Syria - سورية

Ministry of Local Administration and Environment

INITIAL NATIONAL COMMUNICATION

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Vulnerability Assessment and Possible Adaptation Measures of Water Resources (Modeling)

Related to the Project Activity

Programs Containing Measures to facilitate Adaptation to Climate Change

Project Title

Enabling activities for preparation of Syria's initial national Communication to the UNFCCC, (Project Nr.00045323).

National Project Director

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March 2009

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The project implemented in the ministry of local administration and Environment (MLAE)/General Commission of Environmental Affairs (GCEA), in collaboration with Global Environmental Facility (GEF) and United Nation Development Programme (UNDP) in Syria.

Vulnerability Assessment and Possible Adaptation Measures of Water Resources

(Modeling)

(INC-SY_V&A_ Water Model -En)

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March / 2009

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This report has been approved unanimously by the technical committee, during the Technical Workshop which took place on 24/ 03/ 2009 in the Dedeman Hotel Palmyra.

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1. Introduction

Water resources in Syria are under a heavy and increasing stress. Any alteration in climatic patterns that would increase temperatures, and reduce rainfall would greatly exacerbate existing difficulties. Changes in climate will be amplified in the water environment.

Syria is divided into seven hydrological basins (Fig. 1). The main water user is the agricultural sector, which consumes from 94 % (Tigris & Khabour basin), to 71 % (*Barada & Awag* basin) (Fig. 2). Most of the basins suffer from water shortage, and the situation expected to worsen in 2026 due to growth of demands with the exception of Coastal basin which has a positive water balance (Table 1). The average overall water deficit of Syria (*Kayal*, 2006)[1] from 1995-2005 was (651) m.cm/ y, and is expected to increase to (2077) m.cm/ y in 2026-2027, due only to population and development growth.

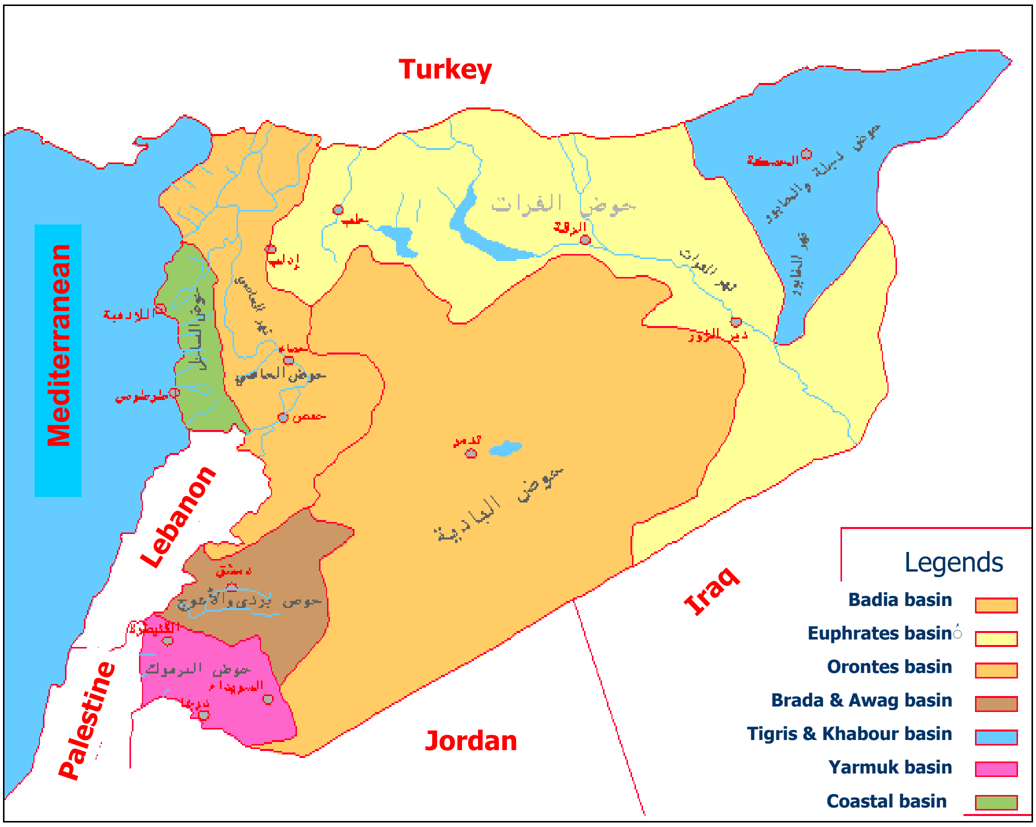

Figure (1): Hydrological basins of Syria.

[1] *Kayal*, 2006, Water management vision in Syria up to 2027, Informal data

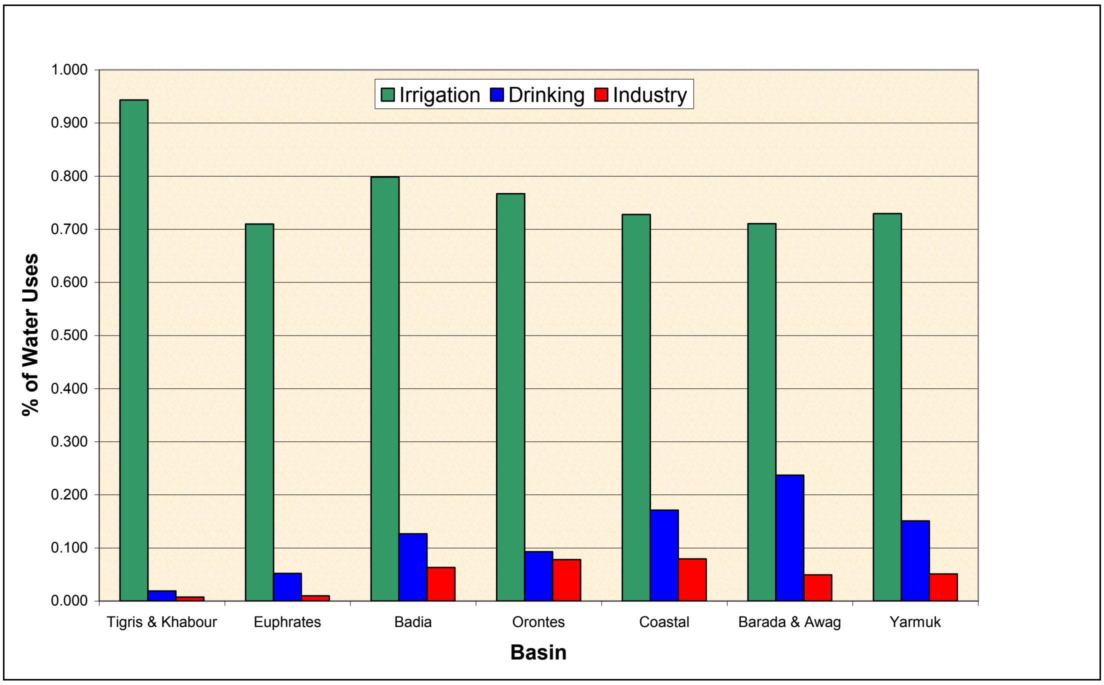

Figure (2): Proportionality of water usages among different sectors *(Kayal, 2006, Informal data).*

