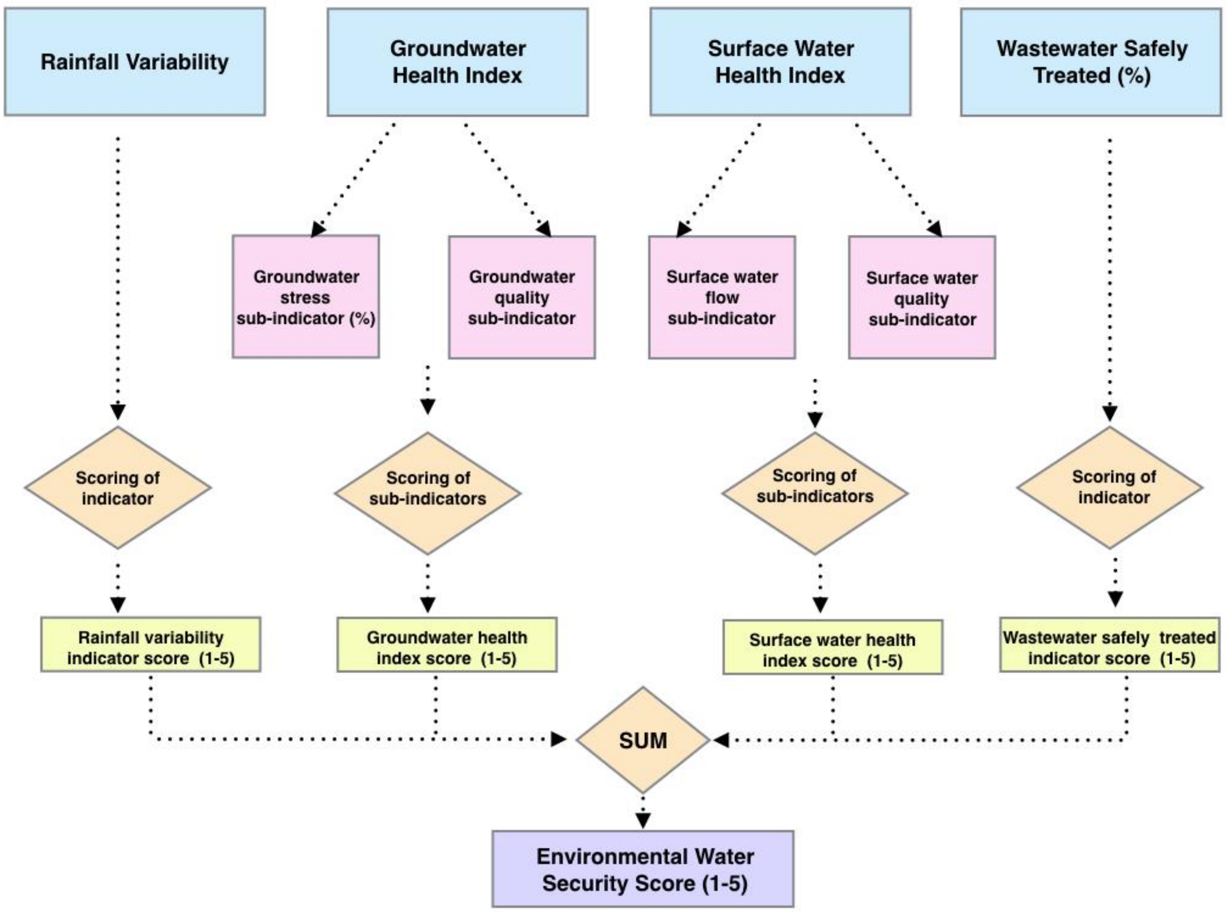

Figure 15. Conceptual Framework for the Environmental Water Security Dimension

DIMENSION SCORE

Sub-Indicator	Method of Calculation	Source for Data and Calculations	Value Calculated for BML	Score (1 low to 5 high)
Groundwater Stress	Percentage withdrawal over abstraction	UNDP and MoEW (2014)	20% (Dry Year) 30% (Wet Year)	3
Groundwater Quality	Nitrate and Chloride Concentrations (mg/L)	Korfali and Jurdi (2007)	Average Nitrate: 3.16 Average Chloride: 937	3
Groundwater Health Index		**3**		
River Flow	Percentage monthly variation in comparison to monthly natural flows	LRA (2019)	Nahr El Kaleb: 74.5% Nahr Ibrahim: 27%	3
Surface Water Quality	Vr x Wi	LRA (2019)	74	3
Surface Water Health Index		**3**		
Rainfall Variability Index	Standard Deviation/Mean	DGCA and AUB	20%	**5**
Percentage of wastewater safely treated Index	Treatment Capacity/Total Wastewater Generated	UN-ESCWA (2012); USAID (2009); Kenny, (2015); Saliba (2018); Farhat (2018)	2.22%	**1**
Environmental Water Security Dimension		**3**		

Environmental Water Security score: 3/5. This dimension receives an average score, with the main areas of concern being wastewater, with only 2% of wastewater in BML being safely treated. Groundwater health appears to be average; while nitrate levels appear to be low, chloride concentrations are extremely high indicating saltwater intrusion and subsequent contamination of the groundwater nappe. Rainfall variation appears to be stable in the region and does not constitute a threat to water security or surface water flows. Thus disturbances in environmental flows of Nahr El Kaleb appears to be associated with anthropogenic activities.

ECONOMIC WATER SECURITY ANALYSIS

INDICATOR CONCEPTUAL FRAMEWORK

Three main indices which reflect economic sectors have been used to asses this dimension: agriculture, industry and energy. In general, sub-indicators related to productivity have been used in the assessment. Food security and arable land are two sub-indicators that are used in the agriculture index while hydropower capacity is an additional sub-indicator for the energy index. Figure 16 shows the flow between indices and sub-indicators in determining the dimension's water security score.

