Freshwater Assessment Report (FAR)

A Study on Water Management Under a Changing Climate

Mediterranean Mosaics Project

Shouf Biosphere Reserve - 2019

Freshwater Assessment Report

SHOUF BIOSPHERE RESERVE
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LIST OF ACRONYMS

ACS	Al-Shouf Cedar Society
AMS	American Meteorological Society
ASL	Above Sea Level
B-N	Barouk-Niha
CDR	Council for Development and Reconstruction
CoM	Council of Ministers
CNRS	Centre National de Recherche Scientifique
E	East
EA	Environmental Audit
EBML	Establishment of the water of Beirut and Mount Lebanon
EWS-SPM	Early Warning System for Water Supply Management (River Flow) Through Snowpack Monitoring
EWUIS	Efficient Water Use Irrigation System
GEF	Global Environment Facility
GW	Ground Water
HCUP	Higher Council of Urban Planning
IWRM	Integrated Water Resources Management
LARI	Lebanese Agriculture Research Institute
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water
MoPWT	Ministry of Public Works and Transport
MORES	Management Of Resources and Environmental Solutions
N	North
NPMPLT	National Physical Master Plan for the Lebanese Territory
PA	Protected Area
RET	Real Evapotranspiration
RWHR	Rainwater Harvesting from ground or Roads

S	South
SBR	Shouf Biosphere Reserve
SEA	Strategic Environmental Assessment
SOER	State of the Environment
TAMU	Texas Agricultural and Mechanical University
UNCSD	United Nations Commission on Sustainable Development
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UTWWI	Use of Treated Wastewater in Irrigation
W	West
WUA	Water Users' Association
WWO	World Weather Online
WWTP	Waste Water Treatment Plan
%	Percent
cm	Centimeters
km	Kilometers
km^2	Square kilometers
m	Meters
MCM	Million Cubic Meters
mm	Millimeters

GLOSSARY OF TERMS

Celsius	A temperature scale in which zero is the freezing point of water and one hundred is the boiling point
Climate	The prevalent long-term weather conditions in a particular area. Climatic elements include precipitation, temperature, humidity, sunshine and wind velocity and phenomena such as fog, frost, and hail storms. Climate cannot be considered a satisfactory indicator of actual conditions since it is based upon a vast number of elements taken as an average
Cloudy	Clouds cover more than 60 percent of the sky
Drizzle	Precipitation in the form of liquid drops, with a diameter less than 0.5 mm and falling at a much slower rate than rain
Drought	Abnormally dry weather in a region over an extended period sufficient to cause a serious hydrological (water cycle) imbalance in the affected area. This can cause such problems as crop damage and water-supply shortage. It can also be defined as the prolonged absence or marked deficiency of precipitation (rain or snow)
Flash Flood	A flood that occurs within a few hours (usually less than six) of heavy or excessive rainfall, dam or levee failure or water released from an ice jam
Flood	A condition that occurs when water overflows the natural or artificial confines of a stream or river; the water also may accumulate by drainage over low-lying areas
Frequency	The rate of recurrence of any periodic phenomenon, such as precipitation
Hail	Precipitation in the form of balls or irregular lumps of ice produced by liquid precipitation, freezing and being coated by layers of ice as it is lifted and cooled in strong updrafts of thunderstorms
Heat Wave	A period of abnormally hot weather lasting several days
Humidity	A measure of the water vapor content of the air
Intensity	Expresses the rate of transfer per unit area of a condition or physical quantity, such as rainfall
Irradiance	A radiometric term for the rate at which radiant energy in a radiation field is transferred across a unit area of a surface (real or imaginary) in a hemisphere of directions

Maximum Temperature	The highest temperature during a specified time period
Mean Temperature	The average of a series of temperatures taken over a period of time, such as a day or a month
Minimum Temperature	The lowest temperature during a specified time period
Normal	The long-term average value of a meteorological element for a certain area. Usually averaged over 30 years
Rain	Precipitation in the form of liquid drops with a diameter of 0.5 mm or greater. Rain implies a steady precipitation that might last several hours. A shower implies precipitation of short duration but usually of greater intensity
Temperature	A measure of the warmth or coldness of an object or substance with reference to a standard value
Weather Station	A location where meteorological observations such as surface, upper air, and climatological observations are taken

EXECUTIVE SUMMARY

Several studies have been conducted on water resources in Lebanon that investigate the effects of climate change and confirm the need for adaptive measures. However, none of the studies focused specifically on the use of meteorological data to understand the climate change trends, and to design specific initiatives that would act as pilot interventions for the amelioration of water management on a larger scale. In this study, a water assessment covering the Shouf Biosphere Reserve (SBR) area was conducted under the framework of the Mediterranean Mosaics (MM), a regional project funded by MAVA and implemented in Lebanon by Al-Shouf Cedar Society (ACS), which manages the reserve, and in Italy by Lega Italiana Protezione Uccelli (LIPU) and Italian Landscape Exploration (ILEX). The MM aims at "designing and field-testing adaptive measures for biodiversity conservation, natural resource management and rural development, to help build "disturbance-smart" socio-ecosystems at the landscape level".

The study builds on three main sources of data: (i) bibliography on groundwater resources and climate change including historical meteorological data, (ii) analysis of meteorological data from different sources (from 1939 to the present) and (iii) field visits and observations. The review of available literature showed that (i) available studies justify continued exploitation of groundwater resources which seem to be demand oriented, (ii) the upper localized aquifers are not well studied, (iii) climate change and stresses on aquifers are highlighted in international studies, (iv) adaptation to climate change and mitigation measures are generic, and (v) the role of society and local authorities in adaptation to climate change are almost absent.

Analysis of available meteorological data collected in weather stations within the SBR, historical data from literature review and online data revealed the existence of significant yearly variations in precipitation. Also, that the general trend in precipitation is decreasing compared to historical data and that seasonal distribution of precipitation is shifting towards the warmer months thereby reducing the amount of snow received and its residence time. Additionally, the assessment showed that monthly temperature averages are increasing, and inter-seasonal temperature variations are getting narrower. A continuation of such trends could lead to various consequences, including disruptions in seasonal and annual flora and fauna cycles in the SBR and decrease in water recharge that ultimately feeds groundwater aquifers and surface springs.

Field visits brought to light several issues in the area that underscore the need for improvement in the current management of the water sector, including: (i) prevalence of pollution stresses on soil and water resources including: siltation from quarries, solid waste from haphazard dumping, discharge of untreated wastewater in certain areas, uncontrolled discharge of petroleum hydrocarbons, such as diesel and waste oils, from traffic, retail stations, mechanic shops and from generators and tanks at groundwater pumping stations; (ii) abandonment of agriculture at higher elevations; (iii) conflict between fauna and population; (iv) limited availability of surface water at higher elevations partially leading to expansion of fauna territories and migration of fauna and flora to higher altitudes; (v) continuous pumping of groundwater even at higher elevation with significant surface water/river flow; (vi) existing adaptation measures such as ponds for wild life and hill lakes that need rehabilitation; (vii) potentiality for customized adaptation measures; (viii) lack of awareness of local authorities and population relative to stresses on water resources. Based on these findings, the study recommended water adaptive management and compensation measures to help protect aquifers and surface water resources and, to a certain extent, address expected water shortages under a changing climate. The proposed measures include various rainwater harvesting technologies - such as direct harvesting from land surfaces, roof tops and town squares; pollution abatement measures such as remediation of hydrocarbon pollution and sedimentation ponds; rehabilitation of quarries and sandpits; rehabilitation and creation of ponds and hill lakes; creation of wetlands; installation of gabions as permeable barriers in seasonal water channels and micro-dams along water courses; rehabilitation of unproductive springs; and implementation of water saving technologies in agriculture.

The promotion and implementation of the proposed adaptation and mitigation measures would surely contribute to the amelioration of water management on a larger scale and strengthen resilience of the rural communities and ecosystems. Hence, field-testing of selected measures through small-scale pilot projects allows the local population, land-use planners, researchers, reserve managers and funding agencies to support short and long-term strategy development, and to promote the harvesting of rain and surface water.

INTRODUCTION

1 INTRODUCTION

This Freshwater Assessment Report (FAR) in the Shouf Biosphere Reserve (SBR)" was developed under the framework of the Mediterranean Mosaics (MM) Project: a regional project funded by MAVA and being implemented in Lebanon by Al-Shouf Cedar Society (ACS), which manages the reserve, and in Italy by Lega Italiana Protezione Uccelli (LIPU) and Italian Landscape Exploration (ILEX). The MM project aims at "designing and field-testing adaptive measures for biodiversity conservation, natural resource management, and rural development, to help build "disturbance-smart" socio-ecosystems at the landscape level" (Mediterranean Mosaics, 2016).

The report builds on three main sources of data: bibliography on groundwater resources assessment and climate change including historical meteorological data, meteorological data collected from weather stations located within the SBR and field visits and observations. The report specifically presents the analysis of available meteorological data to assess the presence of climate change trends and whether such trends affect the water resources in the Shouf area. It then recommends water adaptive management and compensation measures to help protect aquifers and surface water resources and address expected water shortages.

The FAR is addressed to individuals and institutions interested in adaptive/sustainable management of water resources under a changing climate, more specifically:

- Scientists interested in the methodology and collected data and its analysis
- Practitioners, such as local authorities, and the residents interested in proposed projects and adaptation measures, and the implemented small-scale pilot projects; and
- Funding agencies and land-use planners who are interested in short and long-term strategy development and fund allocations.

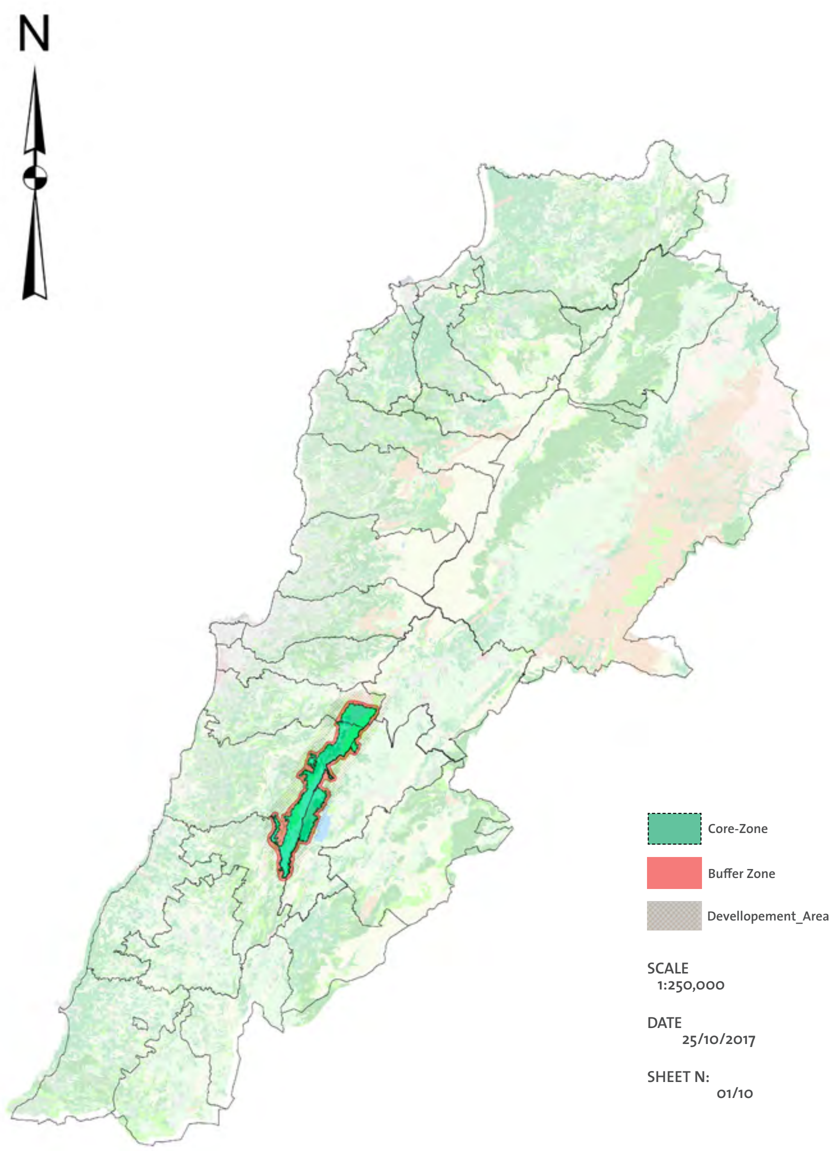
1.1 The Study Area

The Shouf Biosphere Reserve (SBR) covers about 5% of the overall area of Lebanon. It extends along the ridge of the western chain of Mount Lebanon from Dahr-El Baidar in the north to Jezzine in the south, and overlooks both the Bekaa valley to the east and the Shouf valley to the west (see **Figure 1-1**) .
The SBR includes, and is bounded by, twenty-two villages and contains Al-Shouf Cedar Reserve and Ammiq Wetland, which are fast becoming major natural attractions for Lebanon and the region.

The SBR consists of three zones that accommodate multiple functions:

- Core zone (161 km²): the main conservation objectives of the core zone are the protection and rehabilitation of the SBR's natural and cultural values.
- Buffer zone (54 km²): surrounds the core zone and permits only activities compatible with the conservation objectives to take place.
- Transition zone (development zone) (233 km²): includes all the villages surrounding the SBR where sustainable resource management practices are promoted.

The classification of zones is of importance to the study, since the sustainability of proposed adaptation measures could benefit from the inherent objectives, limitations, and administrative frameworks of each zone.



F igure 1-1 Location of the SBR within Lebanon (SBR, 2017)

1.2 Report Structure

This “Freshwater Assessment Report, which studies water management under a changing climate” is made up ofof the following : Chapter 1 is a general introduction to the project and the adopted methodology; Chapters 2, 3 and 4 present the results of literature review; – analysis of meteorological data collected at weather stations within and around the SBR and from online resources, in addition to comparison to available historical data; and observations from field visits; Chapter 5 proposes potential interventions; and Chapter 6 – consists of a conclusion and some recommended studies.

1.3 Methodology

The methodology for this study built on: review of available literature, assessment of meteorological data, field observations and for the development of recommendations for pilot interventions.

1.3.1 Literature review

Literature review covered bibliography related to water resources and climate in the SBR, mitigation and adaptation measures to climate change that could be applied in the area and identified obstacles that prevented the implementation of such projects in Lebanon.

1.3.2 Assessment of Meteorological Data

Review and preliminary analysis of meteorological data from weather stations in and around the SBR were conducted as part of this assessment, including precipitation (rain and snow), temperature, humidity, solar irradiation and wind. Some of the reviewed data span from as far back as the 1930s up to recent years (up to 2016). Findings from the older readings, referred to as historical climate data, were compared to more recent data, and observations were made regarding shifts in climate conditions and patterns.

1.3.3 Field Visits

Field visits were conducted to better understand the terrain, surface water resources (including their historical and current exploitation practices), adopted agricultural practices, as well as human imposed pollution threats and mis-management of water resources. Additionally, the field visits assisted in visualizing plausible interventions in the form of corrective or adaptive measures to support water availability, protection and sustainability.

LITERATURE REVIEW

2 LITERATURE REVIEW

Many studies have been conducted on water resources in Lebanon, and some reports referred to the effects of climate change thereby confirming the need for adaptive measures. None of the studies, however, focused specifically on the use of meteorological data to understand the climate change trends.

Of special focus in this report was the data presented in the recent study by ANTEA Group titled “Groundwater Resources Sustainable Assessment of the Western Slopes of the Shouf Biosphere Reserve”, which studied the western part of the Shouf Biosphere Reserve and presented specific data on springs, rivers, groundwater, and their exploitation. An additional main reference is the 2014 UNDP “Groundwater Assessment for Lebanon” report. Studies on climate change on a national level were also referenced, wherein predicted climate change scenarios and potential impacts have been considered. This section includes extracts from referenced documents to facilitate the analysis of data and development of recommendations.

2.1 SBR’s Water Resources in Literature

2.1.1 Groundwater

According to the UNDP 2014 “Groundwater Resources Assessment of Lebanon”, Mount Lebanon’s geology is characterized by thick limestones from the Jurassic and Cretaceous periods. The outcrops in the Shouf region are composed of karstic limestones and porous aquifers. Water percolates downward through the various formations and feeds the many large springs found on lower western slopes of the Mount Lebanon range. The Arz El Shouf (Shouf Cedar Reserve) protected area is mostly characterized by the Jurassic karst aquifer, referred to as the Barouk-Niha Aquifer, one of the major aquifers in Lebanon. The area is characterized by a groundwater divide located on the hinge line of the Barouk- Niha anticline. According to UNDP studies that included the manual monitoring of groundwater level in a well in Kab Elias in the Eastern Barouk-Niha Jurassic Basin in 1970 and 2013, no major change in the water level has been observed (**Table 2-1**).

Table 2-1 Groundwater Level Variation in E. Barouk-Niha Jurassic Basin (MoEW/UNDP, 2014)

Study	UNDP 2013				UNDP 1970	
Basin Name & No.	Well Name	Elevation (m)	Water Level (as ASL)		Well Name	Water level (as ASL)
			Maximum (Between Dec.-April)	Minimum (Between Dec.-April)		
E. Barouk-Niha Jurassic Basin (1a)	Kab Elias	876	868	858	Kab Elias	858

2.1.2 Springs

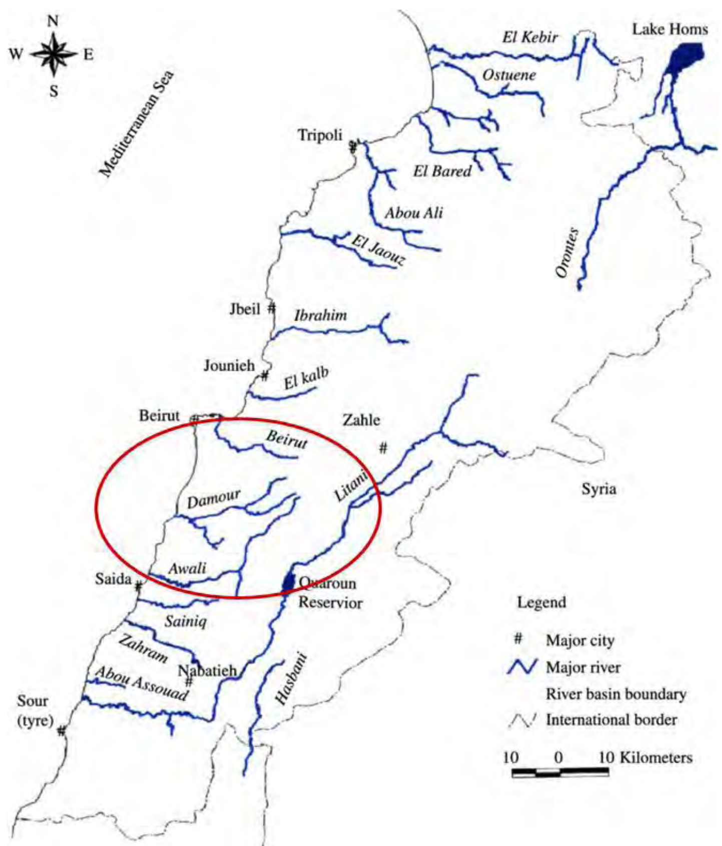
According to Antea Group report, the SBR is primarily composed of karstic limestone aquifers which supply over 200 springs in the area. These springs supply about 21 towns and villages in addition to several perennial rivers such as Litani, Damour, and Awali Rivers. Some of the springs are tapped and others flow freely supplying the downstream ecosystems and agriculture. "The SBR is involved in the protection of the quality and quantity of these springs and related aquifers by protecting the recharge area, as well as testing and investigating the bacteriological quality of all the springs" (Antea Group, 2017).