Table (1): Components of water balance for 2005-2006 and 2026-2027, *(Kayal, 2006, Informal data)*

Basin	Component	Tigris & Khabour	Euphrates	Badia	Orontes	Coastal	Barada & Awag	Yarmuk	TOTAL
		mcm/y							
water resources	GW&SW	2104	7030	338	1505	1109	817	355	13258
	Sweage	80	304	44	283	0	264	46	1021
	Agric drainage	395	751	0	272	80	140	49	1687
	Average Total Available 1995-2005	2579	8085	382	2060	1189	1221	450	15966
	Total Available 2026-2027	2669	8652	409	2644	1844	1532	551	18301
	%	3	7	7	28	55	25	22	15
water uses	Irrigation	4119	5010	265	1811	532	935	329	13001
	Drinking	83	366	42	219	125	312	68	1215
	Industry	32	69	21	184	58	65	23	452
	Evaporation	132	1614	4	148	16	4	31	1949
	Average Total Uses 1995-2005	4366	7059	332	2362	731	1316	451	16617
	Total Uses 2026-2027	4723	8860	459	3024	866	1741	705	20378
	%	-8	-26	-38	-28	-18	-32	-56	-23
Budget	Average 1995-2005	-1787	1026	50	-302	458	-95	-1	-651
	2026-2027	-2054	-208	-50	-380	978	-209	-154	-2077
	%	-15	120	200	-26	-114	-120	-15300	-219

Groundwater is a very important source of water in Syria. Its importance increased considerably during drought strikes. The appraisal report of the Syrian North Eastern Region Rural Development Project (North Eastern Region Rural Development

Project, 2007) [2] showed that in the year 2001 which came at the end of three successive drought years, witnessed a 21 % increase in the number of drilled well, equivalent to about 167000 wells of which only 42 % are licensed. The overall water deficit in Syria showed a considerable increase in the percentage of used water to available water in the drought years (1999-2001) as it shown in Table (2). In year 2001-2002, the deficit was 16 % more than the ten years (1992-2002) average value.

Table (2): percentage of consumed water to available water *(Abed Rabouh, 2007)*

date	1992-1993	1993-1994	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	average
(consumed water/available water)%	101%	93%	107%	119%	111%	112%	116%	121%	124%	132%	115%	114%

Further decreases in groundwater levels are projected because of the lower recharge which is (partly) caused by a shorter length of the recharge season and the drop in water retention as snow. Recent studies (*Döll* and *Flörke*, 2005)[3] projected a change of groundwater recharge between present-day (1961 to 1990) and the 2050s (2041 to 2070) to be more than -30% (Figure 3).

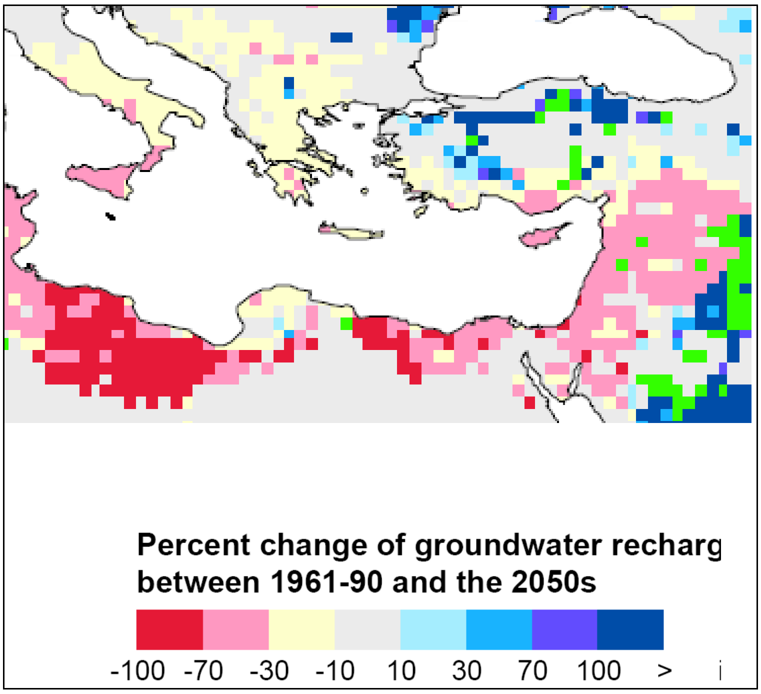

Figure (3): Percentage changes of 30 year averages groundwater recharge between present-day (1961 to 1990) and the 2050s (2041 to 2070) *(Döll and Flörke[2]).*

[2] North Eastern Region Rural Development Project, Design Document – Appraisal Report. Working Paper 3 Irrigation and Water Management. Appendix 1: Data on Water Resources And Irrigation in Syria, 2007.
[3] Döll, P. and M. Flörke 2005. Global-scale estimating of diffuse groundwater recharge. Frankfurt Hydrology paper 03. Institute of Physical Geography, Frankfurt University.

Water quality is an important issue needs also to be raised. Ground water quality is deteriorating in most of shallow aquifer in the country, where major irrigation and industrial activities occur. In Damascus Ghouta, the concentration of Nitrates and Ammonia ions exceeds the allowed levels in some of the state drinking wells (Table 2) which led to an increasing number of the closure of drinking wells.

Table (2): Concentration of Nitrates and Ammonia in drinking water wells in rural Damascus 2005[4].

indicator	Concentration of pollutants(mg/l)	Maximum permitted limit(mg/l)
Nnitrates	100-200	40
Ammonia	3.2	0.3

Increasing of groundwater salinity in Euphrates valley basin and Damascus plain is noticeable. Surface water face the same problem, where most of the rivers in the country suffer from water deterioration due to domestic, industrial and agricultural activities. Euphrates River will be subject to more pollution after completing of GAP project in Turkey. When the major irrigation systems in Turkey were completed, some studies (*Beaumont, 1981*[5] *and Kolars, 1991*[6]) predicted that both the *Balikh and Khabur* flows would be substantially augmented by return irrigation water. While this augmentation could be beneficial and provide more irrigation water in Syria, these studies cautioned that neither the salt nor agricultural chemical load that will be discharged into the rivers could be accurately estimated.

Agricultural sector in Euphrates valley will be vulnerable to such changes since additional water will be required to compensate the increase of leaching fraction in irrigation water.

