Enabiling Activities for Preparation of Syria's Initial National Communication to UNFCCC

Vulnerability Assessment and Adaptation Measures in Syria

Finale Report

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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 Programm (UNDP) in Syria.

Final Report

Vulnerability Assessment and Adaptation Measures to Climate Change in Syria

(INC-SY_V&A_ General Assessment -En)

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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 Dedeman - Palmyra.

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Introduction

This chapter describes vulnerability of major sectors in Syria to climate change (CC). Special attention is being devoted to illustrate trends in CC, climate predictions, vulnerability of water resources, agriculture, energy, and public health sectors to such changes. Other issues like effect of possible sea level rise (SLR; vulnerability of forest and rangeland sectors as well as biodiversity is addressed too. Sectoral adaptation measures are proposed. Socio-economic aspects of climate change were scooped based on sectors vulnerability results.

The indirect effects of climate change are of broad nature and require detailed and comprehensive surveys. Hence, the figures presented regarding simulating climate change, the vulnerability assessment of various sectors, and the associated socio-economic impacts are indicative and must be used with extreme caution.

1. Climate trends and projections

2.1. Climate trends

A 52- year record (1955 - 2006) of 30 selected synoptic stations was used to assess the long term climatic variations and trends in the country. The selection of these stations was based mainly on the length and continuity of their meteorological records. Recorded data consisted of the monthly mean values of the surface air temperature, total rainfall. Trends in extreme daily temperature and precipitin index were examined from 1965-2006 at thirteen station covering the climatic district. The data set are analyzed for outliers, and those identified as outliers to a present threshold value were considered. Finally, the time series analysis for non-climatic event that might have taken place during the life of station, and detection and adjustment of such in homogeneities in the time series are made following a procedure developed by *Hanssen-Baure* and Foreland (1994).

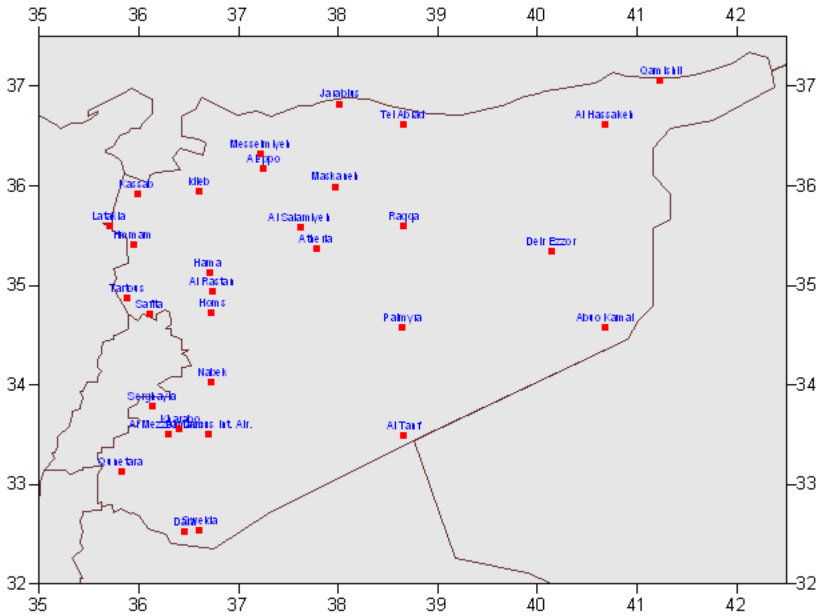


Fig. (1) Distribution of weather stations used in trend analysis.

Selected parameters to describe the general characteristics of the climate during the baseline scenario were surface air temperature, precipitation, winter maximum and minimum surface air temperature, and summer maximum and minimum surface air temperature. Averaged annual and seasonal values of these three parameters were analyzed and displayed in a series of symbol maps. Figure (1) shows the outlays of these stations.

2.1.1. Precipitation

2.1.1.1.Precipitation Trends

Due to a number of difficulties (quality of data, length of records, precipitation variability) involved in developing signals of climate change in terms of changing precipitation, extreme care must be taken in interpreting the significance of the long term trend in precipitation.

Generally speaking, Mann-Kendall trend test showed a coherent area of significant change in precipitation of both winter and autumn seasons. Winter precipitation in northern and north eastern zones of Syria showed a sign of decrease for the last five decades. On the other hand, autumn precipitation increased at the stations that lie mostly in northern zone of the central Syria. The reasons behind these changes are not well understood. Further investigation is needed to define causes of this increase. On the other hand, few stations statistically showed significant changes in winter and autumn precipitation. Figure (2) shows the results of the Mann-Kendall trend test for the annual and the three season's precipitation in the country.

2.1.1.2. Precipitation Extremes Events And Indices

The analysis of precipitation indices of extreme events showed a decrease, though not significant, in the number of days with precipitation ≥25 mm, average precipitation intensity PRCP≥1.0mm/day, max precipitation events and the national average of annual precipitaion anamolise in wet days.

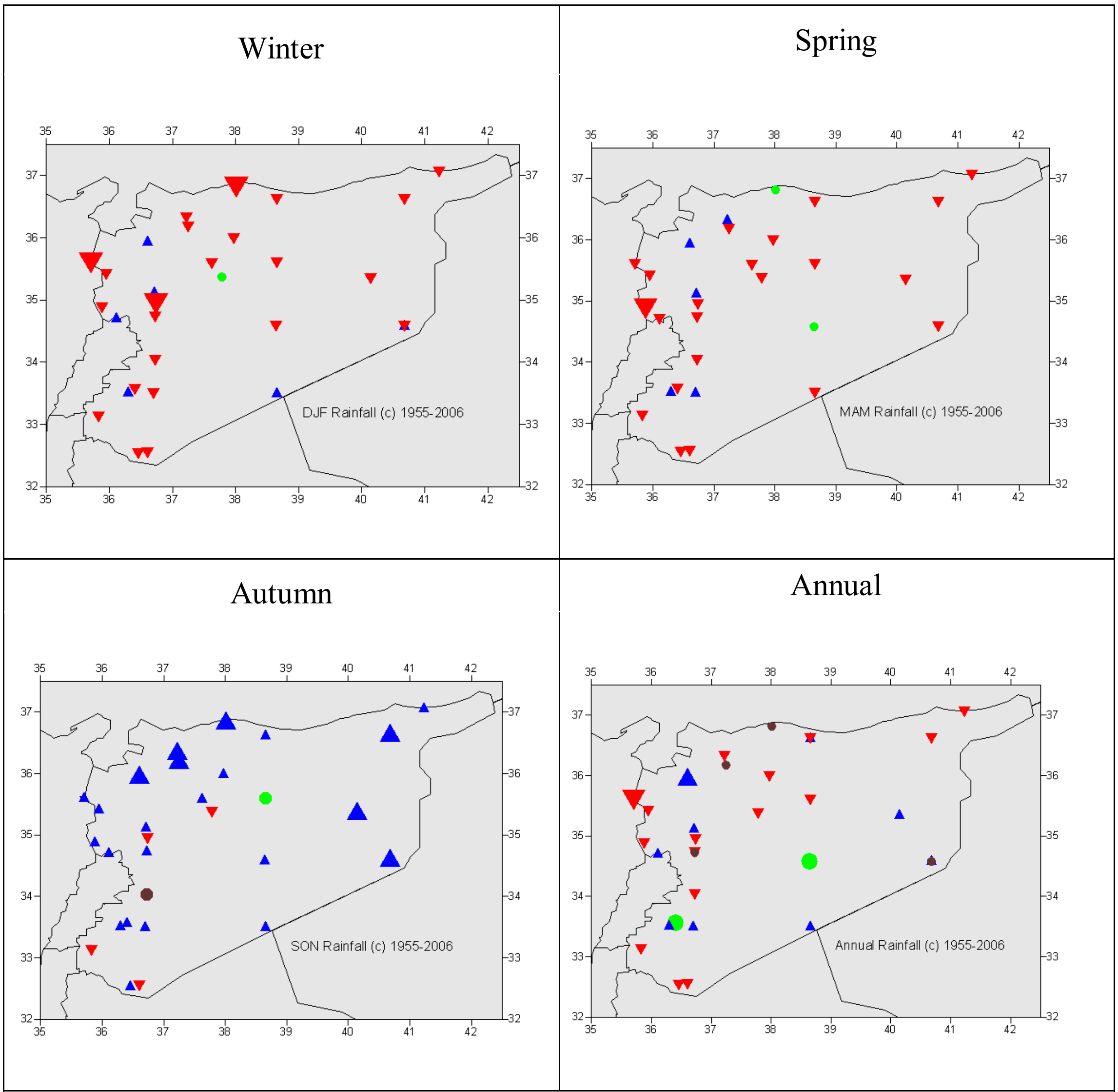


Fig. (2) Seasonal and annual precipitation trends for the period 1955-2006

● *denotes no trend* ▲ *significant increase* ▲ *insignificant increase*

▼ *significant decrease* ▼ *insignificant decrease and* ●*insignificant increase and decreases*

2.1.1. Surface Air Temperature

2.1.2.1. Surface Temperature Trends

The result of Mann-Kendall trend analysis applied to seasonally and annual average surface air temperature series between 1955- 2006 showed a widespread increase in summer temperature in all stations in the country with prominent increase in coastal and western regions. On the other hand, winter temperatures showed a general tendency of decrease in the country. This decrease is mostly noticeable in the costal stations with prominence in spring and autumn.

2.1.2.2. Surface Temperature Extremes Events And Indices

The analysis of temperature indices of extreme events showed significant increase trends in the annual maximum of daily maximum and minimum temperature, the annual minimum of daily maximum of the surface air temperature, the annual minimum of daily minimum of surface air temperature, the number of tropical nights, and the number of summer days. The latest denotes an increase in the number of warmer days and nights in the year. Nevertheless, significant decreases trend in cool nights and days, and diurnal temperatures range were observed too (Figure 3).

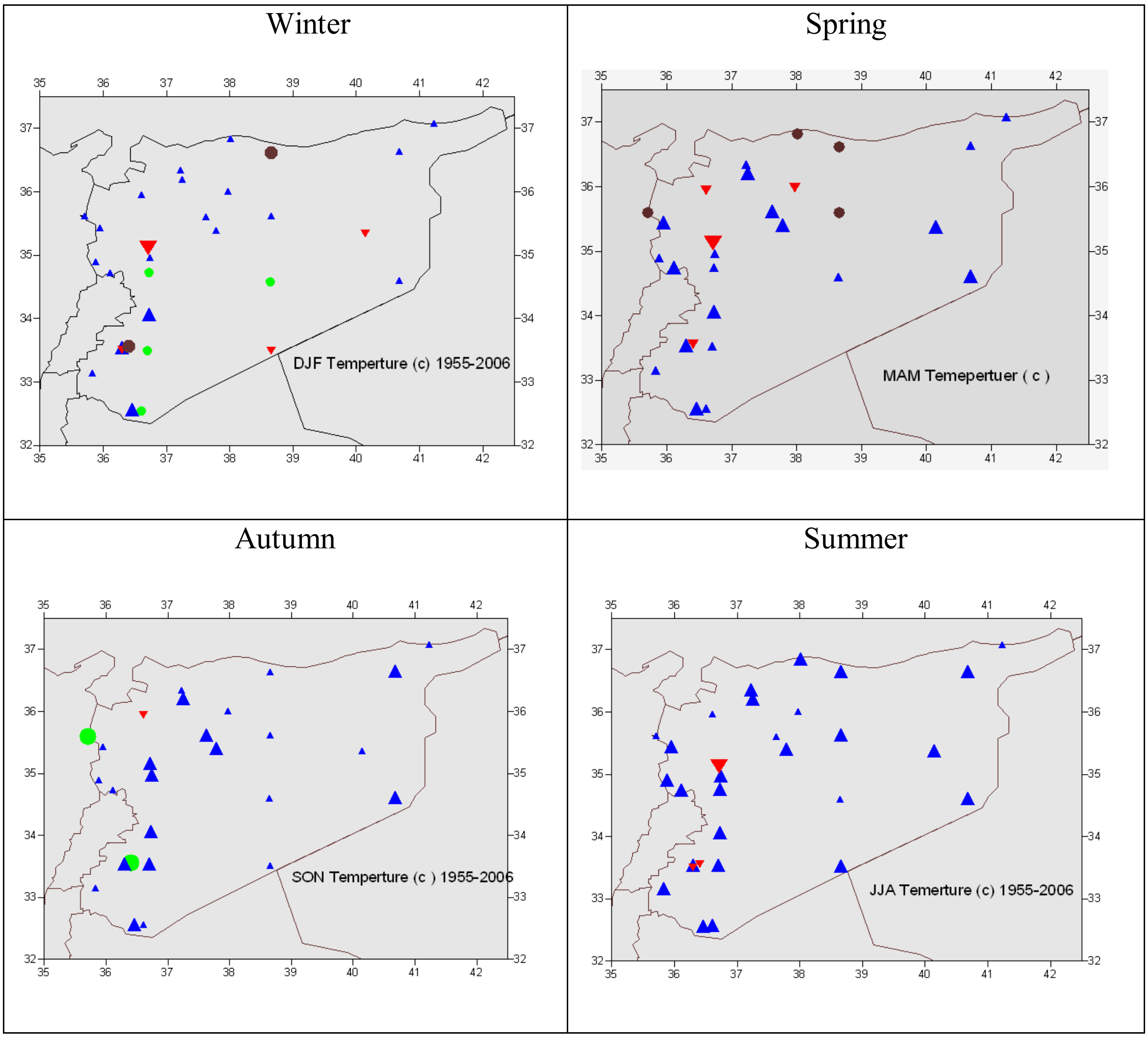


Fig. (3) Mann-Kendall trend analysis applied to seasonally average annual temperature series between 1955-2006.

● *denotes no trend* ▲ *significant increase* ▲ *insignificant increase* ▼ *significant decrease* ▼ *insignificant decrease and* ●*insignificant increase and decreases*

2.1. Climate projection

2.2.1. Climate change scenarios

Climatic change scenarios were developed to predict changes in temperature and precipitation values in 2041 and 2100 using two different models. The Model for the Assessment of Greenhouse Gases Induced Climate Change (version 4.1, September 2003) ((MAGICC) coupled with a climate scenario generator (SCENGEN) was used for 2041 prediction, while predicted data by global models were retrieved from IPCC data base for 2041 -2100 of the 17 GCM models, three models (CCSR96, IAP-97 and MRI-96) were found to very closely simulate climatic trends for Syria (Figure 4).