2.1.3 River Runoff

The western area of the SBR includes three main river basins: the Damour River, the Beirut River and the Awali River, while the eastern slopes of the reserve constitute part of the Litani River watershed (**Figure 2-1**).

"The rivers that flow in the valleys are the major source of agricultural irrigation and supply a dozen Shouf villages with domestic water as well as some Western Bekaa villages. It is also the main source of water for the Ammiq Swamp" (Med. Mosaics, 2014).

The Barouk River source is situated in the northern part of Barouk village. The source waters are abundant through the year and supply drinking water to 80 villages of the Shouf and Aley regions, reaching the outskirts of Saida and Beirut; the Barouk River is the main affluent/tributary of the Awali River.



F igure 2-1 Major Rivers in the SBR Area (within the red circle) (Antea Group, 2017)

2.1.4 Hill Lakes

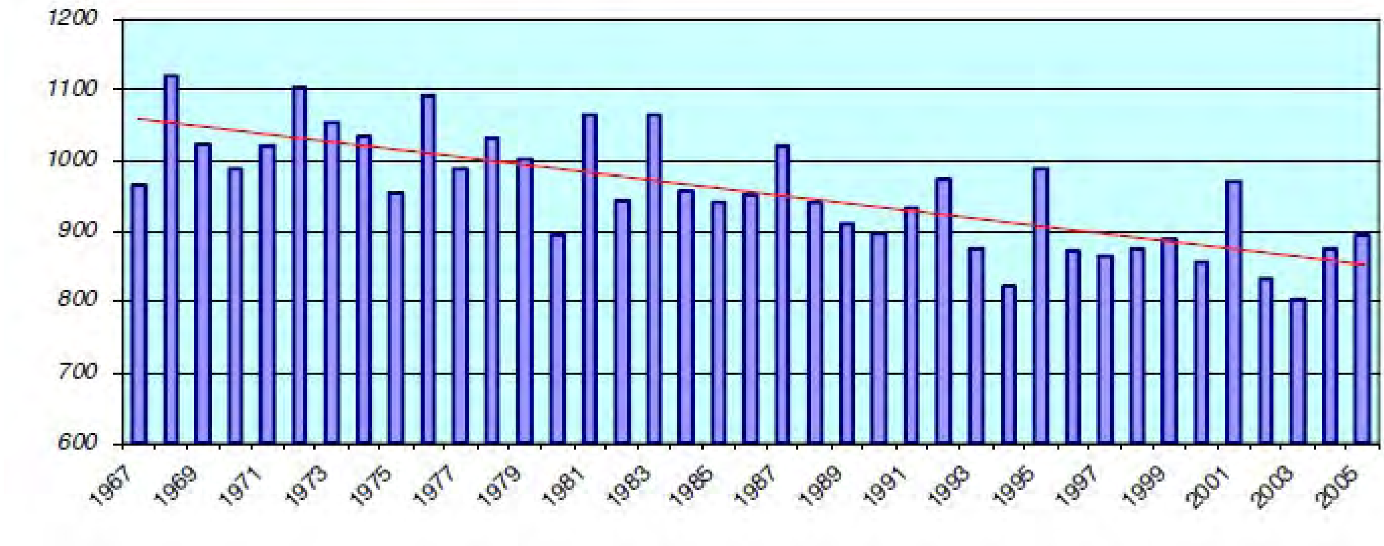
The SBR hosts several hill lakes, which are used to supply water for various ecological activities such as: firefighting, reforestation, and irrigation. Most of the hill lakes are located in the southern section of the SBR with a few to the east of Ain Zhalta. These hill lakes are mostly in the areas without springs and wells (Antea Group, 2017).

2.2 Climate Change in Literature

Lebanon's climate is shaped by its location on the eastern coast of the Mediterranean Sea and its unique topography. It is characterized with four distinct seasons, where precipitation occur between October and March while June to September form the dry season. The Atlas Climatique du Liban divides the country into three broad climatic trends: the coastal, the mountainous and the inland, further divided into eight geo-climatic zones.

Generally, the coastal and western side of the Lebanon mountain range exhibit maritime characteristics while the eastern side is more continental thus drier. The project area falls in two geoclimatic zones: the Central Mountain and Interior Litani. Annual precipitation averages vary between the different climatic zones, ranging between 600 mm and 800 mm on the coastal plain, 1000 mm to 1400 mm in Mount Lebanon (however, precipitation can reach up to 2000 mm annually), 200 mm to 600 mm in northern Bekaa and 600 mm to 1000mm in southern Bekaa (Farajalla et al., 2014).

Over the last decades, the world has been witnessing unusual and more frequent extreme weather events, an increase of +0.6°C in average global temperature, a decrease of the snow-cover worldwide of about 10%, and a mean sea water level rise of 10 to 20 cm, etc. Even though in some regions the precipitation trends are not experiencing an increase or decrease in averages, the changes in distribution and variability are potentially significant and detrimental (Shaban, 2009) (Dar Al Handasah, 2014).In Lebanon, the precipitation average has been relatively stable over a period of 130 years, however the major trend is descending and the first decline in precipitation started in the early 1980s (**Figure 2-2**). Furthermore, during the past years, rainfall has decreased both in the number of precipitation events and overall annual precipitation depth (mm). In 2013-2014, rainfall in Lebanon was one of the lowest compared to the annual national average, and although data was still within the normal precipitation variation range, the recent occurrences have given an indication of a looming water crisis in the near future (Farajalla, 2016). The Intergovernmental Panel on Climate Change (IPCC) assessment report of 2013 states that the frequency and intensity of drought in the Mediterranean region will likely increase into the early and late 21st century (Farajalla et al., 2014).



F igure 2-2 The General Trend of Precipitation Rate in Lebanon between 1967 and 2006 (Farajalla, 2016)

According to Lebanon's Third National Communication to the UNFCCC (MoE, 2016), analysis of historical climatic records of Lebanon from the early 20th century with future emissions trajectories indicates a temperature increase of 1.7°C by mid-century and up to 3.2°C by 2100 and a decrease in precipitation of 4 to 11% with drier conditions by the end of the century. Lebanon's Second National Communication to the UNFCCC, states that a reduction of 6 to 8% of the total volume of water resources is expected with an increase of 1°C and 12 to 16% for an increase of 2°C. In addition, a decline in total and active precipitation is forecasted as well as a shift in rainfall consisting of higher precipitation in November and December, and a steep reduction from January onward (MoE, 2011).

Analysis done by Antea Group on data for precipitation in Beirut showed that:

- December has a global decreasing trend (approximately 0.75 mm per year) over a period of 100 years.
- Since 1929, the month of February shows a decreasing trend of 1.14 mm/year
- October and November seem to show an increasing trend between 0.9 mm/year (October) and 2.26 mm/year (November) since 1950 to 1955 (Antea Group, 2017).

With about 60 to 65% mountainous terrain, Lebanon receives a considerable amount of snow that covers approximately 25% of its area above 1200 m ASL. The snow cover reaches its highest in March, and the precipitation in the form of snow constitute one third of the average yearly precipitation (ELARD, 2010). However, analysis of satellite imagery for different dates shows a noticeable decrease in the area of snow cover accompanied with a decrease in the residence time of snow (Shaban, 2009). Lebanon's Second National Communication to the UNFCCC states that: climate change is expected to induce a reduction of 40% of the snow cover of Lebanon with an increase of 2°C in temperature and will reach 70% decrease in snow cover with an increase of 4°C. Additionally, snow fall will shift from 1,500 m to 1,700 m by 2050 and to 1,900 m by 2090, affecting the recharge of most springs.

"The decrease in snow cover will have adverse impacts on rivers and groundwater recharge, especially that snowmelt will occur in early spring, which does not coincide with high demand for irrigation water such as the summer season. The change in rainfall regimes will increase the manifestation of extreme events: winter floods can increase up to 30% in frequency, and hot summer days and tropical nights can last at least two months longer. This combination of significantly less wet and substantially warmer conditions will result in an extended hot and dry climate and in an intensification of the temperature extremes".

Moreover, as Cedrus libani is highlighted as one of the most vulnerable species to climate change in Lebanon and because the core area of the SBR is mainly composed of cedar forests, it is expected that this nature reserve will be severely impacted by climate change (MoE, 2011).

2.3 Adaptation and Mitigation Measures in Literature

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation and mitigation measures as the following:

- "A Mitigation Measure is an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases in order to permanently eliminate, or reduce the long-term risk of climate change to human life and property".
- "An Adaptation Measure is an adjustment in natural or human systems to a new or changing environment, in response to actual or expected climatic stimuli or their effects. Types of adaptations include: anticipatory, reactive, private, public, autonomous and planned."

In general, mitigation measures include: (i) the use of renewable energies to reduce the consumption of fossil fuels, (ii) reforestation and afforestation, (iii) the reduction of the carbon footprint, (iv) the reduction of water pollution sources, and (v) efficient management of available water and water sources.
Adaptation measures to climate change are various; the following presents adaptation technology options in the water sector suitable for implementation in the SBR.

2.3.1 Rainwater Harvesting

Rainwater harvesting is an adaptive strategy to climate change, mainly for areas with high rainfall variability. This technology includes any method that collects rainwater into a container in an organized fashion (Rainwater Harvesting Guide, 2017). Rainwater harvesting presents several advantages, namely: it reduces the demand and consumption of groundwater, provides an alternative water source in the dry season, reduces the vulnerability of agriculture and population to climate change, and reduces flooding, sewer overflowing and soil erosion by reducing water runoff (CEF, 2017).
Rainwater harvesting systems consist of three principal components: the catchment area, the collection device, and the conveyance system. These systems can be classified according to the catchment area and collection device types.

2.3.1.1 Rainwater Harvesting from a Land Surface or Rock Catchment

Land surface catchment areas are basin shaped areas, bounded by natural features such as hills or mountains, which guide water flows into streams, rivers, and wetlands. Rainwater harvesting from a land surface collects the water and stores it in hill lakes or ponds.

2.3.1.2 Rainwater Harvesting from Hill Lakes or Earth Lakes

Rainwater harvesting from hill lakes consists of storing rainwater in excavated lakes for agricultural or domestic use. The key prerequisites for the construction of a hill lake are topography, geological conditions, and the amount of precipitation in the area. Moreover, if the hill lake is located on permeable soil, a clay layer or impermeable membrane should be installed to ensure the retention of water (MoE/URC/GEF, 2012).

2.3.1.3 Rainwater Harvesting in Ponds (Birki)

The collection devices in this technique are typically earthen reservoirs surrounded by stone and cement walls, referred to locally as “Birki”. The ponds are usually installed in naturally low-lying areas surrounded by a gentle slope, which enables the collection of naturally flowing water (Hayek, 2009).

2.3.1.4 Rainwater Harvesting from Ground or Roads (RWHR)

Rainwater harvesting from ground surface is achieved by capturing water runoff from roads; and storing it in a reservoir below the surface (MoE/URC/GEF, 2012).

2.3.1.5 Rainwater Harvesting from Rooftops

Rainwater harvesting from rooftops has been used all over Lebanon and the Shouf area since ancient times. In this technology, the rooftop of a building, whether inclined or flat, is designed in a manner that enables water to drain toward a collection system and be directed to a storage tank (Hayek, 2009). At the beginning of a rainstorm, materials deposited on rooftops which contaminate the water are washed off, and the contaminated water is typically diverted from the storage tank by a first-flush device. The Ministry of Energy and Water (MoEW) has officially issued "The National Guideline for Rainwater Harvesting Systems" as part of the National Water Sector Strategy of 2010 on 23 March 2018. The document includes detailed guidelines as well as technical and commercial information related to the sizing and implementation of rainwater harvesting systems from rooftops for rural and urban areas. The guideline mainly targets domestic applications and external uses (MoEW/UNDP, 2016).

2.3.2 Efficient Water Use Irrigation System (EWUIS)

Efficient water use irrigation systems are a combination of several hard technologies (drip irrigation, micro-sprinkler, etc.) and soft technologies (models for plant water needs) that apply water directly to the root zone of the plant when needed, thereby reducing water evaporation and percolation. The advantages of EWUIS include: (i) higher production yields, (ii) increased resilience to climate change, and (iii) increased profit for farmers. This technology can be applied to all the crops grown in Lebanon, however, institutional and organizational arrangements for such systems are needed (MoE/URC/GEF, 2012).

2.3.3 Micro Dams along River Channels to Convey Water in Irrigation Canals

The construction of micro dams along river channels improves surface water exploitation, and provides a sustainable source for irrigation of agricultural lands on river banks and in the surrounding areas.

2.3.4 Use of Treated Wastewater in Irrigation (UTWWI)

UTWWI consists of a model or protocol that aims at reusing treated wastewater in irrigation through ensuring sufficient water supply for the plants without negatively affecting human health or the environment. This technology increases water availability while avoiding the pollution of aquifers. UTWWI is a combination of crop selection, irrigation methods, and appropriate management practices. The wastewater treatment sector in Lebanon is facing organizational and institutional challenges, including the absence of laws and regulations, financial mechanisms to sustain operating treatment plants and the non-acceptance of the communities including some farmers to use treated wastewater for irrigation of their crops. (MoE/URC/GEF, 2012).

2.3.5 Early Warning System for Water Supply Management (River Flow) Through Snowpack Monitoring (EWS-SPM)

Snow cover is the main source that feeds and replenishes rivers and groundwater; and the yearly variations in snow cover have a direct impact on the water supply. EWS-SPM aims at providing an early warning system for water supply management, by developing a model that predicts stream flow variation based on snow cover in the river basin, therefore increasing the readiness to deal with climate uncertainty by predicting water supply and developing water safety plans. This technology benefits water authorities and water users, and indirectly affects optimal use of available water resources for all sectors. (MoE/URC/GEF, 2012).

2.3.6 Recycling of Graywater in Public Buildings and Facilities

Greywater is wastewater generated from domestic activities such as laundry, dishwashing and bathing which can be recycled on-site. Recycled greywater of this kind is never safe to drink, but following several phases of filtration and microbial digestion, it can be used to provide water for washing, flushing toilets or garden irrigation. If collected using a separate plumbing system from blackwater, domestic greywater can be recycled directly within the home, garden or company and used either immediately or processed and stored (Manez, 2014).

2.3.7 Water Distribution Improvement

Water distribution improvement consists mainly of controlling water leakage from extensive and aging municipal water distribution systems. This is one of the main causes of water loss, but can also pose a risk to public health by allowing contaminants to enter the pipe system through leak openings. Age, but also a high system pressure, corrosion, winter temperatures, poor quality of joints or ground conditions, can be among the causes of leakage in the water distribution system (Manez, 2014).

2.3.8 Upgrading Storm water and Combined Storm water and Sewage Systems

The increase in frequency and intensity of heavy rainfall events related to climate change overloads the capacity of storm water and sewer systems, resulting in overflow and storm runoff, and increasing water pollution from sediments, nutrients, pathogens, and other pollutants.

2.3.9 Restoration of Old Terraces

The study area includes several locations where old agricultural terraces have been abandoned. The restoration of these terraces reduces water runoff, and allows a better replenishment of underground reservoirs. Moreover, this technology allows a better retention of nutrients in the soil, which improves agricultural yields.

2.3.10 Water Users' Association (WUA)

A WUA consists of a group of individuals formally and voluntarily associated, and whose purpose is to share, manage and conserve a common water resource. The main activity of a WUA is to operate the waterworks and monitor the allocation of water among the members. This organizational "technology" allows the optimal use of irrigation systems resulting in optimal yields (MoE/URC/GEF, 2012).

2.4 Identified Obstacles to Implementation of Adaptation Measures

According to an assessment on updating the national adaptation plan to climate change in the water sector conducted under CapWater project (funded by the World Bank and implemented by the CNRS), several obstacles have been identified that prevented the implementation of previous adaptation measures within the water sector. These obstacles, presented in **Table 2-2**, are expected to influence current or future attempts to adapt to climate change within the water sector.

2.5 Conclusion on Literature Review

The studies reviewed as part of this project show that the SBR is rich in surface water and groundwater resources. However, a reduction in water resources is expected due to the observed and projected changes in climatic patterns including rising temperatures, decreased precipitation, increased drought periods and decrease in snow cover and residence time. Therefore, adaptation measures are needed to improve the management of water resources to overcome the up-coming challenges. Numerous adaptation technologies (described in section 2.3) were found to be applicable to various extents within the SBR, taking into account obstacles that have impeded implementation of such measures on a national scale.

Table 2-2 Classification of Identified Obstacles to Implementation of Adaptation Measures

Barrier	Description	Influence	Measures to overcome
Institutional and policy options	Understaffing of the MoEW leading to poor implementation and follow up of relevant strategies and policies	High	Vacant positions in MoEW filled with skilled individuals.
	Lack of coordination between ministries on key water issues and common priorities	High	Activate communication mechanisms such as inter-ministerial committees and mainstream nexus approaches between interlinked sectors.
	Tariffs policies of flat rates have long discouraged conservation measures	High	Speed up the implementation of the new tariffs measures proposed by the MoEW.
	Minimal success in limiting illegal groundwater abstraction	High	Impose stricter control of wells, increase staffing within water establishments and build the capacity of staff on monitoring of unlicensed wells. Operationalize cooperation mechanisms established with the internal security forces to speed up closure of illegal wells.
	Lack of standards on wastewater reuse	Medium	Establish standards for wastewater reuse using regional standards as a baseline
	Lack of localized management of water resources	Medium	Establish water user's association.
Technical	Lack of centralized data systems and poor maintenance of water monitoring systems	High	Establish one centralized entity for water data collection, management and analysis. The entity will be also responsible for long term monitoring of water systems such as rivers, wells and so on. Human resources and financial resources need to be secured in addition to the pertinent infrastructure.
	Poor knowledge of Integrated Water Resources Management (IWRM)	High	Build capacity of key technical staff on IWRM across basins and their implications at the local levels.
	Insufficient experience with wastewater, grey water, groundwater recharge and storm water reuse (IWRM)	High	Build the capacities of key staff and establish efficient cooperation mechanisms with research institutions. Cooperate with regional and international partners with relevant experience. Use the results of the technology needs assessment where relevant.
Financial	Financial constraints	High	Solicit international donor agencies for support. As for sector priorities, given the enormous capital investments required, the government needs to secure funds from its own budget or ask for loans from funding institutions such as the World Bank. One option that remains to be explored is the public-private financing mechanisms.
Social	Lack of awareness of water conservation measures	M/H	Impose new tariffs to encourage behavioral changes. Increase awareness campaigns.
Political	Political instability, border conflicts, refugee crises	High	Political factors go beyond any action plan but certainly affect it. However, a clear action plan is formed of several phases, some of which can still function in the midst of conflicts and instability such as: capacity building activities, increased awareness campaigns on water conservation measures and so on

Source: Adapted from CNRS, 2015

ANALYSIS OF METEOROLOGICAL DATA AND RELATED PATTERNS

3 ANALYSIS OF METEOROLOGICAL DATA AND RELATED PATTERNS

This chapter presents and analyzes available historical and recent meteorological data in and around the Shouf Biosphere Reserve (SBR). The climatic parameters addressed as part of this assessment include precipitation (rain and snow), temperature, humidity, cloudiness, solar irradiance and wind.

Historical weather data were collected from the Atlas Climatique du Liban (MoPWT, 1966), while recent data was retrieved from LARI weather stations as well as online sources. It should be noted that for analysis purposes, data from locally installed and operated weather stations is considered as more accurate and reliable compared to data available from online sources. Online precipitation data was reviewed and analyzed, and certain variations were observed, which at times were considerable compared to data from the LARI weather stations, therefore the latter were used for the benefit of this study. However, online data was used to analyze other parameters such as humidity, temperature, wind and solar irradiance and nebulosity.

In summary, data analysis compares historical monthly average values to recent ones in the same (or similar) locations and individual parameter values on a monthly and annual basis using recent data, and assesses annual variations in recent data.