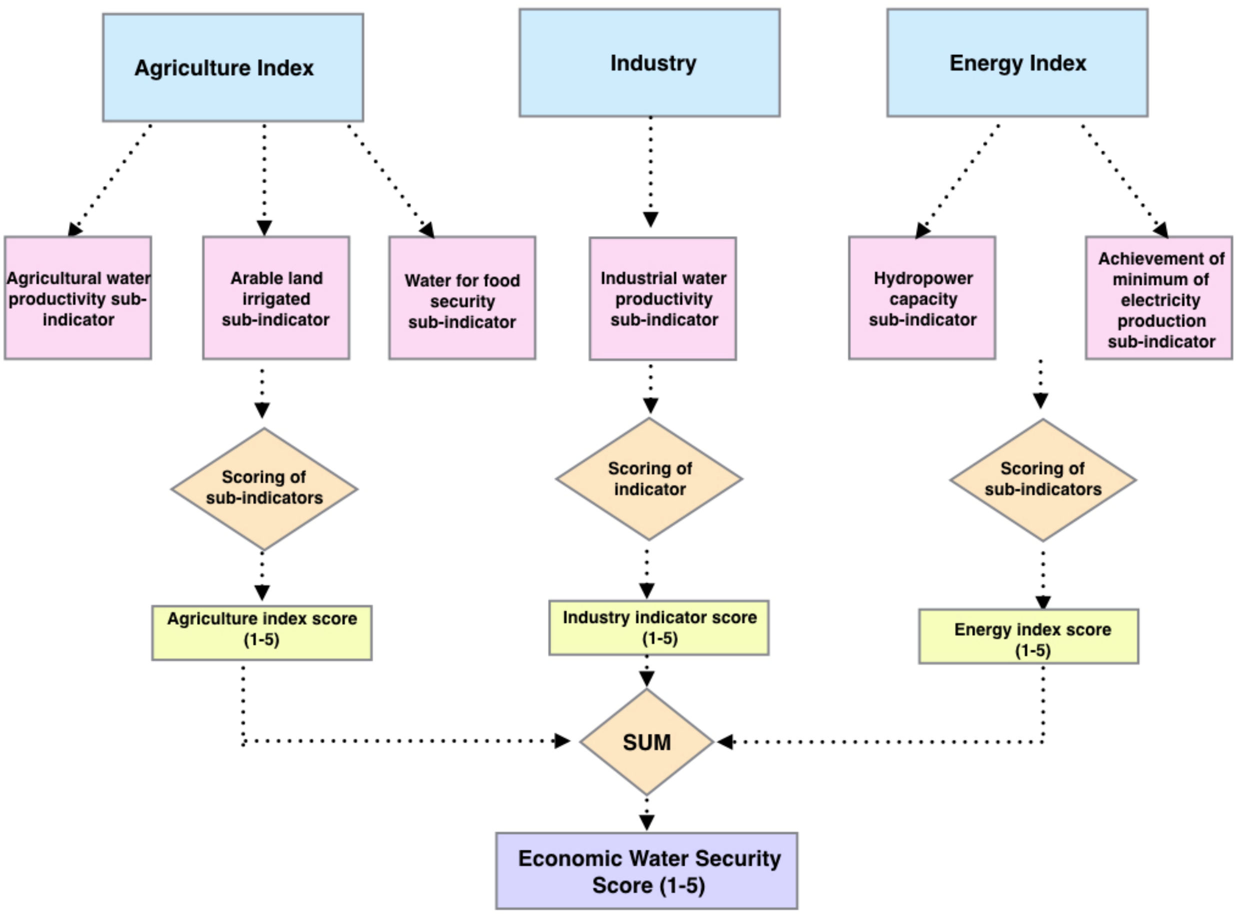

Figure 16. Conceptual Framework for the Economic Water Security Dimension

DIMENSION SCORE

Sub-Indicator	Method of Calculation	Source for Data and Calculations	Value Calculated for BML	Score (1 low to 5 high)
Agricultural water productivity	(Land Cultivated in BML/Total Land Cultivated in Lebanon)*GDP*share of agriculture in GDP/(Cubic Kilometers of Water Withdrawn for Agricultural Purposes in BML)	FAO and Ministry of Agriculture Census (2010) + CAS (2015) + MoEW National Water Sector Strategy (2010)*	390 $million/km3	4
Arable land irrigated	[Arable Land Irrigated in BML/Total Arable Land in BML]*100	FAO and Ministry of Agriculture Census 2010	34%	3
Water for food security	Number derived from the 2010 Agricultural census: the % of irrigated land dedicated to food security crop, e.g. cereals, pulses, tubers, roots and olives	FAO and Ministry of Agriculture, Agricultural Census 2010	26.72%	2
Agriculture Index		**3**		
Industrial water productivity Index	**(Industrial GDP*growth estimation for the period 2007-2010)/(Cubic Kilometers of Water Withdrawn for Industrial Purposes in BML)**	**MoI (2007) and MoEW (2010)***	**97,293.24 $million/km^3**	**5**
Hydropower capacity	Capacity factor	MoEW (2018), Sogreah/Artelia Study (2014)*MoEW (2018)/(World Bank, 2016) + (CAS, 2008)	15%	1
Achievement of a minimum level for "per capita production of energy"	(Installed power generation capacity in BML)/ Population of BML – (Installed power generation capacity in Lebanon)/Population of Lebanon	EDL website (http://www.edl.gov.lb/page.php?pid=37), World Bank(2016) and OCHA (2014)	12%	5
Energy Index		**3**		
Economic Water Security Dimension		**3.7**		

Economic Water Security score: 3.7/5. This dimension received an average score, nearing 'good'. The overall verdict is that water use in productive sectors, most notably industry, has been efficient from an economic perspective, a result no doubt driven by the intensive industrial activity concentrated in the region. As for agriculture production, the BML has lowest share in the total agricultural land and, is, therefore, more vulnerable to food shocks. In terms of energy, the increase rate of urbanization will deeply impact energy needs, the BML has still untapped potential of hydroelectricity that isn't fully utilized. It is important to note that this potential even if fully exploited will meet around 3% of total energy supply.

HAZARD AND RISK ASSESSMENT

INDICATOR CONCEPTUAL FRAMEWORK

Two indices are used in the assessment of this dimension, the drought and flood indices. They measure the adverse risks to water-related disasters, by measuring the hazard emanating from flood and droughts, and the vulnerability and coping capacity of the BMLWE, the economic sectors and the community in BML. Figure 17 shows these relationships.

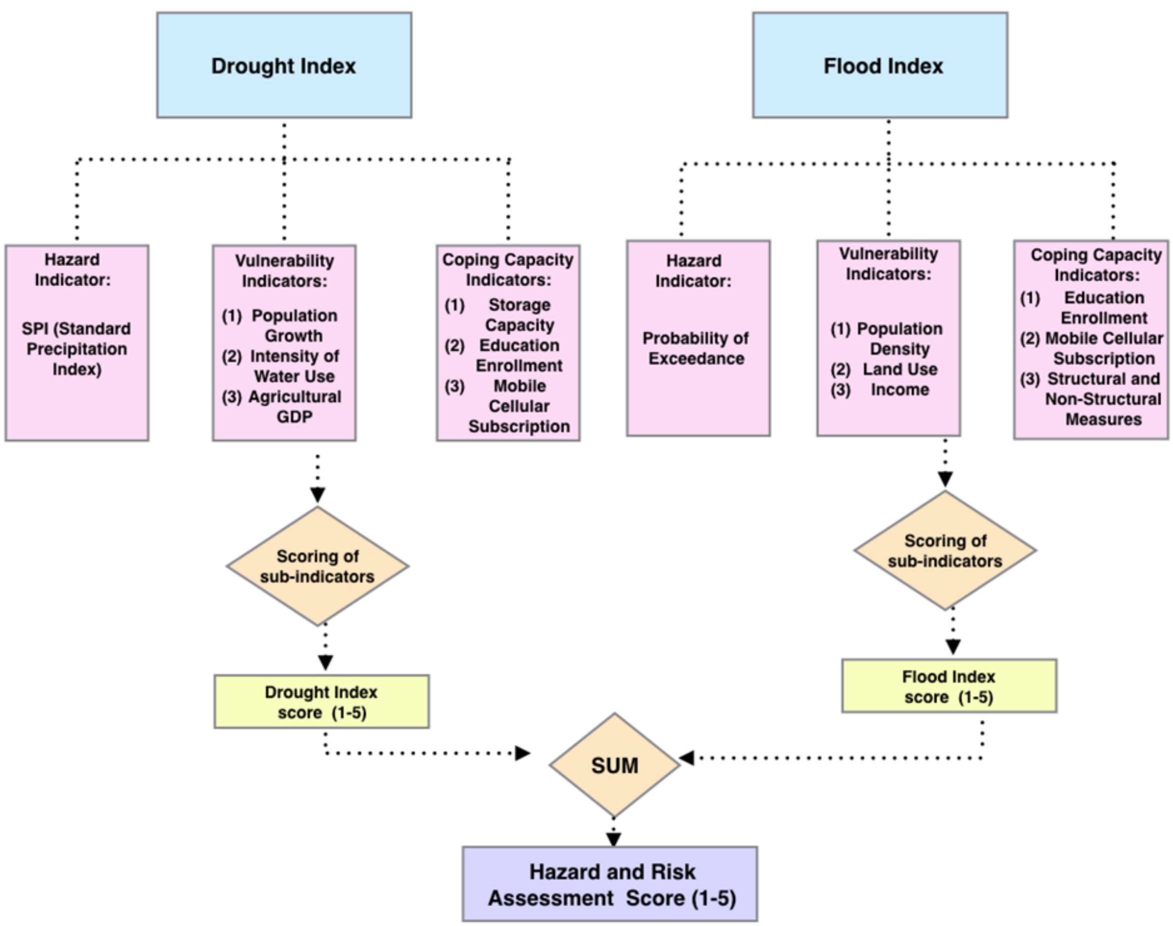

Figure 17. Conceptual Framework for the Hazard and Risk Assessment Dimension

DIMENSION SCORE

Sub-Indicator	Method of Calculation	Source for Data and Calculations	Value Calculated for BML	Score
Standardized Precipitation Index	SPI Tool	Calculated using SPI program by inputting available precipitation data) from Beirut weather station	-4.17	**0.71**
Population Growth	$r = ln\left(\frac{P_n}{P_0}\right) .n^{-1}$	CAS, 1998 CAS, 2004 CAS, 2007 NWSS, 2010 MoPH, 2013 MoPH, 2014 MoPH, 2015 MoPH, 2016 MoPH, 2017	2.6%	1.67
Intensity of Water Use	Total Water Use/Total Renewable Water Resources	MoPH (2017), MoEW (2010a) and FAO and MoA (2010)	0.13	4
Percentage Agricultural Irrigated Land	(Irrigated arable land in BML/total arable land in BML)	FAO and MoA (2010) + CAS (2015)	68%	1
Employment in Agriculture	Share of employment in agriculture in comparison to total employment in BML	CAS (2004)	1.8%	5
Agriculture Vulnerability		3		
Vulnerability to Droughts Score		**2.9**		
Storage Capacity	Per Capita Effective Water Storage (l/cap)= (Total Effective Storage Capacity)/(Population (w/o refugees))	BMLWE (2018) & MoPH (2017)	26.5 days 30.5 days	1.25
Primary Education Attainment	Number of individuals reaching and/or	CAS (2004)	85.15%	2.5

Sub-Indicator	Method of Calculation	Source for Data and Calculations	Value Calculated for BML	Score
	completing primary education			
Mobile cellular subscription per 100 people	Mobile cellular subscription for Lebanon	World Bank (2015)	92%	3.75
Coping Capacity Index		**2.5**		
Drought Index		**2**		
Flood hazard indicator	Probability of Exceedance	LRA (2019)	35.4%	**2**
Population Density in flood areas (person/Km²)	Population in flood areas= (Population in flood zone * areas of flood zone)	Landscan (2017)	3,757	1.67
Land Use	Ratio of built up areas to total area of BML	Calculated based on satellite imagery interpretation	16.2%	4
Income in BML	Percentage of the Population living below the poverty line	Survey	4.8%	4
Vulnerability to Floods Index		**3.2**		
Primary Education Attainment	Number of individuals reaching and/or completing primary education	CAS (2004)	85.15%	2.5
Mobile cellular subscription per 100 people	Mobile cellular subscription for Lebanon	World Bank (2015)	92%	3.75
Structural and non-structural measures	Absence or Presence	SOER, 2010	Absence	1
Flood coping capacity score		**2.42**		
Flood Index Score		**2.54**		
Hazard and Risk Assessment Dimension Score		**2.27**		

Hazard and Risk Assessment Dimension scored a **2.27/5.** Risks from drought and flood hazards appear to be high, with this dimension receiving the poorest score, signifying a high risk with regards to water security. Main concerns appear to be extremely dry conditions, population growth and density, low storage capacity, as well as a lack of structural and non-structural measures for flood defense. Coping capacity in the region are poor as well, precluding communities and the establishment from having a timely and effective response.