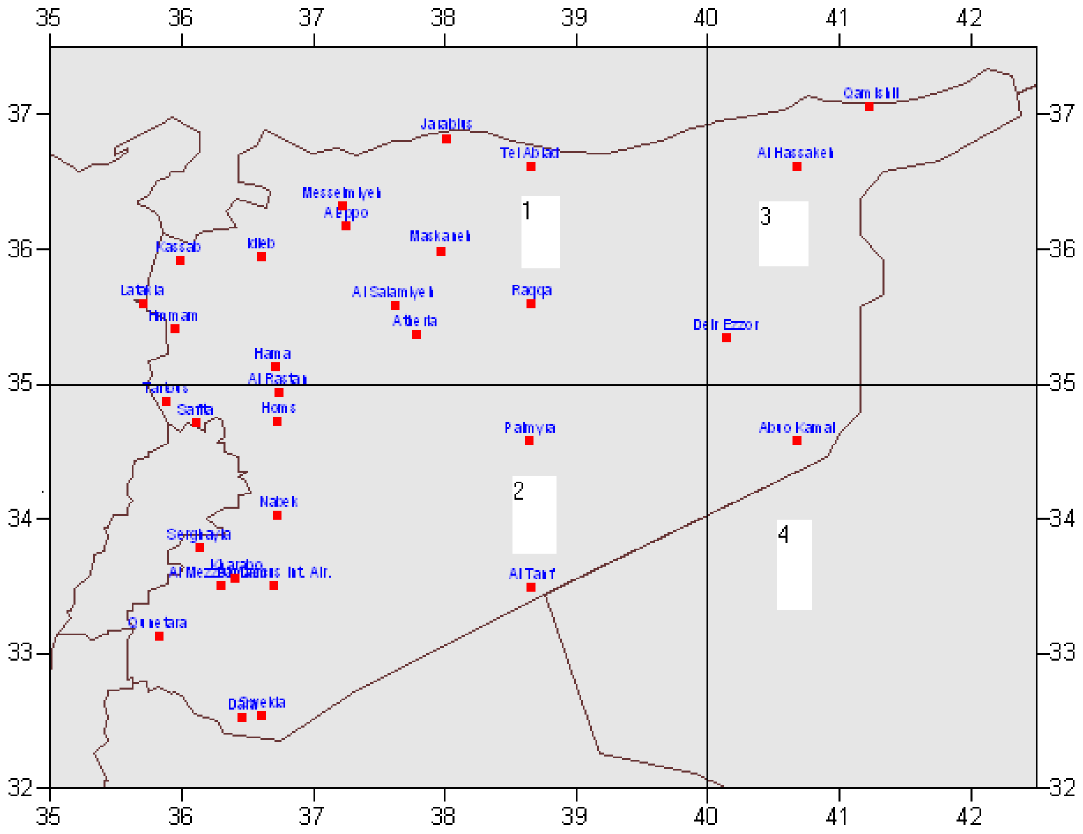


Fig. (4) The four grids covering Syria.

The followings are the main results of the climate predictions:

- The average warming in Syria for the year 2041 will be higher than the global average for both the reference and the policy scenarios.
- The highest warming (2.0-2.1 C^o) occurs in north west and south east (cells 1 and 4), while the lowest (1.0-1.2 C^o) occurs in all over the country.
- The highest increase in precipitation occurs in summer and autumn in all regions.

The results of running a combination of these models for the reference (P50) and the policy (WRE-350) emission scenarios are tabulated and shown in table (1) for each of these cells.

Table (1) Changes in Seasonal, annual mean temperature (C°) and precipitation (%) from CCSR96, IAP_97 and MRI_96 scenarios for the year 2041.

Zone / Emission Scenario		1		2		3		4	
		35 – 40 N		30 – 35 N		35 – 40 N		30 – 35 N	
		35 – 40 E		35 - 40 E		40 – 45 E		40 – 45 E	
		C	P	C	P	C	P	C	P
Winter	Policy*	1.0	-13.3	1.1	-16.2	1.0	-10.3	1.2	-13.6
	Reference**	1.1	-14.4	1.2	-17.5	1.1	-11.1	1.3	-14.7
Spring	Policy	1.4	-3.3	1.4	-10.2	1.5	-8.9	1.5	-13.1
	Reference	1.5	-3.6	1.5	-11.0	1.6	-9.7	1.6	-14.2
Summer	Policy	1.9	-4.0	2.0	79.3	1.9	-6.3	1.9	62.5
	Reference	2.1	-4.3	2.1	85.7	2.1	-6.8	2.0	67.5
Autumn	Policy	1.5	-1.3	1.5	14.9	1.6	-0.7	1.6	7.3
	Reference	1.6	-1.4	1.6	16.1	1.7	-.08	1.6	7.9
Annual	Policy	1.4	-9.7	1.5	-8.0	1.5	-9.1	1.5	-9.9
	Reference	1.6	-10.5	1.6	-8.6	1.6	-9.8	1.6	-10.7

Policy scenario (WRE 350) Global-mean dt:0.81 (°C)
****Reference scenario (P 50%) Global-mean dt:1.1(°C)***
C: temperature, P: rainfall

The results of the MRI_96 were used to construct a 2041 precipitation data for the country using the average rate of change deduced from the model (table 1). Data are displayed in table 2.

Table (2) The calculated average annual rainfall for meteorological stations in Syria for the year 2041 using model MRI_96.

Station	Average 1961-1990 (mm)	Rate of Change (%)	Average Change (mm)	Average 2041 (mm)
Lattakia	802.0	-5.4	- 43.3	758.7
Hmmam	852.9	-5.4	- 46.1	806.8
Safita	1130.9	-5.1	- 57.7	1073.2
Tartous	872.4	-5.1	- 44.5	827.9
Tel Abiad	287.3	-5.4	- 15.5	271.8
Jaraplus	324.0	-5.4	- 17.5	306.5
Aleppo	329.5	-5.4	- 17.8	311.7
Atheria	186.6	-5.4	- 10.1	176.5
Meslmieh	330.8	-5.4	- 17.9	312.9
Idleb	504.5	-5.4	- 27.2	477.3
Hama	348.5	-5.4	- 18.8	329.7
Salamiyh	305.3	-5.1	- 15.6	289.7
Al Rastan	380.5	-5.1	- 19.4	361.1

Station	Average 1961-1990 (mm)	Rate of Change (%)	Average Change (mm)	Average 2041 (mm)
Homs	433.4	-5.1	- 22.1	411.3
Damascus Int. Air Port.	142.2	-5.1	- 7.3	134.9
Mezzeh Air.Dam	200.3	-5.1	- 10.2	190.1
Kharabo	161.6	-5.1	- 8.2	153.4
Dara	265.6	-5.1	- 13.5	252.1
Nabek	120.1	-5.1	- 6.1	114.0
Serghayia	572.4	-5.1	- 29.2	543.2
Qunetara	610.2	-5.1	- 31.1	579.1
Sweida	357.7	-5.1	- 18.2	339.5
Palmyra	134.2	-5.1	- 6.8	127.4
Maskaneh	228.7	-5.4	- 12.3	216.4
Deir Ezzor	157.2	-6.2	- 9.7	147.5
Abuo Kamal	133.7	-5.0	- 6.7	127.0
Raqqa	210.5	-5.4	- 11.4	199.1
Al Tanf	105.0	-5.1	- 5.4	99.6
Qamishlie	435.1	-6.2	- 27.0	408.1
Hassakeh	285.8	-6.2	- 17.7	268.1

The A2 and B2 climate scenario models were used to simulate changes in temperature and precipitation for 2010-2100 in reference to baseline record values of the period 1961 -1990. The results of these predictions are shown in the following sections.

2.2.1.1. Precipitation (the A2 Scenario)

Seasonal changes in the precipitation as predicted by Hadley Model for the years (2010-2039), (2040-2069) and (2070-2099) using A2 scenario are presented in table (3). More details are highlighted in figures in the following sections:

Table (3) Seasonal and annual precipitation variations (mm) for the years (2010-2039) (2040- 2069) and (2070-2099) with respect to normal average 1961-1990.

Years	Winter	Spring	Summer	Autumn	Annual
2010-2039	3.0 : -12.0	3.0 : -8.0	4.0 : -4.0	-4.0 : -16.0	-2.0 : -40.0
2040-2069	-6.0 : -22.0	-3.0 : -22.0	4.0 : -6.0	-4.0 : -28.0	-20.0 : -60.0
2070-2099	-16.0 : -34.0	-6.0 : -38.0	14.0 : -12.0	-6.0 : -40.0	-6.0 -34.0

2.2.1.1.1. A2 Scenario (2010-2039)

The results of A2 scenario application for the period of 2010-2039 indicated that southern region will experience an increase in winter precipitation by 3 mm on average, while the precipitation is expected to decrease in the northeastern and northwestern regions as much as 12 mm. In the central and coastal regions, a decrease of 10 mm rainfall is expected. During spring, there will be a decrease in the precipitation in the northern and northeastern district by 8 mm. In the western and internal district, precipitation is expected to increase by 3 mm. During summer, a 4 mm increase in the precipitation is expected along coastal and southern regions while a decrease in precipitation is expected in northeastern region. In autumn, an overall decrease in the total precipitation in the larger part of the country is predicted. Annual precipitation changes for the period are shown in figure 5.

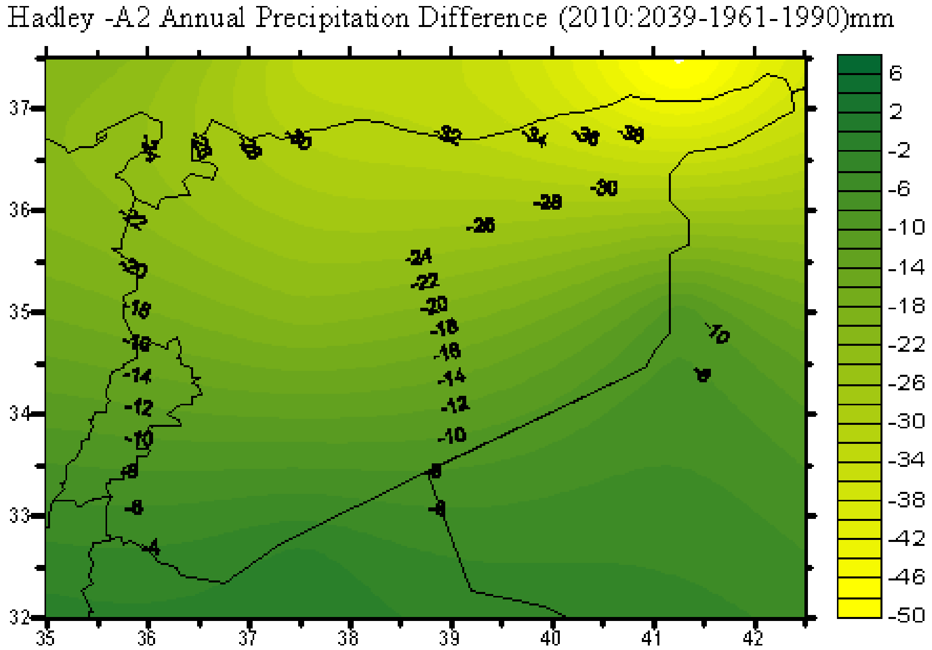


Fig. (5) Annual precipitation changes for 2010-2039 (A2 scenario – Hadley Model-CM3)

2.2.1.1.2. A2 Scenario (2040-2069)

The results of A2 scenario application for the period of 2040-2069 indicated that winter and spring precipitation is expected to decrease by 6-22 and 3-22mm respectively. On the other hand, summer precipitation will increase by 2 mm in the coastal area and southern part of the country while, a decrease is expected in the northeastern part of the country by 3 mm. In autumn, an overall decrease in the total precipitation in the larger part of the country is expected. Figure 6 depicts annual precipitation changes for the period.

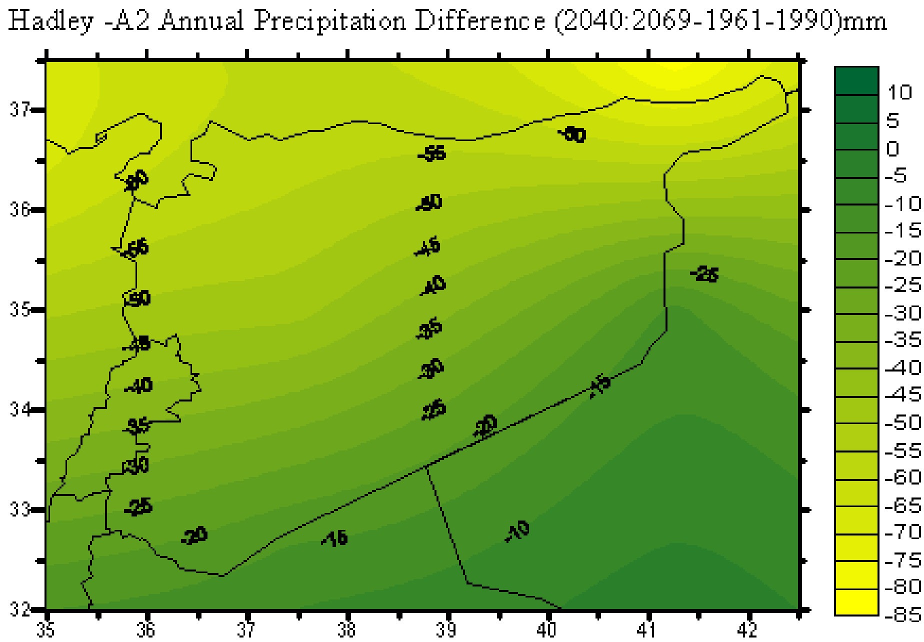


Fig. (6) Annual precipitation changes for 2040-2069 (A2 scenario – Hadley Model-CM3)

2.2.1.1.3. A2 Scenario (2070-2099)

The results of A2 scenario application for the period of 2070-2099 indicated that winter and spring precipitation is expected to decrease by 16- 34 and 6-38 mm respectively. On the other hand, a 14 mm increase in summer precipitation is expected in coastal region and southern part of the country whereas, a 12 mm decrease in precipitation is expected in northeastern regions. In autumn, an overall decrease in precipitation in the larger part of the country is predicted. Annual precipitation changes for the period are shown in figure 7.