Other challenge facing Syria is to manage an unusual combination of high variability and low rainfall especially in the arid part of the country (World Bank, 2007)[7] , where average rainfall is so low that even modest rainfall can represent a huge variation on the mean. Higher precipitation variability in space and time is expected (IPCC, 2007). This requires to concentrate on infrastructure that channels runoff when rainfall does occur and dams that store water or encourage aquifer recharge. Syria has to increase the number of "*hafires*" to collect rainwater. *Badia* basin is an arid basin with an average annual rainfall less than 200 mm and will be most vulnerable to such high variability in rainfall. Presently there are more than 120 *hafires*, most of them located in *Badia* basin. However, with 60 % water regulation degree in this basin (the lowest

[4]Reem ABED RABBOH, 2007. Water demand management in Syria. 3 rd Regional Workshop on: Water and Sustainable Development in the Mediterranean Water Demand Management, Progress and Policies. Blue Plan UNEP / MAP, Zaragoza, Spain.

[5] Beaumont P. 1981.Water resources and their management in the Middle East. In Change and Developments in the Middle East: Essays in Honor of W.B. Fisher, Clarke JI, Bowen-Jones H. (eds). Methuen: London; 40–72.

[6] Kolars J. 1991. The Future of the Euphrates River. World Bank: Washington, DC.

[7]Making the most of scarcity, Accounting for better water management in Middle East and North Africa, MENA development report on water, the World Bank, 2007

of the Syrian main basins, table 3) there is a need for more improvement in rain water harvesting.

Table (3): Water balance for 2001, *K Murad*[8], *(Informal data).*

Water Budget member		Unit	The Hydrologic Basin: Barada & Awag	Yarmouk	Step Badia	Orontes	Coastal	Tiger & Khabur	Euphrates	Total
Average Renewable Resources	Surface water	M.m^3	20	180	163	1110	1557	788	7105	10923
	Groundwater	M.m^3	830	267	180	1607	778	1600	371	5633
	Total	M.m^3	850	447	343	2717	2335	2388	7476	16559
Precipitation Rate 75%		%	83.7	83.7	83.7	83.7	83.7	83.7	83.7	83.7
Flow Rate 75%		%	67.1	67.1	67.1	67.1	67.1	67.1	67.1	67.1
Available Water Resources	Surface water	M.m^3	13	121	109	745	1045	529	6948	9510
	Groundwater	M.m^3	557	179	121	1078	522	1074	249	3780
	Total	M.m^3	570	300	230	1823	1567	1602	7197	13289
	Regulation degree	%	90.0	85	60	85	65	95	98	
	Regulated W.R.		513	255	138	1550	1018	1522	7053	12049
	Domestic & industrial Reuse		254	85	35	352	0	102	172	1000
	Agricultural water reuse		75	35	0	222	72	404	728	1536
	Total Available Water		842	375	173	2124	1090	2028	7953	14585

2. Surface water (Case Study: Euphrates River)

Syria obtains 36 % of its renewable annual resources from the Euphrates, which shows the necessity of an improved transboundary water agreements, that take climate change into account, in order to avoid conflicts e.g. due to increasingly frequency and severity of droughts.

The model-derived climate sensitivity of the Euphrates, Upper Tigris and Greater *Zab* river discharges (Smith et al. 2000)[9] shows that for Euphrates, an increase or decrease in precipitation by 25 % raises or lowers the discharge profile while keeping its shape unchanged. The annual discharge rises to 40655 mcm or drops to 15751 mcm compared to the reference value of 27048 mcm. This is a 50% rise and a 42% drop, nearly twice the imposed percentage change in precipitation. Knowing that regional modeling studies expected a reduction of rainfall in mid 21st century (Evans, 2008)[10] around 40-50 mm in the upper Euphrates and Tigris basin (Fig. 4) which is about 7 % of average rainfall, it is expected to have about 11% drop in Euphrates discharge.

[8] Khaldoon Mourad , 2006. Situation of IWRM in Syria, Malta, (Informal data)

[9] Smith, R.B., J. Foster, N. Kouchoukos, P.A. Gluhosky, R. Young and E. De Pauw. 2000. Spatial analysis of climate, landscape, and hydrology in the Middle East: modeling and remote sensing. Center for Earth Observation Report No.2., Yale University, New haven, USA.

[10] http://web.maths.unsw.edu.au/~jasone/eplots/pics/evans_4_1_lg.png

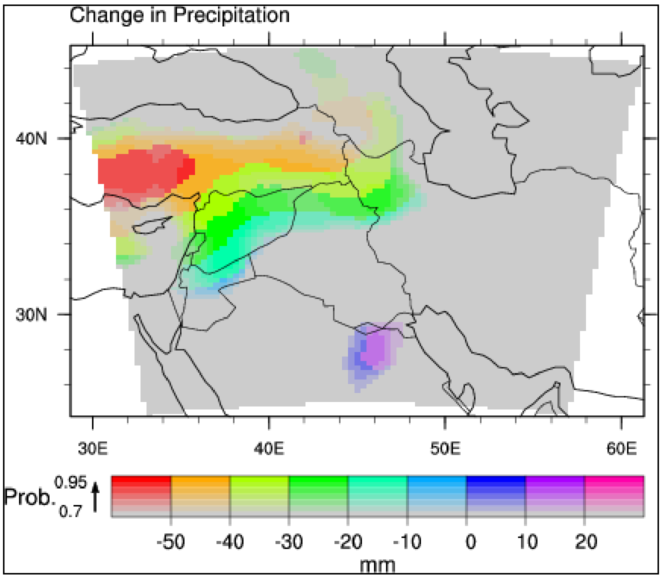

Figure (4): Demonstrates an Evans plot of the change in precipitation by: amount (hue) and significance (sat).

The probability (significance) of the change is calculated as a t-test between the precipitation now and the precipitation simulated in mid 21st century (Evans, 2008)[11].

Other studies (*Lenher et al*, 2001 and EEA, 2004)[12],[13] also predicted around 10 to 25 % reduction in river runoff in the upper *Euphrates and Tigris* basin (Fig. 5) in 2070 versus 2000 which prove the previous argument.