WATER INFRASTRUCTURE ANALYSIS

INDICATORS CONCEPTUAL FRAMEWORK

Four indices describe this dimension, all of which are related to the water storage, and conveyance and distribution networks. Figure 18 depicts the relationship between indices and sub-indicators in determining the dimension's water security score.

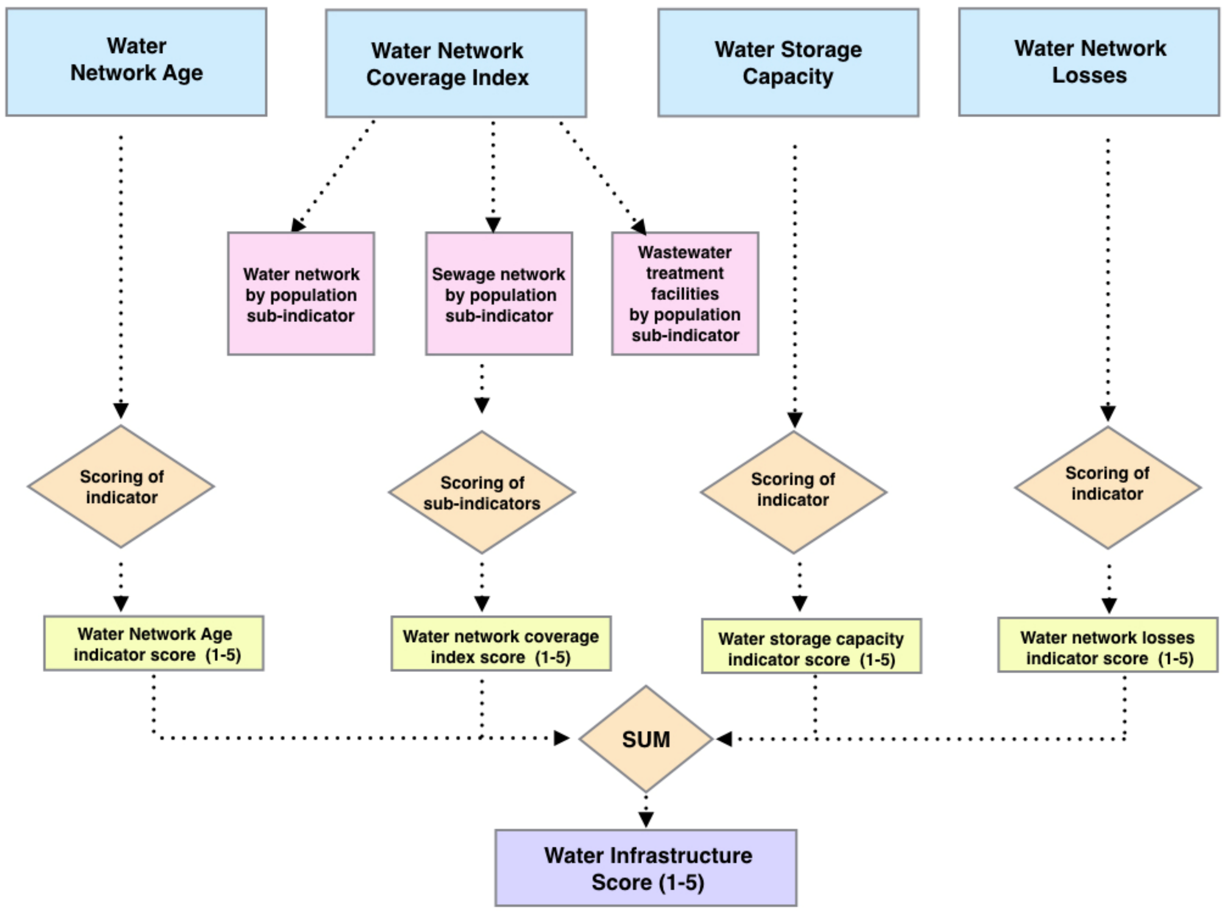

Figure 18. Conceptual Framework for the Water Infrastructure Dimension

DIMENSION SCORE

Sub-Indicator	Method of Calculation	Source for Data and Calculations	Value Calculated for BML	Score
Water Supply Coverage by Population	Provided by BMLWE (2018)	Zoghby (2019) Personal Communication	100%	5
Sewage Network Coverage by Population	Provided in source	World Bank & CDR (2018)	74%	3
Wastewater Treatment Coverage by Population	Total Serviceable Population/Total Population	FAO (2016) and MoPH (2017)	19%	1
Water Network Coverage Index				3
Non-Revenue/Unaccounted For Water due to losses (Index)	Provided in source	Zoghby (2019)	35%	2
Water Network Storage Capacity (Index)	$Per\ Capita\ Effective\ Water\ Storage\ (\frac{l}{cap}) = \frac{Total\ Effective\ Storage\ Capacity}{Population\ (\frac{w}{o}refugees)}$	BMLWE (2018)	318 for population including refugees and 366 for local population only	5
Age of the Water Network Infrastructure (Index)	Average Median Age of Water Networks	BMLWE (2018)	39 years	3
Water Infrastructure Dimension				**3.25**

Water Infrastructure score 3.25/5. The assessment reveals an average condition and score for the water infrastructure in BML. Although water network coverage per population received a good score, sewage coverage remains average and the wastewater treatment plant coverage is very poor. Networks in the region are relatively old, manifested in the high levels of non-revenue water, prompting the need for continuous monitoring and maintenance of the networks.

WATER GOVERNANCE ANALYSIS

INDICATOR CONCEPTUAL FRAMEWORK

Assessment of governance using quantitatively measurable indicators was found to be extremely difficult, given the nature of this dimension which is qualitative. Nevertheless, three indices were determined to be adequate to assess governance through an indicator-based approach. Figure 19 details the indices, their sub-indicators, and their relations.

