MARDI DE LEWAP

LES RENCONTRES RECHERCHÉ ET GRAND PUBLIC

COMPRENDRE LES EAUX SOUTERRAINES DES SOURCES AUX USAGERS

ASSESSMENT OF AQUIFER RECHARGE FROM DIRECT RAINFALL BASED ON EXISTING DATA

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OUTLINE

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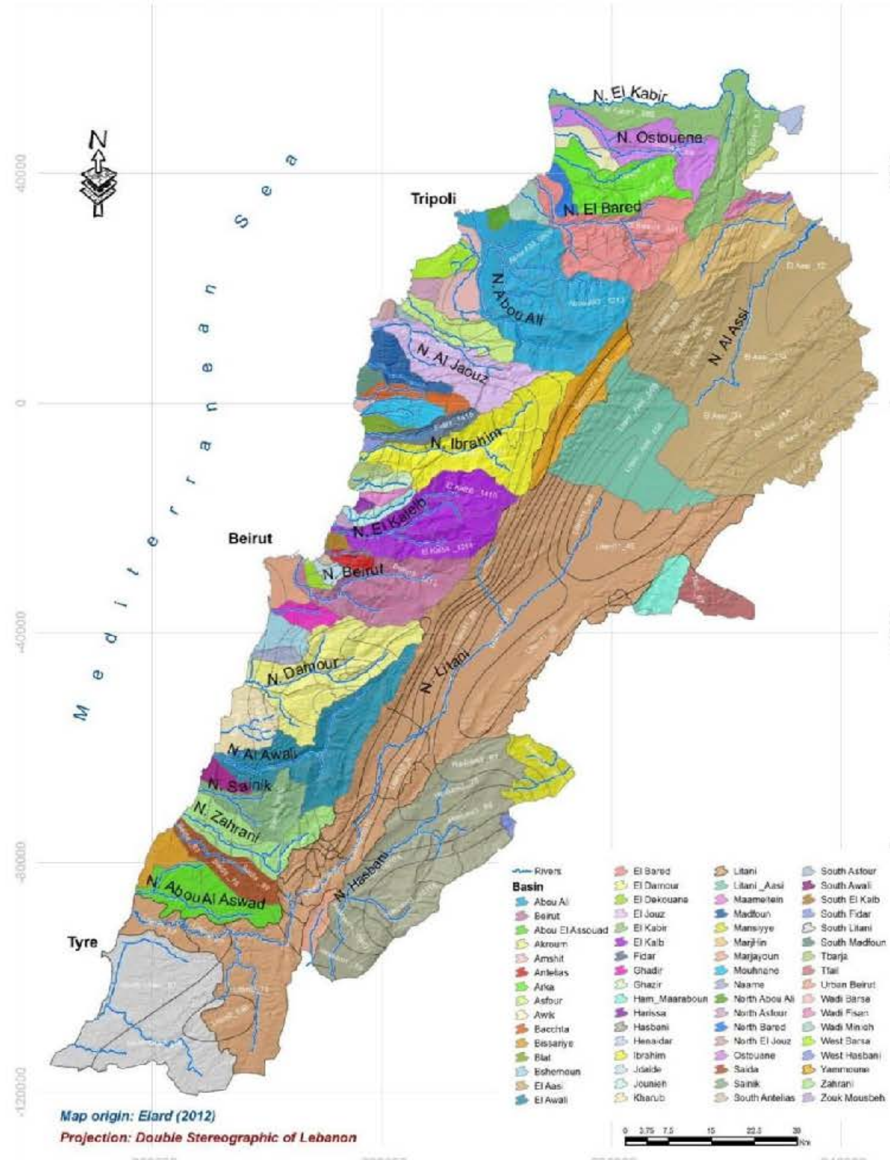
  - EVAPOTRANSPIRATION
  - SURFACE RUNOFF
- IBRAHIM WATERSHEDS RAINFALL/RUNOFF MODELING
- WATER BUDGET AND SAFE YIELD

METHODOLOGY OF SURFACE WATER MODELING

- Collect Data from different existing sources
- Perform Statistical Analysis of the rainfall and flow measurements data using Multivariate Principal Component Analysis
- Estimate Snow Covered Area from MODIS over a period of 10 years for every watershed
- Use HEC-HMS model to simulate Rainfall-Runoff process in Lebanon main Watersheds
- Validate flow measurements by comparing calculated with observed outflows using Nash–Sutcliffe efficiency
- Get Good Results for closed watersheds with few unknowns such as Ibrahim
- Should include Springs in the basin model as upstream boundary conditions
- Should define and measure intakes and discharges into the rivers

WATERSHEDS DIVISION

- **Watersheds** Units according to main rivers and streams
- **Sub-Watersheds** according to 1972 Isohyets
- **Sub-Sub-Watersheds** according to Elevation



PRELIMINARY BASELINE DATA ASSESSMENT - METEOROLOGY

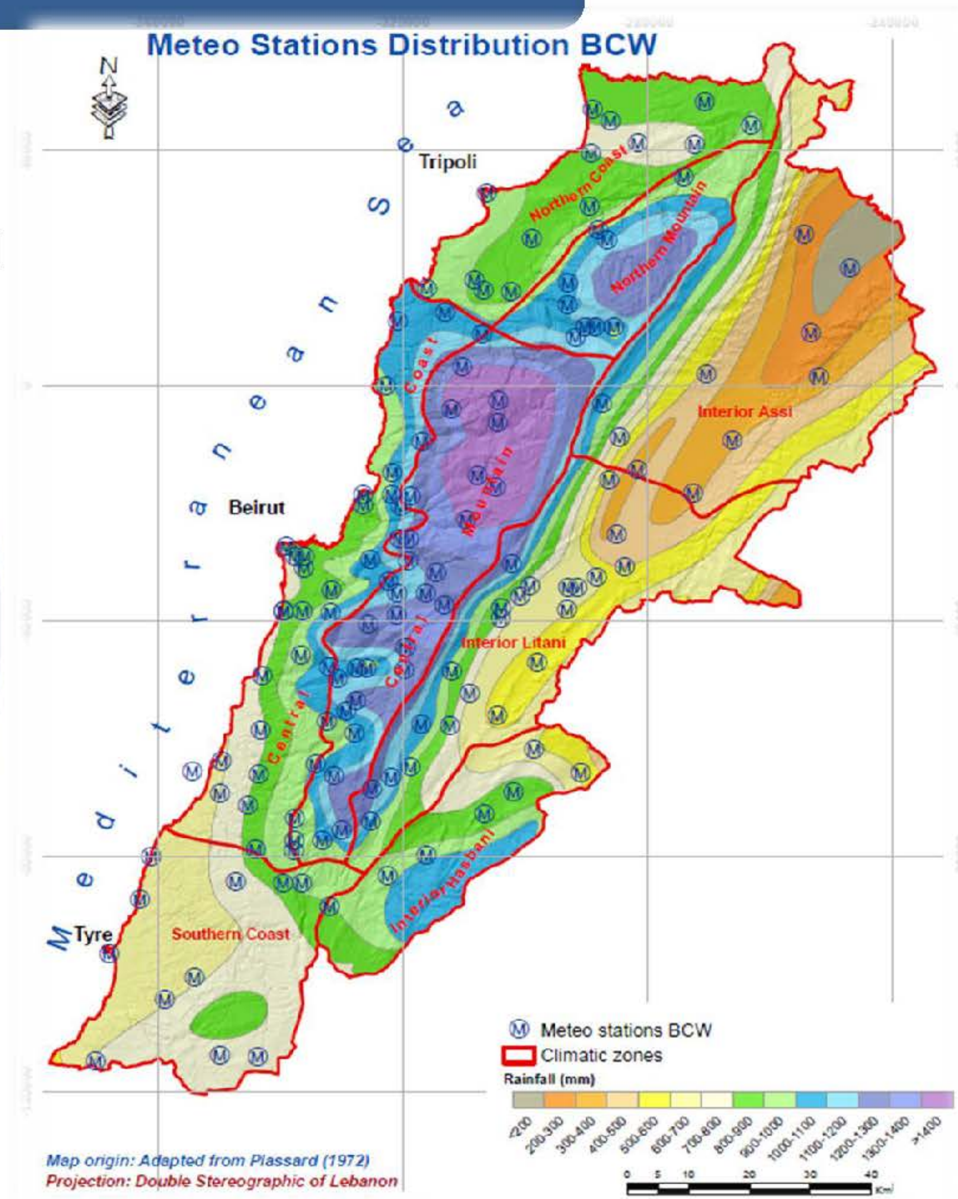
- **Meteorology Before the Civil War**

- 187 stations were installed covering the entire country

- Only 150 operated reliably

- Grouped into 8 climatic zones :