3.1 Presentation and Analysis of Meteorological Data

3.1.1 Precipitation

3.1.1.1 Historical Data

Historical data for precipitation in the Shouf Biosphere Reserve were retrieved from the Atlas Climatique du Liban (MoPWT, 1966). Five weather stations (listed in **Table 3-1**) were selected based on their locations, such that the village or town housing the station is either completely or partially located within the SBR. These stations would best reflect historical precipitation patterns within the SBR.

The earliest readings date back to 1939 at the Machghara station while the last recorded readings were done in 1970 in all 5 stations. The longest consecutive recording spans 32 years (Machghara), while the shortest spans 6 years (Jbaa). The year range and duration of data recording for each station are presented in **Table 3-1**.
Average monthly precipitation recordings in each station as well as total annual precipitation are listed in **Table 3-2**, and presented in **Figure 3-1**

Considering monthly average precipitation values presented in Jbaa, Ain Zhalta, Kherbet Qanafar, Ammiq and Machghara, the overall annual precipitation trend is fairly consistent, following a general annual curve. Precipitation values are the highest in January, December and February, typically in that order. The summer months of July and August are mostly devoid of precipitation.

The spatial variations in precipitation can be clearly noted, mainly in the months of January, March and April. Precipitation amounts and distribution are generally a function of the climatic zone where the weather station is located, its altitude and whether it lies on the northern or southern part of the SBR. In fact, the Eastern slope or the interior flank of the Mount Lebanon mountainous range seems to exhibit less rainfall (Interior Litani climatic zone), while the Western slope including Jbaa and Ain Zhalta (Central Mountainous climatic zone) has comparably more precipitation[1]. Within the Western slope, northern stations recorded more rainfall than those in the South. On the Eastern slope, the station of Machghara received more precipitation than Ammiq, most likely due to its higher elevation.

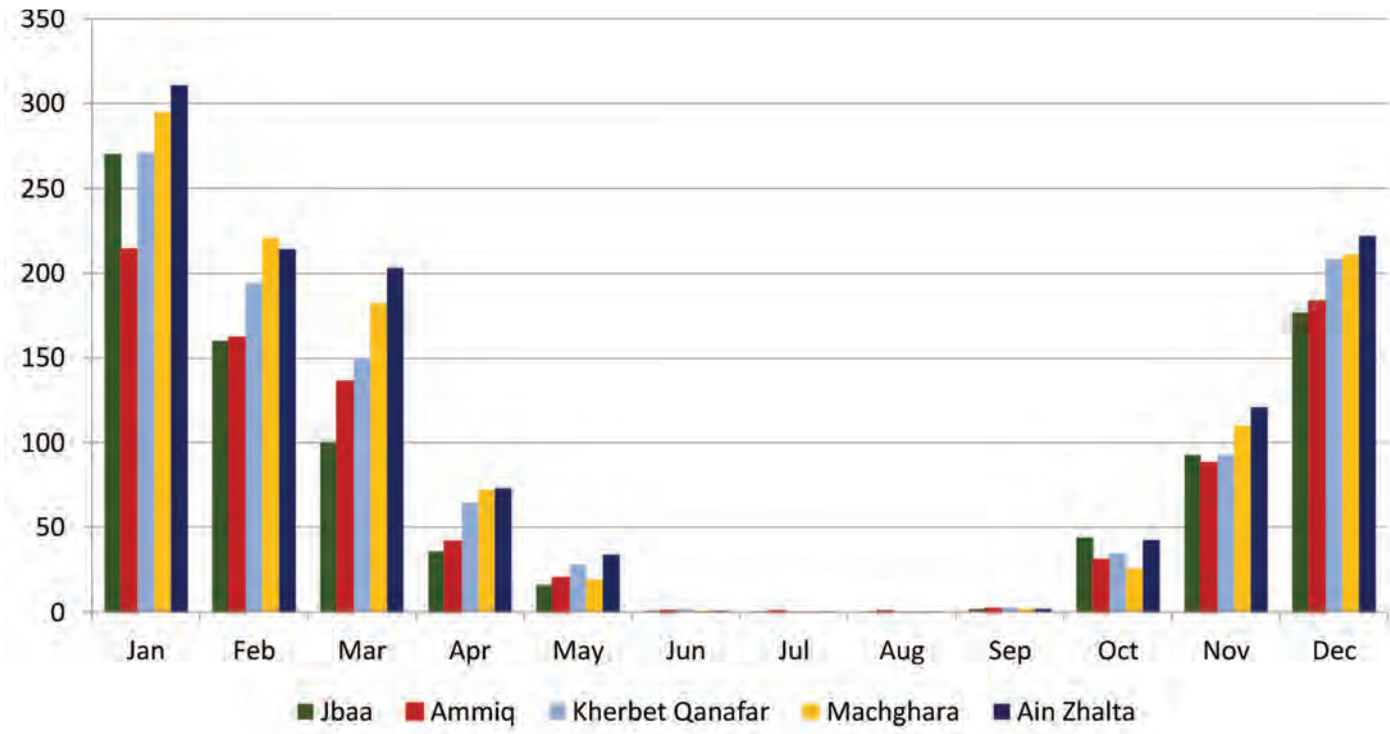
Table 3-1 Data Measurement Duration (Years) at the F ive Selected Weather Stations in the Shouf Biosphere Reserve (MoPWT, 1966)

Location	Period	Number of Years	Elevation (m ASL)
Jbaa	1965-1970	6	800
Ammiq	1962-1970	9	870
Kherbet Qanafar	1956-1970	15	940
Machghara	1939-1970	32	1,070
Ain Zhalta	1940-1970	30	1,080

Table 3-2 Average Monthly and Annual Precipitation Values (mm) at F ive Weather Stations in the Shouf Biosphere Reserve (MoPWT, 1966)

Precipitation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Jbaa	270	160	100	36	16	1	0.5	0.5	2	44	93	177	900
Ammiq	214	162	136	42	20	1	0.5	0.5	2	31	88	183	880
Kherbet Qanafar	271	194	150	65	28	2	0.5	0.5	3	35	93	208	1,050
Machghara	295	221	182	72	19	1	0.5	0.5	2	26	110	211	1,140
Ain Zhalta	311	214	203	73	34	1	0.5	0.5	2	43	121	222	1,225

[1]:In this report, the geoclimatic zones were adopted from the "National Action Plan to Combat Desertification", developed by the Ministry of Agriculture of Lebanon, dated June 2003.



F igure 3-1 Monthly Average Precipitation (mm) in Jbaa, Ain Zhalta, Kherbet Qanafar, Ammiq and Machghara (MoPWT, 1966)

3.1.1.2 Recent Data

i. Total Precipitation

Recent precipitation data covering the period between 2010 and 2016 was collected from the Machghara and Barouk LARI stations. Unlike the case of Machghara, historical data for Barouk is not available. However, its proximity to Ain Zhalta, as well as their similar altitudes and location in the same geoclimatic zone and on the same side of the mountain range makes the comparison between Ain Zhalta's historical data (1940-1970) and Barouk's recent data (2010-2016) reasonable.

The examination of collected data shows that the yearly total precipitation varies significantly between consecutive years in both Barouk and Machghara. For example, in Machghara, precipitation decreased almost by half between 2012 and 2013, and increased by almost 145% between 2014 and 2015 and 136% between 2015 and 2016. The yearly variation in the amount of precipitation is coupled with a variation in the number of days per month experiencing precipitation events at both locations. For example, the number of rainy days in January varies between 8 and 22 in Barouk, and between 6 and 23 in Machghara (WWO, 2017). The total number of precipitation days per year is varying as well (WWO, 2017). Moreover, the number of precipitation days for the same month varies between the two locations. For example, January 2009 had 16 precipitation days in Barouk but only 9 in Machghara, which highlights the spatial variation in precipitation distribution within the SBR. On average, Barouk witnesses more rainy days than Machghara, with an average difference of one day per month (WWO, 2017).

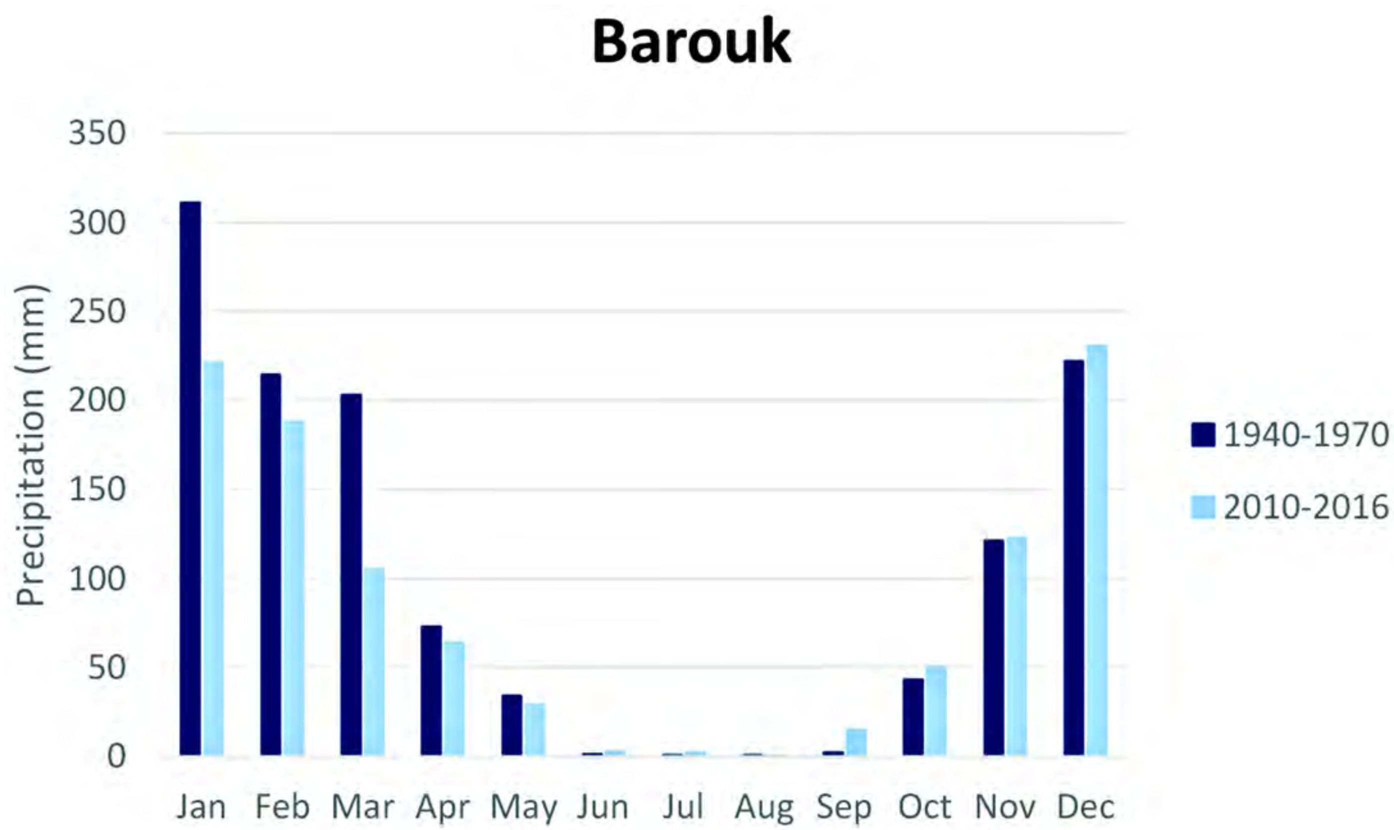


Figure 3-2 Historical (1940-1970) (MoPWT, 1966) and Recent (2010-2016) Average Precipitation in Barouk (LARI, 2017)

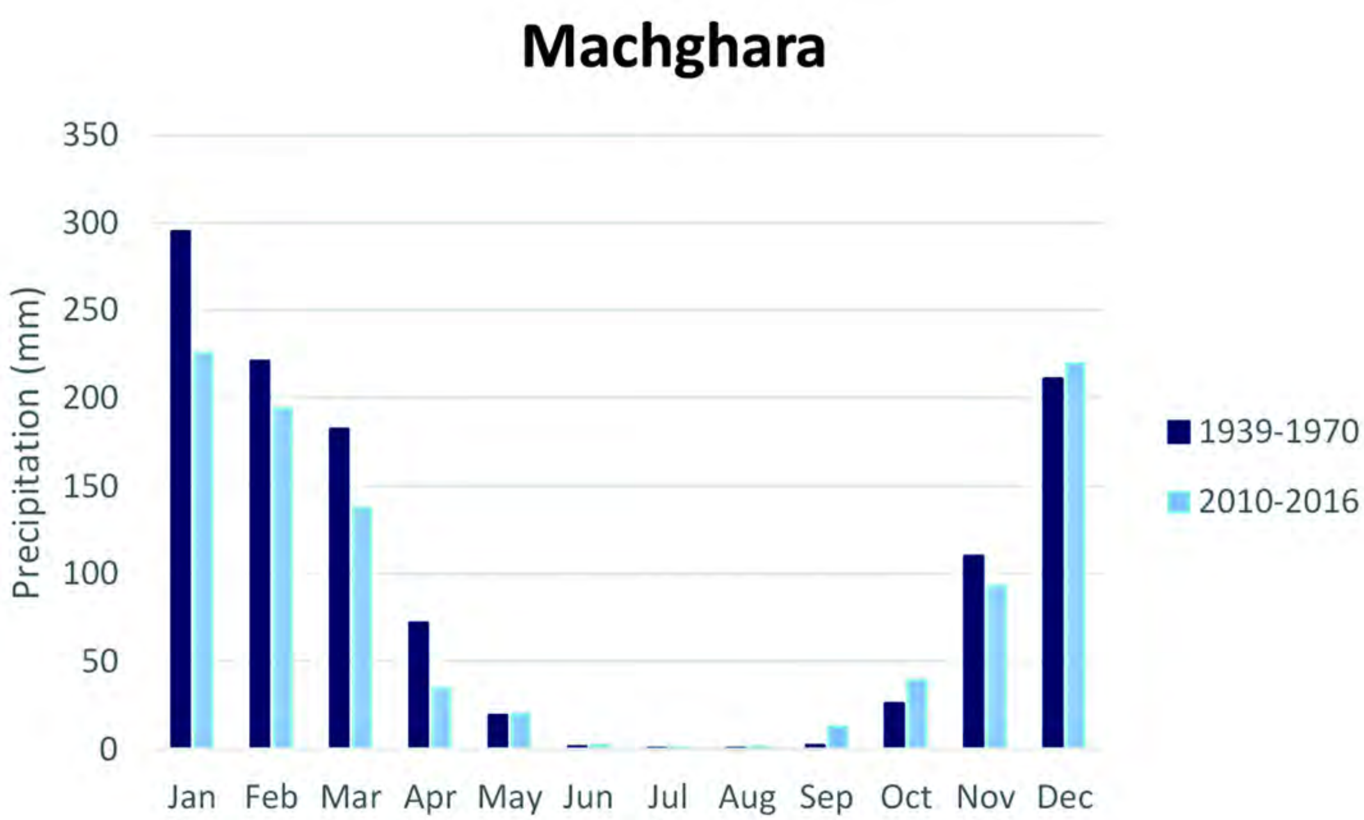


Figure 3 3 Historical (1939-1970) (MoPWT, 1966) and Recent (2010-2016) Average Precipitation at Machghara (LARI, 2017).

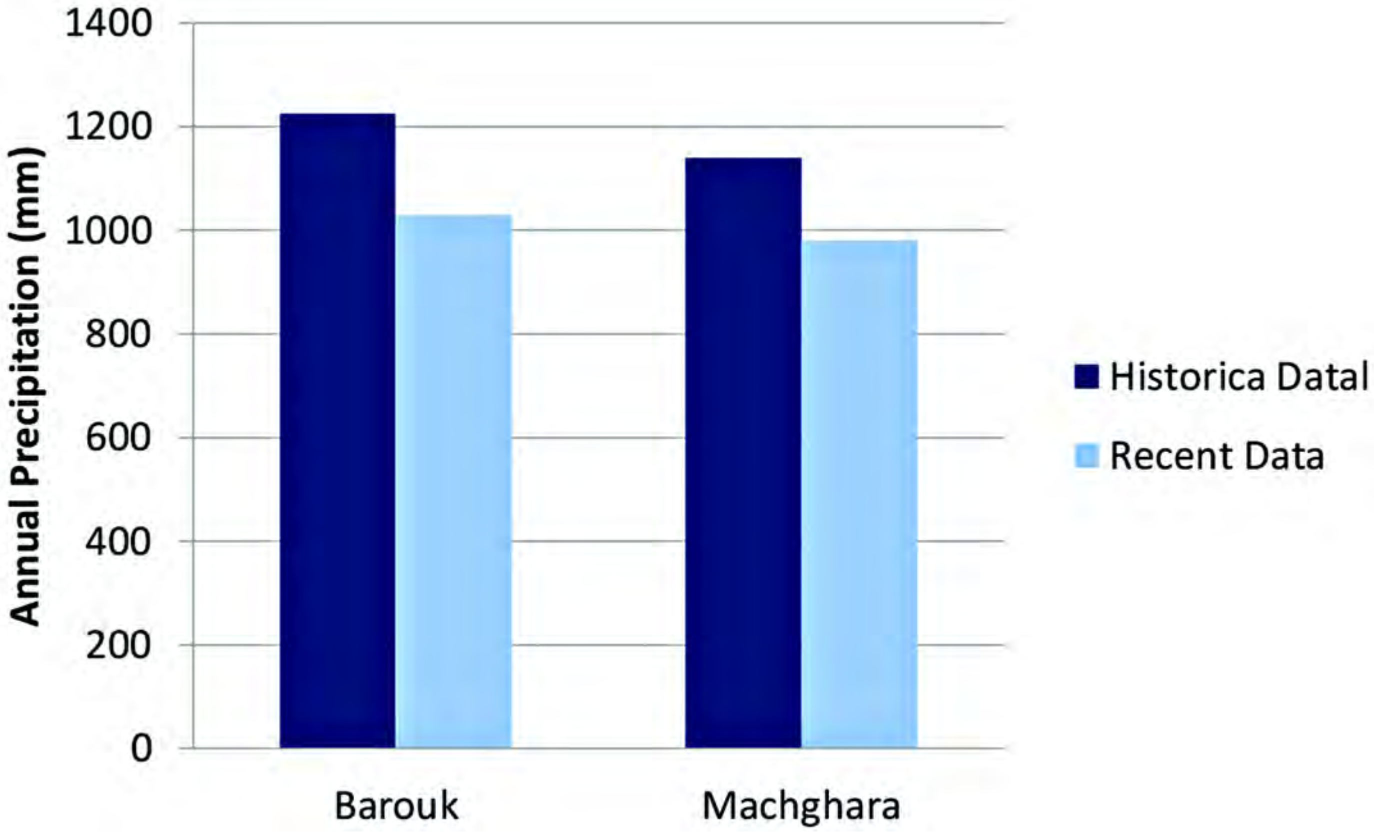


Figure 3-4 Historical (1939-1970)(MoPWT, 1966) and Recent (2010-2016) Total Annual Precipitation in Barouk and Machghara (mm)(LARI, 2017)

Figure 3-5 Variation of Annual Precipitation in Barouk and Machghara (2010 to 2016) (LARI, 2017)

ii. Monthly and Annual Precipitation Distribution in Machghara

Monthly precipitation data recorded at the Machghara weather station within the SBR area for the years 2010 to 2016, summarized in **Figure 3-6**, show inter-annual fluctuation with large variations between individual years. Precipitation in 2013, 2014 and 2016 is inconsistent, with large deviations from mean precipitation values and the historical annual curve. Intense or concentrated precipitation events within certain months coupled with drastic decreases in others and variations in total annual precipitation are reflected in the monthly precipitation data. The shift in precipitation patterns from 2010 to 2016 could indicate a trend of early precipitation, shifting the wet season to fall and prolonging the dry period.