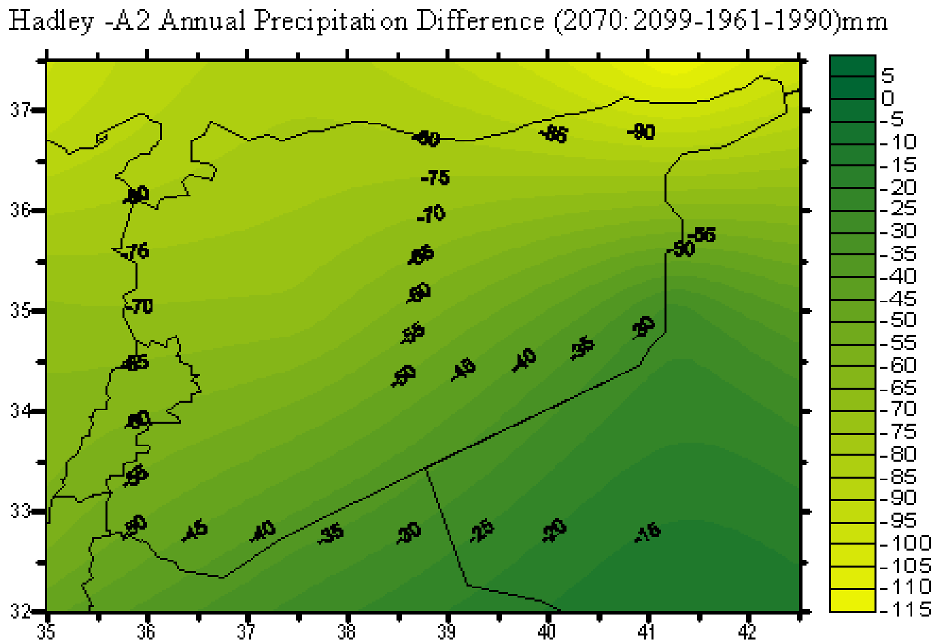


Fig. (7) Annual precipitation changes for 2070-2099 (A2 scenario – Hadley Model-CM3)

2.2.1.2. Changes in Precipitation (the B2 Scenario)

Seasonal changes in the precipitation as predicted by Hadley Model for the years (2010-2039), (2040- 2069) and (2070-2099) using B2 scenario are presented in table (4). More details are highlighted in figures in the following sections.

Table (4) Seasonal and annual precipitation variations (mm) for the years 2039, 2069 and 2099 with respect to normal average 1961-1990.

Years	Winter	Spring	Summer	Autumn	Annual
2010-2039	4.0 : -6.0	4.0 : -10.0	8.0 : -8.0	-4.0 : -20.0	-8.0 : -44.0
2040-2069	-11.0 : -18.0	7.0 : -7.0	9.0 : -5.0	-3.0 : -17.0	-8.0 : -49.0
2070-2099	-12.0 : -18.0	-6.0 : -28.0	10.0 : -12.0	-2.0 : -28.0	-25.0 : -75.0

2.2.1.2.1. B2 Scenario (2010-2039)

The B2 scenario application for the period of 2010-2039 indicated mixed results where, a decrease and an increase by 6 and 4 mm respectively are expected in winter precipitation. Moreover, up to 10 mm decrease and 4 mm increase in precipitation is expected in spring. During summer, an 8 mm increases in the precipitation is expected in the coastal area and southern region of the country while, an 8 mm decrease is expected in northeastern region. In autumn, an overall decrease (up to 20 mm) in the total precipitation in the larger part of the country is predicted. Annual precipitation changes for the period are shown in figure 8.

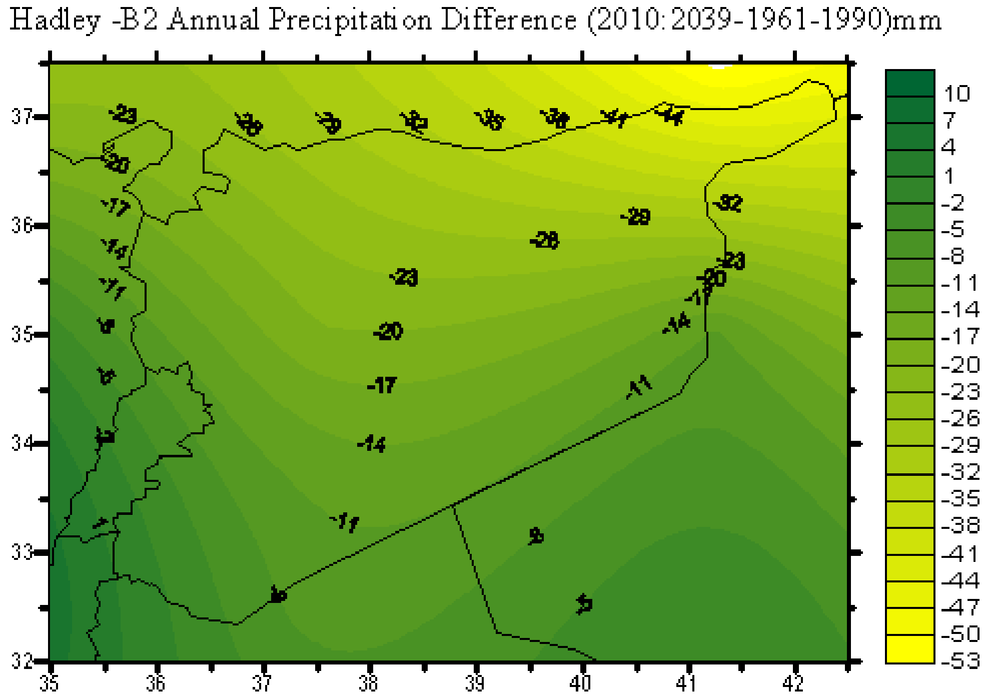


Fig. (8) Annual precipitation changes for 2010-2039 (B2 Scenario– Hadley Model-CM3)

2.2.1.2.2. B2 Scenario (2040-2069)

The B2 scenario application for the period of 2040-2069 indicated that winter precipitation is expected to decrease by 6 -18 mm. On the other hand, a decrease and an increase of 7 mm are expected during spring season. During summer, a 9 mm increases in precipitation is expected affecting western coastal and southern regions with a 5 mm expected decrease in precipitation in the northeastern districts. In autumn, an overall decrease in precipitation in the larger part of the country is predicted. Annual precipitation changes for the period are shown in figure 9.

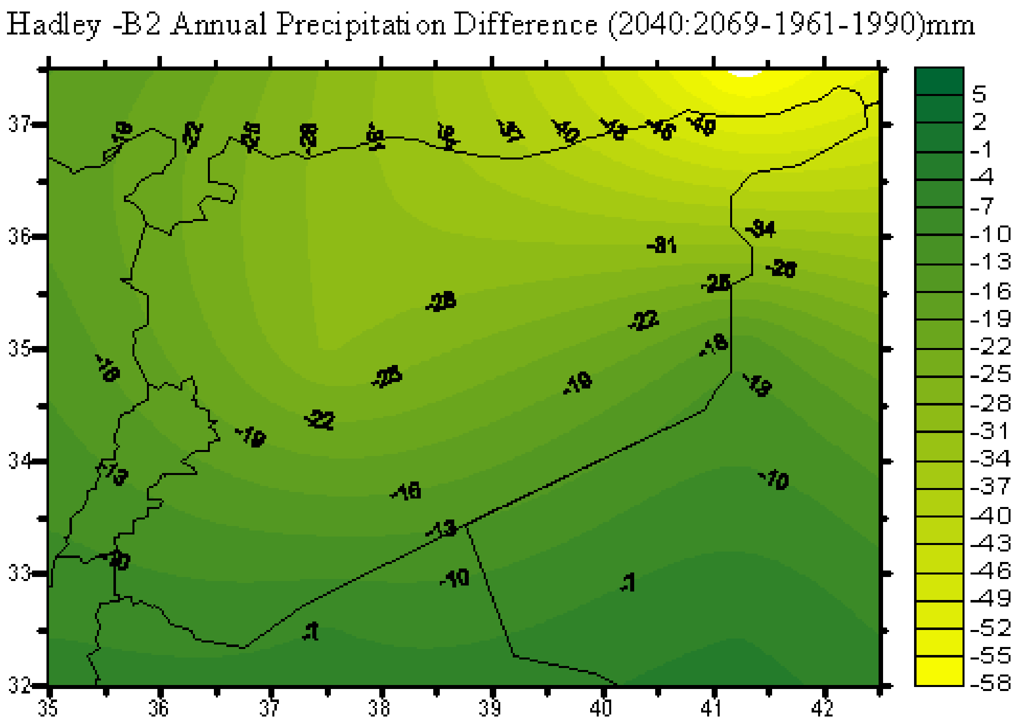


Fig. (9) Annual precipitation changes for 2040-2069 (B2 Scenario- Hadley Model-CM3)

2.2.1.2.3. B2 Scenario (2070-2099)

The B2 scenario application for the period of 2070-2099 indicated that winter and spring precipitation is expected to decrease by 12-18 and 6-28 mm respectively. However, a 10 mm precipitation increases is expected in summer affecting western coastal region and southern districts. On the other hand a 12 mm decrease in summer precipitation is expected in northeastern districts. In autumn, an overall decrease in the total precipitation in the larger part of the country is predicted. Annual precipitation changes for the period are shown in figure 10.

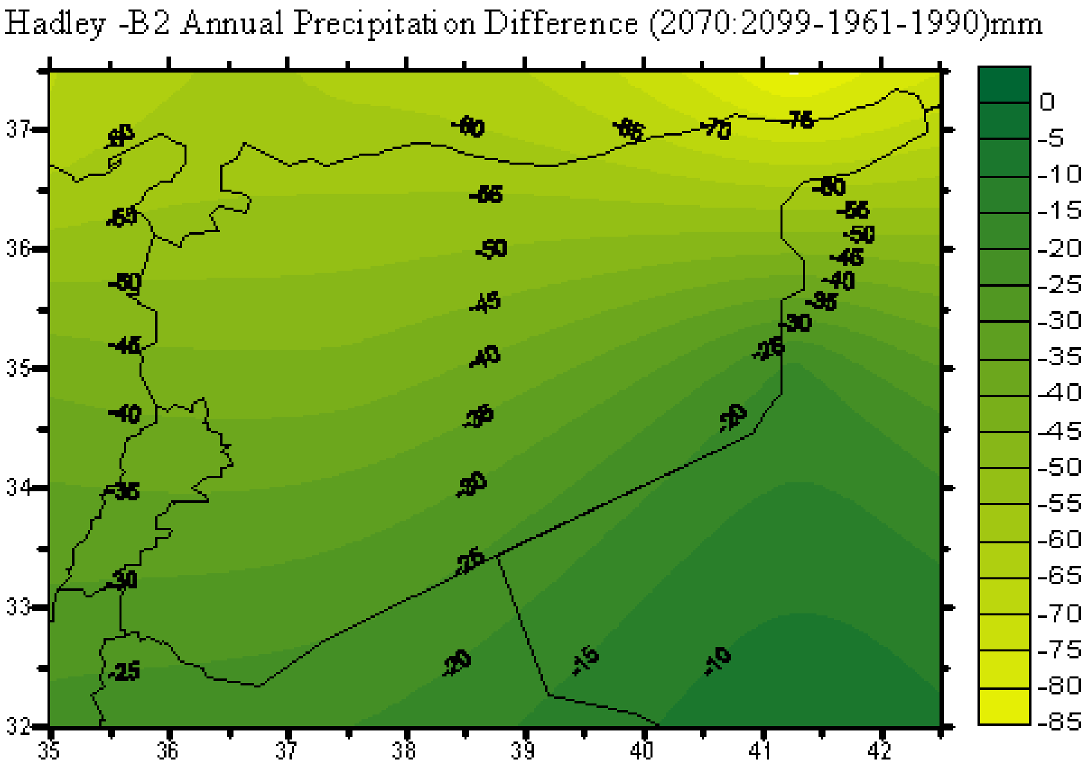


Fig. (10) Annual precipitation changes for (2070:2099 form 1961:1990) (B2 Scenario– Hadley Model-CM3)

2.2.1.2. Temperature

Table 5 shows the seasonal and annual dry air temperature variation (C°) for the years (2010-2039), (2040-2069) and (2070-2099) with respect to normal average (1960-1990) using A2 scenario (model HADCM3).

Table (5) Seasonal and Annual Dry air temperature variation for the years 2039, 2069 and 2099 with respect to normal average 1961-1990.

Years	Winter	Spring	Summer	Autumn	Annual
2010-2039	0.8-1.0	0.7-1.1	1.2-1.9	1.1-1.7	**0.9-1.4**
2040-2069	1.8-2.2	1.8-2.6	2.6-4.4	2.2-3.0	**2.1-3.0**
2070-2099	3.3-4.1	3.3-4.7	4.4-7.0	3.9-5.0	**3.8-5.2**

2.2.1.2.1. Changes in Temperature (the A2 Scenario)

2.2.1.2.1. A2 Scenario (2010-2039)

The results of prediction indicated that an increase of 0.7 C° in the minimum seasonal temperature is expected in spring, while a maximum increase of 1.9 C° is expected in summer. In winter, temperature change varies from a minimum of 0.8 C° in coastal area to a maximum value of 1.0 C° in East, Southeast and North Eastern part of the country. In spring, an overall increase trend of 0.7-1.1 C° is expected in the Western and Eastern regions respectively. Furthermore, a similar increasing trend of 1.2-1.9 C° is expected in the Southwest and the Northeastern regions. In autumn, an increase of 1.1 C° and 1.7 C°

is expected in the Western and Northeastern region consecutively. Annual temperature changes for the period are shown in figure 11.