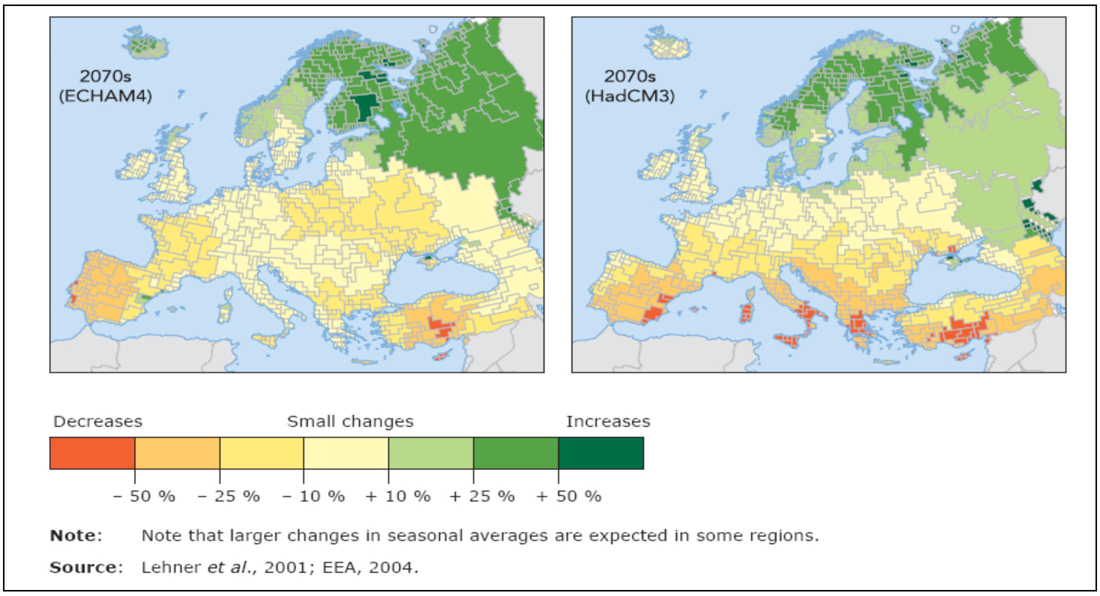

Figure (5): Change in average annual river run-off in Europe 2070 *versus 2000*

[11] http://web.maths.unsw.edu.au/~jasone/eplots/pics/evans_4_1_lg.png

[12] Lehner, B.; Henrichs, T.; Döll, P.; Alcamo, J., 2001. EuroWasser — Model-based assessment of European water resources and hydrology in the face of global change. World Water Series 5, Center for Environmental Systems Research, University of Kassel.

[13] EEA, 2004. Impact of climate change, EEA Report No 2/2004. Available at http://reports.eea.eu.int/climate_report_2_2004/en.

In other hand, an imposed change in temperature changes both the shape and magnitude of the Euphrates discharge. A five degree warming increases evapotranspiration thus lowering the discharge curve dramatically, dropping the annual discharge from 27048 mcm to 16329 mcm (~60%). The warming also eliminates the spring peak by preventing the overwinter storage of water in the mountain snow pack (*Smith et al.* 2000)[14]. The climate change projection for Turkey (First national communication on climate change for republic of Turkey, 2007)[15] shows that major reduction changes in snow water equivalent may occur in the stream flow for the rivers basin in Turkey (including Euphrates and Tigris). The figures expected up to 100 mm reduction in snow water equivalent (Fig. 6) at Euphrates upper stream (*Onol, B. & Semazzi, F. 2006*). This will lead to reduced flows in late summer when water is scarce and demand is greater. Similar sensitivities to temperature change are seen in the Upper Tigris. Also, reducing snow melt flowing through dams will decrease the potential of hydropower production.

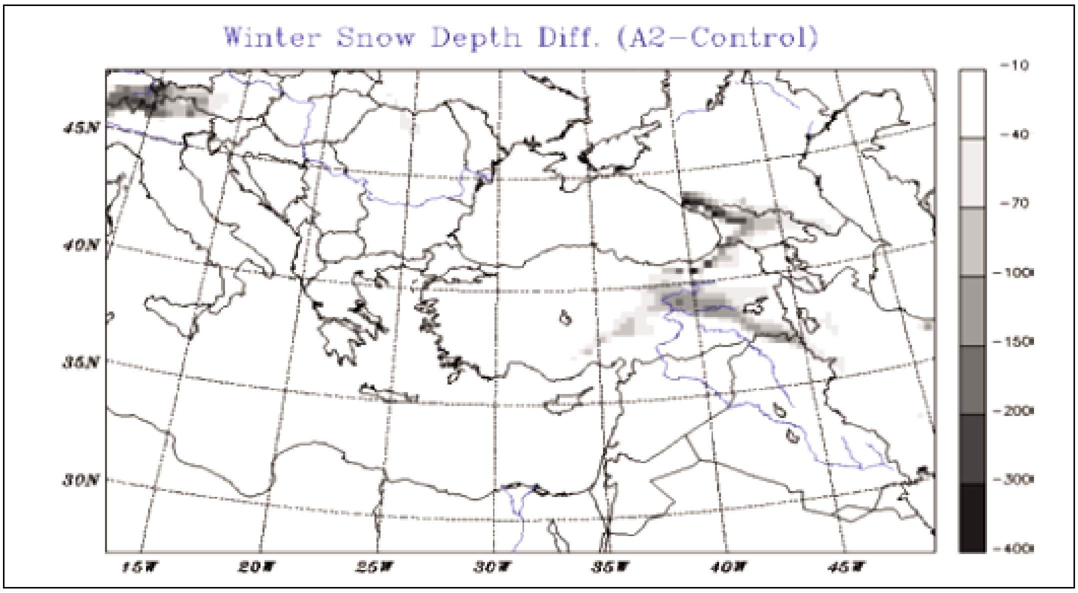

Figure (6): Climate change prediction for Turkey: Changes in snow water equivalent (in mm) affecting Euphrates and Tigris basins *(Onol, B. & Semazzi, F. 2006)* [16].

These reductions in flow discharge will affect several sectors which rely on Euphrates flow. The large irrigation projects on the river basin will be negatively affected since it consumes the largest portion of the water (71%) table1). Improving the irrigation efficiency is therefore very crucial to mitigate the impacts of climate change.

[14] Smith, R.B., J. Foster, N. Kouchoukos, P.A. Gluhosky, R. Young and E. De Pauw. 2000. Spatial analysis of climate, landscape, and hydrology in the Middle East: modeling and remote sensing. Center for Earth Observation Report No.2., Yale University, New haven, USA.

[15] First national communication on climate change for republic of Turkey, 2007

[16] Onol, B. & Semazzi, F. 2006: regional impacts on climate change on water resources over Eastern Mediterranean: Euphrates -Tigris basin. 18th conference on climate variability and change,86th AMS meeting. USA.

3. Ground water modeling (case Study: *Zabadani* Sub-Basin)

Zabadani Sub-Basin is located in the *Antilebanon* mountains covering an area of about 140 km². Geo-morphologically it can be subdivided into three NNE-SSW trending units: the *Chir Mansour* Mountain range in the W reaching up to 1884 meters above sea level (m.a.s.l.), Zabadani and *Serghaya grabens* ranging from 1080 m a.s.l. to 1400 m a.s.l. and the *Cheqif* Mountain range in the E reaching up to 2466 m a.s.l. The basin is drained by the only perennial stream of the region, *Barada* river with *Barada* spring at 1095 m a.s.l. as its source (Fig. 7). The mean annual rainfall is about 700 mm.