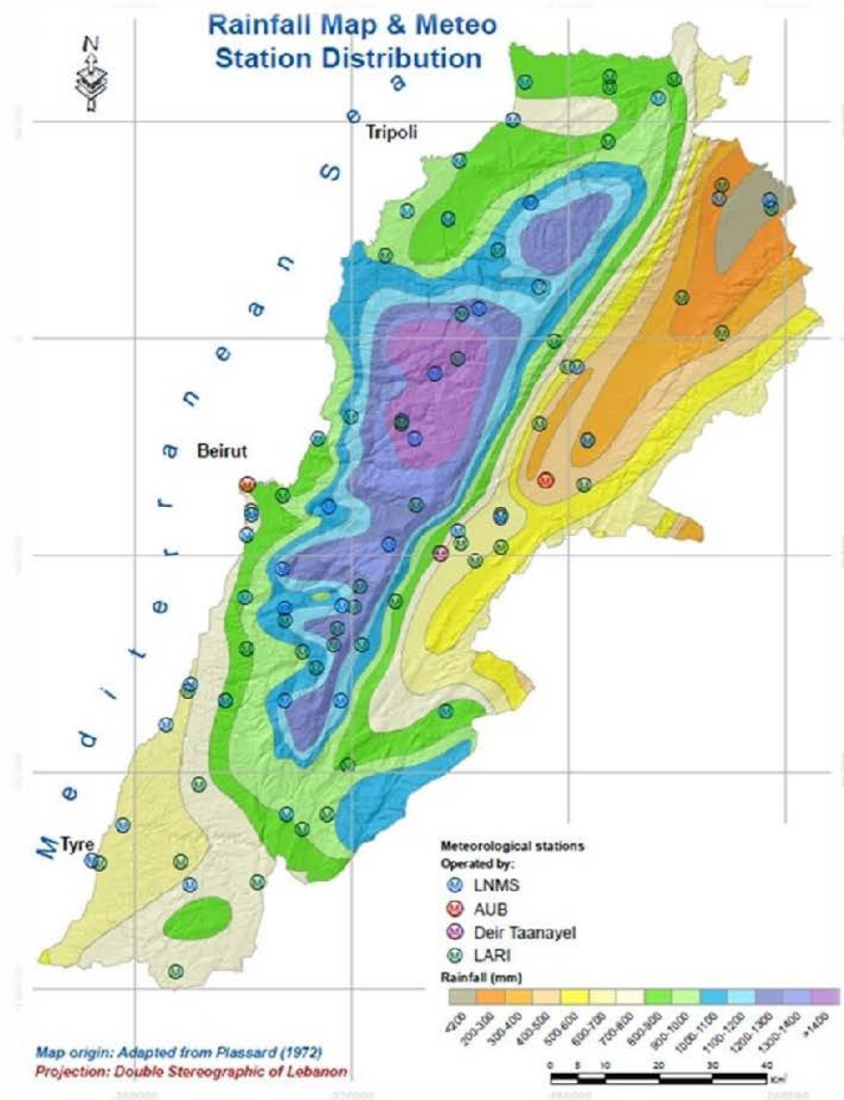
  1. Littoral North (15 stations)
  2. Littoral Central (35 stations)
  3. Littoral South (14 stations)
  4. Mountain North (8 stations)
  5. Mountain Center (36 stations)
  6. Interior Orontes(11 stations)
  7. Interior Litani(24 stations)
  8. Interior Hasbani(7 stations)



PRELIMINARY BASELINE DATA ASSESSMENT - METEOROLOGY

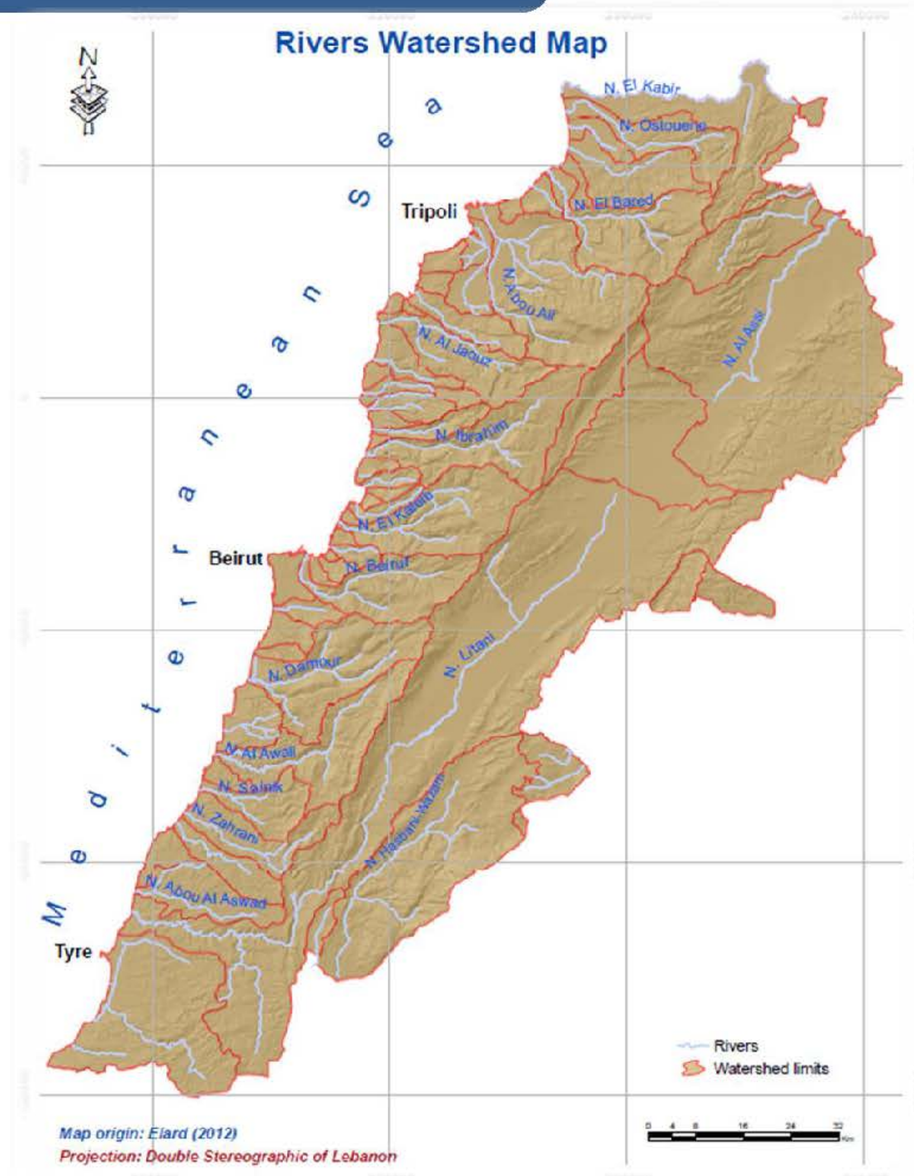
➢ **Meteorology After the Civil War**

- 37 stations are operated by the Lebanese National Meteorological Service (LNMS)
- 50 stations are operated by the Lebanese Agricultural Research Institute (LARI)
- Isohyet zones not containing any station from both networks are:
  - 400-500 mm & 1200 mm (LNMS)
  - 1100 – 1200 mm (LARI)