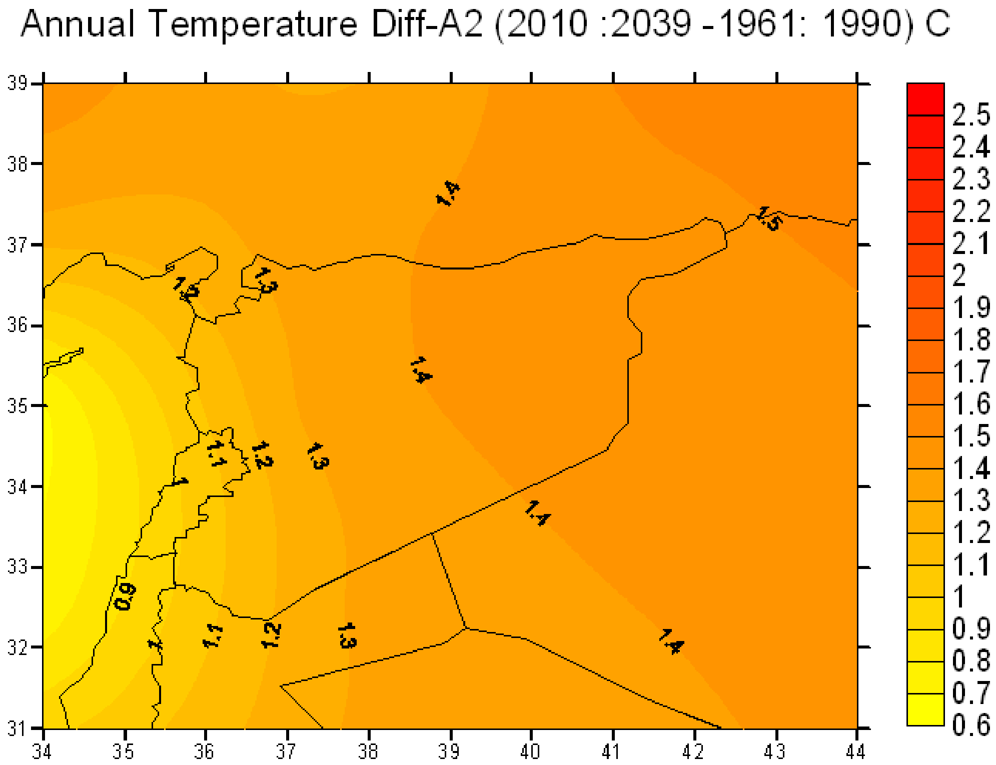


Fig. (11) Annual temperature changes for 2010-2039 (A2 scenario -Hadley Model-CM3)

2.2.1.2.1.2. A2 Scenario (2040-2069)

The scenario predicts an increase in the minimum seasonal temperature by as much as 1.8 C° in winter and spring, while a maximum increase of 4.4 C° is expected in summer. In winter, temperature change varies from a minimum of 1.8 C° in Southwest to a maximum value of 2.2 C° in North Eastern part of Syria. In spring, an increasing trend of 1.8 C°-2.6 °C is expected in Western, Central and Northern part of Syria. In summer, an increasing trend from Southwest (2.6 C°) to Northeast (4.4 C°) is expected. In autumn, an increasing trend from Southwest (2.2 C°) to Northeast (3.0 C°) is forecasted. Annual temperature changes for the period are shown in figure 12.

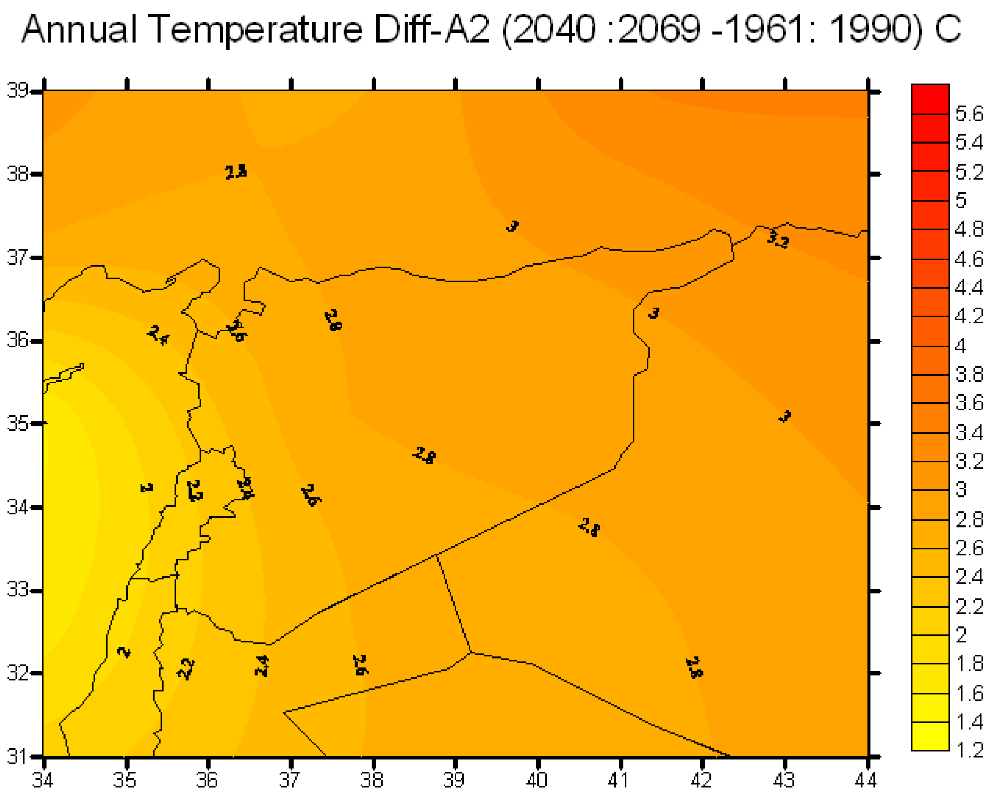


Fig. (12) Annual temperature changes for 2040-2069 (A2 Scenario -Hadley Model-CM3)

2.2.1.2.1.3. A2 Scenario (2069-2099)

The spatial variations on seasonal basis as foreseen by the scenario between 2070-2099 shows expected increase in the minimum seasonal temperature of 3.3 C° in winter and spring while maximum increase of 7.0 C° is expected in summer. In winter, temperature increase varies from a minimum of 3.3 C° in western part of the country to a maximum value of 4.1 C° in Eastern parts of Syria. In spring, an increasing trend from Western (3.3 °C) to Central and North (4.7 °C) is possible. Similar trend of 4.4 C° in Southwest and 7.0 C° in Northeast is expected. In autumn, an increasing trend from Southwest (3.9 C°) to Northeast (5.0 C°) is forecasted. Annual temperature changes for the period are shown in figure 13.

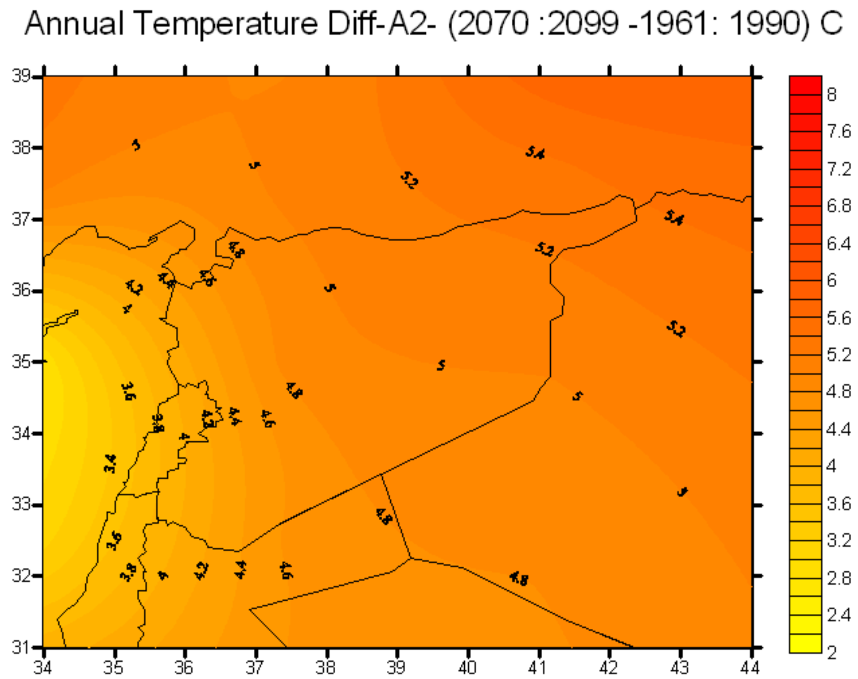


Fig. (13) Seasonal temperature changes for 2070-2099 (A2 scenario – Hadley Model-CM3)

2.2.1.2.2. Changes in Temperature (the B2 Scenario)

Changes in temperature at various periods as predicted by the Hadley model for B2 scenario are shown in table (6).

Table (6) Seasonal and Annual Dry air temperature variation for the years (2010-2039), (2040-2069), (2070-2099) with respect to normal average (1961-1990) from the model HADCM3

Years	Winter	Spring	Summer	Autumn	Annual
2010-2039	1.0-1.3	0.8-1.2	1.1-2.5	1.2-1.8	1.1-1.7
2040-2069	1.5-1.9	1.1-1.8	2.1-3.6	1.7-2.1	1.6-2.4
2070-2099	2.5-2.8	2.4-3.2	3.4-5.1	3.0-3.6	2.8-3.8

2.2.1.2.2.1. B2 Scenario (2010-2039)

In this scenario period a 0.8 C° in the minimum seasonal temperature increase is expected in spring while a maximum increase of 2.5 C° is forecasted for summer. In winter, temperature change varies from a minimum of 1.0 C° on the Southwestern region to a maximum value of 1.3 C° in North East Syria is expected. In spring, an increasing trend of 0.8-1.2 C° in the Western to Central and North is expected. Similar trend of 1.1-2.5 C° in summer is expected for Southwest and Northeastern region. In autumn, increasing trend from Southwest (1.2 C°) to Northeast (1.8 C°) is foreseen. Annual temperature changes for the period are shown in figure 14.

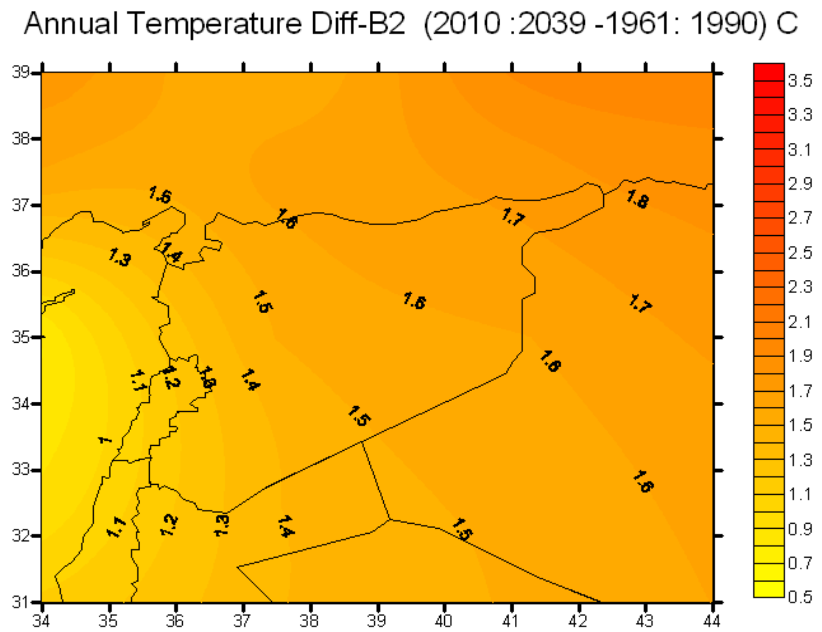


Fig. (14) Annual temperature changes for 2010-2039 (B2 scenario – Hadley Model-CM3)

2.2.1.2.2.2. B2 Scenario (2040-2069)

An increase of 1.1 C$^{\circ}$ in spring minimum seasonal temperature is expected while a maximum increase of 3.6 C$^{\circ}$ is forecasted for summer. In winter, temperature increase will vary from a minimum of 1.5 C$^{\circ}$ on the Southwest to a maximum value of 1.9 C$^{\circ}$ in North East of Syria. In spring, increasing trend of 1.1 C$^{\circ}$ in Western to 1.8 C$^{\circ}$ in Central and Northern region is expected. In summer, an increasing trend of 2.1 C$^{\circ}$ in Southwest to 3.6 C$^{\circ}$ in the Northeast region is foreseen. Lastly, autumn temperatures will elevate by 1.7 C$^{\circ}$ in the southwest to 2.1 C$^{\circ}$ in the Northeast parts of the country. Annual temperature changes for the period are shown in figure 15.

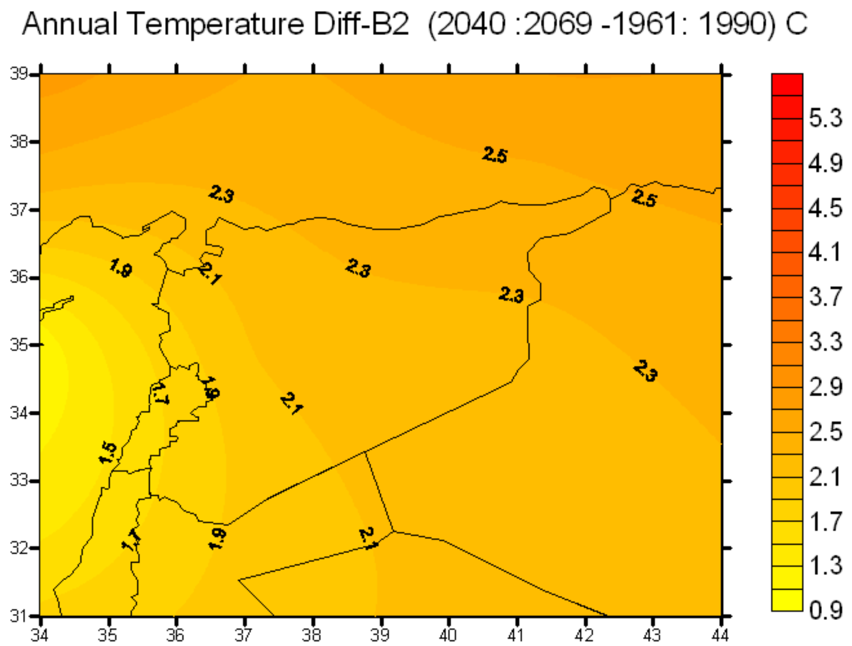


Fig. (15) Annual temperature changes for 2040-2070 (B2 scenario – Hadley Model-CM3)

2.2.1.2.2.3. B2 Scenario (2069-2099)

In this period, a 2.4 C° minimum seasonal temperature increase is expected in spring while a maximum increase of 5.1 C° is predicted in summer. In winter, temperature increase will vary from a minimum of 2.5 C° on the Southwest region to a maximum value of 2.8 C° in North East of Syria. In the meantime, an increasing trend from 2.4 C° in Western region to 3.2 C° in Central and Northern region is expected in spring. Furthermore, an increasing trend of 3.4 C° in the Southwest to 5.1 C° in the Northeastern region is expected in autumn season. In summer, similar increase by as much as 3 C° in the Southwestern region to 3.6 C° in the Northeastern region is expected. Annual temperature changes for the period are shown in figure 16.