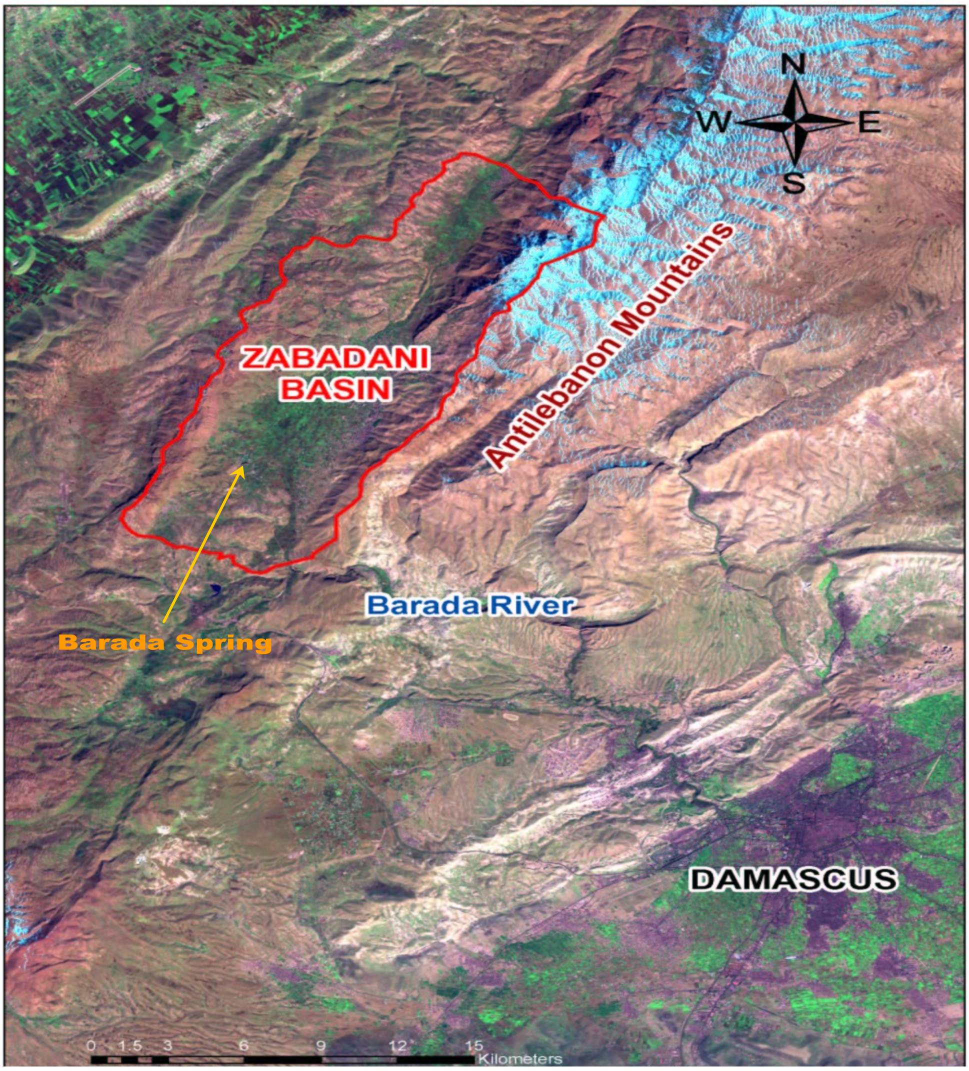

Figure (7): Study area.

There is already water competition in the area between municipal drinking water suppliers, agricultural and touristic activities. In dry years Barada spring (average discharge 3.8 m³/s) ceases completely during summer months, raising conflicts between the farmers (relying on the river discharge) and the drinking water suppliers operating well fields around the spring.

The Decision Support System "DSS" (*Acsad-Bgr* Technical Cooperation Project, 2007)[17] Developed by ACSAD (Arab Centre for the Studies of Arid zones and Dry lands, Syria), BGR (Federal Institute for Geosciences and Natural Resources, Germany) and SEI (Stockholm Environmental Institute) was used to elaborate the impact of climate change on groundwater level through applying different scenarios, using calibrated groundwater mathematical model (Modflow 2000, United State Geological Survey) Linked to Water Evaluation and planning model (WEAP21, Stockholm Environmental Institute). Modflow 2000 was utilized to calculate the groundwater heads, storage and flow according to the conceptual hydro geological model. WEAP calculates groundwater recharge, river stage, irrigation demand and the remaining water balance components. By a dynamic link, results of one model are transferred as input data to the other for each time-step (*Al-Sibai et al, 2008*)[18]. This linkage empowers both models and gives a chance to use the strength of WEAP to build different scenarios and the strength of Modflow to observe the impact of these scenarios on groundwater table. Two Scenarios were examined (*Droubi et al. 2007*)[19]:

Scenario A:

Long term climate change impacts have been assessed (*Kunstmann et al*. 2007)[20] in downscaling the global climate scenario model to a resolution of 18km x 18km in the eastern Mediterranean/ Near East region (figures 6-a). There preliminary calculation results (based on daily precipitation data) which have been derived for two "thirty years" time slices (1961-1990 and 2070-2099), indicates a clear decrease in precipitation of twenty percent. This decrease of twenty percent was applied to the amount of precipitation during the planning scenario (2005 -2017) in order to foresee, on an even shorter time scale, the impact of decreases in precipitation.

[17] ACSAD-Bgr Technical Cooperation Project - No.: 2004.2032.3, Management, Protection and Sustainable Use of Groundwater and Soil Resources; Project Report Phase Iii, 01.04.2004 – 31.03.2008, Development and Application of a Decision Support System (DSS) For Water Resources Management, 2007.

[18] Al-Sibai, M., Droubi, A., Abdallah, A. Zahra, S. Obeissi, M. Wolfer, J., Huber, M. Hennings, V. & Schelkes, K 2008: Incorporate MODFLOW in a Decision Support System for Water Resources Management, Proceeding of Modflow and More international conference, Colorado, USA.

[19] Droubi, A., Al-Sibai, M., Abdallah, A. Zahra, S. Obeissi, M. Wolfer, J., Huber, M. Hennings, V. & Schelkes, K A Decision Support System (DSS) for Water Resources Management, Design and Results from a Pilot Study in Syria. Proceeding of Climatic Changes and Water Resources In The Middle East and North Africa, Ed: Zereine; Springer, Germany.

[20]Kunstmann, H., Suppan, P., Heckl, A.& Rimmer, A. (2007) Joint high resolution climate-hydrology simulations for the Upper Jordan River catchment. Abstract IAHS-Conference 2007 in Perugia, Italy.