Moreover, the comparison of recent precipitation averages (2010 to 2016) to historical ones in Machghara (1939-1973) shows a decrease in total annual precipitation. Not accounting for annual variations, the annual average in Machghara has dropped by 14%, from 1,140 to about 980 mm. Combined with a seasonal re-distribution of precipitation and a large inter-annual variation in total precipitation, the impact of this decrease is significant, as evidenced by drastic water shortages in recent years. The annual deviation from the average total precipitation can be seen in **Figure 3-7**.

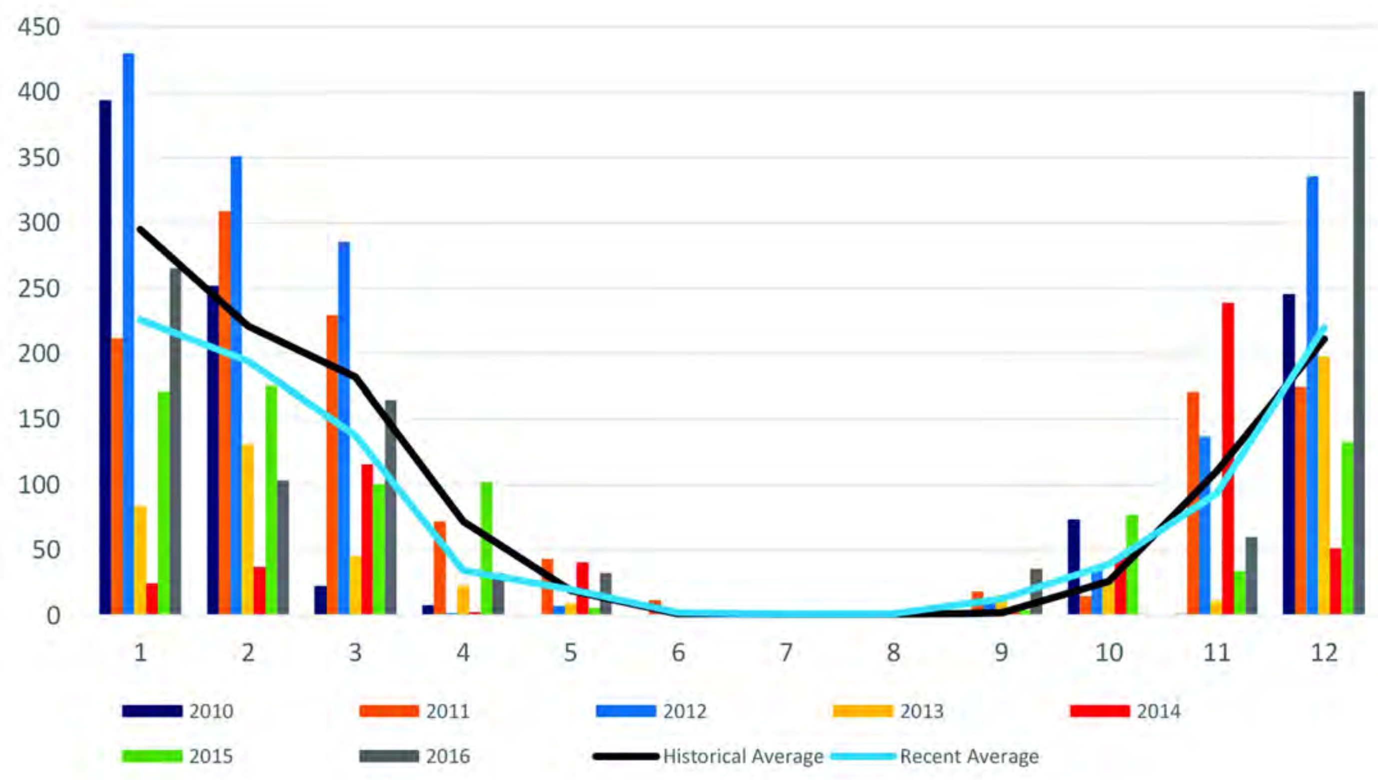


Figure 3-6 Monthly Precipitation (mm) for the Years 2010 to 2016, and Average Recent (2010 to 2016) and Historical (1939 – 1970) Precipitation (mm) in Machghara (LARI, 2017) (MoPWT, 1966)

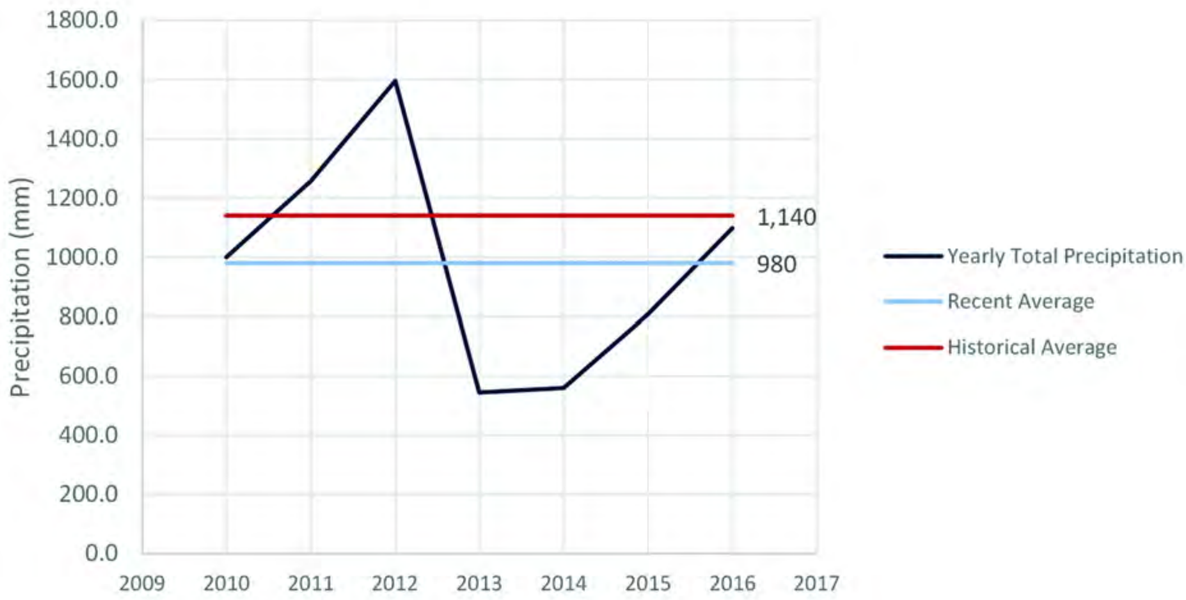


Figure 3-7 Yearly Total Precipitation (mm) for the Years 2010 to 2016 in Machghara (LARI, 2017) (MoPWT, 1966)

iii. Precipitation in the Form of Snow

With regards to precipitation in the form of snow, the average number of snow days in Ain Zhalta and Machghara per year is 15 and 3 days respectively, between December and March (WWO, 2017).

In the period 2009 to 2016, the highest amount of snow received in Ain Zhalta was in 2015 with a total of 29 snow days and 134.5 cm accumulation in 11 days in the month of February; the least amount was recorded in 2014 with 7.4 cm that fell within 1 day (WWO, 2017).

Based on recent data, large fluctuations in snowfall are evident in Ain Zhalta, whereby annual snowfall days range from 1 day in 2014 to 29 days in 2015, noting that these values are from two consecutive years. The average annual snowfall days in Ain Zhalta is 15 days between 2009 and 2016, thus making the recorded variations on the lower (1 and 5 days) and upper (26 and 29 days) end also highly deviating from the norm. Such variations could have significant impacts, since snow cover is considered as an important water replenishment source for groundwater and surface water alike. These fluctuations are shown in **Figure 3-8** below.

Figure 3-8 Annual Snowfall (cm) in Ain Zhalta Between 2009 and 2016 (WWO, 2017)

3.1.1.3 Analysis and Interpretation

The historical data (1939-1970) show a total average annual precipitation ranging from 880 mm in Ammiq (Elevation 800 m; 9 years of recordings), to 1,225 mm in Ain Zhalta (Elevation 1,080 m; 30 years of recordings). The dry season spanned from June (1 mm/month) to September (2-3 mm/month), ending in October with monthly rainfall of 26 to 44 mm. The month witnessing the highest precipitation was January (214-311 mm/month), followed by December (177-222 mm/month) and February (162-221 mm/month).

Comparing historical values (up to 1970) with those of more recent years (up to 2016) from data presented in **Figure 3-2**, **Figure 3-3** and **Figure 3-4**, a decrease in total precipitation is observed. Recorded precipitation values in recent years, particularly in the Barouk and Machghara stations, show a decrease in overall precipitation compared to historical values, as well as an increase in fluctuations or inter-annual precipitation differences, however the annual precipitation curves remain consistent.
In addition to an interpretation of long-term changes, looking at the variation in average annual precipitation in the last 7 years in Barouk and Machghara, shown in **Figure 3-5**, a sharp decline in precipitation is noted from 2012 to 2016. This decline would suggest that the majority of the decrease occurred more recently and quickly, rather than over a long period of time. Based on the presented data, annual precipitation has decreased by 14% in Barouk and 16% in Machghara.

Despite the indications of historical data, and as reflected in the precipitation data analysis herein, water availability data, from rainfall quantities to groundwater replenishment, has changed in the past years.

Observations regarding precipitation trends can be noted in Machghara from **Figure 3-6**, including (a) inter-annual fluctuations that are more apparent in recent years, (b) monthly precipitation shifts and large deviations from the average, whether older or more recent average values, (c) a notable difference between historical and recent precipitation values, and (d) a backwards shift or early rainfall in more recent years with more rainfall in the fall and early winter coupled with an overall decrease in annual precipitation.

The same analysis was performed for precipitation in Barouk, and similar results were found, namely: (a) inter-annual fluctuation in precipitation with noticeable variations between individual years, (b) annual precipitation with large deviations from mean precipitation values and the historical annual curve are observed, (c) concentrated precipitation values within certain months coupled with substantial decreases in others and variations in total annual precipitation, (d) the precipitation data from 2010 to 2016 indicates a shift of the wet season to fall and a longer dry period.

3.1.1.4 Seasonal Precipitation

The seasonal distribution of precipitation in the last 7 years compared to the historical average for Machghara are presented in **Figure 3-9** through **Figure 3-12**. Seasonal variations in precipitation show that summers are consistently dry (0.0 to 1.0 % of total annual rainfall) and although the fraction (%) of precipitation in the spring season has been increasing between 2010 and 2016, the average has dropped from 25.3% to 21.5% in the past 50+ years.

On the other hand, precipitation in autumn has increased from 13.6% to 18.3%, with individual annual values as high as 41.5%, 22.3% and 22.1% in 2014, 2012 and 2011 respectively.

The average precipitation share of the winter season from total precipitation remains somehow the same between 59.9% and 61.0%, with inter-annual variations in recent years of 88.6%, 75.3% and 36.1% in 2010, 2013 and 2014 respectively.

3.1.1.5 Intensity Analysis

Using Machghara and Barouk weather stations data, the breakdown of precipitation events by intensity was divided into 5 categories: 0 mm, 0.1 to 1.0 mm, 1.1 to 10 mm, 10.1 to 20 m, 20.1 to 50 mm and 50.1 mm and above. This breakdown, as presented per annum from 2010 to 2016, shows an increase in extreme events, specifically those exceeding 50.1 mm and 20.1-50 mm of precipitation per day. The occurrence of such precipitation events typically leads to large quantities of runoff storm water, less groundwater replenishment and soil saturation. Such an effect would be more severe in areas with covered topsoil (concrete, asphalt, etc.), sloped areas and/or those with loose topsoil with little vegetation or root systems to capture rainwater.

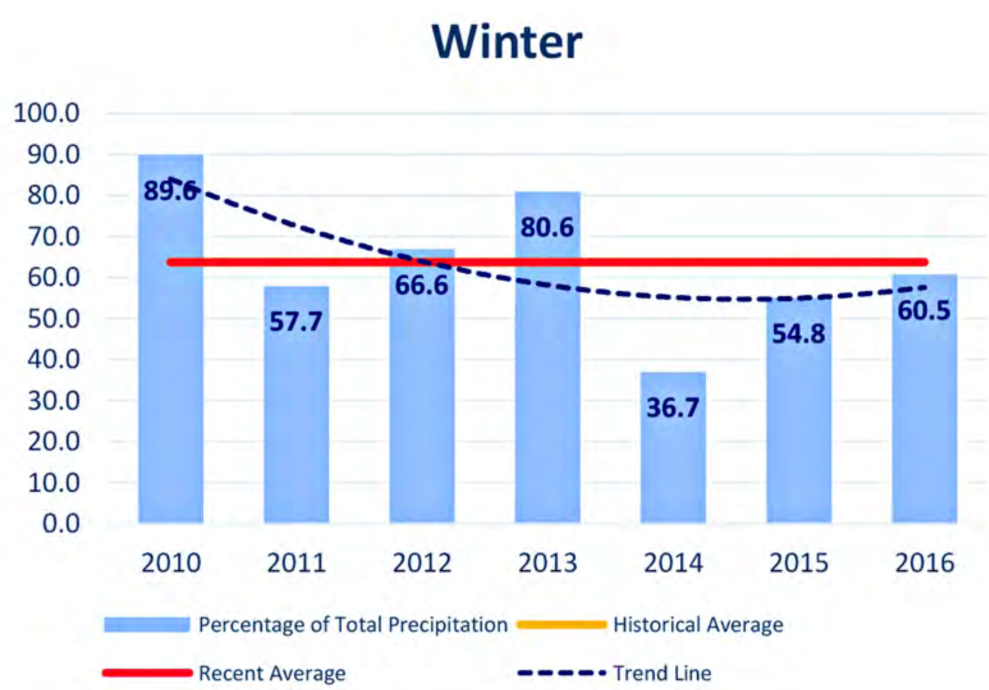


Figure 3-9 Percentage of Precipitation (%) in the Winter Season in Machghara (LARI, 2017) (MoPWT, 1966)

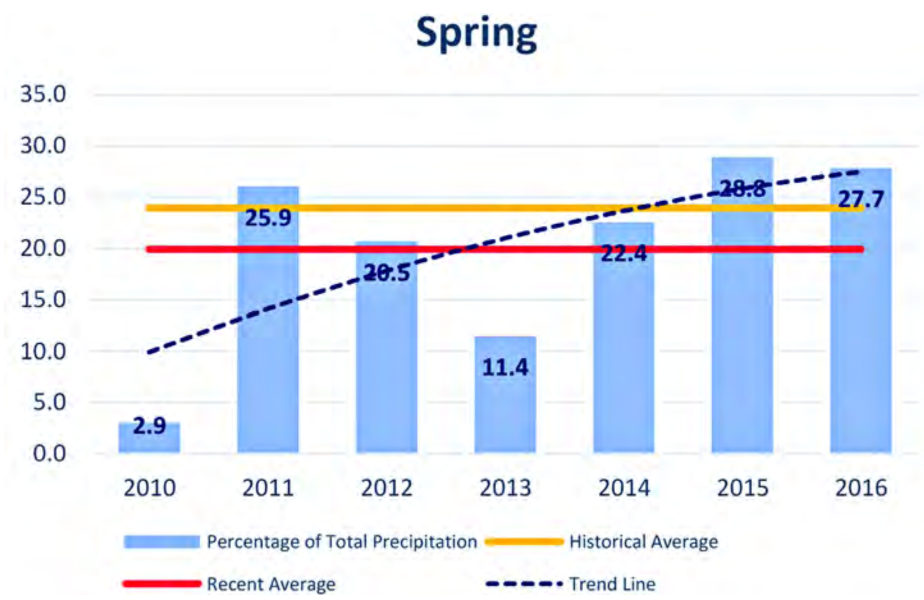


Figure 3-10 Percentage of Precipitation (%) in the Spring Season in Machghara (LARI, 2017) (MoPWT, 1966)

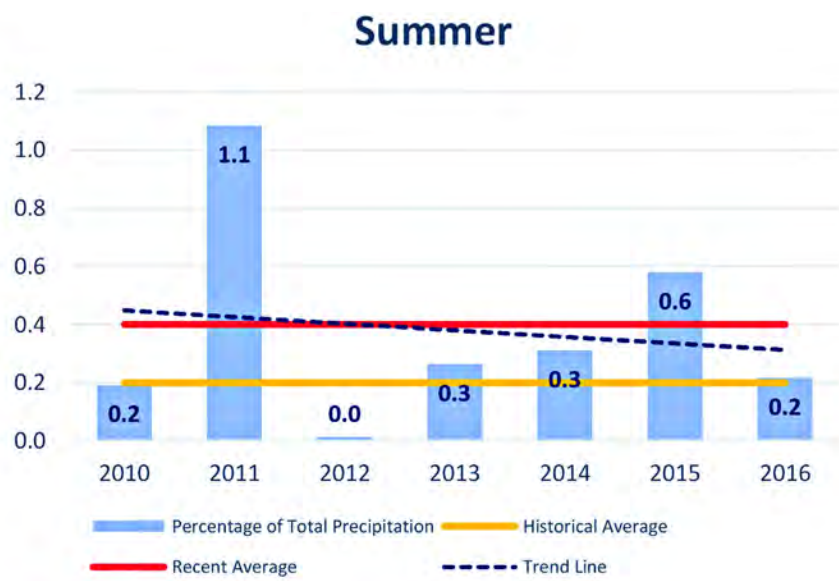


Figure 3-11 Percentage of Precipitation (%) in the Spring Season in Machghara (LARI, 2017) (MoPWT, 1966)

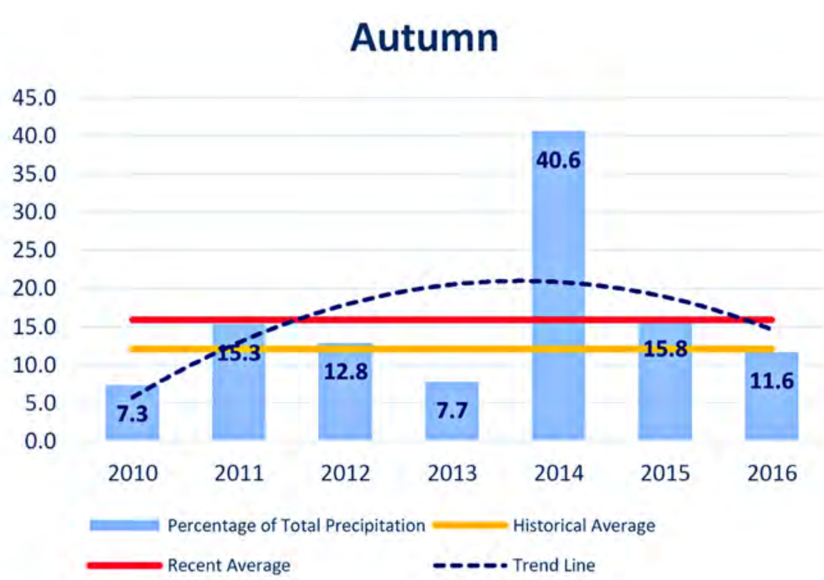


Figure 3-12 Percentage of Precipitation (%) in the Autumn Season in Machghara (LARI, 2017) (MoPWT, 1966)

3.1.2 Humidity

The yearly average relative humidity map of Lebanon is shown **Figure 3-13**. It divides the country into three zones, the 50%-60% zone, the 60%-70% zone and the 70%-80% zone. The zones with the highest humidity levels are those located near the coastal area at relatively low altitudes, and the zones with the lowest humidity levels are located in mountainous regions.

Figure 3-13 Yearly Average Relative Humidity Map (MoPWT, 1966)

The monthly humidity between 2009 and 2016 at Ain Zhalta and Machghara, was retrieved from World Weather Online (WWO) and the yearly average humidity at Ain Zhalta and Machghara between 2009 and 2016 are represented in the graph in **Figure 3-14**.