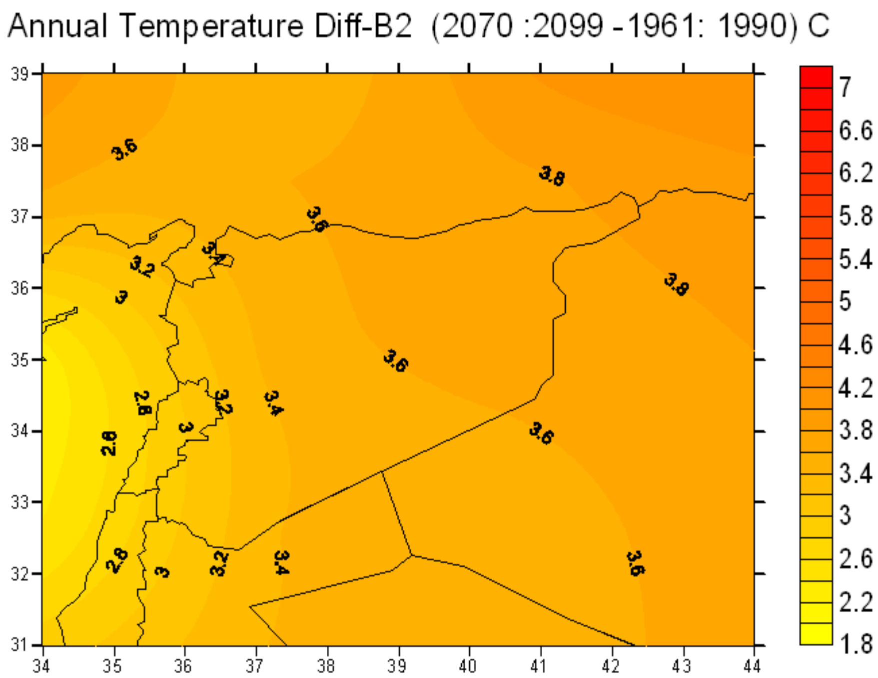


Fig. (16) Annual temperature changes for 2070-2099 (B2 scenario – Hadley Model-CM3)

3. Assessment of Impacts and Adaptation Measures

3.1. Water Resources

3.1.1. Overview

Syria by enlarge is an arid and semi arid country. The prevalence of arid and semi-arid climate is reflected directly on precipitation and the available renewable water resources of the country. The average annual per capita share of water amounts to slightly over 1000 m^3 compared to 7500 m^3 of the global level. The per capita share of water is expected to worsen in the future which might drop to 500 m^3 in 2025. Currently, water resources are under heavy and increasing pressures due to persistent drought, population growth and irrational use of water resources.

Groundwater is very important source of water in arid environment. Its importance increases considerably during drought events. With few exceptions, most of the groundwater basins in Syria are experiencing water deficits. Recent studies projected a change of groundwater recharge between present-day (1961 to 1990) and the 2050s (2041 to 2070) to be more than -30% (*Döll* and *Flörke*, 2005).

The overall water deficit in the country is growing. In year 2001-2002, the average value deficit was 16% more than the ten years of 1992-2000 (*Abed Rabouh*, 2007). Water deficit which was estimated at (651) mcm/ y for the period 1995-2005 is expected to increase to (2077) mcm/ y in 2026-2027 due only to population and development growth (*Kayal*, 2007).

3.1.2. Impact of Climate Changes

A change in current climatic conditions is likely to bring about significant changes in precipitation and temperature patterns (see above section). These changes are likely to put more pressures on water resources thus, exacerbating existing situation unless adaptation measures are seriously considered in the planning for and management of these precious resources.

The impact of climate change on water resources, reflected in an overall decrease in precipitation and elevated temperature on water resources is assessed using two different case studies. The first one deals with the Euphrates River as a major source of surface water in the country. Whereas, the second case deals with the *Zabadani* sub-basin and *Figeh* spring as a case study for climate change impact on ground water resources.

3.1.2.1. Case Study (1): The Euphrates River

The climate change projection for the upper Euphrates and Tigris watershed area shows that major reduction changes in snow water equivalent may occur in the stream flow for these two rivers. The reduction may reach up to 100 mm in snow water equivalent (*Onol* and *Semazzi*, 2006). The model-derived climate sensitivity of the Euphrates River discharge shows that a 25% increase or decrease in precipitation rises or lowers the discharge profile of the river, while keeping its hydrograph shape unchanged (*Smith et al*. 2000). This prediction means that 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 respectively, nearly twice the imposed percentage change in precipitation. Regional modeling studies expected a reduction of nearly 40-50 mm in the upper Euphrates and Tigris basin which is a decrease of about 7% of the average rainfall. Such reduction is expected to have about 11% drops in the Euphrates river discharge (Fig. 17) (Evans, 2008). Other studies predict around 10-25% reduction in river runoff in the upper Euphrates and Tigris basin in 2070 compared to average flow of the year 2000 (*Lenher et al.*, 2001 and EEA, 2004).

On the other hand, an imposed change in temperature alters the shape and magnitude of the Euphrates discharge. A 5 degree warming increases evapo-transpiration significantly, 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. A 100 mm reduction in snow water equivalent at the Euphrates upper stream will lead to reduced flows in late summer when water is scarce and demand is greater. Similar sensitivities to temperature change were observed in the Upper Tigris.

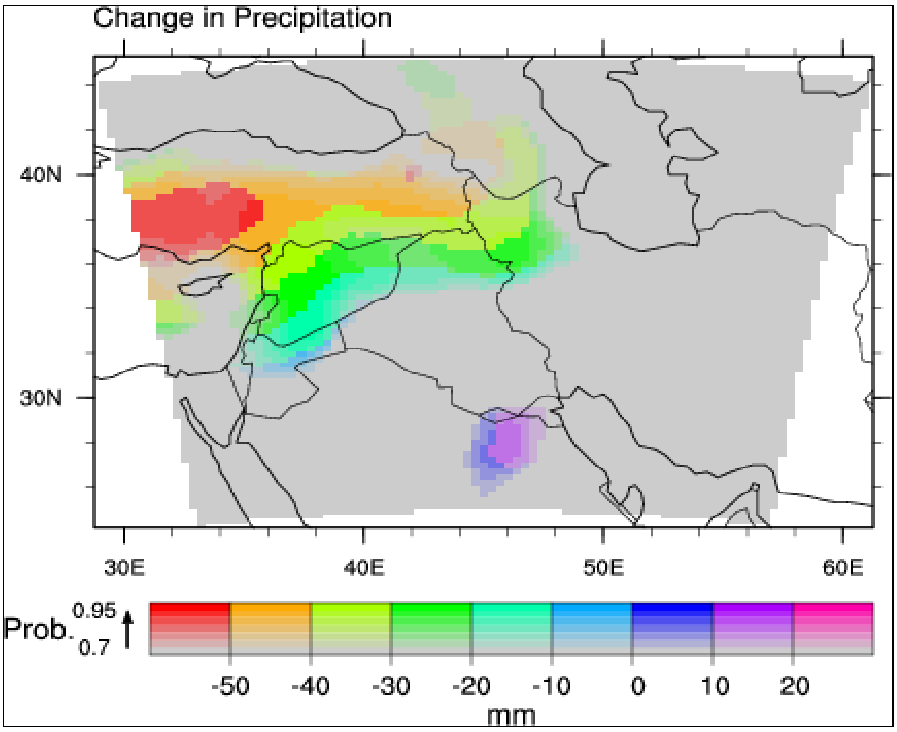


Fig. (17) Probability change in precipitation by amount (hue) and significance (sat).

Syria obtains 36% of its renewable annual water resources from the Euphrates River. Hence reductions in flow discharge will affect several sectors relying on water derived from Euphrates river flow. The large irrigation projects on the river basin will be the most vulnerable to such changes in terms of quantity and quality of irrigation water, thereby affecting cropping area and yield. Also, reducing snow melt flowing through dams will decrease stored water negatively affecting the potential generation of hydropower. Furthermore, the decline in water level in the Tigris and Euphrates will decrease irrigated areas (181000 ha.) by 1.5 ha/ yr, which represents an annual loss of one million tons of agricultural products valuing 20 million S.P. (U.S. $ ~425,000).

3.1.2.2. Case Study (2): Zabadani Sub-Basin

Located in the Anti-Lebanon Mountains, the *Zabadani* Sub-Basin receives 700 mm of annual rainfall. The sub-basin covers 140 km² and drained by the only perennial stream of the region, the *Barada* River with the *Barada* spring at 1095 m above sea level . as its source (Figure 18). The *karst* spring of *Barada* constitutes an important resource for the drinking water supply of Damascus. To add on, there is already a water competition for spring water among municipal drinking water suppliers, agricultural and tourist activities. In dry years *Barada* spring (average discharge 3.8 m^3/ s) ceases completely during summer months, mounting the potential of such conflicts.

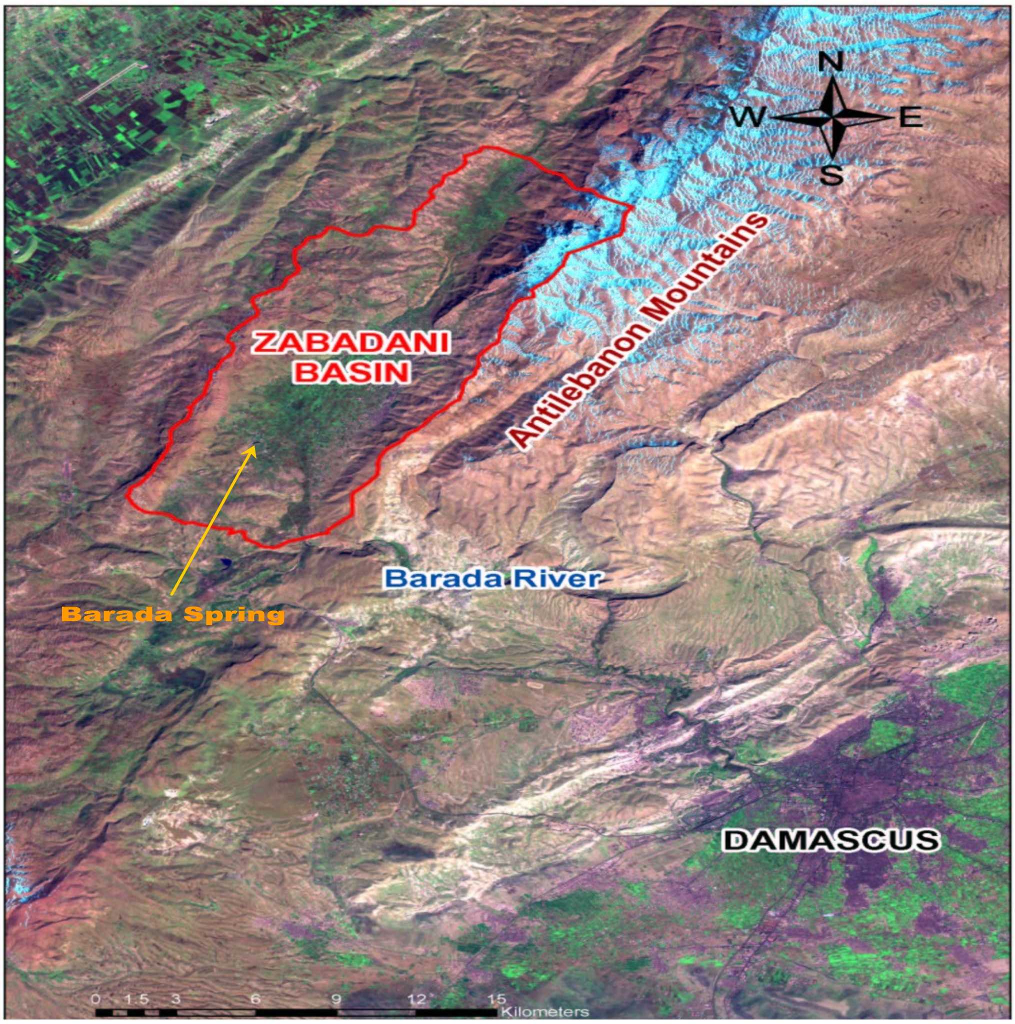


Fig. (18) *Zabadani Sub-Basin*

The Decision Support System "DSS" developed by ACSAD, BGR and SEI was utilized to explore the impact of climate change on groundwater levels using the dynamic linkages between the calibrated groundwater mathematical model (MODFLOW2000, United State Geological Survey) and water evaluation and planning model (WEAP21, Stockholm Environmental Institute) (*Al-Sibai et al.*, 2008). The impact of climate change on *Barada* spring discharge was further studied using the calibrated model “Stream flow simulator 2007”. The simulation results showed that a decrease of 5.1% in annual rainfall in 2040 accompanied with the same pattern of rainfall and pumping rate of year 2006-2007 would result in a continuous decrease in spring discharge, a gradual disappearance of the low flow period of the spring, and restriction of the spring dishrags mainly in peak time. The model expected a decrease of 37% in annual discharge by 2039 (Figure 19).