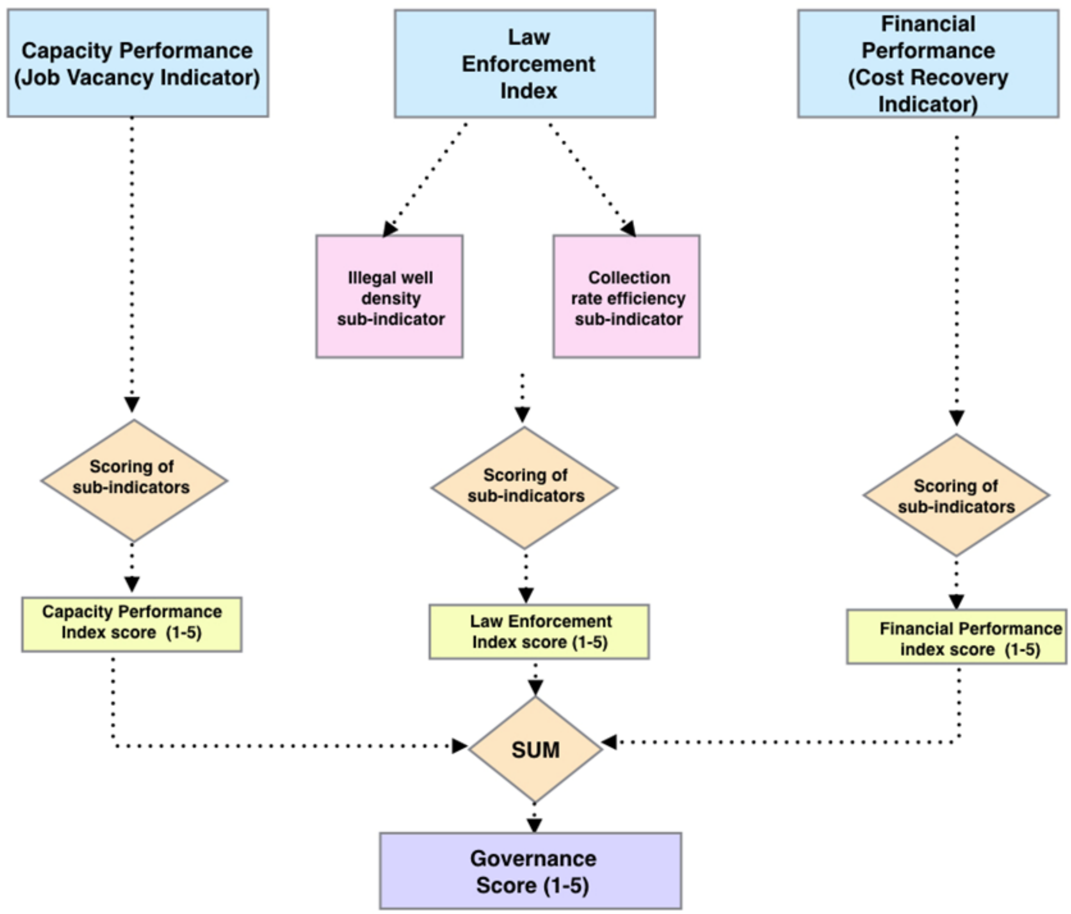

Figure 19. Conceptual Framework for the governance dimension

DIMENSION SCORE

Sub-Indicator	Method of Calculation	Source for Data and Calculations	Value Calculated for BML	Score
Job Vacancy Rate	JVR	BMLWE (2018)	62.5 %	1
Capacity Performance				**1**
Illegal Wells Density	[Number of Illegal wells/Surface area]	CAS, 2010 UNDP, 2014	4.7 wells/Km^2	1
Collection Rate Efficiency	Number provided in source	BMLWE (2018)	75 %	4
Law Enforcement Index				**2.5**
Cost recovery in water supply services at a 50% collection rate	Number provided in Source	BMLWE (2018)	429%	5
Financial Performance Index				**5**
Governance Dimension				**2.8**

Governance scored **2.8/5.** This dimension receives a poor score, nearing average. The BMLWE is capable of recovering the cost of water services provision in an optimal manner. The establishment also receives a good score on bill collection rate, despite the high level of illegal wells in the region. The main issue is apparent at the level of employment at the establishment, manifested by the very high job vacancy rate indicating a poor attraction and retention of employees.

WATER SECURITY INDEX FOR BEIRUT MT. LEBANON

SYNTHESIS

Water security in Beirut and Mount Lebanon receives a poor score-nearing average- of 2.97 over 5, reflecting a generally fair status of water security in the region. Most dimensions scored between poor and average, with the poorest dimension being hazard and risk, reflecting an urgent need to improve the region's resilience to droughts and floods.

The assessment depicts an overall average yet unsustainable management of water resources, characterized with a poor public supply of water resources, very high levels of untreated wastewater, a very high exposure and sensitivity to the impacts of floods and droughts, high network losses, and poor governance. The score of the water security index for BMLWE is represented in Figure 20.

In looking at detailed aspects of the assessment, the conducted water security assessment confirms in most cases the analyzed trends and baseline conditions. The physical aspect of the selected indicators readily mirrored the trends that were investigated. For example, the score for rainfall variability indicators was 'optimal', reflecting the lack of statistically significant trend in rainfall described in section 4.1.1. The score for surface flow variation was average, echoing the decreasing flows of rivers detailed in section 4.1.2, particularly Nahr El Kaleb. Finally, the increasing stress on groundwater resources noted in section 4.1.4 was further confirmed in the WSA analysis, whereby groundwater resources were highly contaminated from saltwater intrusion, which could be associated with an increased abstraction from groundwater.

Finally, it should be noted that this assessment may be further refined, but not changed, by improving the accuracy of available data and regularly updating databases pertaining to Beirut and Mount Lebanon. Further improvements in data collection and continuous monitoring are crucial for the proper use of the water security assessment methodology that has been developed and presented.

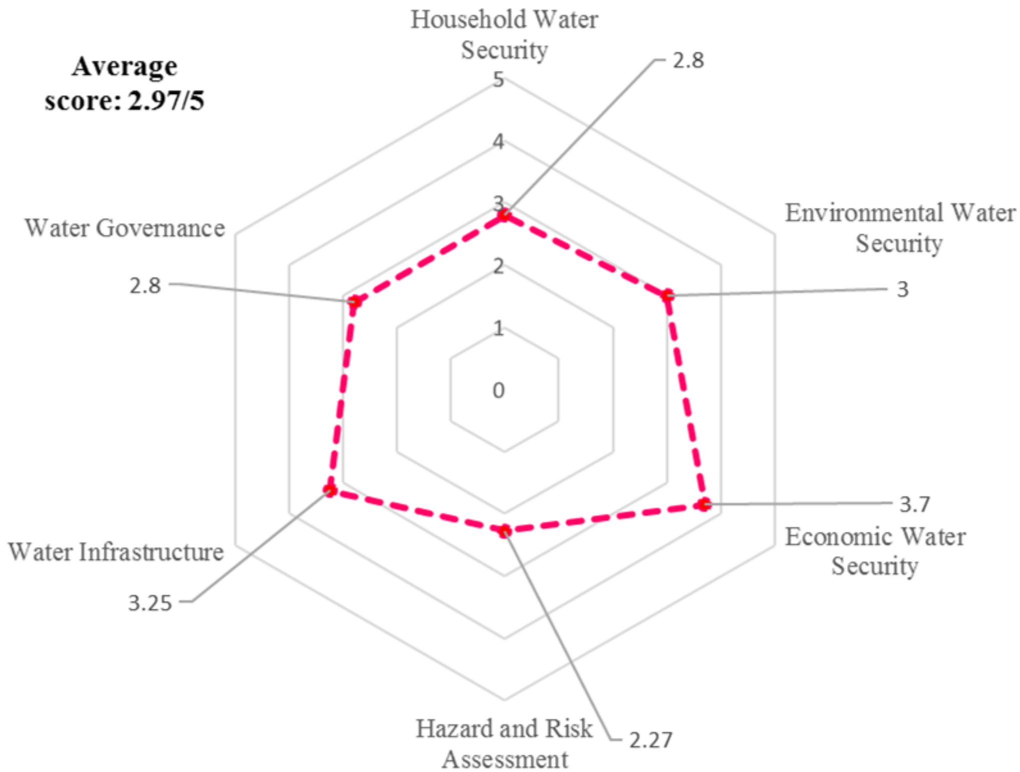

Figure 20. Water Security Score in BML

Accordingly a synthesis of each dimension is presented below:

- Household Water Security **2.8/5**: this dimension reflects receives a generally poor score, nearing an average score. This score reflects an average access to water resources mirrored by very low hours of public water supply, and a general state of water scarcity in the region. Domestic needs are therefore not met at the household level, reflecting a deficiency in water supply to meet the community's needs and a high price for water-related services, which constitutes over 30% of average income in poor and vulnerable households. In parallel, this dimension received a fair score for the access to safe water and sanitation index, having the highest rate of wastewater connections in the country, and a generally low risk of waterborne disease transmission reflecting a good water quality. This dimension however remains an area of concern, which should be addressed in order to improve water security in the region and meet consumers' need at the household level. With the future prospect of climate change and the threat of population growth, the score of this dimension might be subject to even further degradation.
- Environmental Water Security **3/5**: the score of this dimension reflects a fair state of ecological integrity and health of water ecosystems, as well as hydro-climatic variabilities and anthropogenic stressors which impact the state of water bodies. A major area of concern stems from the very low percentage of wastewater being treated, which constitutes a pervasive source of pollution to water

bodies, decreasing their overall health. Surface flows appear to have decreased in BML, particularly for Nahr El Kaleb. Given the lack of variation in rainfall patterns, this could be very likely associated with over-abstraction. The latter appears to occur at the level of groundwater resources, manifested in the high levels of chloride recorded. Thus, environmental water security appears to be hindered in Beirut and Mount Lebanon due to man-made factors. The establishment should focus on increasing WWTPs capacity and promote demand-side management to decrease pressure on surface and groundwater.