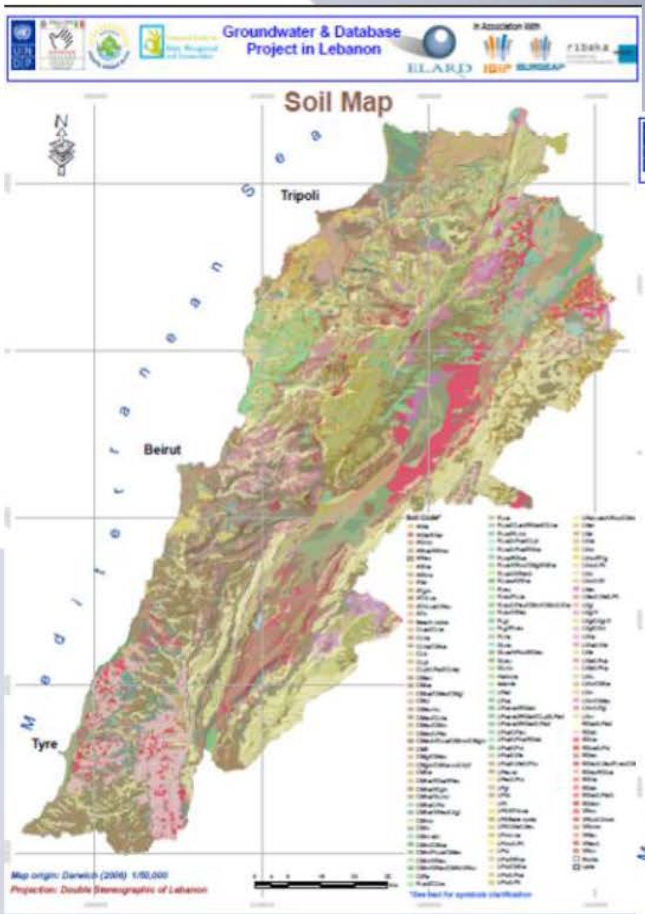


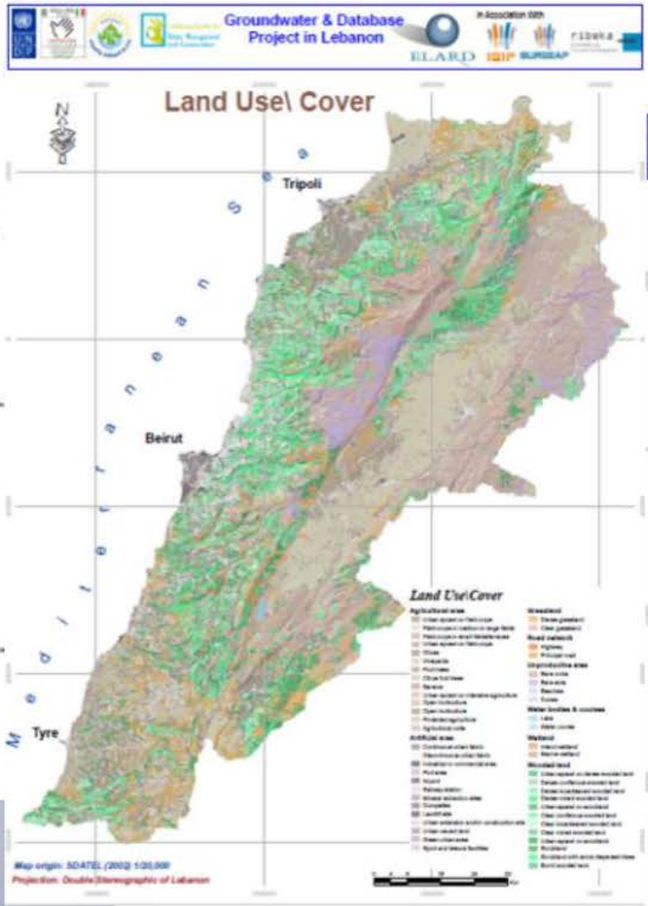
PRELIMINARY BASELINE DATA ASSESSMENT - HYDROLOGY

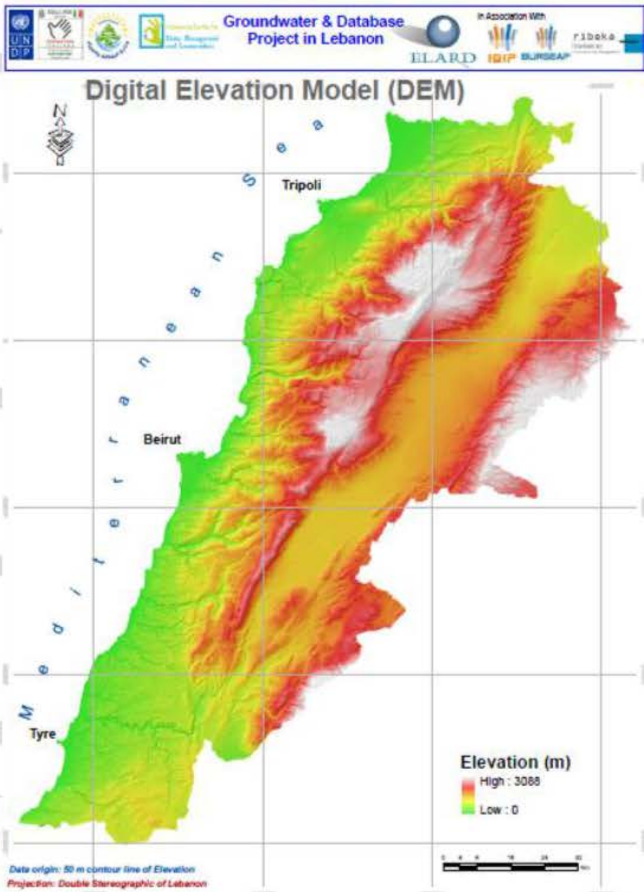
- Gauging activities stopped during the civil war
- In the early 1990s 20 stations were partially rehabilitated
- In 1998 the number of stations rose to 58 with the renovation of equipment of 38 other stations
- These stations are distributed over the different basins



GENERATED MAPS FROM EXISTING DATA







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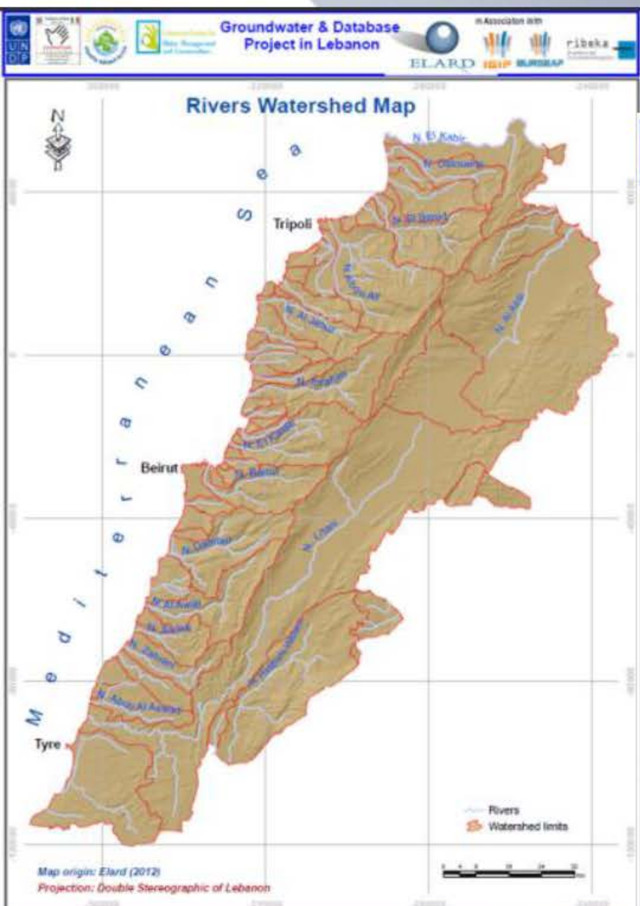
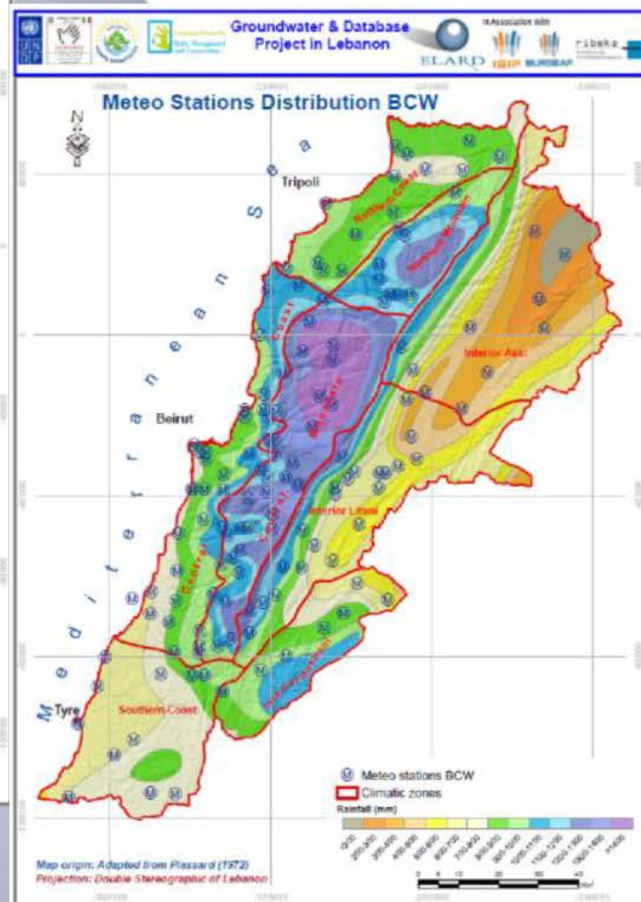
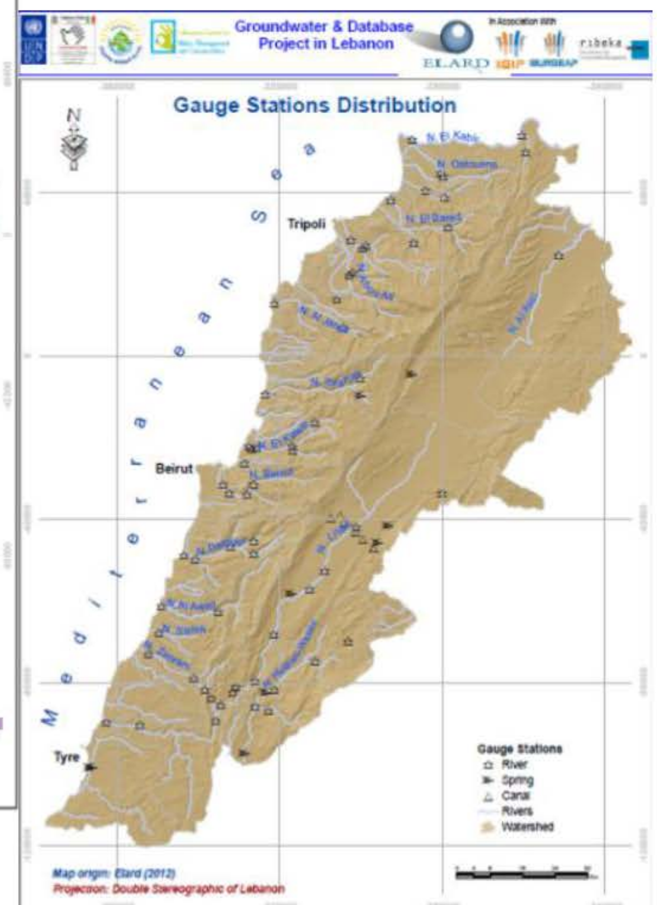