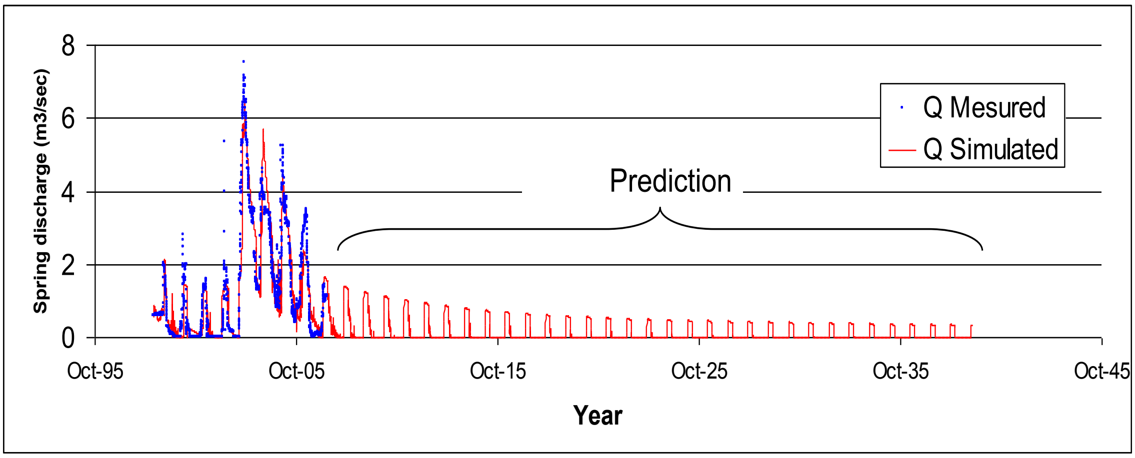


Fig. (19) Simulated daily spring discharge after 2007.

The socio-economic and political impact of groundwater decline is of great concern. With *Barada* and *Awaj* basin having the highest proportion of drinking water (24%) among the other basin, the domestic sector living in the basin will be the most vulnerable. Generally speaking, aside from the environmental impacts of lowering ground water level, the decline of water wells by 20 meters will increase the cost of irrigating crops by 5 billion S.P. This covers deepening agricultural wells and additional costs associated with pumping for irrigated total area of 812921 hectares.

Priority for adaptation to water scarcity would be the reduction of the vulnerabilities of people, particularly the poor and disadvantaged, living mainly in rural areas. Any strategy should focus on two main issues; sustaining the agriculture production and preserving the environment. This requires making major changes in water management, water policies, and water related infrastructure.

3.1.3. Adaptation

The predicted impact of climate change on water resources could be managed with measures guided by the philosophy and methodology of integrated water resources management. The following bullets are suggested as possible adaptation measures:

- ✓ Preparing a national water master plan in the framework of integrated water resources management and integrating water policies and strategies related to water uses into the plan.
- ✓ Strengthening institutional and technical capacity of water related agencies to ensure systematic collection, processing and exchange of data and information, and better coordination and cooperation between various water stakeholders.
- ✓ Enforcement of laws and regulations. These include springs protection zones, well drilling permissions, drilling supervision and specifications, protection of groundwater recharge zones, groundwater pumping schemes, protection of groundwater and surface from pollution, and water resources development.
- ✓ Improving irrigation efficiency by reducing water demand for irrigation through changing the cropping calendar, crop mix, irrigation method and area planted.
- ✓ 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 basins infrastructure for increased water storage capacity.
- ✓ Strengthening existing observation networks (metrological and surface and ground water).
- ✓ Capacity-building to integrate climate change adaptation strategies into sectoral and cross-sectoral development plans.

3.2. Agricultural Production

3.2.1. Overview

Syria's economy has traditionally been dominated by the agricultural sector which employs 25- 30% of total workforce and contributes to about 25-30% to the country's GDP (Statistical Abstract, 2004). Nearly 70% of the cropped area (5,523,356 ha) in the country depends on rainfall (Statistical abstract, 2005). Consequently, variations in the amounts and timing of rainfall can immediately cause substantial shifts in areas planted, productivity and yields in most of the major agro-ecological zones in the country.

The expected increase in temperature and decline in rainfall will have an impact on the crop water supply-demand relationship, crop water use efficiency, reduction of the growing season and decreases in water availability. This depends by itself on the extent of changes in the form of precipitation and the timing of its events.

By enlarge; the two most important crops in the country are wheat and cotton. Wheat is considered as the most important staple and strategic crop in Syrian agriculture (NAPC, 2002). It occupies 34% of the cropping area in the country with 55% of this production is coming from irrigated farming (Statistical Abstract, 2005). Furthermore wheat occupies 70% of the irrigated land that is devoted to strategic crops. The crop is of paramount importance for food security of the country because it is the main source for protein and energy.

Also, raw cotton is by far the single most important agricultural export in the country. It occupies 25% of the irrigated land devoted to strategic crops. It accounts for 29.5% of the agricultural export value and 13.8% of agricultural trade volume (NAPC, 2002). Moreover, it is the largest employer of labor within the agricultural sector. Almost all the cotton is grown on irrigated land, largely in north Eastern part of the country.

Of the tree crops, Olive constitutes the most important fruit tree in Syria. The country was ranked as the world sixth olive oil producer in 2005 (IOOC, 2006). In 2006, the area planted by olive tree reached 564,938 hectares and the production reached 1,200,000 tons of olives (Statistical Abstract, 2006).

3.2.1. Impacts of climate changes

The likelihood of climate change impact on wheat and cotton production was assessed in *Al-Hassakeh* governorate as being the main agricultural area for wheat and cotton. On the other hand, Aleppo governorate was selected to assess the effect of such impact on olive trees production since the governorate contributes 23 % to the National production.

CROPWAT is an irrigation management model developed by FAO Land and Water Management Division used to evaluate crop water requirements and irrigation needs (Smith, 1992). The model was utilized to assess the effect of climate change on wheat (irrigated and rainfed), cotton, and olive trees water use and yield.

The results should be used as indicatives on the effect of climate change on agricultural crops due to inherent deficiency in the model itself, the assumption that nutrients are not limiting, and the inconsideration of the effects of warming on length of growing season. The following sections highlight the results.

3.2.2. Impacts on Irrigated wheat

Using CROPWAT model fitted with the current climate conditions, it was estimated that the wheat water requirements (ETm) are 563 mm. However, the actual crop water use is estimated at 402 mm. Consequently, the difference between actual and potential evapo-transpiration is 161 mm. This indicates that wheat is water stressed under current crop management system and the yield reduction due to this stress is about 30% (Table 7).

Table 7. Actual crop water use for wheat under current climate conditions.

ETo (mm)	ETc (mm)	Ky[1]	Ya[2] t/ ha	Ym[3] t/ ha	Ks	Etc $_{actual}$ (mm)	Yield reduction (%)
613	563	1.00	3.5	5.0	0.7	402	30

[1] *Irrigation and Drainage Paper No. 33 (Doorenbos and Kassam, 1979)*
[2] *Yield average of 15 years in Al-Hasakah governorate*
[3] *from Irrigation and Drainage Paper No. 33 (Doorenbos and Kassam, 1979) and local data*

The predicted changes in temperature and precipitation for B2 scenario – Hadley Model-CM3 for the period 2070 to 2100 for *Al-Hassakeh* governorates was used in CROPWAT model to calculate crop water use for potential optimum production under climate change conditions. The findings revealed that an increase in atmospheric temperature and a decrease in precipitation would lead to increase wheat crop requirement from 563 to 617 mm. This means an increase of 9.6% in water use, for irrigated wheat, compared with crop water use under current conditions. If no additional irrigation water is added to compensate for this increase in demand, the crop production would be reduced by 15.7 % (from 3.5 to 2.95 ton/ha, table 8).

Table 8. Actual crop water use (mm) for irrigated wheat under climate change conditions.

ETo (mm)	ETc (mm)	Ky	Ya t/ ha	Ym t/ ha
670	614	1.00	2.95	5.0

3.2.2.2. Impacts on rainfed wheat

Crop productivity under rainfed condition largely reflects rainfall conditions. Rainfed wheat productivity in Al-*Hasakah* governorate ranges between 280 kg/ ha to 2377 kg / ha for a range of rainfall between 95 to 530 mm with some years of total crop failures. Therefore, a drastic change in climate will adversely affect rainfed wheat production (Figure 20).

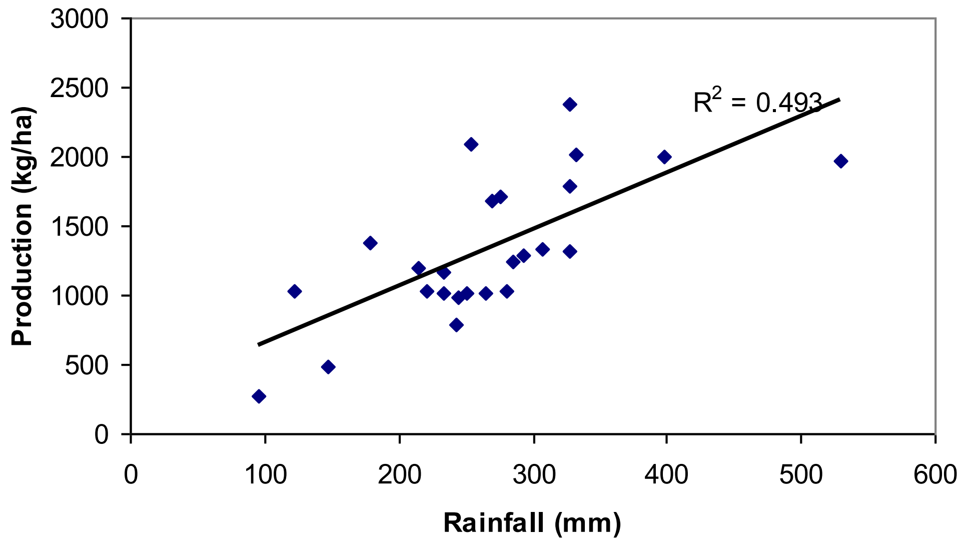


Fig. (20) Relationship between rainfall and rainfed wheat production at *Al-Hassakeh* governorate

Following the previous methodology, it was calculated that the potential crop water requirements for rainfed wheat is 428 mm and the actual crop water requirements for rainfed wheat is 203 mm. This means a loss of yield production by 52.5% compared to optimum conditions production (table 9).

Table 9. Actual crop water use for rainfed wheat under current climate condition

ETo (mm)	ETc (mm)	Ky1	Ya2 t/ ha	Ym3 t/ ha	Ks	ET cactual (mm)	Yield reduction (%)
494.3	428.4	1.05	1.40	2.95	0.475	203	52.5

[1] Irrigation and Drainage Paper No. 33 (Doorenbos and Kassam, 1979)
[2] Yield average of 15 years in Al-Hasakah governorate
[3] from local data

Under the climate change scenario, the crop water requirements for rainfed wheat would jump to 469 mm. This equals an increase of 9.6% crop water demand reducing yield by 21% unless adequate water was added (Table 10).

Table 10. Actual crop water use for rainfed wheat under climate change condition

ETo (mm)	ETc (mm)	Ky	Ya t/ ha	Ym t/ ha
541.1	469	1.05	1.1	2.95

The decline in the crop production due to climate change will result in a decrease in the value of plant production by as much as 7.8%. This decline will affect food security on the long run. It is very difficult to predict economic consequences for such effect. However, the consequences of the severe drought of 1998/1999 which caused a loss of 21.6 billion S.P. (current prices) can be used as an indicative figure for such impact.

3.2.2.3. Impact on Cotton

Following the methodology explained earlier it was found that the crop water requirements for cotton are 1169 mm. The difference between required water and Et crop actual (982 mm) would reduce yield production by 20% (table 11).

Table 11. Actual crop water use for cotton under current climate condition

ETo (mm)	Etc (mm)	Ky[1]	Ya[2] t/ha	Ym[3] t/ha	Ks	ETc_{actual} (mm)	Yield reduction (%)
1307	1169	0.8	4.0	5.0	0.84	982	20

[1] Irrigation and Drainage Paper No. 33 (FAO 1979)
[2] Yield average of 15 years in Al-Hasakah governorate
[3] from Irrigation and Drainage Paper No. 33 (FAO 1979) and local data

Under the climate change scenario, the crop water requirements for cotton (ETc) is increased from 1169 mm to 1287 mm (10.1%). If no additional irrigation water was added to compensate for this increase in demand, the crop production will be reduced by 7.5 % (Table 12).

Table 12. Actual crop water use for cotton under climate change condition

ETo (mm)	ET crop (mm)	Ky	Ya t / ha	Ym t/ ha
1415	1287	0.85	3.7	5.0

3.2.2.4. Impact on Olive trees production

Using the same methodology explained earlier it was found that the crop water requirements for olive tree (ETc) are 858 mm (table 13).

Table 13. Actual crop water use for olive under current climate condition.

Parameter	ETo (mm)	ETc (mm)	Ky[1]	Ya[2] Kg/ tree	Etc_{actual} (mm)
Irrigated	1446	858	1.1	17.5	463

[1] from calibration of local data
[2] Yield average of 15 years in Aleppo governorate

Under the climate change scenario, the crop water requirements for olive tree (ETc) is increased from 858 to 945 mm (10.2%). If no additional irrigation water was added to compensate for this increase in demand, the production for irrigated olive will be reduced by 17 % (Table 14).

Table 14. Actual crop water use and yield for olive tree under climate change conditions

Parameter	ETo (mm)	ETc (mm)	Ya* Kg/tree	ETc_{actual} (mm)
Irrigated	1588	945	14.5	437

**Yield calculated using CROPWAT*

3.2.3. Adaptation

The present level of adaptation to climate risks in agricultural sector is limited to calls for using irrigation water efficiently through a national program, restricting cropping areas, calls for new farming practices, and lately establishing a farmer support fund. Adaptation in agricultural sector must be pursued with a strategic vision proportional to the value and importance of agricultural sector contribution to national economy and food security of the country. Future strategies for adapting to climate change in agricultural sector may involve the following measures:

- Reviewing agricultural policies and strategies regarding agricultural crops in relation to CC.
- Development and implementation easily accessible drought forecast and drought monitoring information systems to improve drought preparedness within the national plan of mitigating the effects of drought.
- Development of Agricultural Research and extension services. Changing crop practices (optimum sowing date, heat-tolerant cultivars, and water ration and planting density).
- Capacity building at the human, institutional and systematic levels.
- Modernizing water irrigation practices and improving irrigation management.
- Increasing rain effectiveness by applying conservation farming and water harvesting and storage structures.

3.3. Natural ecosystems

3.3.1. Forests

3.3.1.1. Overview

The total area of Syria occupied with forests exceeds half a million hectares or 2.71 % of the total area of the country. Nearly 53.56% of these forests are man-made. Ninety nine percent of forests are state owned and managed by forestry service. Forests are managed according to general guidelines and broad goals without clear policy. Forestry bureau are of limited resources, insufficient capacity and inefficiency in coordinating inter-agencies forest related activities.