- Economic Water Security **3.7/5**: this dimension received an average score, the highest amongst all other dimensions and depicts an average use of water in the agricultural, and energy sectors, and an optimal productive use of water in the industrial sector. This reflects a productive use of water across these sectors, and high economic returns for volumes of water utilized. This good score should incentivize water bodies to maintain this high performance while aiming for improvements when possible. Looking at each indicator individually, it is important to mention the need for further data collection, regarding the efficiency of agricultural practices in the Beirut and Mount Lebanon.
- Hazard and Risk Assessment **2.27/5:** risks from drought and flood hazards appear to be very high, with this dimension receiving the poorest score, signifying a high risk with regards to water security. Flood and drought hazards appear to be high, and so does the vulnerability of the community and establishment in the face of increasing hazards. High population growth, very dry conditions, very low storage capacity in the case of a drought, high population density around flood areas, and lack of structural and non-structural measures increase risks of drought and floods. Coping capacities in Beirut and Mount Lebanon appear to range between poor and average, warranting an increased education rate and higher access to mobile cellular phones.
- Water Infrastructure **3.25/5**: the assessment reveals an average score. Although water network coverage per population received a good score, other aspects of water infrastructure are in poor conditions, particularly the wastewater treatment plant coverage which is very poor. The latter echo results of the 'environmental' and 'household' water security dimension assessments. Other under-performing indicators are apparent through the high NRW. Storage capacity appears to be optimal, and despite an aging network, the age of infrastructure in BML is fair. This analysis unveils main measurements to be taken in realm of improving performance of water infrastructure, which can be summarized as:
    - Investing in increasing wastewater treatment coverage in order to insure better collection and proper discharge of wastewater according to environmental and ecological standards.
    - Reducing physical and commercial losses engendering non-revenue water.

- Maintaining proper maintenance and renovation rates of the infrastructure.

- Water Governance: **2.8/5.** This dimension received a poor score reflecting a very poor capacity performance as well as a high level of illegal practices, demonstrated by the high abundance of illegal private wells, illegal water connections. In terms of law enforcement, BMLWE outperforms other establishments, having a generally good bill collection rate and an optimal cost recovery rate, even generating profits. Thus to improve its overall performance, the establishment should focus on improving its job vacancy ratio and reduce the number of illegal wells through increased law enforcement.

According to the analysis, the following water security index was developed, after allocating equal weights to all dimensions:

Household Water Security (a)	Environmental Water Security (b)	Economic Water Security (c)	Hazard and Risk Assessment (d)	Water Infrastructure (e)	Water Governance (f)	Overall Water Security Index ([a+b+c+d+e]/6)
2.8	3	3.7	2.27	3.25	2.8	2.97

PROJECTIONS

In this section projections for essential parameters, namely population, urbanization and precipitation, are conducted, to obtain preliminary results regarding natural and social factors which might impact water security, on the short (2025), mid (2045), and long (2065) term. Projection of hydro-climatic and anthropogenic variables enables the provision of contextualized recommendations, in the face of continually changing conditions. Variables are projected according to two scenarios developed by the Intergovernmental Panel on Climate Change (IPCC), RCP 4.5 which depicts a 'positive' scenario, and RCP 8.5, the 'negative' scenario, with regards to future atmospheric carbon dioxide concentrations (IPCC, 2014).

PRECIPITATION AND TEMPERATURE PROJECTIONS

The average precipitation for BML is estimated at 865 mm/year for the period of 1874-2017. RCP 4.5 and RCP 8.5 models for Lebanon predict a decrease in rainfall between 4% and 11% percent respectively compared to the period 1945-1965 and an increase in temperature between 1.2^{o}C and 1.7^{o}C (MoE et al., 2016). Accordingly, the projected precipitation values indicate that in 2025, precipitation will decrease to between 837.8mm/year and 855mm/year (Figure 21) and temperature will increase to 21.5^{o}C-21.6^{o}C (Figure 22). In 2045-2065, precipitation will decrease to 769.9 mm/year-830 mm/year (Figure 21) and temperatures will increase to 22.3^{o}C – 22.8^{o}C (

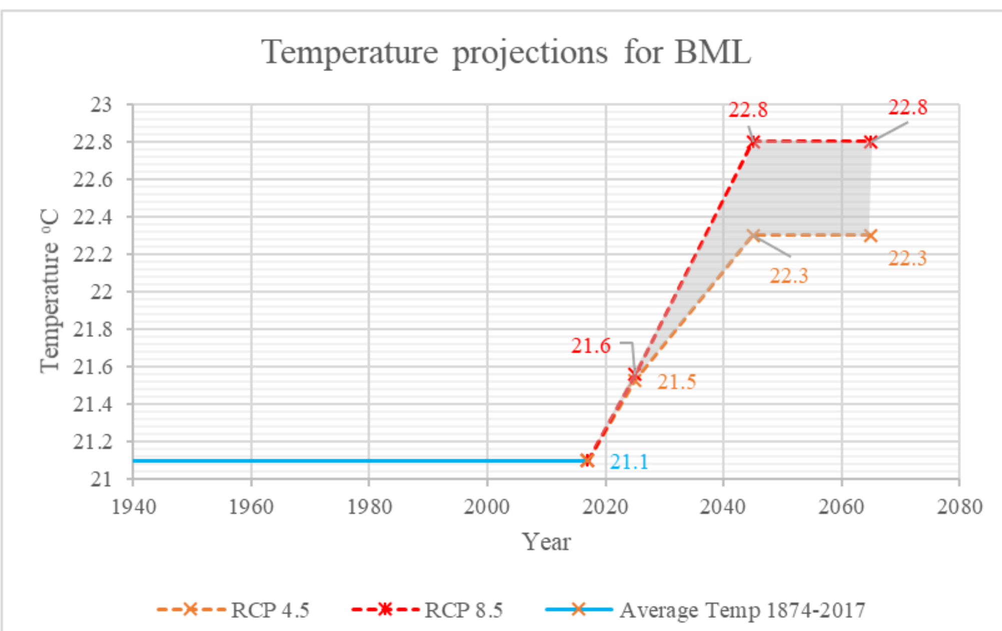

Figure 22). Such temperature and rainfall variability might impact other aspects of water security, predominantly overall water availability in the region.

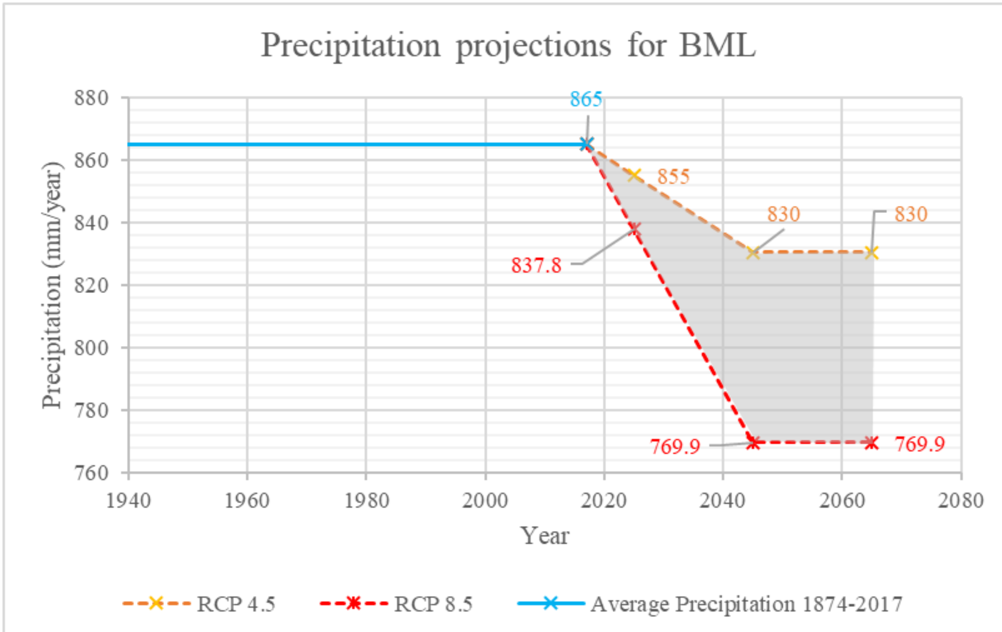

Figure 21. Projected rainfall patterns for BML (based on MoE et al., 2016 projections)