INFILTRATION ESTIMATION METHODOLOGY

SCS Curve Number Method

- Assessment of:
  - P : Precipitation (rain and snow)
  - RET : Evapotranspiration
  - Q : Surface Runoff
- Estimation of:
  - **I : Recharge to groundwater**
  - Soil Conservation Service (SCS) method:

$$I = A - RET = P - Q - RET - \Delta SM$$

A : Total Abstraction

ΔSM : Change in Soil Moisture

- (4) hydrologic cycles (2008-2012)

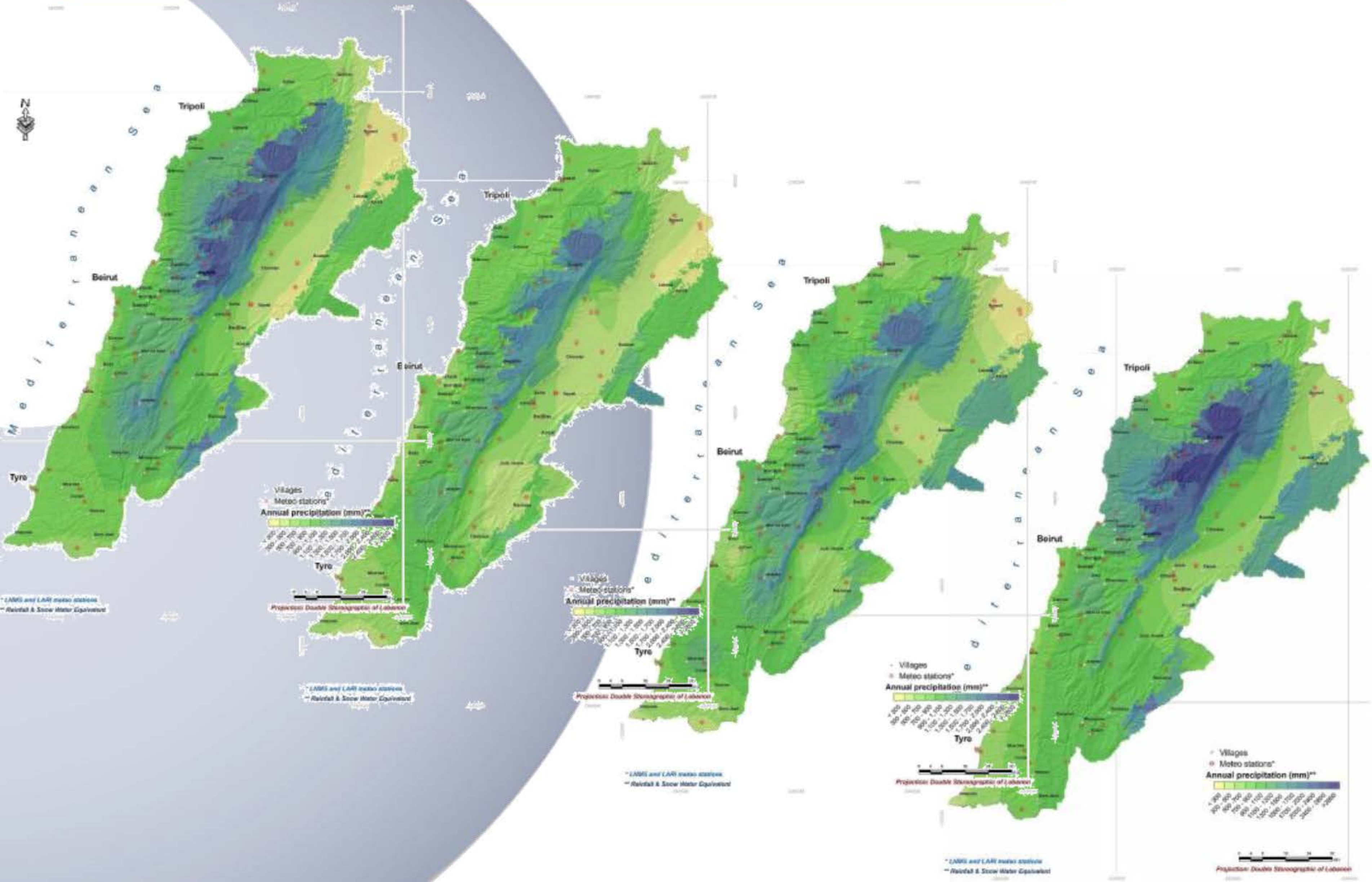
HYDROLOGICAL COMPONENTS - PRECIPITATION

- **Rainfall**
  - Lebanese National Meteorological Service (LNMS)
  - Lebanese Agricultural Research Institute (LARI)
- **Snow Water Equivalent**
  - Modis/Terra
  - HDF-EOS format
  - maximum snow extent
  - 8-days
  - 500-m pixel
  - From 14000 masl to 3100 masl
  - 68 cells for every sub-watershed:
    - 100m interval (17intervals)
    - North, East, South and West (4 orientations)

SWE (MCM) = S x Th x D

S : Snow covered area (Km2)
Th : Thickness of Snow (m)
D : Apparent density

HYDROLOGICAL COMPONENTS - PRECIPITATION



HYDROLOGICAL COMPONENTS - EVAPOTRANSPIRATION

- **Potential Evapotranspiration (PET):**
  - Turc (Turc,1961)
  - FAO Penman – Monteith (Allen et al., 1998)

- **Real Evapotranspiration (RET):**
  - RET = PET if PET < P (Precipitation)
  - RET = P if PET > P