Forest clearing, wild fires and quarrying industry are main pressures that cause forest degradation in Syria today. Pressures of these activities, especially fires, have increased during the last twenty years. Hence intensifying agents of forest disturbance will increase vulnerability of these forests to climate change and jeopardize their ecosystem services.

3.3.2.2. Impact of climate change

Although no quantification of the effects of climate change on forest vegetation is done, it is generally accepted that such effect may take temporal and spatial forms. Regressing of climax forests is quite possible under the destructive agents of change, which in turn, reflects a temporal shift in forest vegetation. On the other hand, a decrease of precipitation and an increase in temperature may cause spatial “un upward shift” in some plant species of forest vegetation zones in mountain areas. A 200 meter upward shift was reported in Lebanon and Turkey. If happened, this may change vegetation association as change may affect community composition in the first place. In actuality, rareness and disappearance of some species from certain mountain zones has been reported by some Syrian researchers.

Brutia pine forests which constitute 27.5% of natural forest area will be the most vulnerable to climate changes due to possible increase in the frequency, intensity and extent of fires. The effect will be mounted with increasing frequency of drought spells, and prevalence of longer and warmer summer days. This is evident through the large increases in forest areas lost to fires during the past years where for instance, a single forest fire in late December of 2004 caused a loss of nearly 0.4 % of the total forest area in the country.

Man made forests which make-up more than 53% percent of country’s forests, will be vulnerable to climate change as most of these forests are planted in low rainfall areas in the interior part of the country (edge forests). Moreover, the severity of insect attack incidents and disease infections are expected to increase due to favorable climate for spread of ailing agents.

Finally, water shortage will become a major constraint for increasing and even maintaining forest plantations as scarce water is diverted to other uses. Hence, a forestation work which has been stretched species beyond their natural limits of distribution will be limited to the areas of species natural range.

3.3.3. 3. Adaptation

With stocking capacity of nearly 16 million tons of carbon and an annual sequestration of 1.6 tons of atmospheric CO_2 per year, Syrian forests play a major role as being a carbon sink contributing to curbing CO_2 emissions. To strengthen and maximize this function, the following measures are suggested.

- ✓Adoption and execution of a formal forest policy for forest development and conservation.
- ✓Strengthening forestry bureau activities that directed towards accentuation of protecting existing forests against wild fires and other destroying agents.
- ✓Rehabilitation of burned and degraded forests to increase their capacity of carbon sequestration.
- ✓Establishment a network of functional protected areas, to ensure the conservation of the most valuable forest ecosystems in the country.
- ✓Capacity building at institutional and staff levels.

3.2.1.1. Rangelands

3.2.1.1.1 Overview

Syrian range lands (the *Badia*) constitute 55.1% of the country total area. *Badia* vegetation is fragile in nature due to the limited amount of rainfall, cold temperature periods, frequent drought spells, land tenure and the current grazing patterns prevails. Rangeland productivity is low and varies depending principally on rainfall, soil and site conditions. Main cause of rangelands degradation and desertification is land tenure which led to common grazing rights, over and early grazing, fuel wood collection, and flood plains plugging.

Frequent drought is common in the Syrian rangelands and its impact is immense. For instance, the drought of 1989/1999 season caused a loss of 38.7 million S.P. in sheep sector alone (1999 prices). Furthermore, the total forage loss was estimated at 0.8- 1 million tons of forage equaling a total value of 10 billion S.P. (Current prices)

3.3.2.2. Impact of climate change

Climate change will augment the existing problems of desertification, water shortages and low forage productivity. Moreover, it will introduce new threats to herders and livestock owners' wellbeing, rangeland ecosystem services and national economy. On the other hand, land degradation and desertification affects availability of crop residue fodder during the drought periods.

3.3.2.3 Adaptation

Despite some of the shortcomings in rangeland management, there is great potential for improving the *Badia* vegetation and enhancing its resilience to climate change. The following measures need to be strengthened:

- ✓ Effective implementation of set of drought management strategies including setting an effective feed reserve policy.
- ✓ Supporting the use of renewable energy in rangeland development.
- ✓ Expansion of plantation programs of drought tolerant native and exotic species. Expanding programs of combating desertification.
- ✓ Solving issues of land user's rights.
- ✓ Diversification of income sources for Bedouins population.

3.3.3. Biodiversity

3.3.3.1. Overview

In general, biodiversity in Syria is under pressures due to population growth and the unwise use of biodiversity related resources. The number of threatened species in the country totals 68 of various animals' taxonomic groups (IUCN 2008). Seven of these species are listed as critically threatened, whereas 26 and 35 other species are considered endangered and vulnerable respectively (IUCN 2008).

3.3.3.2. Impact of climate change

Climate change may add additional pressures on already stressed ecosystems and species thus increasing their endangerment and possible extinctions. Furthermore, increasing demand for irrigation water lowers ground water table in most basins of the country. This in turns would have negative impact on swamps and other wetlands as these ecosystems may dries up affecting some water dependent species survivals. Further increase in sea water temperature may also increase the rate of "tropicalization" of the Mediterranean Sea, contributing to invasive species problem along the Syrian coast.

3.3.3.3. Adaptation

The following are possible adaptation measures to mitigate the impact of climate change on biodiversity components.

- ✓ Updating national biodiversity strategy and action plan.

- ✓Integration of Biodiversity strategy and action plan within national climate change adaptation plans and programs.
- ✓Promotion of conservation measures and sustainable use of biodiversity components.
- ✓Formulation of a long-term research initiative on species status and their adaptability to changing environment.
- ✓Promotion of public awareness on the importance of biodiversity and the likely impact of climate change.

3.3.4. Land degradation and desertification

3.3.4.1. Overview

More than 70% of arid land area in Syria is highly vulnerable to degradation. Another 23% (semi arid lands) is vulnerable but with a lesser degree. The vulnerability of the different land use forms, however, varies between and within categories according to their distribution in the different agro-climatic zones in the country. Main forms of land degradation include; wind erosion affecting 9 % of the country land area, water erosion 6 %, sand encroachments 2 %, and salinization 0.1%.

During the last twenty years substantial changes in land use occurred in Syria (figure 21). These changes are brought about by drought and land use mismanagement. For instance, the expansion of agricultural production has not been accompanied by appropriate use of technology, effective agricultural policies, sustainable farming systems, and planned urban development resulted in land resources degradation.

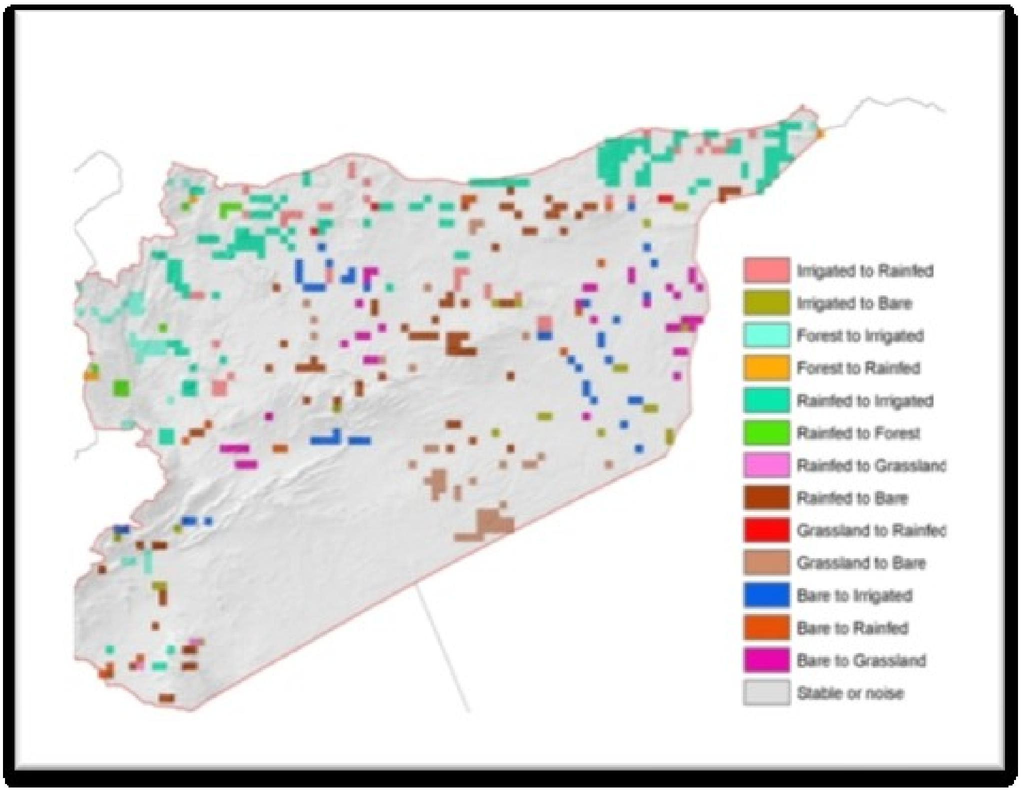


Fig. (21) Land use / Land cover changes in Syria between; 1982-1999 (*Celis, et al*., 2007).

3.3.4.2. Impact of climate change

Climate change will affect land use pattern and accelerate the pace of land degradation. Proper land use policies and proper farming systems must be devised and applied in most dynamic ways to mitigate this effect. The challenge lies ahead is to sustain and optimize the use of natural resources to improve agricultural production and the livelihood of the people.

3.3.4.3. Adaptation

Great opportunities to overcome land resources degradation and increase food production in Syria exist. The following bullets are suggested adaptation measures:

- ✓ Setting proper land use policies and strategies to manage land resources and mitigate climate change.
- ✓ Mobilization and mainstreaming resources to protect natural base of resources.
- ✓ Adoption and application of integrated management techniques, multi and inter-disciplinary and participatory approach in assessing and managing the scarce land resources.
- ✓ Applying and disseminating conservation agriculture.
- ✓ Modernizing farm management and applying proper techniques and technology in the production process.
- ✓ Supporting research activities and extension services.
- ✓ Facilitating exchange of information and experiences between researchers, extension services and farmers.
- ✓ Capacity building of institutions.

3.4. Sea Level Rise

3.4.1. Overview

The coastal region forms only about 2% of the total country area, but it resides more than 11% of the total population and contributes more than 12% to the Gross National Production (MOLA 2007). The coastal area forms the food basket of the country; especially for green house farming and fruit orchards (CBS 2006). Also, the area contributes to nearly, 38% of cement production and 50% of national oil refining in the country. These establishments are located just on the shoreline Fig. (22) (*Ibrahim* 2003).

Sea level rise may adversely affect a number of physical, ecological, biological, and socioeconomic characteristics of the coastal zones, which are already under stress. The following sections highlight methodology assessment and consequences of SLR.

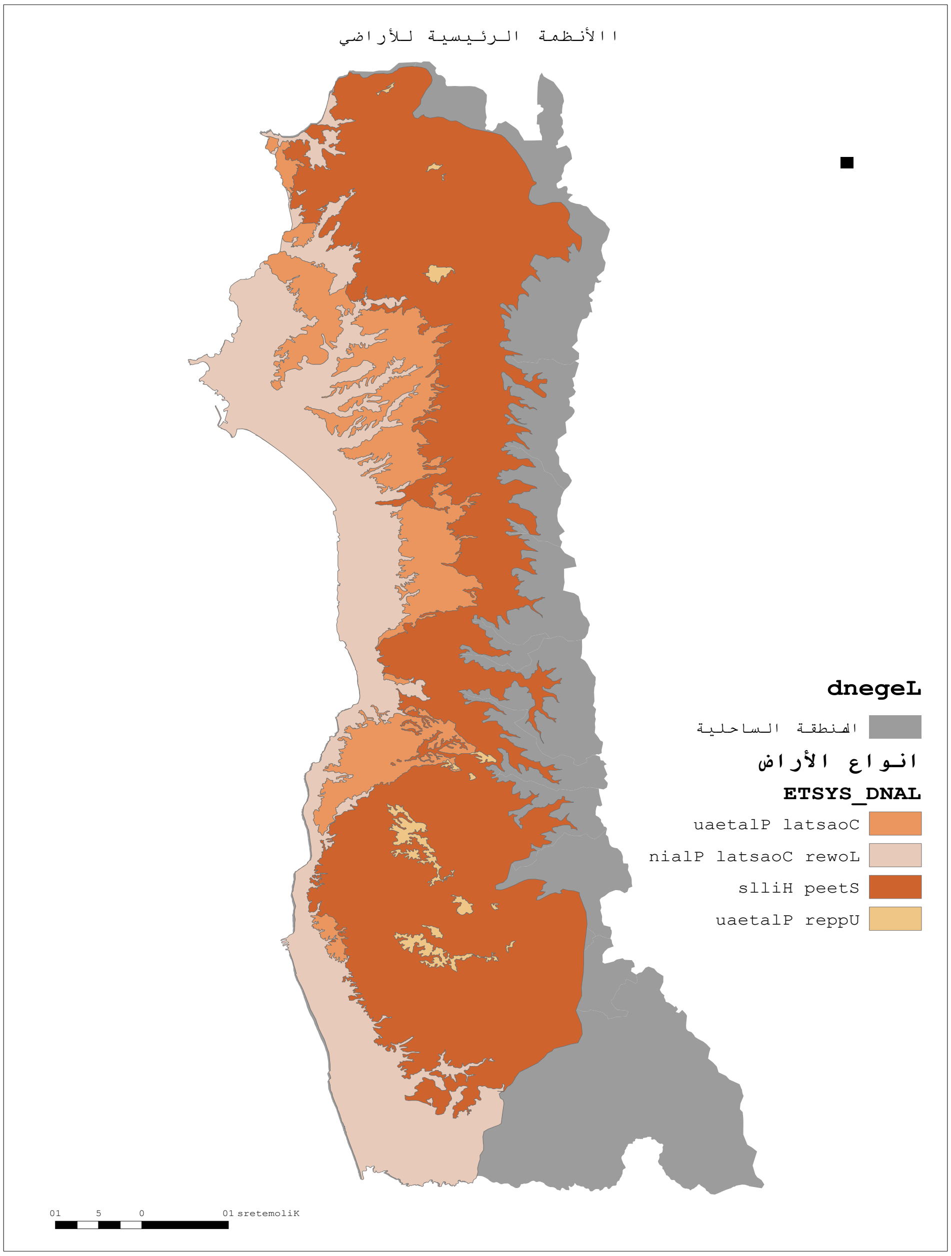


Fig. (22) Geomorphological divisions of the coastal areas (GORS 2006).