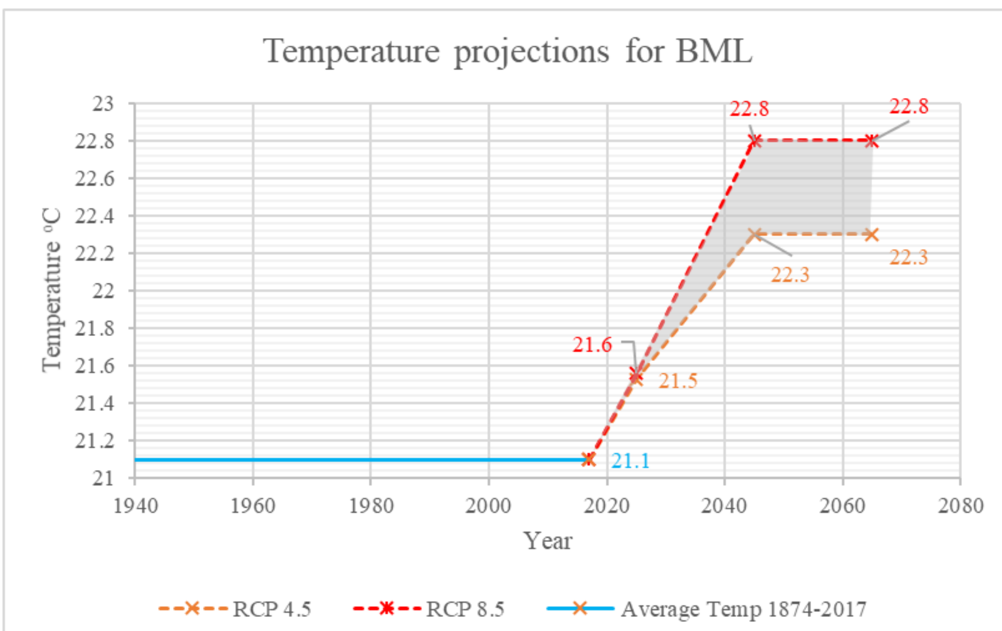

Figure 22. Projected Average Annual Temperature for BML

POPULATION PROJECTION

As of 2017, the BML population accounts for 1,969,429 local residents and 298,585 refugees. The total population for that time period is therefore 2,268,014 persons (MoPH, 2017). The latest available growth rates in year 2017, for the BML population as per our assessment are 0.73% and 0.19% respectively for population without refugees and with refugees respectively.

The projected population for BML in 2025, 2045 and 2065 is calculated assuming that these rates persist in the following future period, for population with and without refugees. Results summarized in Table 3 and shown on Figure 23 highlight population increase including refugees. Predictions regarding the possible rate of return of refugees to their country of origin is very difficult and depends on a multitude of socio-political and economic factors which are beyond the scope of this report. Thus, projections should be viewed with caution and altered according to future social and geo-political events in the region.

In 2025, the BML population (with refugees) is projected at ~2,303,000 people, versus 2,087,000 without refugees. In 2045 the local population projection is at ~2,414,000 and slightly exceeds the population projection with refugees, indicating that around this time refugees in BML may have left and only locals remain. In 2065, ~2,792,000 are anticipated to be living in BML as per the projection for that time. The Establishment will therefore be catering for a much larger population and should upgrade its infrastructure accordingly.

Table 3. Short, mid and long term projected population for BML – without and with refugees

Year	Population (Local)	Population (Local + Refugees)
2025	2,087,426	2,302,718
2045	2,414,280	2,391,819
2065	2,792,315	-

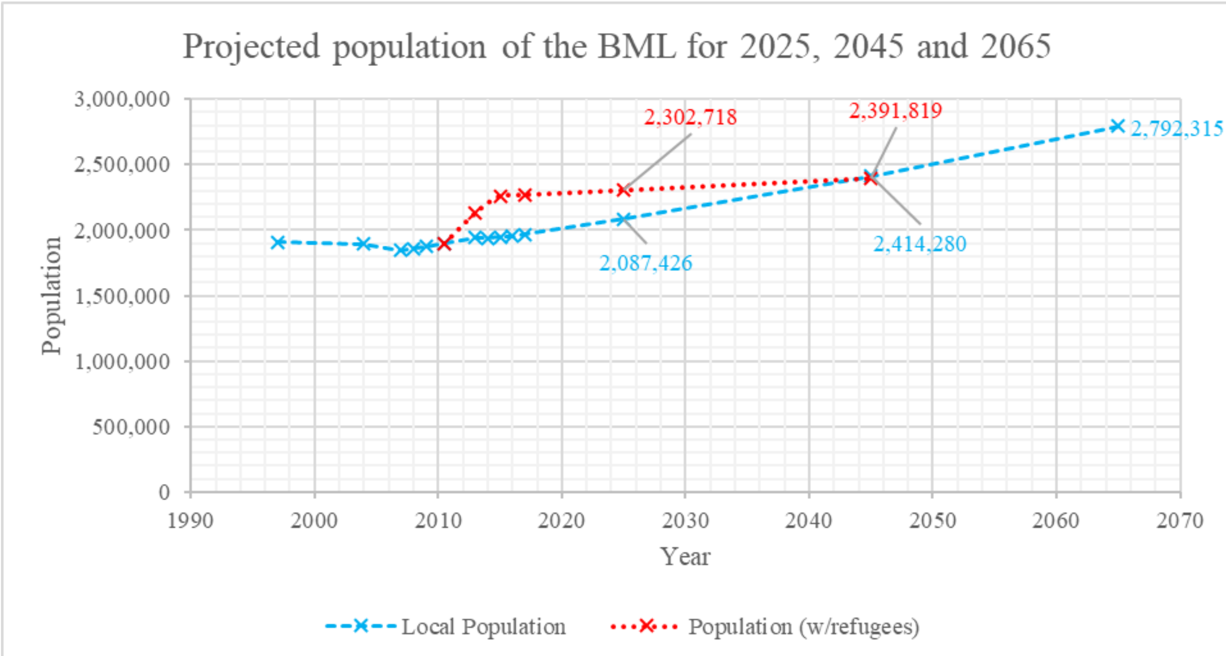

Figure 23. Population Projections for BML

STRATEGIES AND RECOMMENDATIONS

Strategic recommendations for BMLWE were devised in this section according to projections for rainfall, population and temperature for the years 2025, 2045, and 2065 which represented the short, mid, and long term periods. The recommendations:

Strategic recommendations for BMLWE were devised in this section, based on the following:

- Projections for rainfall, population and temperature for the years 2025, 2045, and 2065;
- Recommendations primarily targeted the lowest scoring dimensions: household water security, environmental water security and water infrastructure dimensions. The lowest scoring indicators within each dimension were primarily chosen as target indicators, upon which core recommendations were built;
- Recommendations targeted an improved water security score;
- Recommendations and the timeline for implementation were founded upon the expert consultation meeting, expert consultation online survey and the stakeholder consultation meeting;
- Policy recommendations were inserted, tackling the governance dimension, targeting the overall capabilities of BMLWE to overcome core water security challenges.

The strategic recommendation detailed in Table 4 targets an improved water security in the region, based on actions which should primarily be undertaken at the Establishment level, with the assistance of the MoEW, CDR, other ministries, agencies, establishments and international organizations.

Table 4. Strategic recommendation for BLWE (2019-2065)

Themes	Required Tasks	Related Dimensions	Target Indicators	Target Score	Time Frame			Implementing Agency	Cost at NPV (USD)
					Short (2019-2025)	**Mid (2025-2045)**	**Long (2045-2065)**		
Water Supply	Build additional **55,000** water connections	Household Water Security	Access to water	4	X			Direct Implementers: * BMLWE * MoEW * CDR Supporting bodies: * Municipalities * Ministry of interior and Municipalities * Judiciary * NGOs	**USD 13.38 million**
	Build additional **77,000** water connections	Household Water Security	Access to water	5		X			**USD 23.03 million**
	Build additional **145,000** water connections	Household Water Security	Access to water	5			X		**USD 29.48 million**
	Increase hours of public water supply to **12 hours** per day	Household Water Security	Hours of public water supply	3	X				-
	Increase hours of public water supply to **18 hours** per day	Household Water Security	Hours of public water supply	4		X			
	Increase hours of public water supply to **24 hours** per day	Household Water Security	Hours of public water supply	5			X		
	Promote rainwater harvesting across the region to deal with current water scarcity in BML	Household Water Security	Total renewable water resources	-	X	X	X		
	Complete the Janneh, and Bisri Dam to cope with the increased risk of drought.	Hazard and Risk Assessment	Hazard and Risk Assessment	3.75	X				**USD 420 million**
	Build storage amounting to a total capacity of **47** Mm^3	Hazard and Risk Assessment	Hazard and Risk Assessment	5			X		**USD 300 million**