According to the yearly average relative humidity map of Lebanon **Figure 3-13**, the SBR (encircled in red on the figure) extends over two relative humidity zones: the 50-60% and 60-70%; however, its majority lies within the 50-60% zone. The two chosen locations where humidity data was collected lie in different zones: Ain Zhalta is situated in the 60-70% zone while Machghara is in the 50-60% zone.
In recent years, the average yearly humidity oscillated between 60% and 64% in Ain Zhalta and Machghara during the period 2009 to 2015; however, it dropped to 59% and 55% respectively in 2016, displaying values below the historical average for Ain Zhalta.

Figure 3-14 Yearly Average Humidity between 2009 and 2016 at Ain Zhalta and Machghara (WWO, 2017).

3.1.3 Temperature
3.1.3.1 Ammiq

Historical temperature data for Ammiq was retrieved from the Atlas Climatique du Liban and compared to recent data from online sources. Figure 3-15 and Figure 3-16 respectively present the historical and recent monthly maximum high, minimum low, average high and average low temperatures in Ammiq.

Table 3-3 Monthly Average Temperature (°C) at Ammiq in 1962 to 1970, 1985 to 2015 and 2009 to 2016 (MoPWT, 1966) (Meteoblue, 2017) (WWO, 2017)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly average
2009 to 2016	8.5	10	12	16	20	24	26	27	24	21	15	10	18
1985 to 2015	7	7	10	13.5	17	20	22	22	20.5	18	13	9	14.9
1962 to 1970	7	8	10.5	14	16.5	20.5	22.5	23	21	17.5	12	8.5	15.1

Looking at temperature recordings in Ammiq from 1962 to 2016, an increase in lower end temperatures is noticeable, coupled with a decrease in average higher end temperatures. It should be noted that these changes do not reflect temperature spikes or intense temperature readings but an overall trend and movement towards lesser inter-seasonal temperature variations, whereby temperature differences between fall, winter and spring for instance are less perceptible – especially considering average low temperature values. A continuation of such a trend could lead to disruptions in seasonal and annual flora and fauna cycles in the SBR.

Moreover, the average monthly temperature has increased in recent years in Ammiq, and the increase ranges from about 1°C in January and February to about 4°C in August. This observed variation suggests a general trend of temperature increase in the SBR area that is consistent with observed and expected national climate shifts and temperature increase.

3.1.3.2 Barouk and Machghara

Monthly average temperature trends in Machghara and Barouk seem to be similar over the period 2010 to 2016. In Machghara, the lowest temperatures are recorded during the months of January and December, and the peak temperatures are recorded between June and September. The lowest temperature average of 4.4 °C was recorded in January 2015, and the highest average 25.9 °C was recorded in August 2010. Additionally, recordings of the lowest minimum were in January 2015 (-10.9 °C), the highest minimum was in August 2010 (13.6 °C); and the lowest maximum was in January 2012 (12.4 °C), with the highest maximum being in August 2010 (39.1°C) (LARI, 2017).

It is noted that extreme temperatures, both on the lower and higher end, are occurring more frequently in recent years, with temperatures reaching below -10 °C in 2015 and up to 39 °C in 2010. Apart from such spikes, the temperature in winter is getting milder with higher low temperatures and shorter cold periods.

Monthly temperature analyses indicate a shorter cold season and an earlier and extended hot season that is consistent with the seasonal shift observed in precipitation result analysis. The long-term continuation of such a trend could possibly lead to homogeneity or blending of the seasons; for example, into two distinct seasons (wet and dry) as opposed to four seasons that historically exist in the SBR, or into one homogeneous warm season with clustered rainfall events.

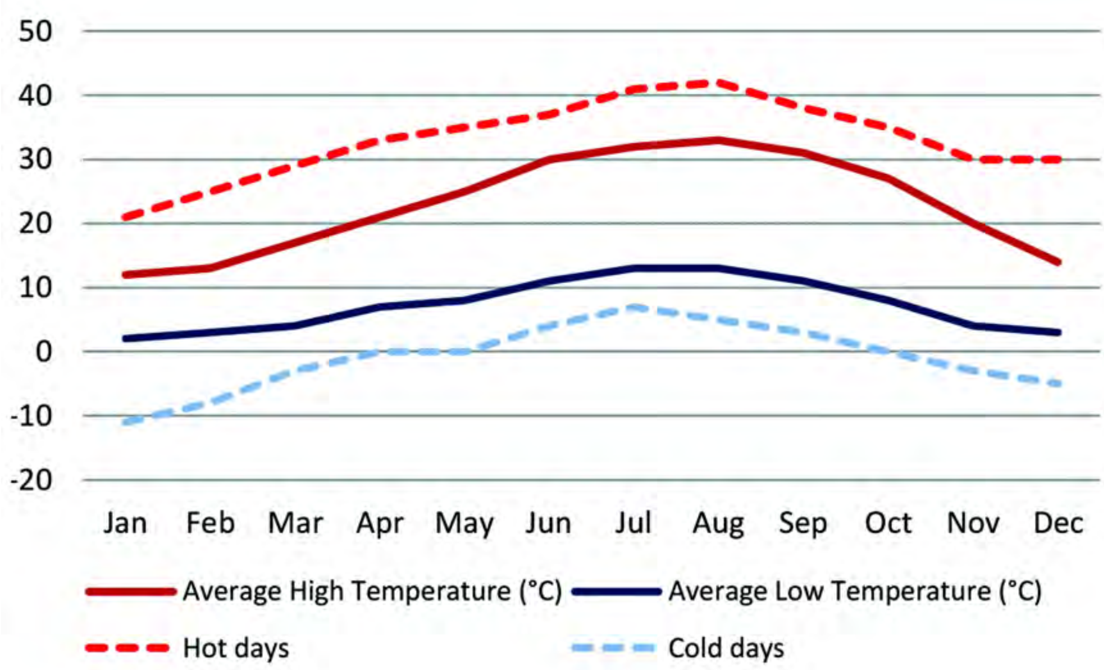


Figure 3-15 Historical Maximum, Minimum, Average High and Low Temperatures (°C) in Ammiq (1962-1970) (MoPWT, 1966)

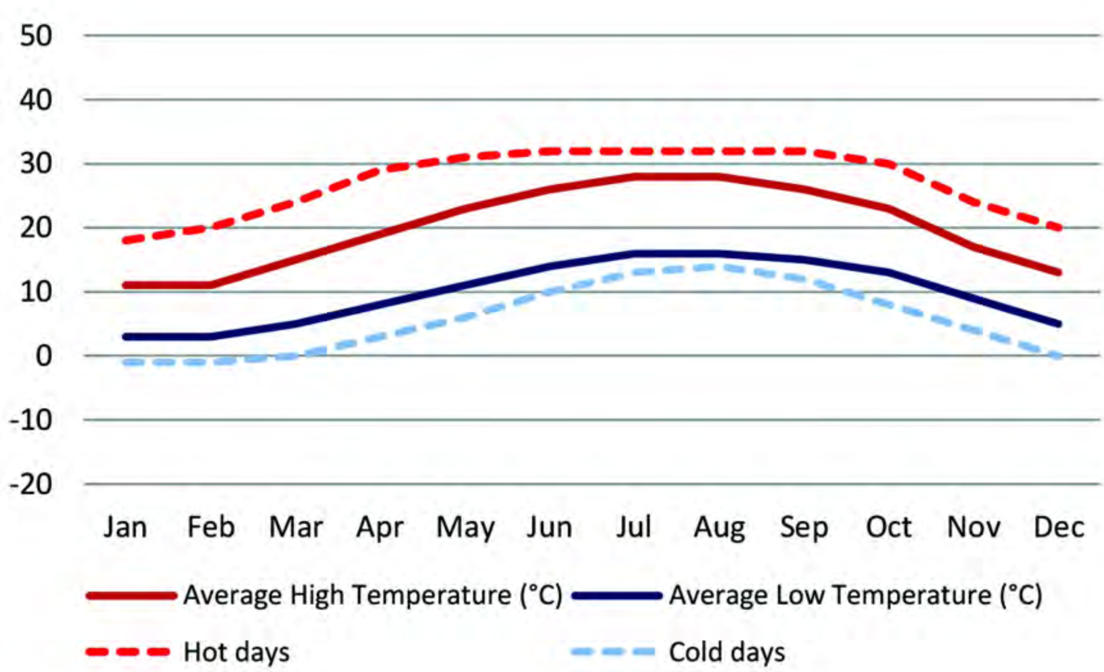


Figure 3-16 Recent Maximum, Minimum, Average High and Low Temperatures (°C) in Ammiq (1985 – 2015) (Meteoblue, 2017)

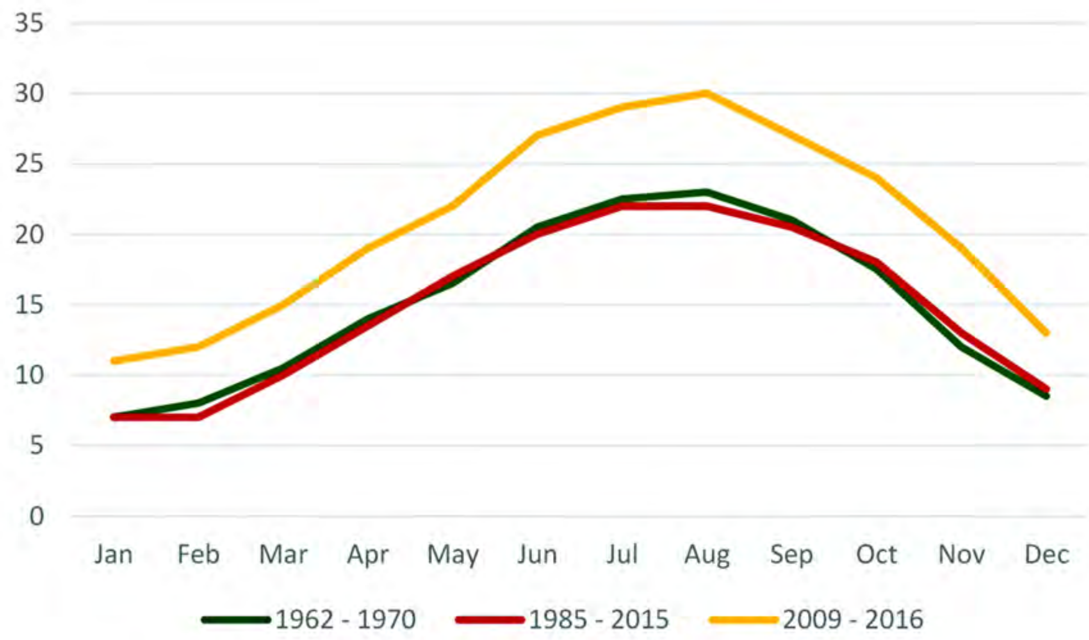


Figure 3-17. Monthly Average Temperature (°C) at Ammiq in 1962 to 1970, 1985 to 2015 and 2009 to 2016 (MoPWT, 1966) (Meteoblue, 2017) (WWO, 2017)

3.1.4 Wind

Historical and recent wind roses in Dahr El Baidar are presented in **Figure 3-18** and Figure 3-19. Wind data in Dahr El Baidar show a possible shift in the more frequent wind direction from West and North-West to West and South-West over the past 50 years (historical versus recent data), which could indicate a more frequent occurrence of desert winds (or Khamsin wind) originating in North Africa and/or Egypt that influence the South-West direction. Such observations should be made with care, as data from online sources is considered less reliable. According to local residents in and around the SBR, the Khamsin events have been increasing and occurring more frequently in the past 7 years. They are typically characterized by dry hot winds carrying desert sand resulting in low visibility conditions.

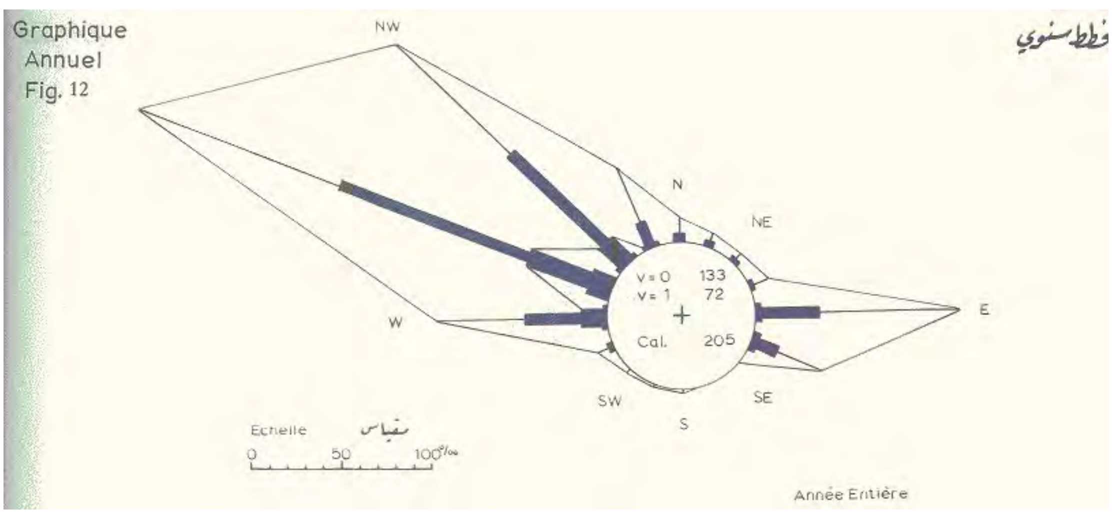


Figure 3-18 Wind Rose Dahr El Baidar (MoPWT, 1966)

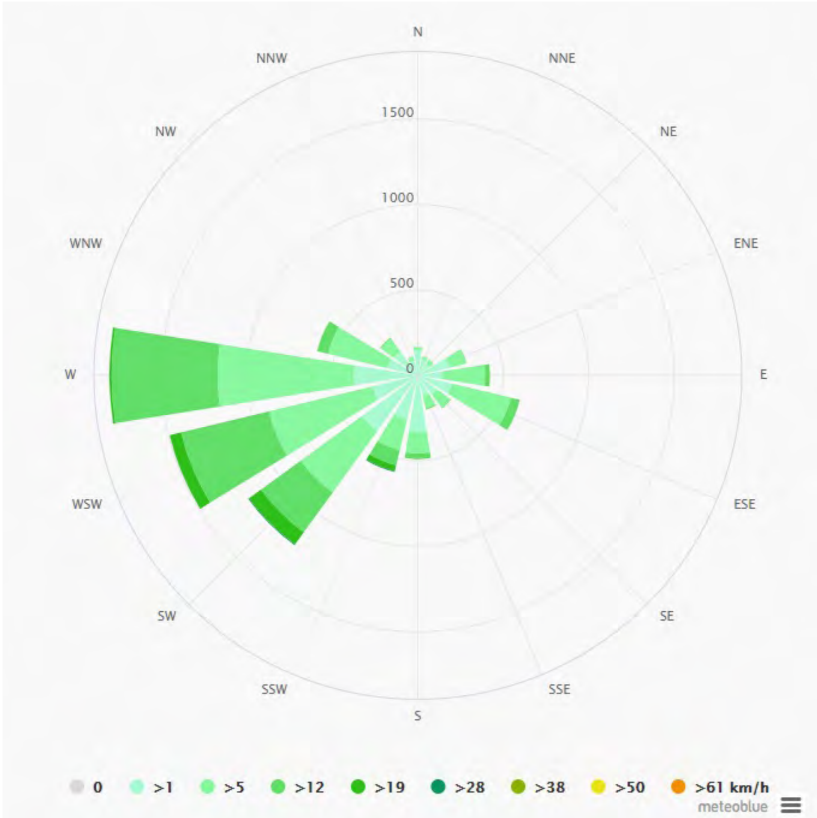


Figure 3-19 Wind Rose, Dahr El Baidar (Meteoblue, 2017)

3.1.5 Solar Irradiance and Nebulosity

Solar irradiance data in the SBR was retrieved from the Solar Med Atlas (Solar Med Atlas, 2017). Direct Normal solar irradiance in the SBR ranges approximately between 1600 to 2800 kWh/m2, and Global Horizontal Irradiance varies between 1600 and 2100 kWh/m2. Peaks and higher elevations typically receive more sunlight and have higher irradiance values, a fact that is applicable to the SBR, where the central mountainous spine-like area has higher irradiance, more notable towards the North where elevations are higher.

Figure 3-20 compares the cloud cover in Dahr El Baidar for the periods 1962 to 1970 and 2009 to 2016. This area is historically known for its cloud cover and mist, partially attributed to its high elevation, and geographical and topographical characteristics. Cloud cover figures in Dahr El-Baidar show a significant decrease in cloudiness in the past 8 years as compared to historical values, mainly in the 1960s. The decrease in cloudiness over 50+ years is significant, with average monthly cloud cover dropping from 70% to 30% in January, 59% to 26% in December and 60% to 23.1% in March. The decrease in cloud cover per month ranges from 55.9% in December to 76.7% in July. Cloud cover and precipitation parameters are directly correlated, and these results are consistent with the noted decrease in precipitation (mm).

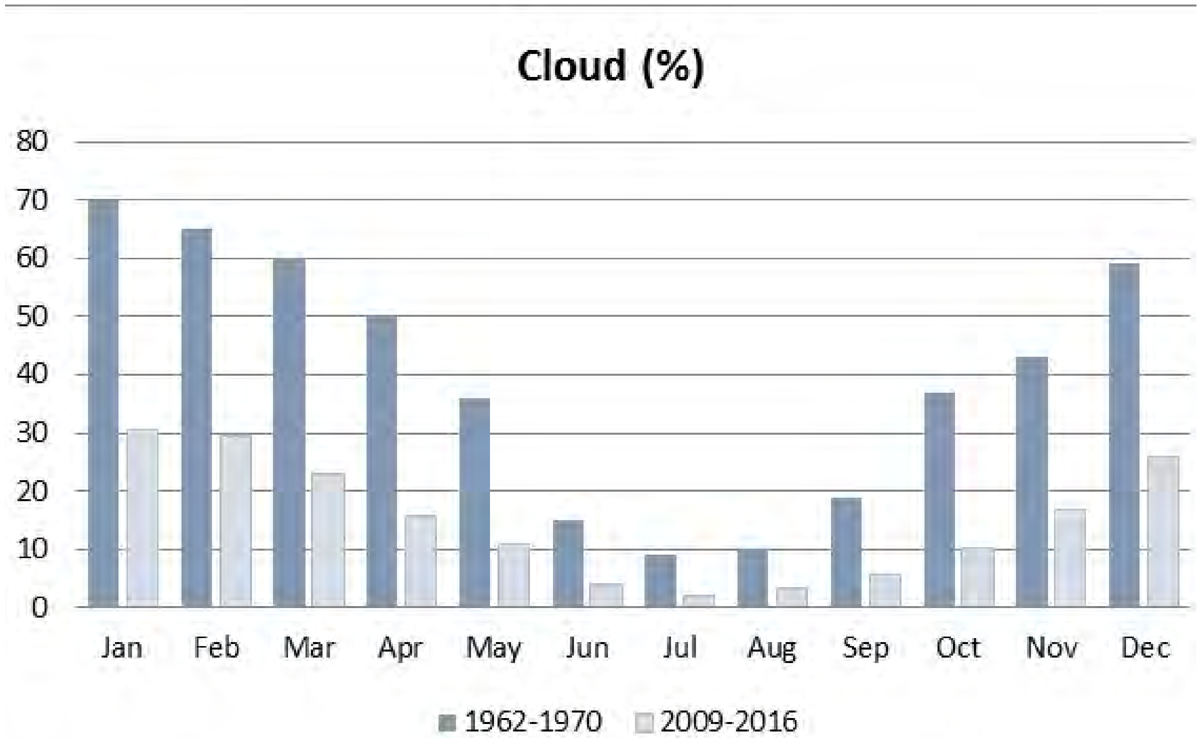


Figure 3-20 Cloud Cover (%) at Dahr el Baidar from 1962 to 1970 (MoPWT) and from 2009 to 2016 (WWO, 2017)

3.2 Conclusion on Meteorological Data Analysis

Based on the preliminary analysis of meteorological data, and comparison of historical data dating back to the 1930s and published in the 1960s to more recent data covering approximately the past 10 years, trends indicating qualitative and quantitative changes can be inferred. Such changes are found in sharp swings as well as gradual but steady shifts. It should be noted that one should account for a reasonable range of error due to differences in methodology of measurements and accuracy of equipment.