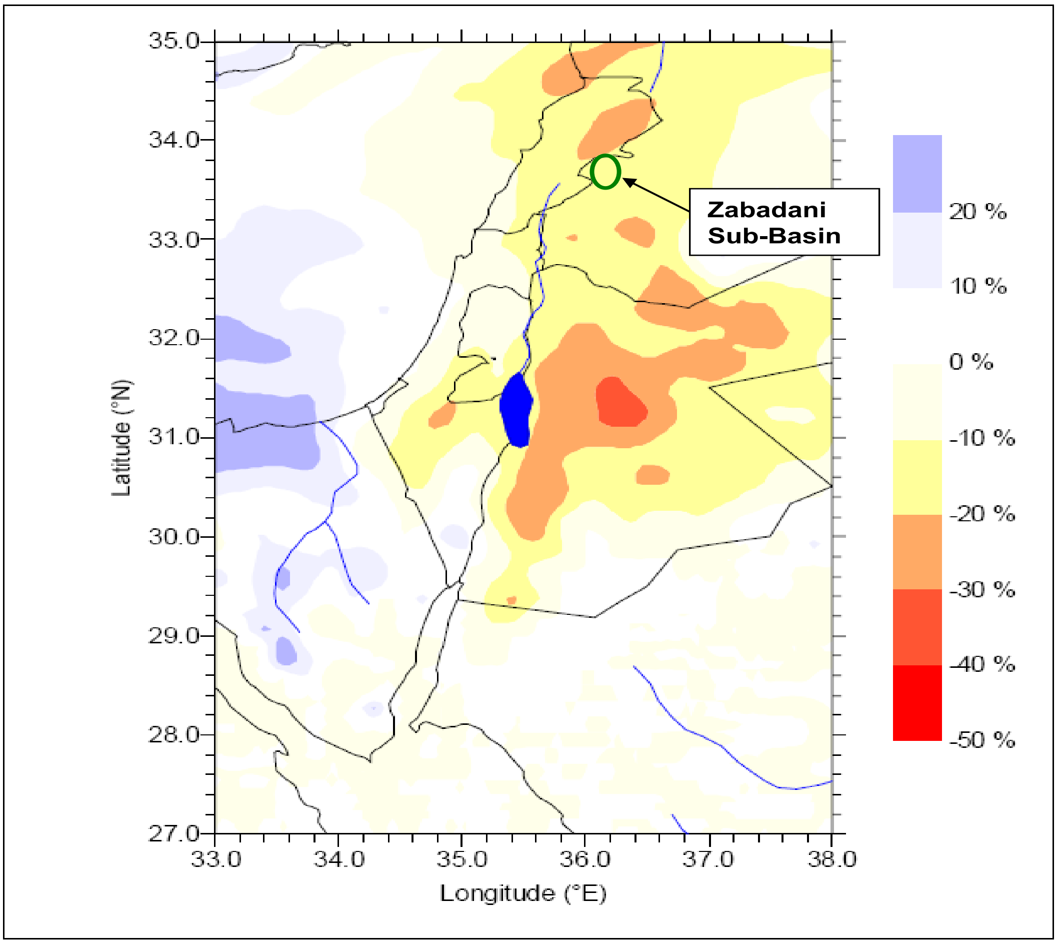

Figure (6-a):.Relative change in precipitation, difference between 2070-2099 and 1961-1990, based upon ECHAM 4, B2 scenario, MM5 regional model, with 18km resolution, *(Kunstmann et al. 2007).*

Scenario B:

The historic precipitation measurements of Damascus station show that there is roughly every thirteen years a "drought" year with less than half of the mean annual rainfall. From 1999 to 2001 there had been three "drought" years in a row, causing severe impacts on the domestic and irrigation water supply. Therefore an additional planning scenario was created by reducing the average precipitation of the year 2004/ 2005 to 50% and calculating the impacts of consecutive drought years.

The hydraulic head fluctuations predicted by the model (Fig. 7-a) show that the most severe drawdown occur in scenario B. Similar impact was observed in 2001 after three consecutive dry years where the basin suffered from an average drawdown of 5 m in groundwater table. Such models are prerequisites for any groundwater basin planning and management. Continuous calibration and modifications of these models are crucial to be used as operational models.

This decline in groundwater level will force farmers to deepen their wells and will increase pumping costs.

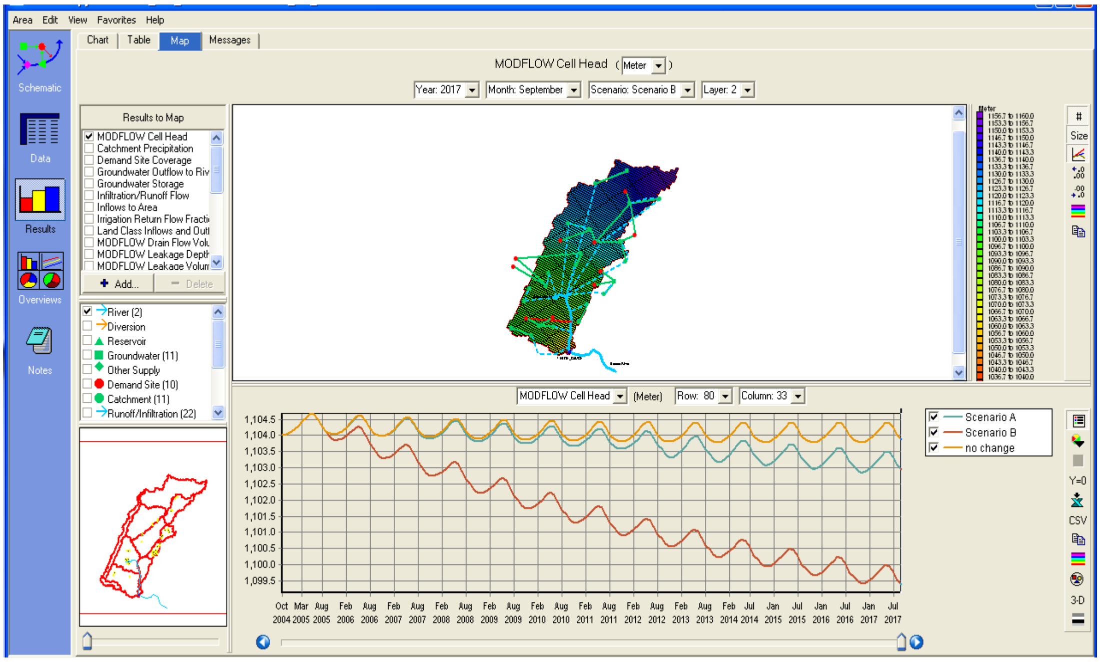

Figure (7-a): Calculated hydraulic head for the planning scenarios. The window below shows the impacts of scenarios A & B on the water table at one of the selected cell.

4. Modelling of Barada spring

The main springs in Syria are *karst* spring such as *Figeh*, *Barada, Sen, Ras ElEin* and others. Modelling of such system is very complicated especially with the heterogeneity in *karst* and scarcity of data.