Wastewater	Build additional **5,000** wastewater connections	Household Water Security	Access to sanitation	4	X			Direct Implementers: * BMLWE * MoEW * CDR Supporting bodies: * Municipalities * Ministry of interior and Municipalities * Judiciary * NGOs	**USD 1 million**
	Build additional **77,000** wastewater connections	Household Water Security	Access to sanitation	5		X			**USD 9.11 million**
	Build additional **145,000** wastewater connections	Household Water Security	Access to sanitation	5			X		**USD 14.48 million**
	Upgrade existing WWTPs to operate at full installed capacity	Environmental Water Security	Percentage of wastewater safely treated	5	X				**USD 322 million**
	Upgrade existing WWTP in Ghadir to ensure its full operating capacity with secondary treatment. Construct the 'planned' Bourj Hammoud WWTP and ensure full operating capacity, resulting in 95% treatment.								
	Monitor in parallel the incidence of water borne diseases in BML, to measure improved benefits on the community's health								
	Construct 'planned' WWTPs in Tabarja Keserwan and ensure its full operating capacity.	Environmental Water Security	Percentage of wastewater safely treated	5		X			**USD 640 million**
	Continue monitoring in parallel the incidence of water borne diseases in Beirut and Mount Lebanon, to measure improved benefits on the community's health								
	Construct 'planned' WWTP of Jbeil, Hrajel, Barouk and Nabaa El Safa and ensure their full operating capacity.	Environmental Water Security	Percentage of wastewater safely treated	5			X		**USD 754 million**
	Monitor and rehabilitate existing septic tanks in remote villages, and promote the construction of small-scale WWTPs	Environmental Water Security	Percentage of wastewater safely treated	-	X	X	X		
Drought and flood resilience	Improve agricultural water efficiency in BML through the adoption of sprinklers and drip-irrigation. This will potential reduce agricultural runoff and deep percolation, improving the quality of water bodies	Hazard and Risk Assessment	Drought Index	-	X	X	X	Direct Implementers: * BMLWE * MoEW * CDR Supporting bodies: * Municipalities * Ministry of interior and Municipalities	-
	Start clearing major intrusions into the main channels of the major rivers and springs in BML	Hazard and Risk Assessment	Flood Index						
	Improved irrigation practices through the promotion of drip irrigation to reduce agricultural vulnerability to droughts	Hazard and Risk Assessment	Drought Index						

	Establish the mechanisms and policies which enable the establishment and other entities to declare drought and flood emergencies	Hazard and Risk Assessment	Drought and Flood Indices					* Judiciary * NGOs	
	Develop emergency plans for both floods and droughts	Hazard and Risk Assessment	Drought and Flood Indices						
	Improve agricultural practices, and promote the use of drought tolerant crops	Hazard and Risk Assessment	Drought Index						
	Create financial and policy incentives for improved water-efficient irrigation	Hazard and Risk Assessment	Drought Index						
	Install the right infrastructure for and promote the reuse of wastewater through proper treatment, for agricultural purposes	Hazard and Risk Assessment	Drought Index						
	Drought monitoring and development of early warning systems	Hazard and Risk Assessment	Drought Index						
	Public aid for crop insurance	Hazard and Risk Assessment	Drought Index						
	Develop a fiscal mechanism to fine farmers and other responsible parties for water wasting in drought periods	Hazard and Risk Assessment	Drought Index						
	Promote awareness about drought preparedness	Hazard and Risk Assessment	Drought Index						
	Develop early warning systems for floods	Hazard and Risk Assessment	Flood Index						
	Continuously monitor rivers flows and rainfall patterns for flood forecasting	Hazard and Risk Assessment	Flood Index						
	Develop policies to enable flood zoning and ban the built up of residential areas around flood plains	Hazard and Risk Assessment	Flood Index						
	Develop a flood historical maps	Hazard and Risk Assessment	Flood Index						
	Promote natural based solutions for flood protection such as sustainable urban drainage systems	Hazard and Risk Assessment	Flood Index						
	Promote demand management in view of population growth	Hazard and Risk Assessment	Drought and Flood Indices						

	Promote access to information related to hazards in remote areas through awareness sessions and coordination with existing municipalities	Hazard and Risk Assessment	Drought and Flood Indices						
Water governance	Rely on permanent employees instead of contracted	Water governance	Job Vacancy Ration	-	X	X	X	BMLWE in coordination with MoEW where applicable	
	Ensure the attraction of well qualified personnel		Job Vacancy Ration						
	Improve law enforcement to reduce illegal tapping into the water network and illegal groundwater exploitations. Cooperate with other entities to ensure proper law enforcement (such as the MoI municipalities, and the MoEW)		Illegal Wells						
	Policy reforms to enable the establishments to enforce laws and monitor any illegal activities, through a proper delineation of roles and responsibilities of stakeholders in the water sector		Illegal Wells						
	Develop financial mechanisms to improve the establishment's financial performance		Financial Index						
	Introduce a monitoring mechanism for bills and revenue collection								
Non-revenue water	Upgrade the network and ensure continuous maintenance	Water Infrastructure	Non-Revenue Water	-	X	X	X	Direct Implementers: * BMLWE * MoEW * CDR Supporting bodies: * Municipalities * Ministry of interior and Municipalities * NGOs	-
	Reduce NRW to 30 %			3	X				**USD 274 million**
	Reduce NRW to 20 %			4		X			**USD 462 million**
	Reduce NRW to 10 %			5			X		**USD 502 million**
	Install real-time monitoring systems to improve leak detection for water and wastewater networks			-	X	X	X		-
	Ensure continuous maintenance of water networks for leakages or other incidents				X	X	X		
	Install meters at the establishment and household levels, enabling a more accurate estimation of physical and commercial losses				X	X	X		
	Ensure and maintain proper metering through continuous monitoring				X	X	X		

Awareness	Conduct awareness campaigns about demand management, and the need to reduce water consumption at the household and individual level Conduct awareness campaigns at the farmer level, regarding water-saving irrigation techniques, non-intensive water crops, organic farming, and sustainable agriculture Conduct awareness campaigns at the industrial and tourism level regarding water efficient practices and sustainable production Implement policies to promote demand-management practices Raise awareness about the importance of reporting leakages at the household level, as well as the means of reporting these incidences, in order to decrease NRW Conduct awareness campaigns about demand management, and the need to reduce water consumption at the household and individual level Conduct awareness campaigns at the farmer level, regarding water-saving irrigation techniques, non-intensive water crops, organic farming, and sustainable agriculture Conduct awareness campaigns at the industrial and tourism level regarding water efficient practices and sustainable production	All dimensions	Cross-cutting		X	X	X	BMLWE in coordination with international organization	**USD 400,000**
Data management	Consistent and thorough data collection Install a weather monitoring station Improved sampling strategy based on WQAP requirements Develop a data management framework/system at the national and regional level Liaise with other water establishments as well as the MoEW, to align databases formats in terms of data collection methodologies and measured parameters Align collected/targeted data and their formatting according to WEAP and ArcGIS requirements	All dimensions	Cross-cutting	-	X	X	X	BMLWE in coordination with international organization	-

	Align collected/targeted data with internationally recognized indicators (World Bank, SDGs, FAO, WHO, EPA etc.)								
	Develop a formal communication and data exchange protocol with agencies collecting climatic data (namely. LARI and Weather Service)								
	Enhance and improve customer database and the implementation of an online payment option								
Training	Implement staff training as per the WQAP	All dimensions	Cross-cutting	-	X	X	X	BMLWE in coordination with international organization (variant dependent on the type of training)	-
	Conduct staff training for accurate and timely reading and registration of water meters' values								
	Training on water security assessment methodology								
	Training on the use of ArcGIS								
	Training on WEAP software and appropriate scenario planning								
	Training on mainstreaming IWRM pillars into water and wastewater management								
	Improve understanding of climate change, and climate change impact on water security								
	Continuous training on water and wastewater technical and management aspects								

MAINSTREAMING CLIMATE CHANGE

Growing climate consensus has emerged across the scientific community, reaching a 97% consensus and solidifying the likelihood of future climate change. Nonetheless inherent uncertainties and limitations lie in future climate projections, due to differences in Global Climatic Models used to predict impacts of climate change (AMCOW and GWP, 2013; MoE et al., 2016). Appendix L details the uncertainty of climate projections for the case of Lebanon, making it difficult to provide specific recommendations for climate resilience. Instead general recommendations to improve the community and the establishment's resilience to climate change will be developed in this section. Both rainfall and temperature in Lebanon will be affected from climate-related risks, and Beirut and Mount Lebanon is considered to be one of the most vulnerable areas to climate change (UNDP, 2011; MoE et al., 2016). Thus improving climate-resilience in this region is imperative.

Mainstreaming climate change and the resilience strategy were developed according to the following:

- Recommendations are in line with Lebanon's 'Intended Nationally Determined Contributions' (INDCs), developed following the Paris Agreement, prioritizing adaptation measures in the biodiversity, forestry and water sectors.
- Recommendations draw on the promotion of ecosystem services and 'nature climate solutions' (Griscom et al., 2017).
- Recommendations focus on improved resilience to climate-risks such as risks of floods and droughts, threats to WEF (water-energy and food nexus) and the health of water bodies.

Suggested actions are detailed in Table 5.