Precipitation data in Barouk and Machghara stations shows a noticeable decrease in total annual precipitation. Comparing recent data with historical values, annual precipitation decreased by 43.5% in Barouk and 43.1% in Machghara over a span of 30 years. In addition to an interpretation of long-term changes, looking at the variation in average annual precipitation in the last 8 years in Barouk and Machghara, a sharp decline in precipitation is noted from 2009 to 2016.

A comparison of average monthly temperature data in Ammiq between older values (1939-1970) and more recent measurements (2009-2016) showed an increase in average monthly temperature. The increase ranges from about 1°C in January and February to 4°C in August. This reflects a general trend of gradual temperature increase in the SBR area, which is consistent with observed national climate shifts and temperature increase.

A continued in-depth analysis of meteorological data, specifically targeting key parameters, such as precipitation and temperature, is needed to draw further conclusions regarding climatic trends and shifts in local weather patterns.

FIELD OBSERVATIONS

4 FIELD OBSERVATIONS

Four field visits were conducted between February 2017 and March 2018 that covered most of the SBR. The northern flanks of the western slopes were visited on 17 February 2017 to understand the water sources of the Damour River, mainly covering the Ain Dara and Ain Zhalta regions. The central and southern slopes were visited on 24 February 2017 to get an overview of the Barouk/Awali River basin and to note current human development practices and their potential effect on the surface water in that region. The third visit was done 8 March 2017 covering the northern and central parts of the eastern flanks of the SBR within the Litani river basin. The fourth visit to the western Bekaa was conducted on 12 March 2018 to identify potential projects that could be implemented within that area.

Base maps were developed covering geology, morphology, river basins, water resources, etc. and included presentation of selected potential pilot adaptive measures for water harvesting, and support to biodiversity (Appendix A).

During the visits, potential interventions were identified following discussions with selected farmers and locals knowledgeable of surface water resource needs, primarily for agriculture and livestock herds.

The main findings of the field visits included:

1. Pollution stresses on soil & water resources
2. Abandonment of agriculture at higher elevations
3. Existing adaptation measures need rehabilitation
4. Conflict between fauna and population
5. Limited surface water at higher elevations countered by expansion of fauna territories and migration of flora to higher altitudes
6. Continuous pumping of groundwater, even at higher elevation with significant surface water/river flow
7. Potentials for customized adaptation measures to climate change
8. Local authorities and populations are not fully aware of the causality of water stresses

The result of most of these findings include land and groundwater water quality degradation and over exploitation of aquifers. However, the prevalence of agricultural land and historical interventions to supply water for flora and fauna creates room for the rehabilitation of existing structures that can act as adaptation measures to climate change. Some of these observations are further presented hereafter along with selected photo-documentation.

4.1 Pollution Stresses on Soil & Water Resources

Several sources of pollution were observed to be affecting water quality and efficiency of water infiltration in the area, including:

- Siltation from quarries and sandpits
- Solid Waste from haphazard dumping
- Petroleum hydrocarbon contamination

4.1.1 Siltation from Quarries and Sandpits

Quarries and sandpits are abundant in the SBR. Limestone quarries and associated industrial activities are prevalent along the northern flanks of the reserve in the Ain Dara region, and the sand pits throughout the silica-rich sandstone formation. In general, the dust from quarries and sandpits is dispersed over the surrounding landscape and carried down by storm water runoff, surface water and water infiltration. That dust and water siltation furthermore progressively clog crevices and groundwater recharge pathways. Both the quarries and pits are major sources of pollution to the air, soil and water resources, and are associated also with structural failures. **Photo 4-1** to **Photo 4-4** document quarrying, siltation and operating industrial machinery.

The limestone quarries are specifically major sources of pollution from dust emissions and from potential hazardous pollution emanating from their quarrying activities and the operation of industrial machinery, stationary and mobile. The use of solvents and lubricants, and storage and use of petroleum hydrocarbons derivatives (fuels), and the generation of waste oils create potential pollution sources to the soil and groundwater that would affect the major groundwater aquifers in the region, specifically in the Jurassic aquifer. That aquifer represents the main source of drinking water (exploited form springs and groundwater wells) that serves the Shouf and Aley areas and beyond. The remediation of any such pollution is a major endeavor and one would rely on source removal and intrinsic remediation, which is almost impossible if associated with heavy metals and non-degradable chemicals. With the limestone quarries being in the karstified Jurassic formation, there is very limited natural protection through geological layers from migrating pollution. The industrial mining (quarrying) was noted by the Antea report as being potentially harmful, and the area of the Ain Dara quarries is of medium to very high vulnerability to pollution.
It is adamant that quarrying and cement production be prohibited in this particular area., and sandpits stopped from further exploitation and rehabilitated.

Photo 4-1 Quarries on the Eastern Flanks

Photo 4-2 Quarries in the North-East

Photo 4-3 Sandpits on the Western Flanks

Photo 4 -4 Discoloration of Water Is Attributed to Turbidity (High Suspended Solids)

Photo 4 -4 Discoloration of Water Is Attributed to Turbidity (High Suspended Solids)

4.1.2 Solid Waste from Haphazard Dumping

Haphazard solid waste dumping was observed in several locations including larger dumps seemingly used by local authorities, and limited ones near water sources, as noted in **Photo 4-5** to **Photo 4-10.**

Photo 4-5 Open Burning of Solid Waste

Photo 4-6 Open Dumping of Solid Waste

Photo 4-7 Solid Waste in Water Source/Wetland

Photo 4-8 Waste within a Spring Catchment

Photo 4-9 Open Dumpsite

Photo 4-10 Haphazard Dumping of Waste

4.1.3 Petroleum Hydrocarbon Contamination

Petroleum contamination in the form of fuel oil and waste oil was noted near operating individual electricity generators, fuel oil reservoirs and at retail stations and mechanic workshops thorough the area. Of special concern is the observed surface contamination at and close to public water pumping stations, who are mainly extracting water from water wells. Surface contamination not contained within well-sealed and water-proofed enclosures is a potential pollution to soil and groundwater that could ultimately enter the potable water system. **Photo 4-11** through **Photo 4-14** document some petroleum hydrocarbon contamination.

Photo 4-11 Oil Leakage Near GW Pumping Station

Photo 4-12 Used Oil and Fuel Leakages Near a Water Pumping Station

Photo 4-13 Used Oil Leakages

Photo 4-14 Empty Oil Canisters Left in Situ

4.2 Abandonment of Agriculture at Higher Elevations

Abandoned agricultural lands with collapsed terraced walls were observed through the region. A direct result of this phenomena was erosion through the loss of top soil that is carried down-hill by rain and surface run-off leading to land degradation. **Photos 4-15** include examples from the study area.

Photos 4-15 Abandoned Agricultural Areas

4.3 Existing Interventions Needing Rehabilitation

Numerous existing interventions could be considered as adaptation measures to climate change and include surface water sources for wild life, such as hill lakes and ponds. Some of these structures were identified as needing rehabilitation such as Mrusti Hill lake (a concrete, HDPE-lined reservoir) **(Photo 4-16)** and what is known as "the Japanese pond" in Ain Zhalta **(Photo 4-17)**. Other abandoned structures observed in the area could also be reconstructed to act as adaptation measures, although their original purpose was different otherwise, such as the abandoned concrete reservoir and concrete pond in Maasser El Shouf **(Photo 4-18 and Photo 4-19)** and "Birkit El Hariri" in Ain Zhalta **(Photo 4-20)**.

Photo 4-16 Hill Lake in Mrusti Needing Rehabilitation

Photo 4-17 Hill Lake in Ain Zhalta Needing Rehabilitation

Photo 4-18 Abandoned Reservoir in Maasser El Shouf

Photo 4-19 Abandoned Concrete Pond in Maasser El Shouf

Photo 4-20 "Birkit El Hariri" in Ain Zhalta

4.4 Area Potential for Adaptation Measures

4.4.1 Rainwater Harvesting from Hill Lakes or Earth Lakes

Field observation revealed that hill lakes are a common method of rainwater harvesting used in the SBR. A number of hill lakes exist, some of which need rehabilitation. Also, few new locations were identified where hill lakes can be established.

It should be noted that hill lakes need to be constructed with the use of impermeable membranes, except if the identified suitable location is within a geologically impermeable formation, like within the C3 cretaceous marls. Numerous hill lakes within the study area were constructed in the sandy, bottom of the Cretaceous C1 Sandstone formation. Such hill lakes were seen to have been constructed as part of restoration plans after having exploited the area through sandpits/industrial mining. As such, some of the lakes have failed and/or may not be suitable for rehabilitation due to morphological unfavorable conditions. A number of such lakes are solely dependent on melting snow, although few are down-gradient from seasonal springs either at the junction between an impermeable geological formation and an aquifer, or are structurally controlled along a fault zone that promoted impermeability and water retention.

To improve the efficiency of water collection in the hill lakes, water runoff on the catchment surface can be enhanced by earth moving, and increasing of surface slopes.

Most hill lakes in the area were constructed by the local authorities under support from the Green Plan and international funding agencies. A number of hill lakes were the result of private initiatives or were done under grant to the Al-Shouf Cedar Society (ACS).

4.4.2 Rainwater Harvesting from Ground or Roads (RWHR)

This RWHR technology could be a potential source of water collection along certain crossroads and town squares in the study area, possibly in the towns of Ain Zhalta, Maasser El Shouf and Khreibe, and in areas with a minimal slope allowing water runoff towards a collection point that can be outfitted with an element for decanting and collecting sediments.

4.4.3 Rainwater Harvesting from Rooftops

Rainwater harvesting from rooftops has been practiced in the Shouf area since ancient times. Although the reservoirs are still being used for storage, people are mainly filling them using the water conveyed to them by the public network. Some locals, specifically farmers and land-owners, believe that rainwater harvesting from rooftops should be revived, and included as a requirement in new buildings.

4.4.4 Micro Dams along River Channels to Convey Water in Irrigation Canals

The construction of micro dams has been practiced for a long time in the Shouf area, using different methods and technologies, ranging from the deposition of rocks, or rocks and plastic films to retain river water, to engineered concrete micro-dams. These dams allow the retention of river water, and facilitate its extraction and use, mainly by gravity, and conveyed in traditional open canals for irrigation.

4.4.5 Deployment of Permeable Gabions along Seasonal Water Channels

Permeable gabion could be deployed to act as water barriers along seasonal water channels, increasing water retention time and thus further promoting infiltration and groundwater recharge, thereby resulting in pooling of water for wild life use, and possibly water diversion for agricultural use.

4.4.6 Use of Treated Wastewater in Irrigation (UTWWI)

Five WWTPs are currently operational within the SBR, and two are under construction. The treated water is currently discharged in the water springs and rivers. The quality of treated water ought to be tested, and if found convenient, the water could be used in irrigation of agricultural lands.

PROPOSED CLIMATE CHANGE ADAPTATION PROJECTS

5 PROPOSED CLIMATE CHANGE ADAPTATION PROJECTS

This chapter represent preliminary project concepts that are recommended for implementation within the SBR as climate change adaption interventions. These proposed projects could act as pilot to be studied and replicated.

1. Settling pond, Ain Dara below the quarries

Potential projects that would to a limited extent alleviate pollution potential include the construction of settling ponds at and down-gradient of quarries. Additionally, the implementation of good housekeeping practices and spill-containment measures along access and service roads leading to these areas is a must. It is adamant that quarrying in the area be rethought and stopped, as the location is that of a vulnerable potable water recharge area. It should be noted that current practices by water supply establishment treat biological contamination through chlorination, but do not address contamination related to industrial practices that potentially include solvents, petroleum hydrocarbons and heavy metals. It is recommended that a thorough study be conducted to assess the presence of such contamination in the quarry areas, paying special attention to visual observation for soil discoloration, and examining stationary and mobile machinery, including storage tanks, trucks and cisterns, for leakages and spills.

Photos 5-1 Quarries in Ain Dara

2. Water Harvesting from Town Squares and Pavement Surfaces in Ain Zhalta, Khreibe and Maasser El Shouf

Ain Zhalta, Khreibe and Maasser El Shouf towns have paved areas along road intersections that constitute catchment areas and are suitable for the installation of rainwater harvesting systems. The selected areas are hydraulically up-gradient from agricultural lands and can accommodate appropriate size reservoirs. The harvesting system needs to be designed in such a way that would divert the first washout, and then direct the cleaner rainwater stream to the storage reservoir that could be tapped-in for irrigation.

3. Artificial Hill Lakes along the Road between Barouk and Maasser El Shouf

The construction of hill lakes on the road between Barouk and Maasser El Shouf would allow the collection of water during rainfall season and snow melt season. Two locations have been chosen, both having within their sites and abutting properties impermeable silt and clayey geological formations that can either form an impermeable base for the hill lake or would support the installation of an impermeable HDPE membrane. Both locations are strategically located to supply irrigation water to down-gradient abandoned terraces and agriculturally developed lands.

- Near the historical Roman Mill
- In the Marabih Area where two seasonal streams intersect

4. Stream stabilization and catchment by Gabions (Dalboun and Al Houar)

Potential sites have been identified for building water barriers by gabions to stabilize seasonal water streams where storm water and snowmelt flow, thereby limiting erosion. The installation of these systems would allow the deceleration and storage of water runoff so it could supply nearby agricultural lands, make water available for wildlife and promote water infiltration.

Photos 5-2 Potential Streams for Installation of Gabions

5. Restoration of Old Abandoned Terraces

The restoration of old terraces would increase the surface area for groundwater recharge, and preserve topsoil. The chosen area in Ain Zhalta can also be developed to become a camping and recreational site.

Photo 5-3 Abandoned Old Terraces in Ain Zhalta

6. Good Housekeeping and Pollution Source Removal Near Water Courses

The Nabeh El Safa and Al Raayan Springs are among the most important water sources which supply a large area, and their pollution, mainly by fuel and oils, poses a risk to public health. Environmental Audits (EA) ought to be conducted on all water supply and pumping facilities in the SBR buffer zone, especially those managed and operated by national institutions, such as the Establishment of the Water of Beirut and Mount Lebanon (EBML). The reports for each location should cover various aspects of pollution. Training material and standard operating procedures ought to be developed for water supply locations where machinery is used. Due to their high impact on the quality of water, it becomes adamant that such facilities apply good housekeeping guidelines.
A further advantage to conducting such work would be to include such audits as part of identification of the watersheds of the specific water supply source. These audits would provide guidance on how to best manage and protect watersheds from potential sources of pollution. It should be noted that these needed interventions were verbally proposed to EBML, and it has initiated some remedial works and pollution abatement measures.

Photo 5-4 Hydrocarbon Pollution Near Drinking Water Source

Photo 5-5 Hydrocarbon Pollution Near Drinking Water Source

Photo 5-6 Solid Waste Near Water Course

Photo 5-7 Solid Waste and Hydrocarbon Disposal Near Water Course

7. Rehabilitation of Japanese pond, Ain Zhalta

In Ain Zhalta, the Japanese pond collecting rainwater and snowmelt needs rehabilitation: The geo-membrane should be protected by ensuring that approaching wild animals, specifically wild boars that are more likely to dig into the ground, would not destroy the liners. To do so, ingress should be covered with a concrete mix that uses round edged cobble stones. These consolidated mixes will have two benefits: one to hold the tart material in place and protect it from destructive actions of wildlife, and the other is to protect wild animals from sliding into the pond and be trapped in it.

Photos 5-8 Japanese Lake, Ain Zhata

8. Rehabilitation of a Natural Concrete Reservoir in Ain Zhalta (Birkit El Hariri)

The project consists of rehabilitating an existing concrete reservoir into a wild life water supply pond and laying cobble stones at the bottom to prevent animals from drowning. Even though the characteristics of this area seem favorable for the deployment of a hill lake, it is recommended that no such impermeable structure is built because the semi-coned morphology could be part of a more elaborate doline that acts as natural conduits for water recharge from rain and snow melts.

Photos 5-9 Birket EL Hariri, Ain Zhalta

9. Rehabilitation of a Hill Lake and Nearby Animal Drinking Water Pond, Barouk

Similar to Ain Zhalta's "Japanese pond", the geo-membrane in the Barouk hill lake ought to be protected from the actions of wild animals. A possible way is to cover the exposed areas with round-surfaced cobble stones consolidated by a fine concrete matrix.

Photos 5-10 Barouk Hill Lake

10. Rehabilitation of Hill Lake in Mrusti

Surface run-off, rainwater and water from melting snow is directed to fill in the lake in Mrusti during winter and spring seasons. Currently, the conduits along its periphery are placed few centimeters above the ground surface, possibly to limit the accumulation of aggregates within the lake. However, the conduits' levels do not maximize flow from melting snow nor capture precipitation/run-off in the surroundings. Additionally, stored water is not accessible to wildlife.

The proposed project suggests lowering inlet holes along the perimeter of the lake, and cleaning and waterproofing a basin at the lake outlet that is located outside the fenced area. This method would increase the amount of channeled water from precipitation and snowmelt into the lake and create a permanent source of water for wildlife.

Photos 5-11 Hill Lake in Mrusti

Photo 5-12 Current Position of Inlet Holes

11. Spring Catchment and Infrastructure, Maasser El Shouf Reserve Entrance

The project consists of studying and developing a catchment of a spring and melting snow possibly in a location above the Maasser El Shouf reserve entrance. The collected water would then be transmitted through pipes to a reservoir that services the restrooms at the entrance, and to a proposed pond that would provide drinking water for wildlife.

Photo 5-13 Location of Spring in Maasser El Shouf

Photo 5-14 Restroom at Reserve Entrance

12. Spring Catchment, Al Lijje Spring

The Al-Lijje spring currently forms a small pond that is a drinking water destination for shepherds and their domestic herds and whose immediate surrounding is being overgrazed. The proposed project includes the limited expansion of the pond and controlled transmission of the water into artificial drinking water basins at around 50 to 75 m below the current location.

Photo 5-15 Water Pipe out of Al Lijje Spring

Photo 5-16 Current Drinking Pond for Domestic Herds

Figure 5-1 Satellite Imagery with a Schematic for Transmission Pipes and Basin at Ain El Lijje

13. Creation of a Wetland between Khreibe and Maasser El Shouf

The concerned area between Khreibe and Maasser El-Shouf continues to hold water or be moist throughout the year revealing its impermeable character and its plausibility to be developed into a wetland.
The proposed intervention could include a study of the soil nature and thickness of any silt or clay layer, thereafter possibly deepening certain parts of the area to promote water accumulation and retention. The location can then be further planted with appropriate flora that would promote biodiversity enrichment.

Photos 5-17 Potential Location of a Wetland

14. Rehabilitation of Quarries and Sandpits

The rehabilitation of quarries and sandpits is proposed to take place through leveling, terracing and reforestation, where plausible. Detailed studies should precede the works to ensure national standards are being followed and to address short and long term health and safety concerns, including ground, and quarry walls stability. Visions for the long-term use of the land should be developed to ensure sustainability of rehabilitation, and promotion of biodiversity by selecting and planting appropriate flora species, such as “Umbrella Pine” for the sandpits within the geological Grès-De-Base siliceous formation.