HYDROLOGICAL COMPONENTS - SURFACE RUNOFF

SCS Method:

$$Q = (P - Ia)^2 / (P - I_a + S) \qquad \text{for } P > I_a$$

Q : cumulative runoff depth (mm/day),

P : cumulative rainfall depth (mm/day),

S : potential maximum retention after runoff begins (mm/day) calculated from CN as follows:

$$S = 25400/CN - 254$$

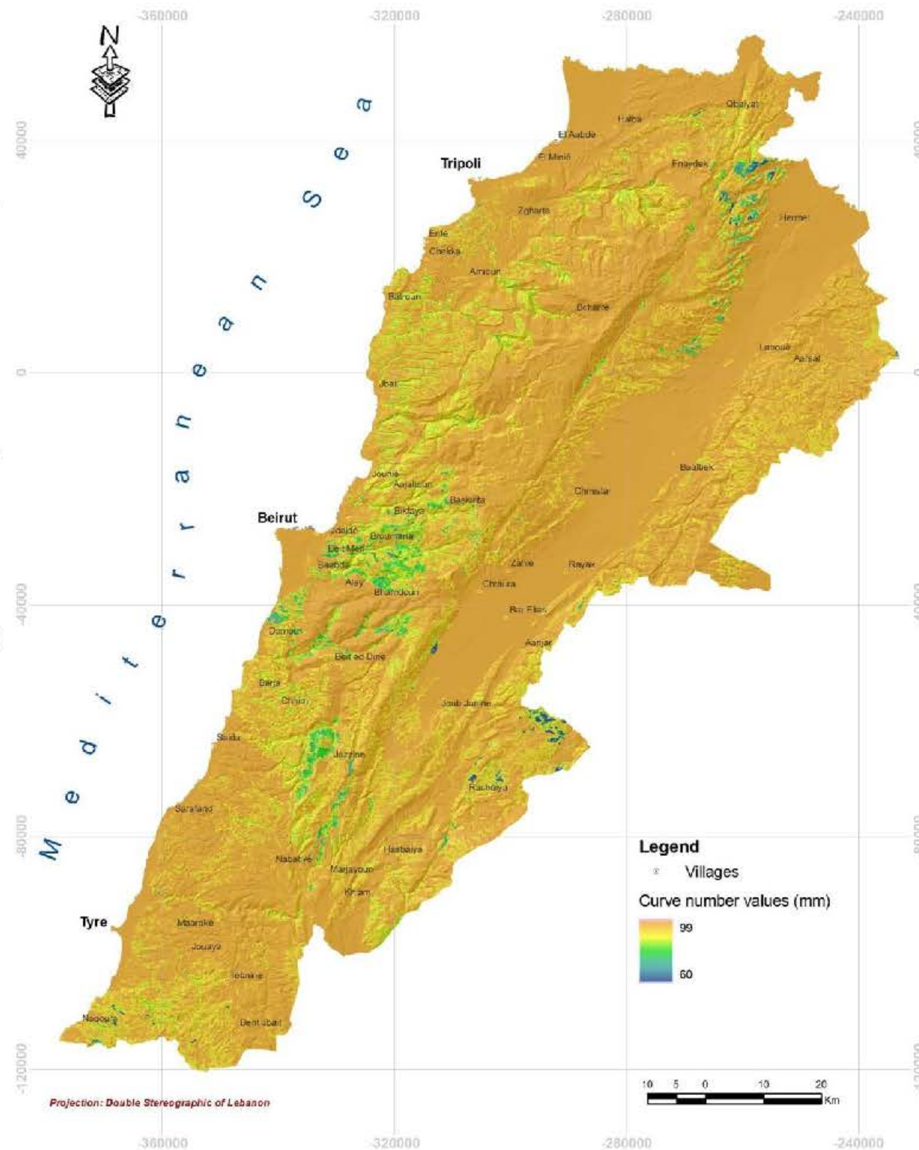
Ia : initial abstraction (mm/day) defined as a percentage of S and usually estimated as follows:

$$Ia = \lambda \times S \quad (\lambda \text{ usually taken equal to 0.2 or less})$$

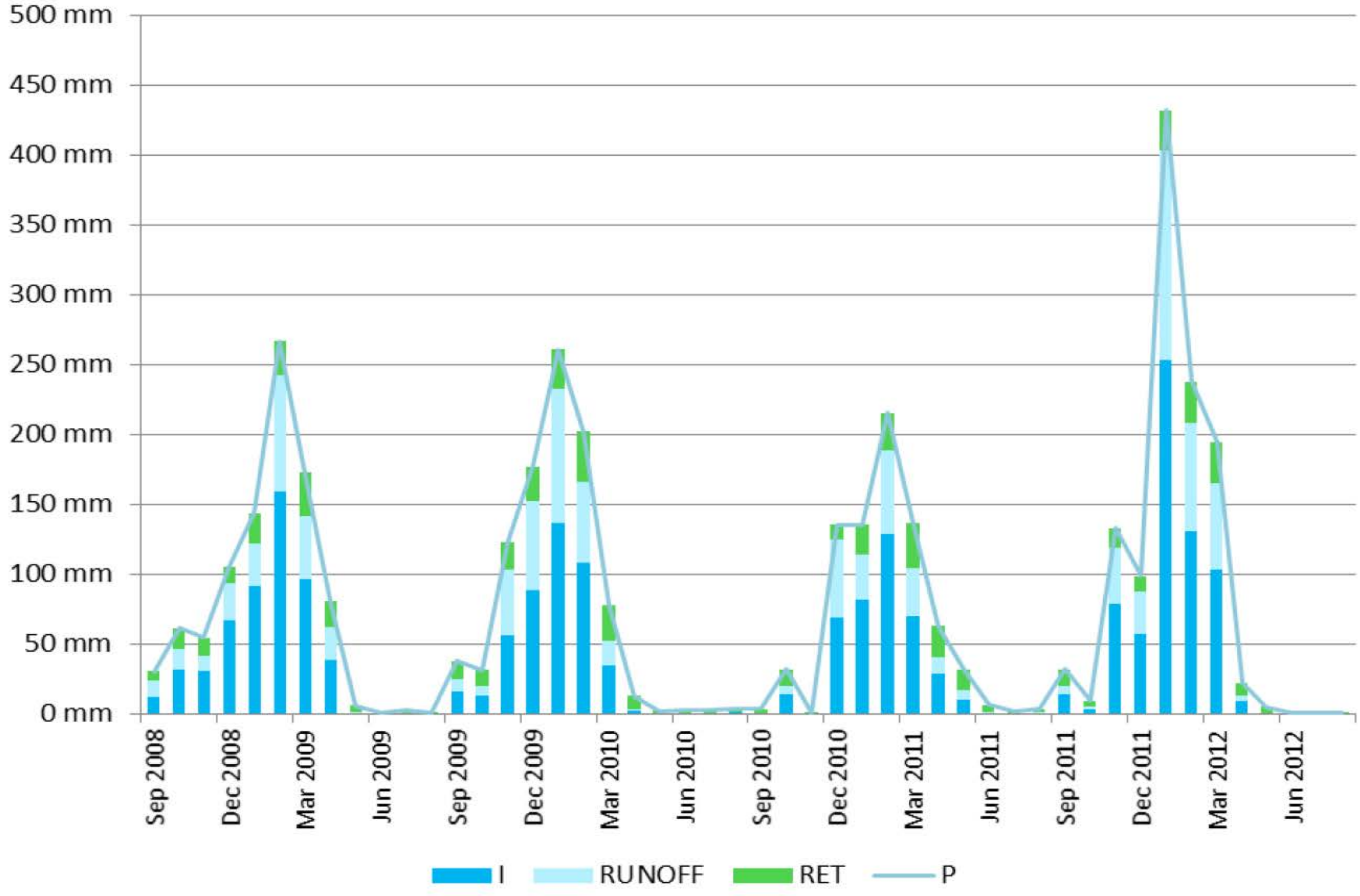
HYDROLOGICAL COMPONENTS - SURFACE RUNOFF

- **Curve Number (CN):**
  - Dimensionless catchment parameter
  - From zero (0) to hundred (100)
    - Zero : catchment retaining all rainfall (no runoff regardless of the rainfall amount
    - 100 : limiting condition of perfectly impermeable catchment (all rainfall becomes runoff)
  - Adjustment for a slope (a) :