Table 5. Mainstreaming Climate Change for improved resilience

	Milestones	Actions	Relevance to Water Security	Sources
Domestic Practices	Property level protection measure (PLPM)	PLPMs entail measures such as the installation of automatic air brick covers, gates for doors, bituminous coatings, water resistant external walls, waterproof flooring, repositioning of electrical sockets and boilers etc.	PLPMs enable households to take flood defense measures, contributing to increased flood resilience and resistance, thus contributing to increased levels of water security at the household level.	(Pitt, 2008)
	Water reuse	Use treated wastewater e.g. for toilet flushing or laundry	Reduces stress on water resources and provides an alternative mean to water in case of droughts or shortages.	(EPA, 2017)
		Use greywater e.g. toilet flushing	Reduces stress on water resources and provides an alternative mean to water in case of droughts or shortages.	
	Rainwater Harvesting	Use rainwater in household activities, such as flushing toilets and laundry	Reduces stress on water resources and provides an alternative mean to water in case of droughts or shortages.	
Agricultural Practices	Water reuse	Use treated wastewater, greywater for irrigation	Reduces stress on water resources and provides an alternative mean to water in case of droughts or shortages.	(EPA, 2017)
	Rainwater Harvesting	Use rainwater to irrigate	Reduces stress on water resources and provides an alternative mean to water in case of droughts or shortages.	
	Planting of drought-resilient crops	Use of local and improved crop varieties and livestock breeds	Reduces agricultural water footprint and ensures crops grow in case of water shortages	(UNCCD, 2017)
		Maintaining agroecosystem variability to enhance adaption capacity	Reduces agricultural water footprint and ensures crops grow in case of water shortages	(Koohafkan et al., 2012)
	Maximizing infiltration and water holding capacities of soil	Construct Micro-catchments; these are small basins built around plants that harvest rainwater and lead to its infiltration and its storage in soil profiles	Decreases runoff and associated flood risks and increases groundwater recharge	(Rockström, 2003; Waelti and Spuhler, 2017b; Matthew and Bainbridge, 2000; ICIMOD, 2017)
		Construct contour bunds (soil and stone) - multi-step terraces developed along contour lines of slopping terrains.	Decreases runoff and associated flood risks and increases groundwater recharge	(Rockström, 2003; Waelti and Spuhler, 2017a)
		Construct Fanya Juu Terraces: terraces comprising embankments (bunds), constructed by digging ditches and layering the soil on the upper sides to form the bunds	Decreases runoff and associated flood risks and increases groundwater recharge	(Rockström, 2003; Eip-Water, 2017)
Water Storage	Storage of water, ideally before it enters sewers	Construct wetlands for cleaning and storage of storm-water run-off. This will increase the storage capacity and groundwater aquifer recharge	Decreases runoff and associated flood risks and increases groundwater recharge. This will also reflect on higher water availability	(Skelton, 2012)
	Create more physical storage	Build more water tanks to store water	Increases water availability	
Landscape/Urban Planning	Sustainable drainage systems	Reduce impermeable urban surfaces, e.g. build permeable pavements	Reduces flood risks and increases groundwater recharge	(Skelton, 2012; EPA, 2017b)
		Rely on: -Bioswale: green storm water infrastructure consisting of channels that can retain and treat running water. These channels can also be vegetated, covered with mulch, or xeriscaped - Rain gardens and rooftop greenings for retention and cleaning of storm-water	Reduces flood risks, increases groundwater infiltration and decreases pollutants concentration.	(Skelton, 2012; EPA, 2017b)
	Reforestation	Increase the surface area of forests in the region	Decreases built up surface areas and therefore impervious surfaces; reduces risks to floods.	

	Streams Conservation	Build riparian buffers - an area along shorelines, wetlands or streams where development is restricted or prohibited- around streams and wetlands to protect these from adjacent land use and ensure better quality of their water	Preserves the quality of water bodies	
Renewable Energy	Hydropower	Develop efficient use of hydropower resources	Reduces pollution associated with fuel energy	
	Solar and Wind Energy	Rely on Solar cells and wind turbines to boost green energy production	Reduces pollution associated with fuel energy and reliance on water resources to produce energy	
Integrated Risk Management	Monitoring	Install droughts and floods monitoring and early warning systems	Increases resilience to floods and droughts	(FAO, 2017)
	Forecasting	Forecast for floods and droughts hazards based on collected data	Increases resilience to floods and droughts	(OECD and IEA, 2015; Hamidov and Davies, 2017)
	Planning	Conduct climate risk assessments and plan accordingly for better resources management and prevention measures.	Increases resilience to floods and droughts	(OECD and IEA, 2015; Hamidov and Davies, 2017)
	Capacity Building	Train water sector staff on: -Monitoring and forecasting hydrological variability. - Monitoring dams and water facilities health and safety -Water resources management	Increases resilience to floods and droughts	(IHA, 2017)
Water Efficiency	Reduce NRW	Metering water supply and consumption and reducing water leaks	Decreases water resources losses and ensures more water availability	
	Wastewater Treatment	Increase wastewater treatment level to drinking water standards	Increases water availability	
	Introduce IWRM	Mainstream IWRM into the planning cycle in water governance, while integrating its inherent principles (pillars of sustainability)	Contributes to improved water governance	(Van Beek and Lincklaen Arriens, 2014)

CONCLUSION

Based on the recommendations above, water security in Beirut-Mt. Lebanon is set to improve gradually over the years as portrayed in Figure 24.

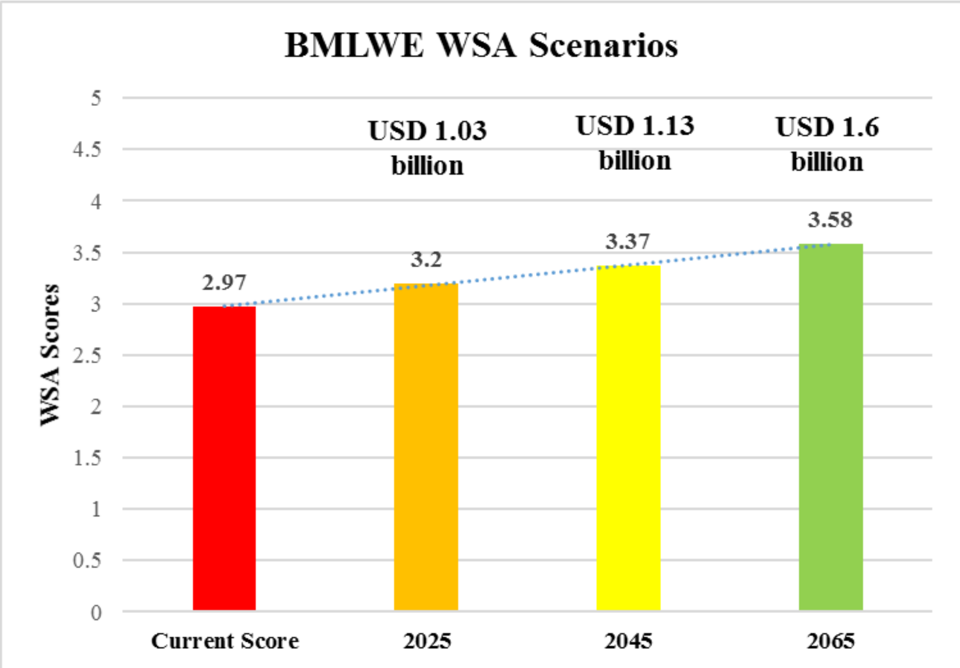

Figure 24. WSA projected scenarios and scores

It's important to mention that the scores displayed in Figure 24 represent **minimum score improvements.** Indeed, recommendations do not take into account interactions between indicators and across dimensions and consider all non-targeted indicators/dimensions as static. Moreover, various mentioned recommendations produce cross-cutting improvements which were not quantified due to high uncertainties and data gaps. Nonetheless, steady water security enhancement is expected if recommendations are comprehensively followed.

By 2065, overall water security in Beirut and Mount Lebanon will reach a minimum score of 3.58, describing average water security conditions. Recommendations mainly tackle the access to water and sanitation in the region, the percentage of wastewater safely treated, hours of public water supply, percentage of households with access to water and sanitation, and NRW. Good governance is a pre-requisite for good water security, and all policy recommendations, suggest capacity building activities, and data management recommendations target this concept. Moreover, recommendations focus on improved data collection and management, which the establishment significantly suffers from. Overall recommendations will have a total cost of approximately USD 3.76 billion, with costs on the short-term being USD 1.03 billion, USD 1.13 billion on the mid-term, and USD 1.6 billion on the long-term.

The mentioned strategies stem from a human-centric approach to water security, which nonetheless generates positive impacts on the ecological integrity of water systems in BML. Although the current situation in BML is average, improvement is very much achievable.

On the other hand, the climate resilience strategy will further contribute to improved levels of water security. All recommendations promote natural-based solutions, encouraging the use of ecological services to ensure improved water security, and shaping climate-resilient infrastructure developments and urban planning around nature and its benefits. Accordingly, Beirut and Mount Lebanon will be enabled to better face water-related risks which might emanate from climate change. At the same time improved water storage through enhanced natural climatic solutions will lead to a higher level of water security, ensuring positive impacts on water supply, biodiversity and ecosystem health. Food and energy security will also be indirectly tackled, through sustainable agricultural practices, low carbon strategies and renewable energy practices.

Water governance in Beirut and Mount Lebanon will be improved, promoting practices in line with IWRM. Finally, behavioral changes across the society will be encouraged.