The karst spring of Barada constitutes an important resource for the drinking water supply of Damascus city. The study of this spring is essential for understanding the functioning of the aquifer, especially since pumping groundwater becomes very important with the growth of the population supplied primarily by the spring of *Figeh*. The hydro geological conceptual model of Barada Spring is based on the recharge of the *karstic* system by rainfall and snow melting. Infiltrated water is divided in two parts: a flow through the conduits (fast flow) and a slow flow fed by groundwater stored in the epikarst, infiltration- and phreatic zones, and narrow karst features which delay the flow. Consequently, the conceptual model contains two reservoirs, one for the slow discharge corresponding to the low flow stage and one for fast flow mainly feeding the flood flow (Fig. 8). Infiltration water is shared between these two parts according to the sharing coefficients X1 and X2 allocated to each reservoir.

The model is running using rainfall time series as the system input. The model will simulate the discharge time series. This type of model presenting two discharge reservoirs was tested on several karst springs in Europe (*Fleury, 2005*) and Lebanon (*El Hakim, 2005*)[21] and seems to be well appropriated to model karst spring hydrograph.

[21] EL HAKIM, M. (2005) Les Aquiferes Karstiques de L'Anti-Liban et du Nord de la Plaine de la Bekaa: Caracterisitques, Fonctionnement, Evolution et Modelisation, d'âpres L'Exemple du Systeme Karstique Anjar-Chamsine (Liban). PhD Thesis, University Montpellier II & University Saint Joseph, Beirut, Lebanon.

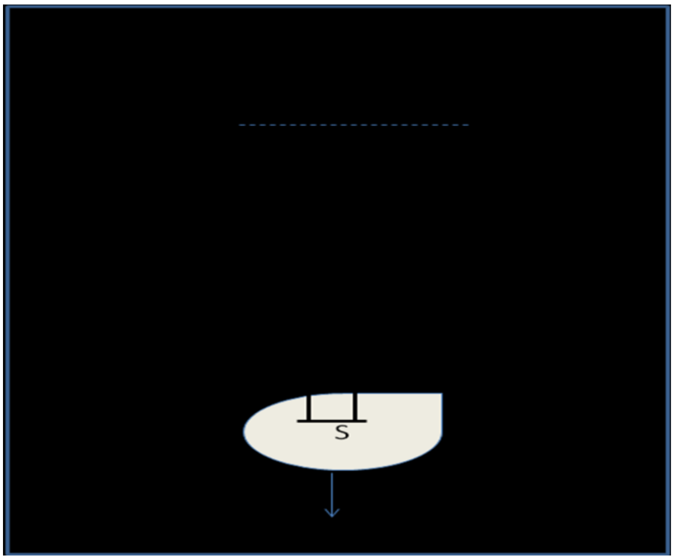

Figure (8): General structure of karst spring model.

The Stream flow model (simulator, 2007)[22] developed by ACSAD and BGR of the Barada karst system was applied. The model had been calibrated according to the daily rainfall data (from 1985 to 2007) for four stations: *Madaya*, *Zabadani, Serghaya and Bloudan*, and flow rates of the spring. Two sets of parameters were obtained for the periods before and after the beginning of pumping respectively. The model gave very satisfying simulation results for the pumping period (Fig. 9).

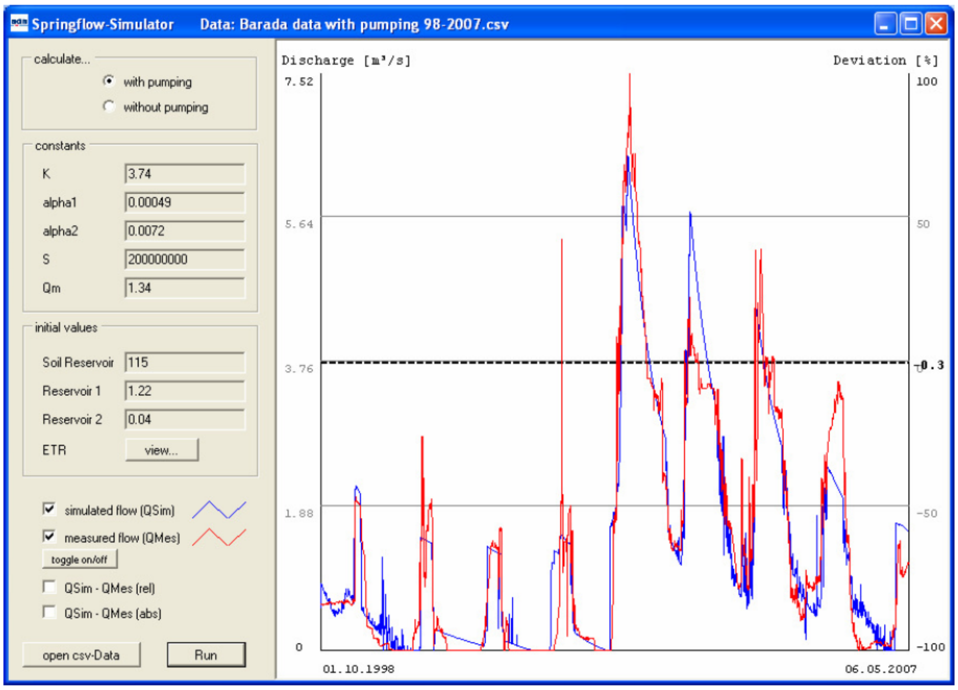

Figure (9): Calibrating results, Calculated (Blue) and measured (Red) values for Barada spring discharge. The values on the left bar are the calibrated parameters.

[22] Manual of Spring flow Simulator Vers. 1.0.2, ACSAD-BGR Technical Cooperation Project - No.: 2004.2032.3, Management, Protection and Sustainable Use of Groundwater and Soil Resources

The model is used to predict the impact of climate change on Barada spring discharge. A decrease of 4% in annual rainfall (equivalent to 25 mm annual reduction in rainfall as shown in figure 4 accompanied with an increase of 2.5% in annual pumping (to compensate the increase in demand due to population growth) starting from 2007 was applied using the same pattern of rainfall and pumping of year 2006-2007.
The model result is shown in figure 10, where the continuous decrease in spring discharge is clear. The low flow period of the spring disappears gradually and the spring dishrags mainly in peak time. The model expected a decrease of 35% in annual discharge after six years (Fig. 11).