$$CNa=CN(322.79+15.63(a))/(a+3.2355)$$



HYDROLOGICAL COMPONENTS



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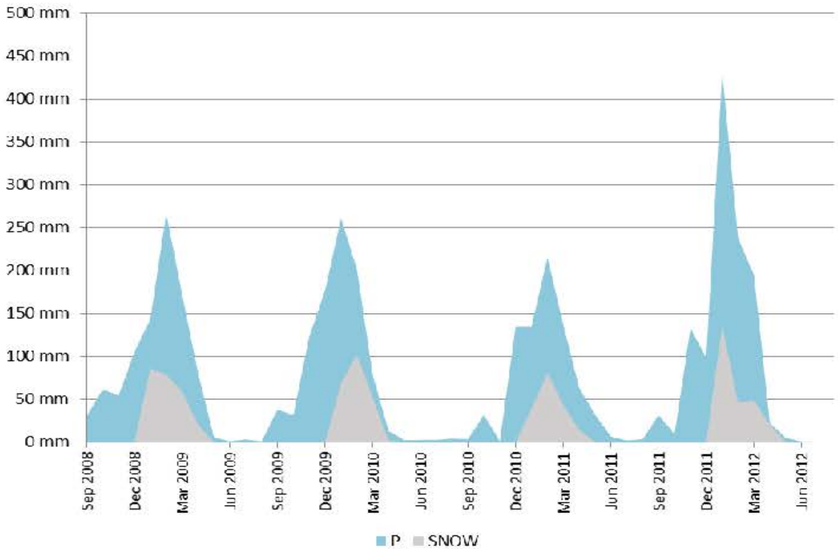
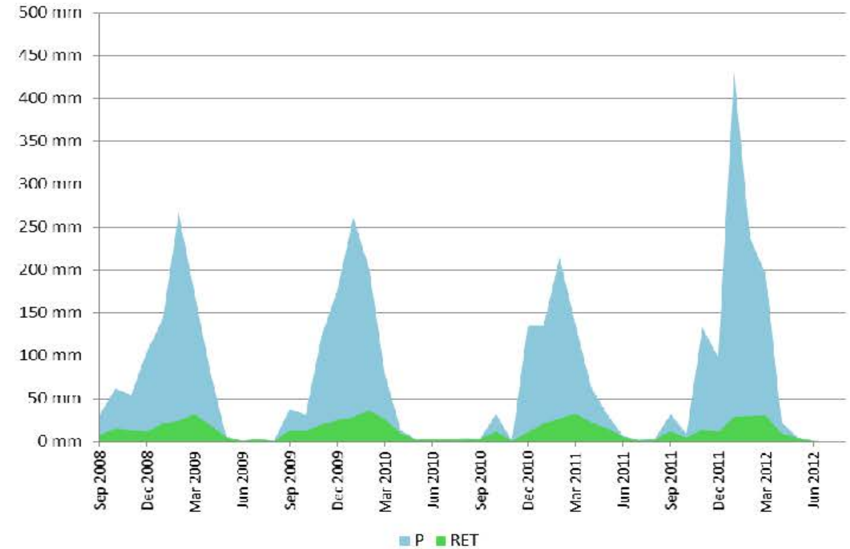
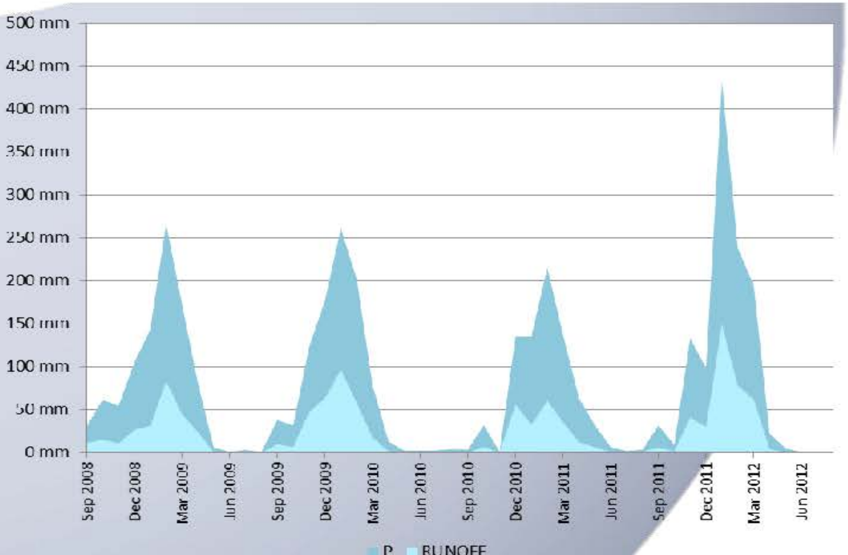
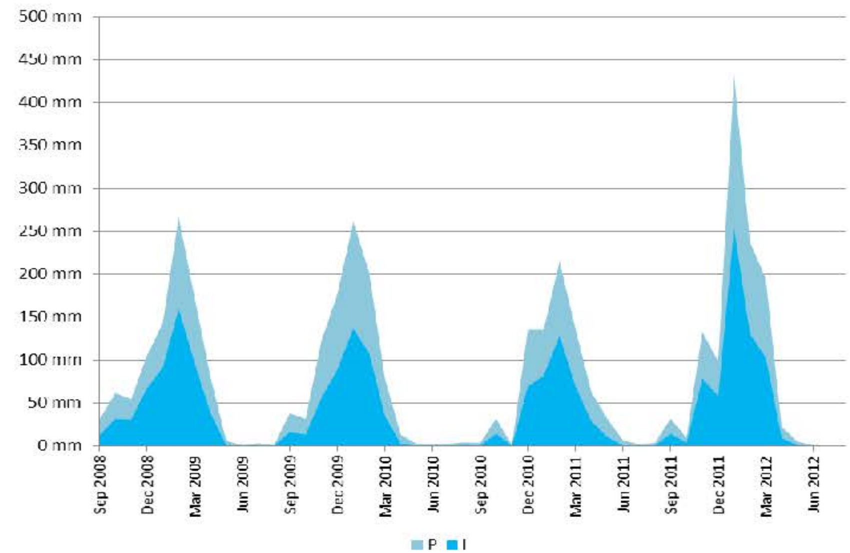