Photos 5-18 Sandpit in Mrusti

Photos 5-19 Sandpits in the SBR

15. Installation of Micro Dams along River Courses

The construction of micro dams along river channels would improve surface water exploitation, and provide a sustainable source for irrigation of agricultural lands on riverbanks and in the surrounding areas. This technology exists along the Barouk River in Jdeidet El Shouf. Water is withdrawn from the river and diverted to irrigation canals, or pumped to ponds. The construction of micro-dams increases water availability, decreases the reliance on groundwater and reduces the vulnerability of agriculture to rainfall variation and climate change.

Photo 5-20 Small Dam Built from Rocks in Jdeidet El Shouf

Photo 5-21 Irrigation Canal in Jdeidet El Shouf

Photo 5-22 Concrete Dam along the Barouk River in Jdeidet El Shouf

Photo 5-23 Water Pond for Irrigation Water in Jdeidet El Shouf

16. Pond Enlargement in Haouch El Saalouk

The project consists of rehabilitating and enlarging an existing water pond in Housh El Saalouk in order to provide water for nearby agricultural lands; a safe drinking source for wildlife and enhance groundwater replenishment. It would also create an ecotourism destination.
The pond would be developed to reduce water runoff and allow the storage of rainwater and its slow infiltration to recharge groundwater. The stored water will be used to irrigate surrounding agricultural area. The layout of the pond is suitable as a safe drinking source for wildlife, for which an existing tunnel would be rehabilitated and enhanced to allow their safe passage under the highway, creating an access route to the pond.

Figure 5-2 Satellite Imagery Showing the Potential Pond Design

17. Construction of Two Water Ponds in Ain Abed

Two locations have been identified as suitable for the construction of water ponds in Ain Abed. One has an area of 1310 m2 and another of 3500 m2. Drainage channels will be established to collect and transfer storm runoff and snowmelt towards the pond. The construction of the ponds will be done using the natural materials present on site. The project would help create a microclimate with a safe drinking spot for wildlife.

Photo 5-24 Potential Location of First Water Pond in Ain Abed

Photo 5-25 Potential Location of Second Water Pond in Ain Abed

18. Rehabilitation of Water Pond and Rainwater Collection System in Ain Ettaine

The project consists of rehabilitating and waterproofing an existing water reservoir located in Ain Ettaine to store rainwater. A transfer system will be installed to convey rainwater and storm runoff from a nearby stream to the reservoir. The transfer system consists of High-Density Polyethylene pipes (HDPE), valves, connectors, etc. Water from the reservoir will be used to irrigate nearby agricultural lands, livestock production farms as well as make water available for restaurants and churches in Ammiq.

Photo 5-26 Existing Reservoir at Ain Ettaine

19. Water Ponds in Deir Tahnish

The project consists of enlarging an existing water pond in Deir Tahnish, and the rehabilitation of a quarry by creating a pond for collection of rainwater. Both ponds will be used to store water for irrigation of agricultural lands (more than 2 hectares), and to supply livestock production farms with water.

Photos 5-27 Old Quarry in Deir Tahnish

20. Rehabilitation of Irrigation Channel in Batloun

In Batloun, the existing channel previously used for irrigation of agricultural areas is damaged in different locations. About 70% of the channel is leaking, with 40% being heavily cracked and 30% totally destroyed. Rehabilitation and construction works will be performed according to the needs of each section of the channel which will be equipped with small exits located at specified locations. These exits will serve as connection points to the nearby agricultural areas. The project is expected to serve about 293 farmers.

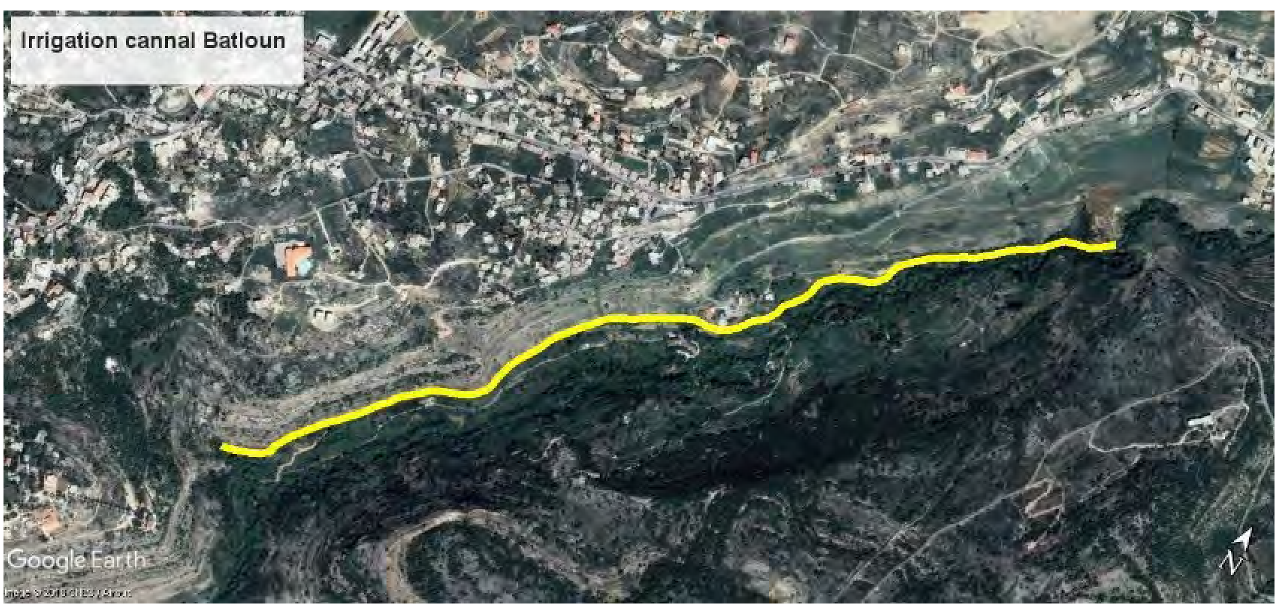


Figure 5-3 Satellite Imagery showing the Location of the Potential Irrigation Canal

21. Rehabilitation of Existing Concrete Reservoir and Water Network in Maasser El Shouf

The project consists of: i) rehabilitating water reservoirs that exist under demolished reinforced concrete structures that were constructed by Israeli occupation forces above Maasser El Shouf to store rain water and snow melts; ii) rehabilitation of existing concrete canals that feed rainwater and snowmelt into the reservoir ; iii) establishing a pond to act as a drinking water source for wildlife in the area; iv) installing a water network (surface and piping) to connect the reservoir to the pond, and to a water filling point for firefighting and reforestation.

Photos 5-28 Demolished Concrete Structures

22. Rehabilitation of Existing Concrete Pond in Maasser El Shouf

The project consists of rehabilitating an existing concrete pond to harvest rainwater and snowmelt. The pond will act as a drinking source for wildlife, and will store water that can be used for irrigation of newly planted seedling in reforestation projects.

Photo 5-29 Existing Concrete Pond in Maasser El Chouf

Photo 5-30 Surroundings of Concrete Pond

CONCLUSION

6 CONCLUSION

The fresh water assessment study of the Shouf Biosphere Reserve (SBR) area concludes that climate change is a fact that needs to be accounted for in daily management and long term planning for natural resource preservation, amelioration and sustainability. Results of the literature review, analysis of meteorological data, and field observations confirm the need for the deployment of adaptation and mitigation measures that improve water harvesting and remediate polluted and degraded areas.

The review of available literature revealed the richness of the reserve in water resources, despite the fact that upper localized aquifers in the area are not well studied. Water resources in the area are expected to decrease due to projected climatic changes. Nevertheless, available studies justify continued exploitation of water resources but seem to be demand oriented. Climate change and stresses on aquifers are highlighted in international studies. However, adaptation to climate change and mitigation measures are generic, and do not address the potential roles of society, NGOs and local authorities in adaptation to climate change.

The analysis of available meteorological data collected in weather stations within the SBR, the historical data from literature review, and online data revealed the existence of significant yearly variation in precipitation, that the general trend in precipitation is decreasing compared to historical data, and that seasonal distribution of precipitation is shifting towards the warmer months, thereby reducing the amount of snow received and its residence time. Moreover, the assessment showed that monthly temperature averages are increasing, and that there is a movement towards lesser inter-seasonal temperature variations.

A continuation of such climatic trends could lead to various consequences such as disruptions in seasonal and annual flora and fauna cycles in the SBR, and lesser amount of water recharges that ultimately feed surface springs and groundwater aquifers.

The above findings, in addition to the conducted field visits show that there is a need for improvement in the current management of water resources. Field visits and observations brought to light several issues related to poor management of resources. In fact, groundwater is continuously exploited throughout the year even in locations with significant surface water and river flow. The existing adaptation measures such as ponds and hill lakes need rehabilitation.

The higher elevations of the project area are suffering from limited availability of surface water. This is causing migration of fauna and flora to higher altitudes and expansion of fauna territories, thus creating a conflict between fauna and population.

Numerous pollution stresses are posing serious threats to soil and water resources. These stresses include:

- Siltation from quarries;
- Solid waste from haphazard dumping and open burning;
- Discharge of untreated wastewater in the environment;
- Uncontrolled discharge of petroleum hydrocarbons.

The observed abandonment of agriculture at higher elevations increases the risk of soil erosion, and decreases groundwater recharge.

However, the area presents a potential for implementation of customized adaptation measures, despite the lack of awareness of local authorities and population relative to stresses on water resources and the needed adaptive management.

The study recommends water adaptive management and compensation measures to help protect aquifers and surface water resources and, to a certain extent, address expected water shortages under a changing climate.

The proposed measures include:

- Various rainwater harvesting technologies, including: direct harvesting from land surfaces, roof tops and town squares;
- Pollution abatement measures such as remediation of hydrocarbon pollution and sedimentation ponds;
- Rehabilitation of quarries and sandpits;
- Rehabilitation and creation of ponds and hill lakes;
- Creation of wetlands;
- Installation of gabions as permeable barriers in seasonal water channels and micro-dams along water courses;
- Rehabilitation of unproductive springs; and
- Implementation of water saving technologies in agriculture.

The promotion and implementation of the proposed adaptation and mitigation measures would contribute to the amelioration of water management on the larger scale and strengthens resilience of the rural communities and ecosystems.
Hence, the field-testing of selected measures presents the local population, land-use planners, researchers, reserve managers and funding agencies with small-scale pilot projects to support in short and long-term strategy development, and promote the harvesting of rain and surface water.

For a better understanding of the current situation in the area, the following projects are recommended:

- Understanding smaller and perched aquifers in the Cretaceous and upper Jurassic formations
- Awareness raising and advocacy programs for local authorities and population on stresses on water resources and their sustainable management (such as adaptive measures to climate change)
- Assessment of upper watersheds with specific attention to pollution stresses and abatement measures to water supply stations
- Valorization of surface water sources in upper watersheds, and limiting over exploitation of aquifers

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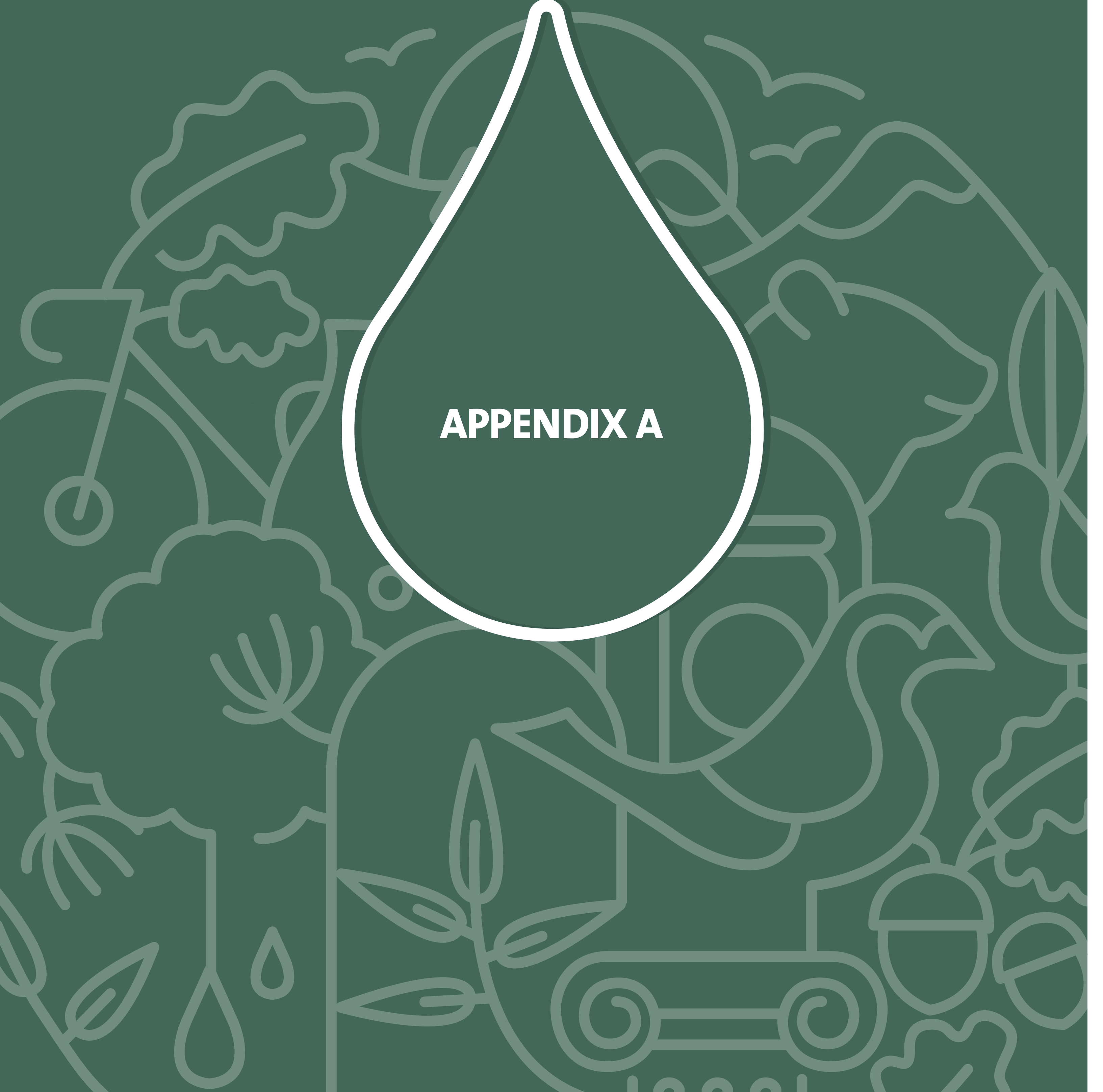


APPENDIX A

APPENDIX A - MAPS

The enclosed base maps present locations of proposed interventions against thematic backgrounds, including:

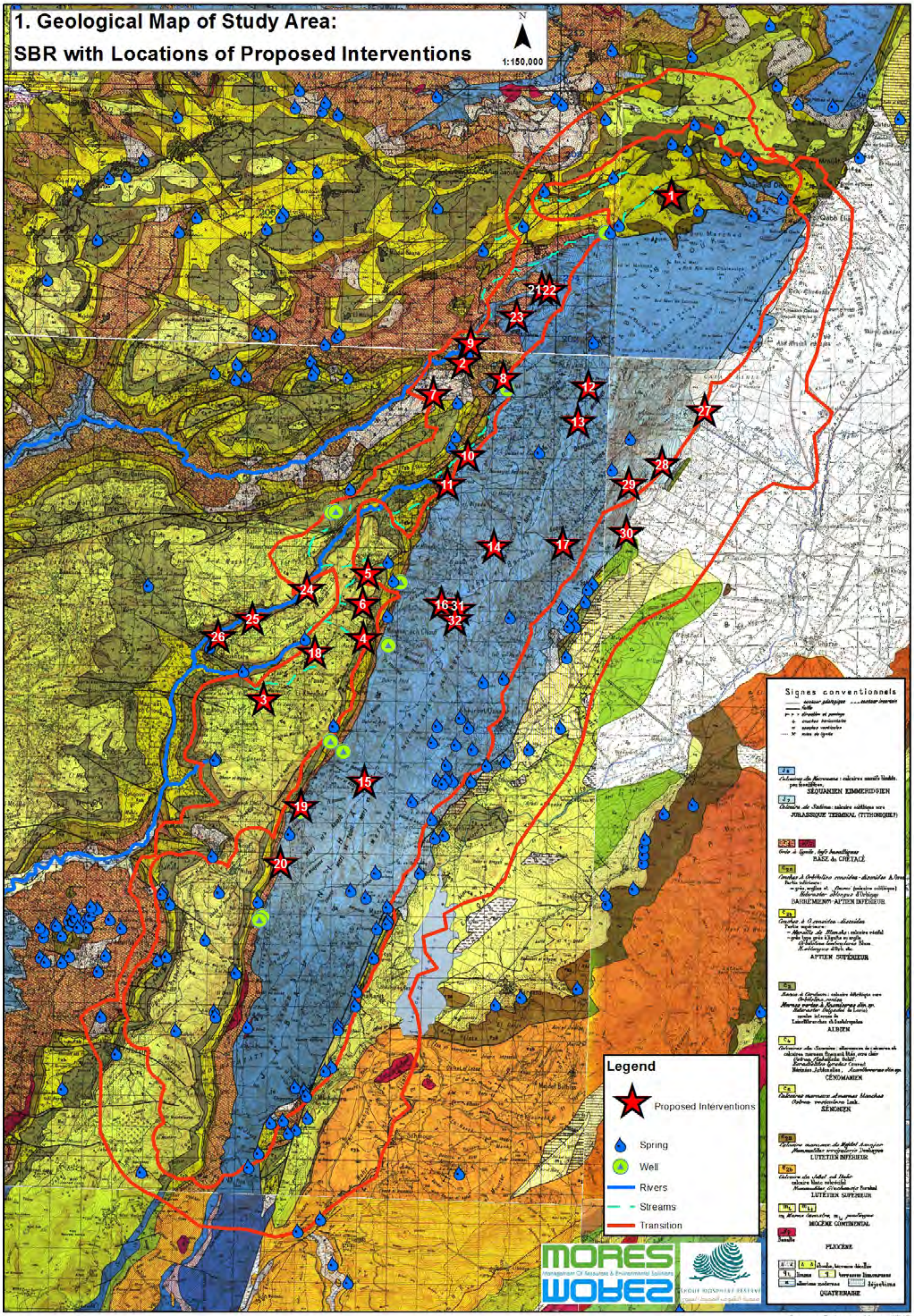
1. Geological Map of Study Area/SBR with Locations of Proposed Interventions
2. Topographic Map of Study Area/SBR Showing Locations of Proposed Interventions
3. Soil Map of Study Area/SBR Showing Locations of Proposed Interventions
4. Watershed Map of Study Area/SBR Showing Locations of Proposed Interventions
5. Satellite Imagery showing Locations & List of Proposed Interventions
6. Zoom in from Satellite Imagery to location of proposed Interventions

The proposed interventions are classified alphabetically under twelve (12) types:

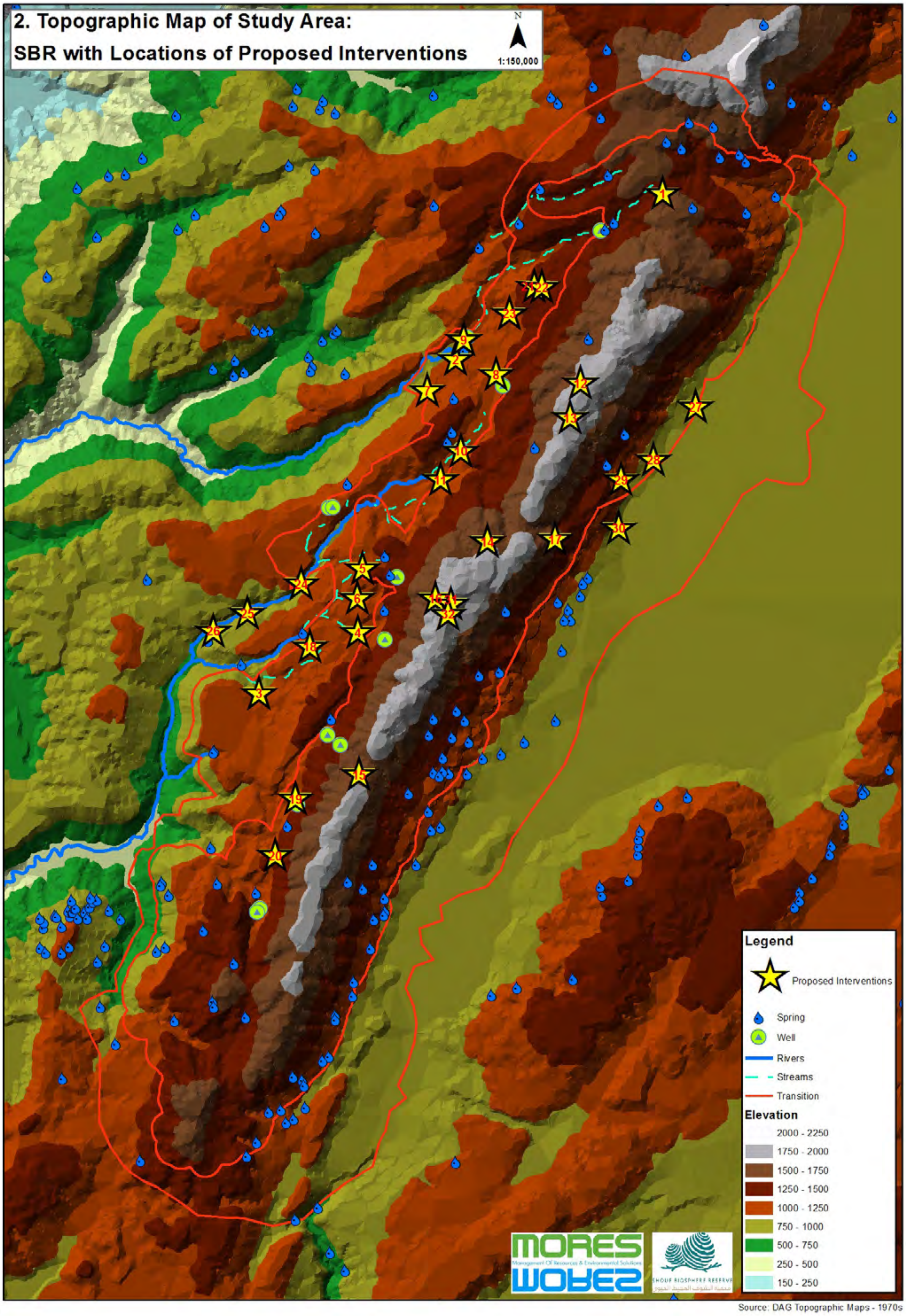
Class	Intervention Type
A	Construction of Settling Pond
B	Water Harvesting, Town Squares, Paved Surfaces
C	Water Harvesting and Collection in Hill Lakes
D	Stabilize Stream flow by Gabions
E	Restoration of Old Abandoned Terraces
F	Good Housekeeping &Pollution Source Removal Near Water Source
G	Rehabilitation of Existing Adaptation Interventions
H	Spring Catchment and Development
I	Creation of Wetlands
J	Rehabilitation of quarries and sandpits
K	Installation of Micro-Dams Along River Courses
L	Construction and Enhancement of Water Collection Systems

The table below lists the interventions with reference numbers as marked on the maps and class types as listed above.

#	Intervention Name	Location	Class
1	Construct Settling Pond	Below quarries, Ain Dara	A
2	Water Harvesting, Town Square, Paved Surface	Ain Zhalta	B
3	Water Harvesting, Town Square, Paved Surface	Khreibe	B
4	Water Harvesting, Town Square, Paved Surface	Maasser El Shouf	B
5	Construct Hill Lake	Near Barouk & Maasser Road	C
6	Stabilize Stream flow by Gabions	Dalboun, Al Houar Barouk & Maasser	D
7	Restore Abandoned Terraces & Create Touristic Site	Ain Zhalta	E
8	Restore Abandoned Terraces & Create Touristic Site	Ain Zhalta	E
9	Good Housekeeping, Remedy Pollution	Ain Zhalta	F
10	Good Housekeeping, Remedy Pollution	Barouk	F
11	Good Housekeeping, Remedy Pollution	Barouk	F
12	Rehab Pond	Japanese pond in Ain Zhalta	G
13	Rehab Concrete Pond	Birket El Hariri, Ain Zhalta	G
14	Rehab Hill Lake & water source for wildlife	Barouk	G
15	Rehab Hill Lake	Mristi	G
16	Spring Catchment & Conduit	Maasser El Shouf	H
17	Spring development, piping, trough for domestic herds	Al Lijje Spring in Aana	H
18	Develop Wetland	Between Khreibe & Maasser	I
19	Rehab of quarries & sandpits	Mrusti	J
20	Rehab of quarries & sandpits	Jbaa	J
21	Rehab of quarries & sandpits	Ain Dara	J
22	Rehab of quarries & sandpits	Ain Dara	J
23	Rehab of quarries & sandpits	Bmahray	J
24	Install Micro Dams along River Course	Barouk River	K
25	Install Micro Dams along River Course	Barouk River	K
26	Install Micro Dams along River Course	Barouk River	K
27	Enlarge Pond	Haouch El Saalouk in Ammiq	L
28	Construct water ponds	Ain Abed in Ammiq	L
29	Rehab water pond & rain collection system	Ain Ettaine in Ammiq	G
30	Construct Water Pond	Deir Tahnish in Aana-Ammiq	L
31	Rehab Concrete Reservoir & Water Network	Maasser El Shouf	G
32	Rehab Concrete Pond	Maasser El Shouf	G



Source: Dubertret Map - 1945



2. Topographic Map of Study Area:
SBR with Locations of Proposed Interventions
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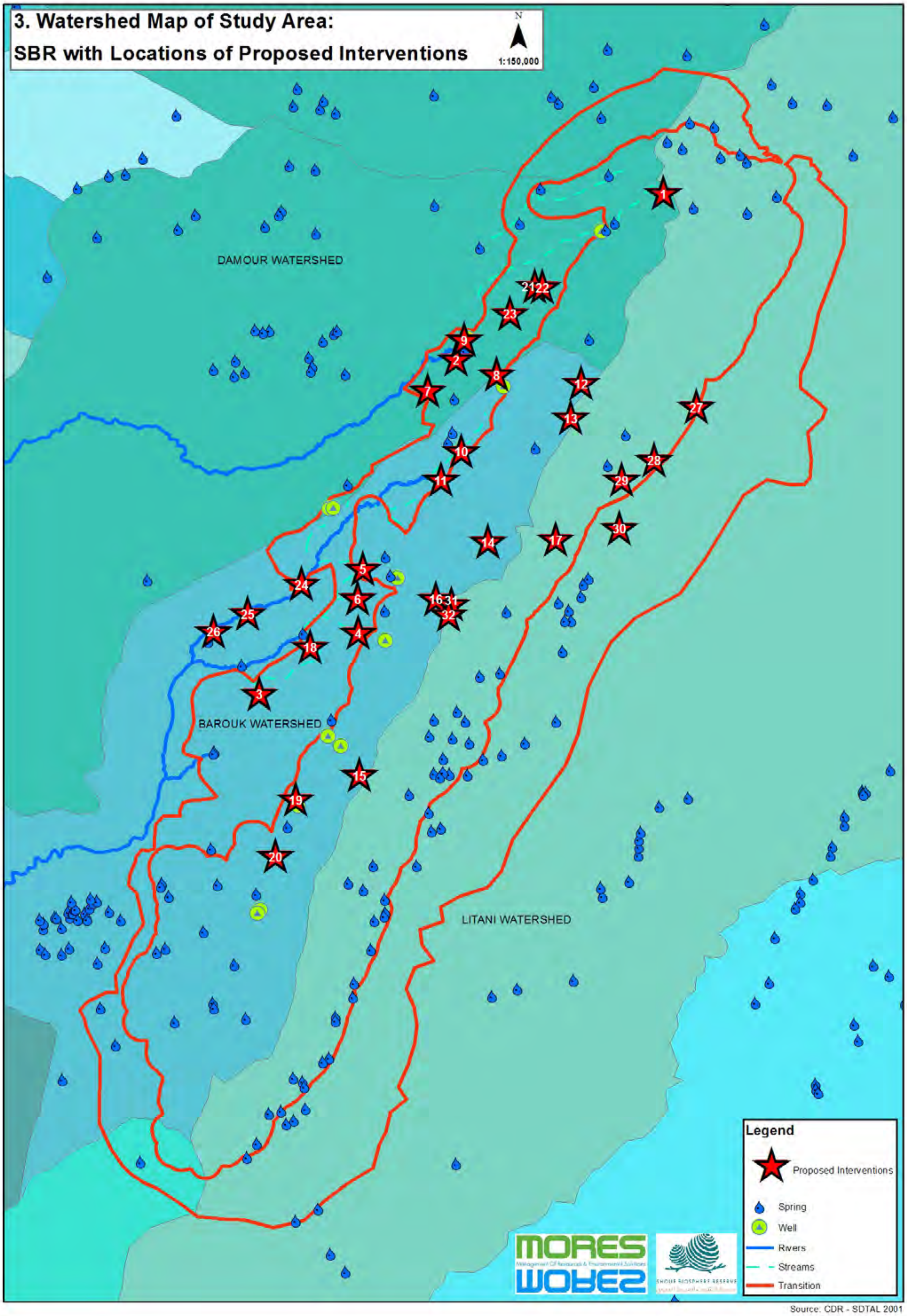
1:150,000
Legend
Proposed Interventions
Spring
Well
Rivers
Streams
Transition
Elevation
2000 - 2250
1750 - 2000
1500 - 1750
1250 - 1500
1000 - 1250
750 - 1000
500 - 750
250 - 500
150 - 250
MORES
Source: DAG Topographic Maps - 1970s


3. Watershed Map of Study Area:
SBR with Locations of Proposed Interventions
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BAROUK WATERSHED
LITANI WATERSHED
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Proposed Interventions
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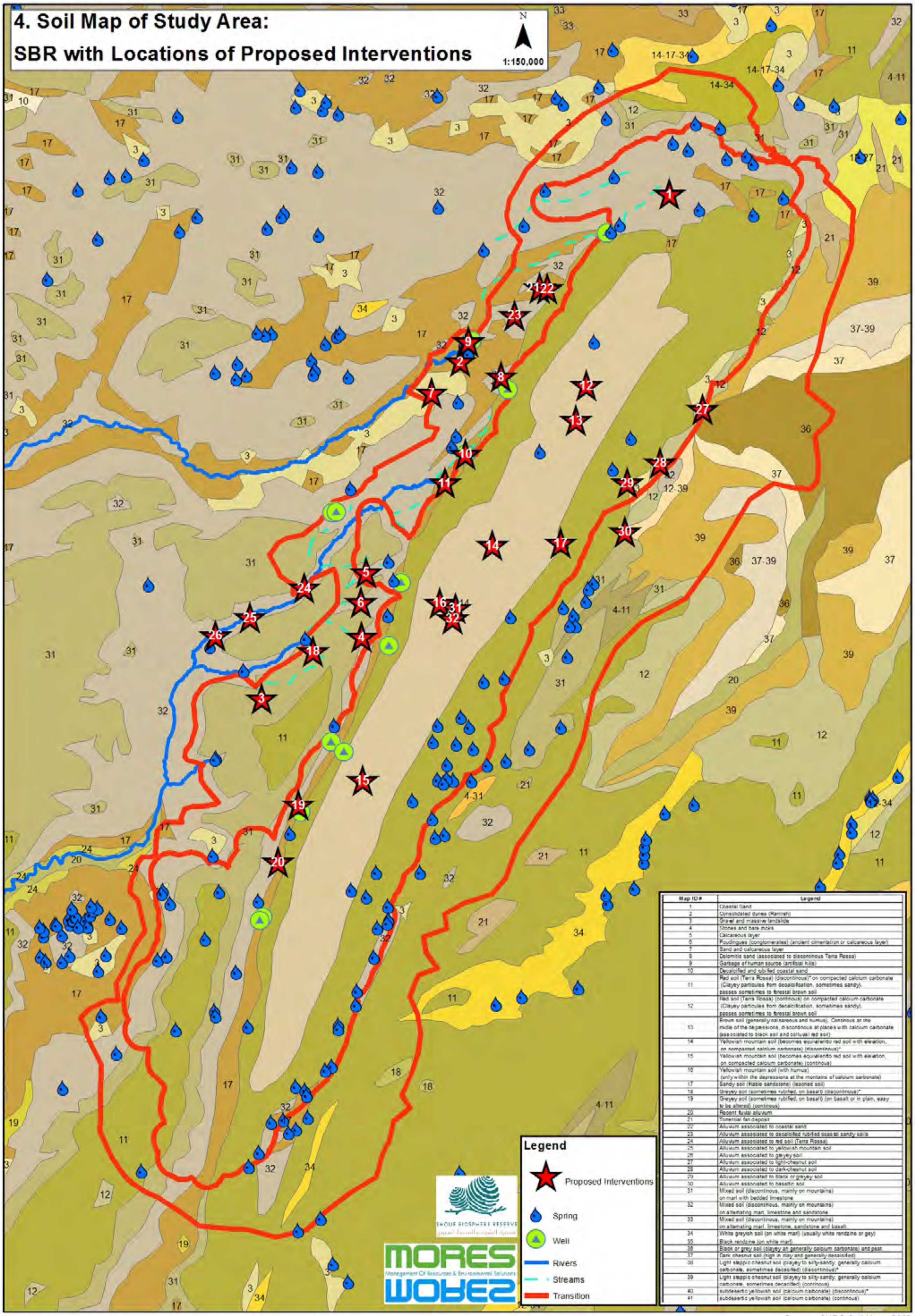
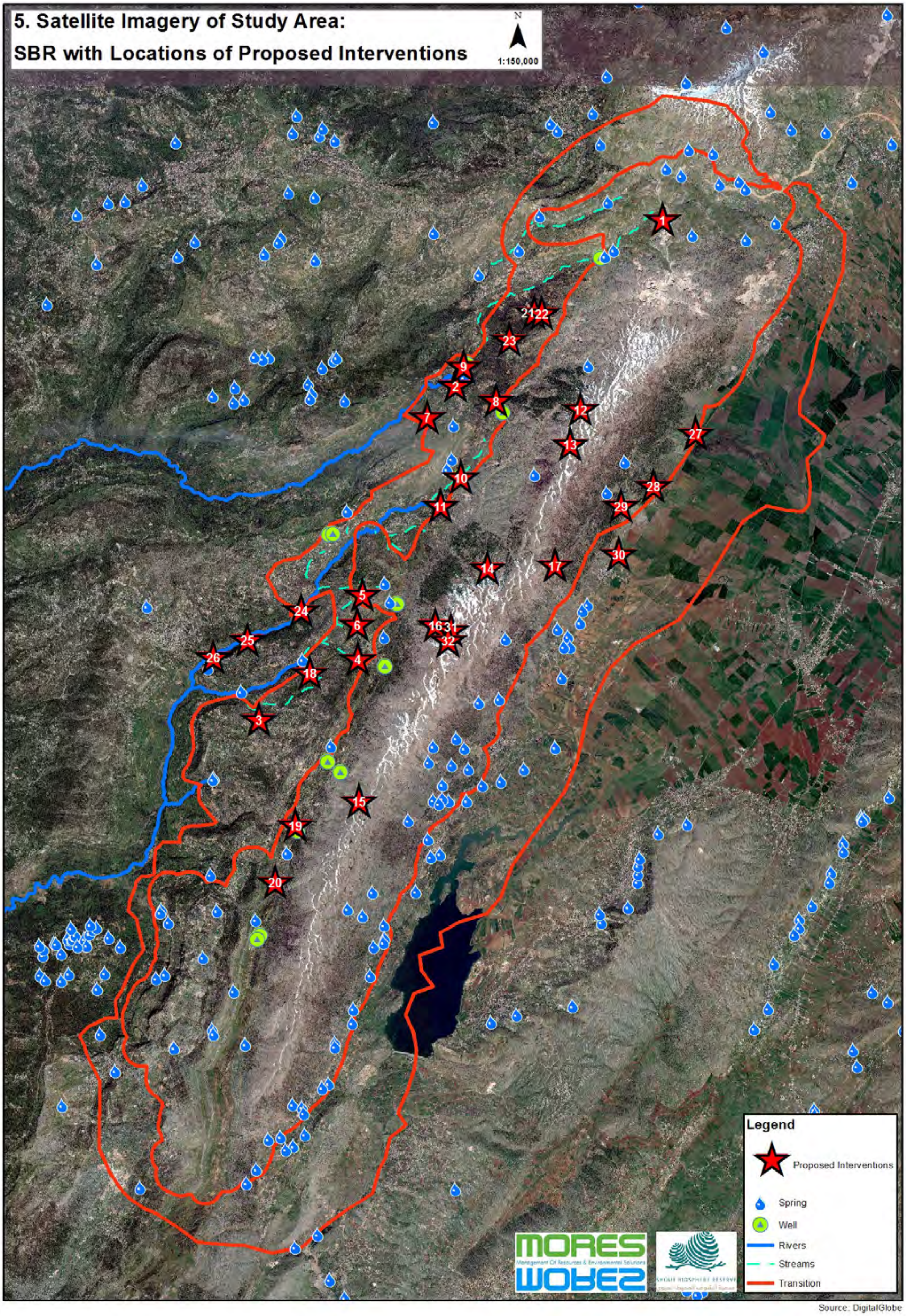
Streams
Transition
MORES
Source: CDR - SDTAL 2001



Source: CNRS Soil Maps 2006


5. Satellite Imagery of Study Area:
SBR with Locations of Proposed Interventions
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Legend
Proposed Interventions
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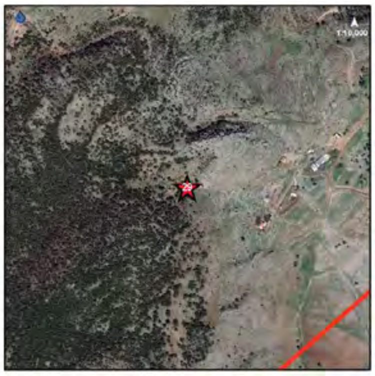
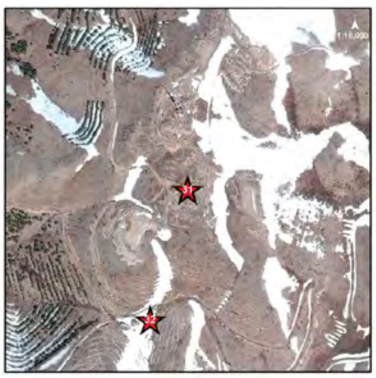
Well
Rivers
Streams
Transition
MORES
Management Of Resources & Environmental Solutions
Source: DigitalGlobe

6. Zoom in from Satellite imagery to Locations of Proposed Interventions

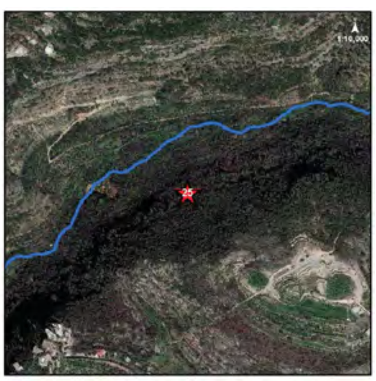








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