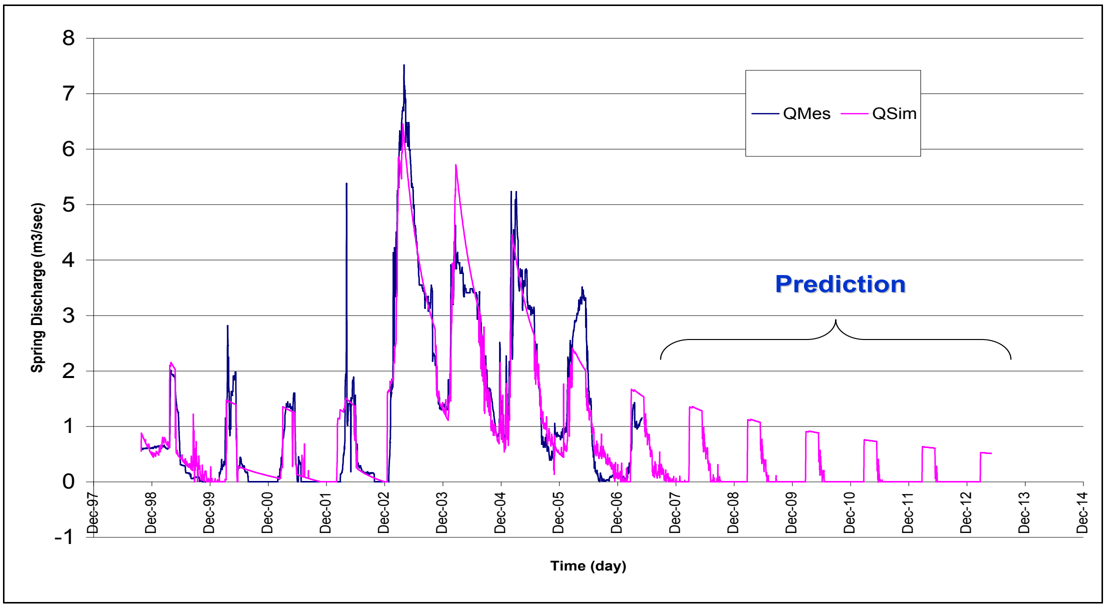

Figure (10): Simulated spring discharge after 2007 according to the model assumptions (red line is the simulated result).

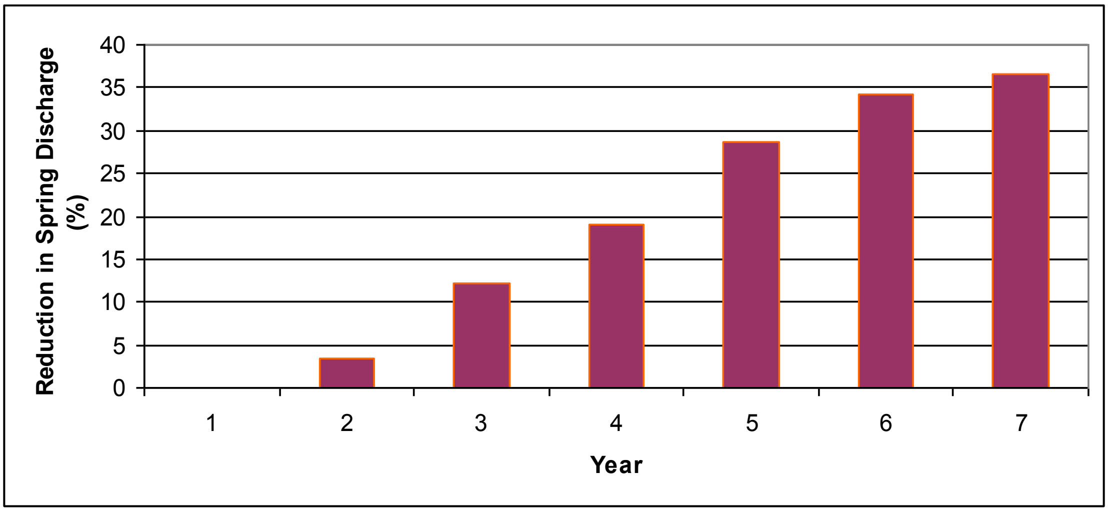

Figure (11): Expected reduction in spring discharge resulting from 4% annual decrease in rainfall accompanied with 2.5% annual increase in pumping.

With *Barada* and *Awag* basin having the highest proportion of drinking water (24%) among the other basin (Fig. 2), the domestic sector will be the most vulnerable. Damascus city has done considerable improvement in its drinking water network and more work is planned for Damascus countryside. Groundwater quality is deteriorating in Damascus plain due to over-irrigation, over-fertilization, and pollution from domestic and industrial waste (Tabla 2). This causes the closing of more than 200 wells in 2005 (*Abed Rabouh, 2007*) and exerted more pressure on fresher water of *Barada* and *Figeh* springs. Adequate conservation of groundwater is required by reducing irrigation from groundwater by using treated water and improving irrigation efficiency. Protecting groundwater quality from all types of pollution (domestic, agriculture, and industrial) is also a high priority.

Better delineation of the Syrian major springs' recharge zones is prerequisite for any management plan. There are some hydrological studies for some of these springs but they should be updated and verified frequently. Defining protection zones for the springs "especially those used for providing drinking water" is very important to preserve these fragile sources from different kind of pollution. The tendency to increase pumping from springs' adjacent areas to meet the increase in water demand should be guided according to detailed hydro geological and environmental studies.

5. Adaptation Policies

- ✓ The best approach to manage the impact of climate change on water is that guided by the philosophy and methodology of Integrated Water Resources Management (Global Water Partnership, 2007)[23].
- ✓ Development and implementation of water protection and conservation.
- ✓ Regulations which include spring protection zones, well drilling permission, drilling supervision and specifications, groundwater recharge zones, groundwater pumping schemes, protection of groundwater and surface from pollution, water resources development
- ✓ Construction of wastewater treatment plants and implementation of wastewater reuse schemes.
- ✓ Implementation of modern leakage detection and control schemes in major cities.
- ✓ Improving irrigation efficiency for large and small farms.
- ✓ Improvement of Rain Harvesting Techniques.
- ✓ Rationalization of water use and application of water saving measures.
- ✓ Rehabilitation of existing dams as well as improvements in water basin infrastructure for increased water storage capacity.
- ✓ Adequate WRM in the coastal basins.
- ✓ Reduction in water demand for irrigation by changing the cropping calendar, crop mix, irrigation method, and area planted.
- ✓ Artificial groundwater recharge.
- ✓ Improve the observation network (metrological and surface & ground water).
- ✓ Expansion of rain-fed farming systems.
- ✓ Adequate funds should be allocated today to support enhanced management that climate change will need tomorrow.

[23]Global Water Partnership. 2007. Policy Brief on Intelligent Water Strategies for Adapting to Climate Change.

- ✓ capacity- building to integrate climate change into sectoral development plans.
- ✓ Intelligent institutions are needed to coordinate responses and support difficult decisions: A key challenge is to orient water managers to the potential impact of the emerging new climates. Intelligent institutions are needed that can go beyond managing water on a day-to-day basis to identify water use trends, areas vulnerable to climate change and opportunities to respond as best possible to the emerging challenges. It is about building dynamic organizations that are able to respond strategically and effectively to changing circumstances.

6. Gaps in knowledge:

- Several gaps in knowledge exist in terms of observations and research needs related to climate change and water. Observational data and data access are prerequisites for adaptive management, yet many observational networks are shrinking.
- There is a need to improve understanding and modelling of changes in climate related to the hydrological cycle at scales relevant to decision making.
- Information about the water-related impacts of climate change is incomplete, especially with respect to water quality, aquatic ecosystems, groundwater, including their socio-economic dimensions.
- need for down-scaling atmospheric models

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