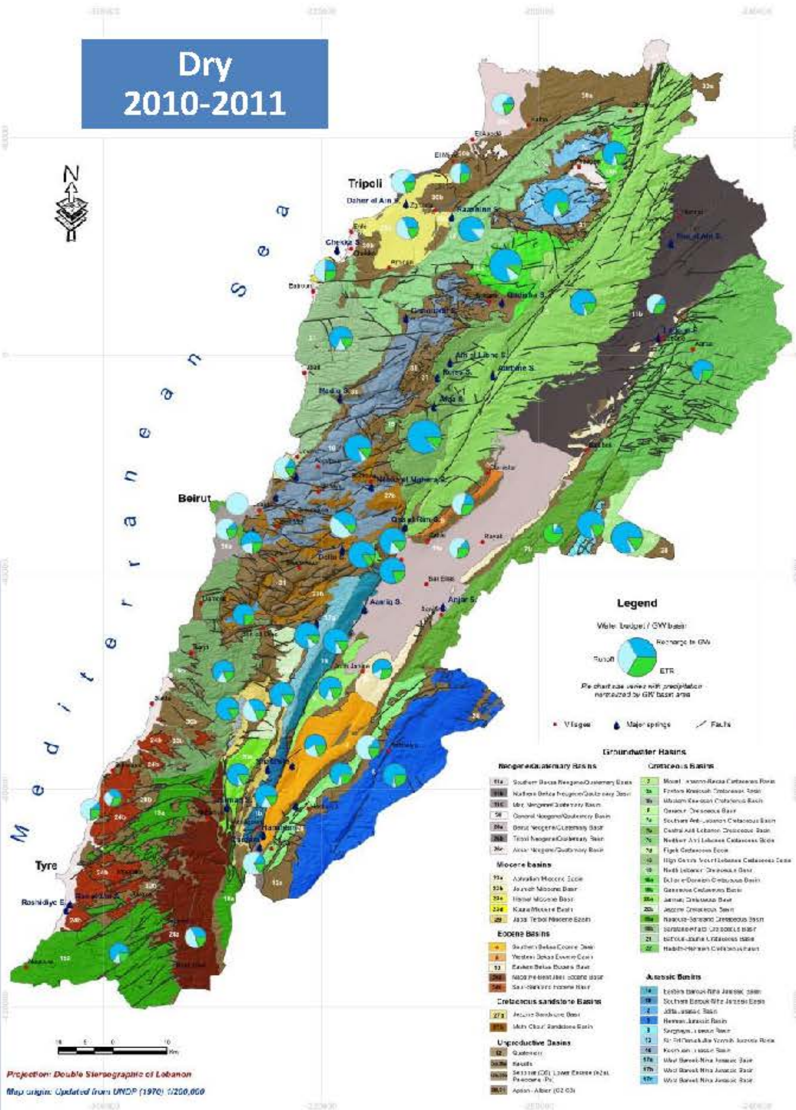




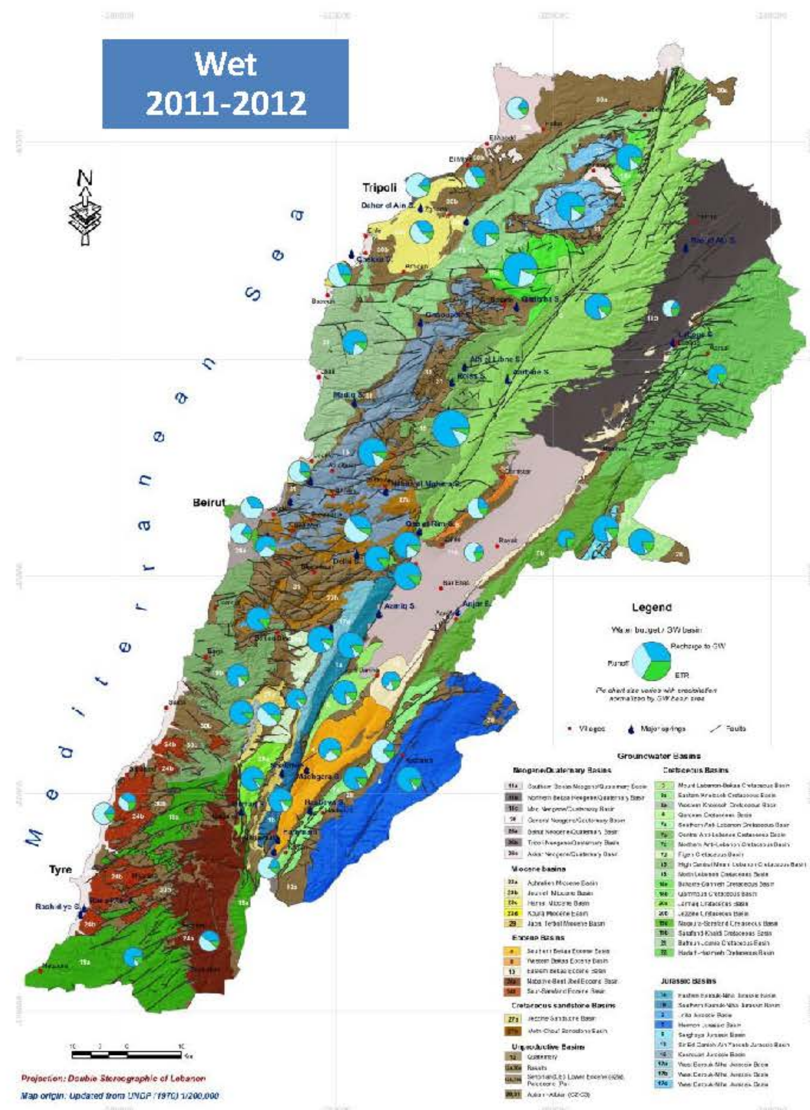


HYDROLOGICAL COMPONENTS

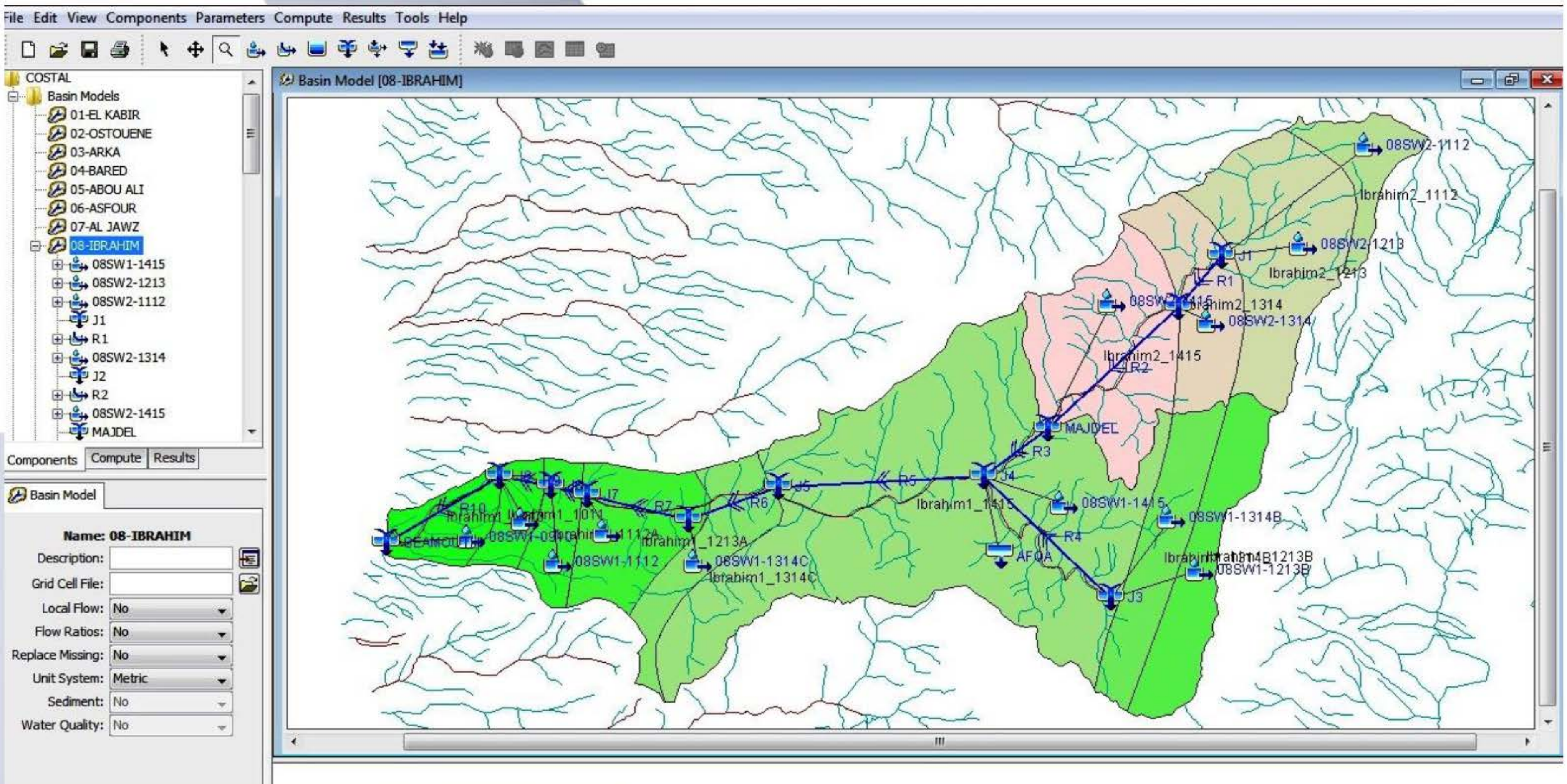
Dry
2010-2011



Wet
2011-2012



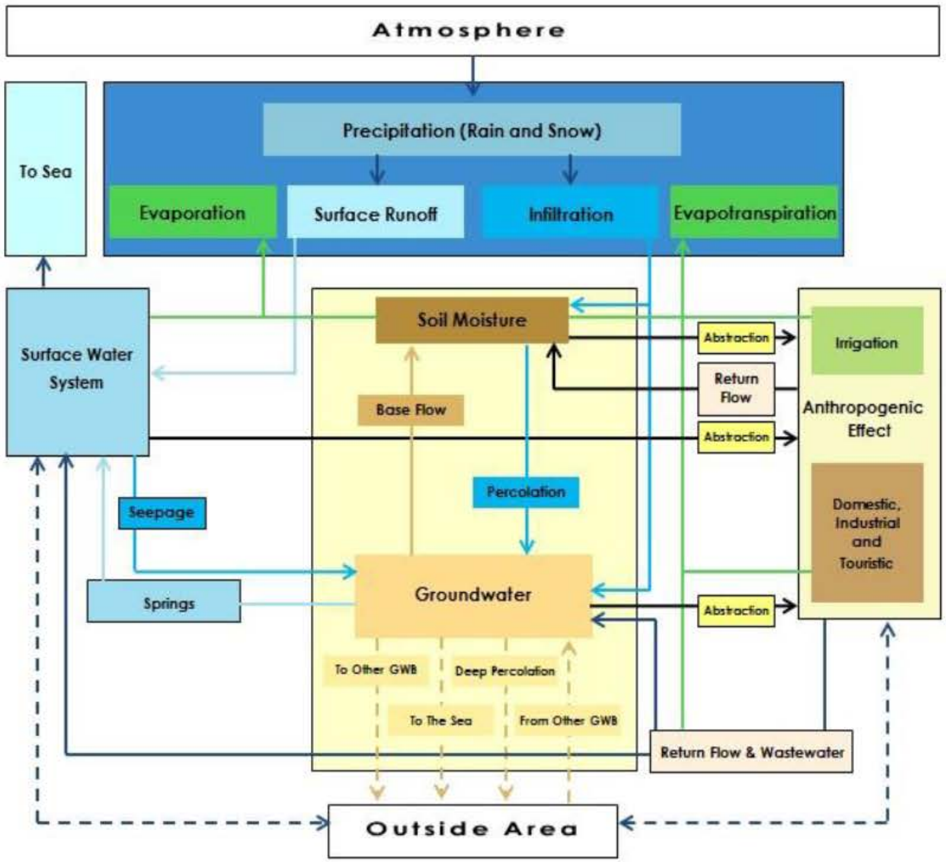
IBRAHIM WATERSHEDS RAINFALL/RUNOFF MODELING



WATER BUDGET AND SAFE YIELD

Groundwater Cycle:

- Three main components categorized as recharge:
  - natural infiltration from rainfall and snowmelt
  - return flow
  - groundwater gains from other basins/aquifer
- Three main components categorized as discharge:
  - groundwater usage for irrigation, domestic, industrial and tourism
  - groundwater losses to the sea
  - natural discharge of springs
  - losses to other basins/aquifers



WATER BUDGET AND SAFE YIELD

Groundwater Balance:

- GW Balance = Recharge – Discharge

$$\Delta S = (I + RF + GA) - (Dom + Irr + SD + GL + LS)$$

Construction of a Spreadsheet Model:

- Sorts data from different sheets and calculates the Balance for every GWB over the two retained hydrological cycles

WATER BUDGET AND SAFE YIELD

Acro	Data	Sources
	GW Balance	
St	Groundwater storage in the aquifer	Was not possible to estimate each one separately. St, LS and DP were jointly estimated from the difference between Recharge and Discharge
DP	Deep percolation	
	Recharge	
I	Infiltration	Discharge to Groundwater component calculated in Annex 1 (Hydrology Report)
RF	Return flow from domestic, industrial and touristic usages and	Calculated in Annex 1(Domestic, Industrial and Touristic Water Usage)
	Irrigation practices	Calculated in Annex 2 (Irrigation Water Usage)
	Return flow from Losses in the Domestic Supply Network	Calculated in Annex 1 (Domestic, Industrial and Touristic Water Usage)
GA	Groundwater gains from other basins/aquifers	Was not possible to estimate in this project
	Discharge	
Dom	Domestic, Industrial and Touristic Supply	Calculated in Annex 1 (Domestic, Industrial and Touristic Water Usage)
Irr	Irrigation water Usage from wells and from springs	Calculated in Annex 3 (Irrigation Water Usage)
SD	Springs discharge from GW-basins	Partly estimated in the Springs Report
GL	Loss to other basins/aquifers	Was not possible to estimate in this project
LS	Losses to the Sea (point and/or diffused)	Was not possible to estimate for individual basins; however the total expected volume was estimated from literature.

WATER BUDGET AND SAFE YIELD

		Subtotal Med.	Subtotal Interior	Total
Area Km2		5589	4664	10253
Infiltration MCM	Dry 10-11	2215	1901	4116
	Wet 11-12	3671	2979	6651
Return Flow MCM		360	251	612
Gain MCM		ND	ND	ND
Total Recharges MCM	Dry 10-11	2576	2152	4728
	Wet 11-12	4032	3231	7262
Domestic Supply Sources MCM	Public Wells	157	25	182
	Springs	193.9	12	206
	Private Wells	274	156	430
Agricultural Usages MCM	Wells	210.7	382	593
	Springs	87.5	48	136
Springs MCM		492	550	1042
Loss MCM		ND	ND	ND
Total Discharge MCM		1415	1173	2588
Budget MCM	Dry	1161	979	2140
	Wet	2617	2057	4675
Budget/Area mm	Dry	208	210	209
	Wet	468	441	456

WATER BUDGET AND SAFE YIELD

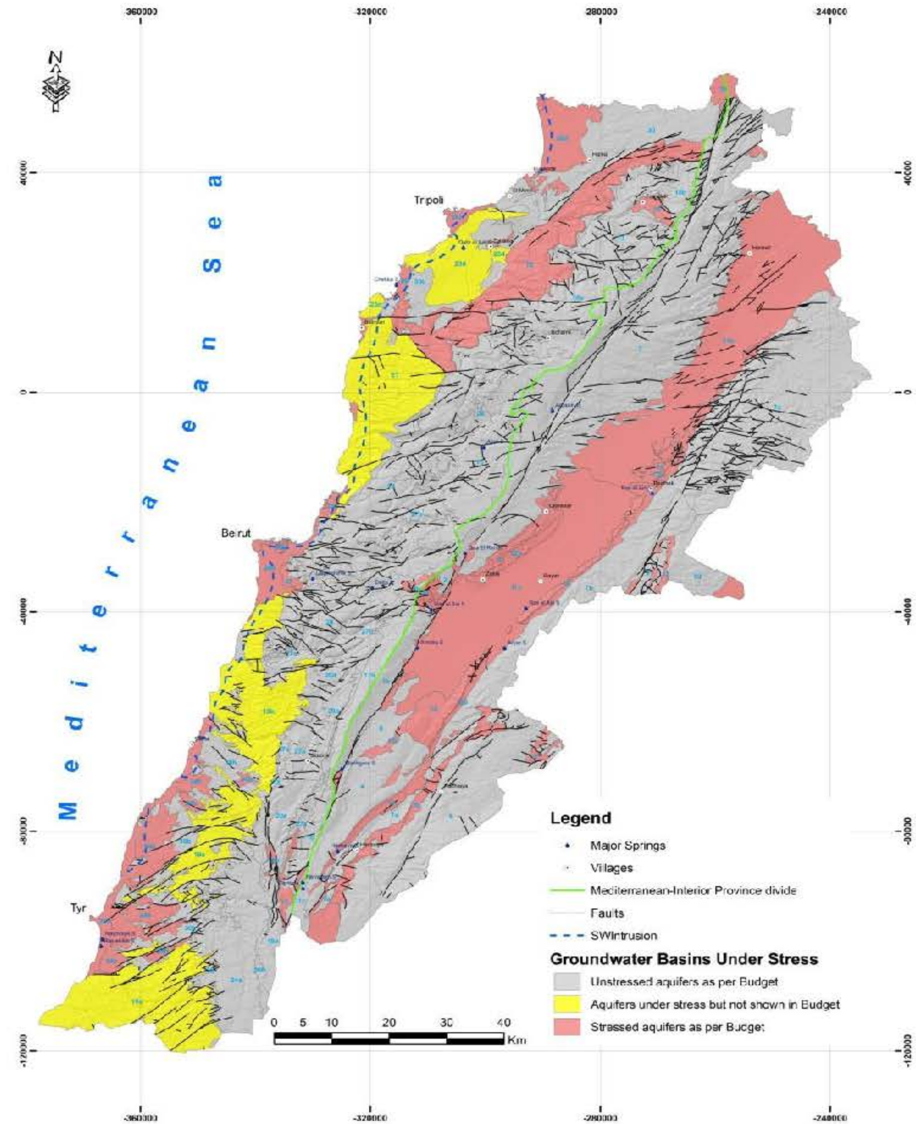
Preliminary GW Budget of Lebanon				
Parameter	Names/Description	Dry 10-11 (MCM)	Wet 11-12 (MCM)	Explanation
Recharge				
I	Infiltration	4116	6651	Values obtained from the Hydrology Report
RF	Return Flow	612		Return Flow from Domestic, Irrigation and Losses in the Network
GA	Addition from other basins/aquifers	ND	ND	Not Defined
Discharge				
Dom	Domestic, Industrial and Touristic Usage	818		Values obtained from Annex 1 (Domestic, Industrial and Touristic Water Consumption)
Irr	Volume of Irrigation Usage	728		Values obtained from Annex 2 (Irrigation Water Consumption)
SD	Natural Springs Discharge	1042		Values obtained from Springs Report
GL	Losses to other basins/aquifers	ND	ND	Not Defined
DP	Deep percolation	ND	ND	Not Defined
LS	Losses to the Sea	600-1000		From FAO (1973)
Balance / Deficiency in Budget				
Balance / Deficiency in Budget		2140	4675	Which includes LS, DP, GL, & St for they are not estimated and con not be extracted from the values obtained. Care should be considered when using those values.

WATER BUDGET AND SAFE YIELD

Preliminary Results

- Preliminary Groundwater Basins Budgets
  - Deficiency in budget analyses for the Mediterranean and Interior provinces for the two hydrological Cycles
  - Assessment of the risk exploitation of the different basins
- Safe Yield
  - Water budget of GW basins location of extraction points
  - Extraction rates (surface and groundwater)
  - Potential local or regional recharge sources
  - Variations of groundwater regimes
  - Socioeconomic factors, environmental considerations and climate change
- Preliminary Country Budget

vary from **2,140 MCM for a dry cycle**
and **4,675 MCM for a wet cycle**



Thank you