3.4.2. Sea level rise scenarios

In order to assess possible impact of SLR on coastal areas, a digital elevation model (DEM) was built using Arc GIS software for the entire coastal zone. The spatial resolution of the DEM was 10 m and its vertical accuracy was between 5-10m (the DEM in this case is rather of low accuracy) (Figure 23). Land use/cover map developed by GORS, using visual interpretation of Multispectral Land sat Satellite images with FAO legend, was used for overlay and risk assessment. Also, a one-meter spatial resolution IKONOS image, taken in 2006 and covering the entire area, was used for the visual interpretation of coastal geomorphology. Multi-temporal satellite images acquired by the satellite Land sat were used to estimate shoreline erosion.

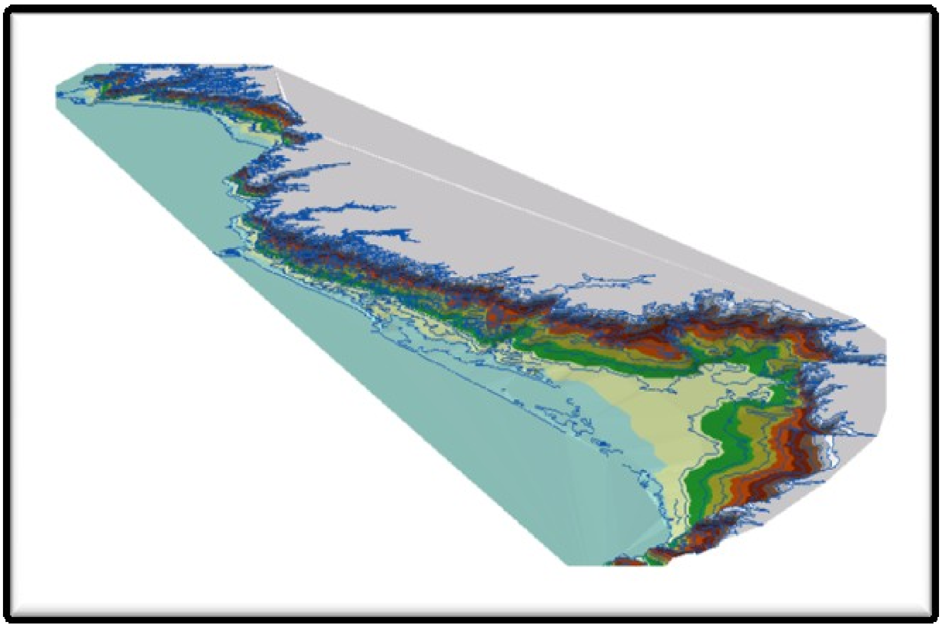


Fig. (23) DEM of the Syrian Coast

Six scenarios for SLR ranging from very low to extreme risk were developed (see table 15). Coastal vulnerability index (CVI) was developed by incorporating geomorphology, coastal slope, rate of relative SLR, shoreline erosion and accretion rates, mean tidal range, and mean wave heights into the index. The index allows the six variables to be related in a quantifiable manner that expresses the relative vulnerability of the coast to physical changes due to sea-level rise.

3.4.3. Impact of sea level rise

The results of these scenarios indicate that, different segments of the coastline are vulnerable to sea level rise as consequences of the expected climate changes. This rise would have an impact on beaches, urban settings, and agriculture zones. Furthermore, additional problems may arise due to salt-water intrusion and increase in water and soil salinity.

Yet, the socioeconomic impact of SLR on coastal lowlands would vary depending on the level of inundation, the degree of land use and development activities. The likely inundated sea shore area varies between 17.56 km^2 for the very low risk scenario to 118.90 km^2 for the extreme risk scenario (Tables 16 and 17). Coastal vulnerability indices are shown in six maps presented in the annex, noting that the three first scenarios represent the most likely one to materialize.

Table 15. Inundated areas in 2100 due to various scenarios of sea level rise

Scenario	Trend (cm/ yr)	Variation 2000-2100 (cm)	Inundated area (km^2)
Very low	0.6	60	17.56
Low risk	0.9	90	20.27
Moderate risk	1.3	130	23.89
Intermediate risk	1.9	1.9	27.57
High risk	2.5	250	30.35
Extreme risk	>5	500 up to 750	118.90

Table 16. Categories of coastal vulnerability index and effect

Class Risk	Description	Length (km)	Total Length (%)
1	Very low	2.74	1.5
2	Low	40.31	22.0
3	Moderate	74.72	40.8
4	High	29.48	16.1
5	Very high	35.75	19.5
Total		183.00	100.0

Possible physical impacts of SLR include: (1) inundation and displacement of lowlands and wetlands, (2) increased salinity of coastal aquifers, (3) increased coastal erosion, and (4) increased coastal flooding and damage. It can be inferred that the most vulnerable coastal areas are: Flat and low-lying coastal plains (sandy and rocky within 0–1 m above MSL), deltaic and estuaries coastal plain areas and sandy shores characterized by gentle slopping beach face.

It is expected that nearly 3.8% of coastal populations will be affected by SLR when applying the extreme risk scenario. The impact of SLR on major land uses due to inundation is illustrated in figure 24.

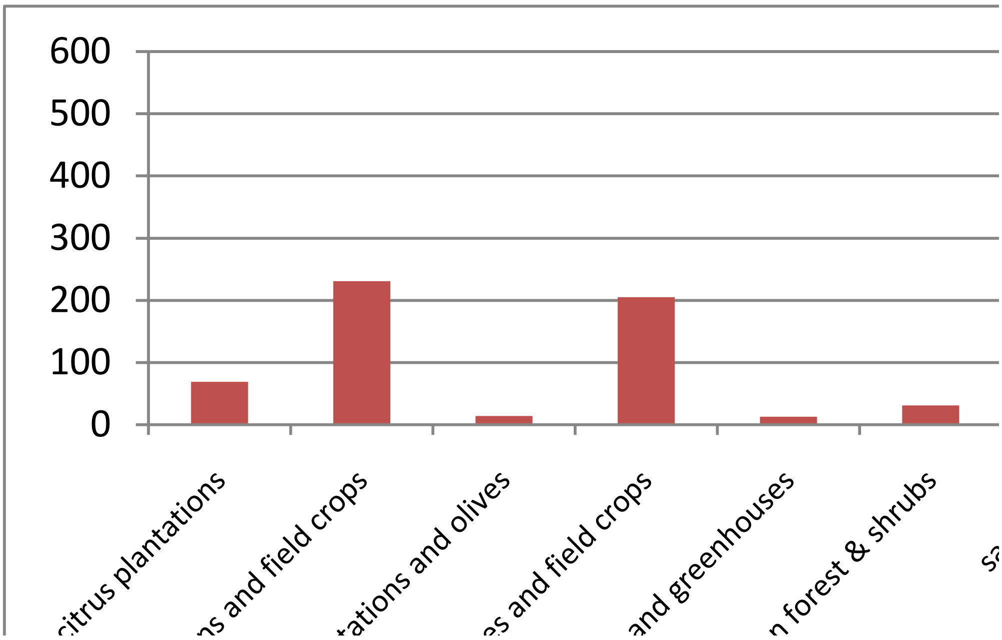


Fig. (24) Impact of SLR on Land use/ Cover (ha).

It is very difficult to precisely evaluate the socioeconomic impact of sea level rise on local communities in the affected areas due to multiple stresses associated with SLR on these communities and the complexity of the problem itself. However, based on the land use categories of the affected areas, rough examining of the economic losses due to SLR alone is amounted to 50 billion Syrian pounds. This figure represents direct average economic losses resulting from permanent loss of 4,108 hectares of agricultural and forest areas, 450 hectares of beech tracts and 1090 hectares of urban areas. However, these losses may declines to 10 billion S.P. in case of 0.6 m SLR scenario and may reach 84 billion S.P. in case of extreme SLR scenario.

Nearly 2000 agricultural families and another 4000 will be in danger of losing their economic activities as well as their dwellings. This signals the possibility of migration of these families to new areas putting more pressures on these areas. Table 17 shows possible economic losses due to 2.5-3m SLR.

Table 17. Possible economic losses due to 2.5-3m SLR along the Syrian coast.

Scenario	Total economic loss (S.P.)
Citrus plantations	13205
Olives	432
Greenhouses	8303
Crops (vegetable and field crops)	15023
Forest	191
Sandy soil	1800
Urban areas	10900
Total	49854

3.4.4. Adaptation

As adaptation is the only option to address the threat of sea level rise, hence, a series of hard and soft adaptation measures may be considered to encounter this threat. However, a framework to incorporate policies which handle cross-cutting issues and those of sectoral measures must be developed. The following bullets may be considered in this direction:

- ✓ Assessing present pressures-impact and possible climate change impact (SLR, wind, temperature rise) on coastal system
- ✓ Mapping institutions related to coastal activities and assessment of their capacity
- ✓ Scrutinizing adaptation measures including engineering and non-engineering options
- ✓ Formulation of a framework that incorporate integrated coastal zone management (ICZM), disaster management (DM), and research as vital cross-cutting adaptation options with sectoral measures to alleviate the potential threat of climate change on coastal areas.
- ✓ Capacity building of related institutions
- ✓ Public awareness of risks posed by SLR

3.5. Energy

3.5.1. Overview

The Syrian energy system is characterized by its low per capita energy consumption and its dependency on fossil fuel. The primary energy consumption per capita in Syria was 0.99 toe (ton of oil equivalent) compared to 1.77 toe of the world average and 2.64 toe of the Middle East (IEA statistics, www.iea.org). The primary energy supply during the period 2003-2005 was dependent mainly on oil derivatives, natural gas and small amounts of renewable "hydro power" (figure 24).

The generation of electricity consumes 15% of primary energy sources in the country. The total gross electricity generation in 2005 amounted to 34.9 TW h, whereas the total final electricity consumption amounted to 26.81 TW h that's about 76.82 % of the total generated electricity. The total installed capacity and the structure of the Syrian electricity generation system in the year 2005 are shown in figures 25 and 26.

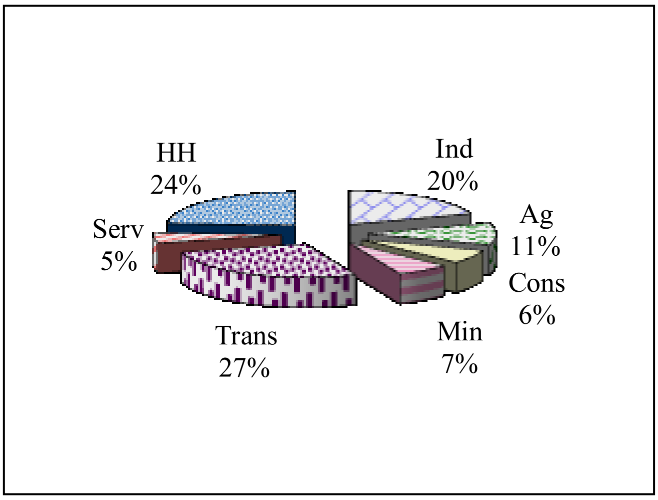


Fig. (24) Final Energy consumption by sector in 2005.

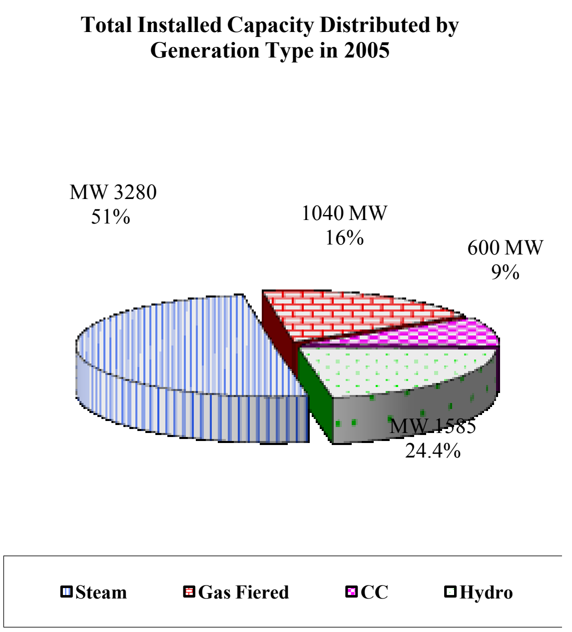


Fig. (25) Total Installed capacity by Generation Type.

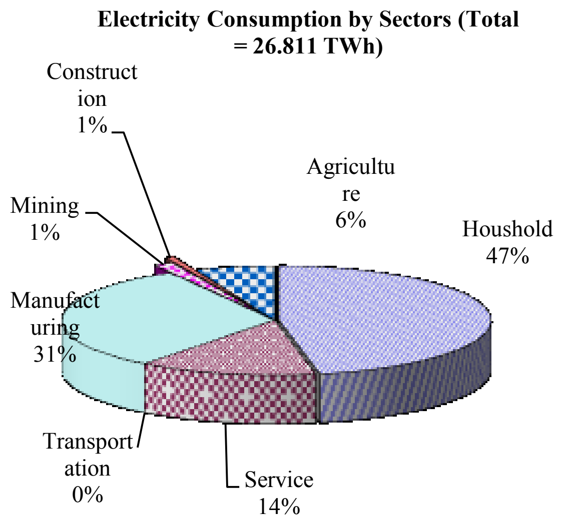


Fig. (26) Electricity Consumption By Sectors.

The power sector (electricity generation) consumed in the year 2005 was about 4152 k ton fuel oil and 3727 Mm^3 natural gas, which amounted to 78% and 68% of the total consumed fuel oil and natural gas respectively (FEB, 2005). It is worth mentioning here that the CO2 emission of electricity generation amounted to ca. 40% of the total CO_2 emission of the energy sector.

Due to the comprehensive nature of climate change impacts on different socio-economic activities, it is most likely that all consumption sectors could be affected. This includes residential sector, transportation, agriculture and industry. Electricity generation, water and agriculture seem to be the most sensitive sectors to climate change. The residential sector will suffer the most under the new conditions whereas; the most sensitive segments of the society would be the low income households.

Increased scarcity of water for the various applications, will affect power production as of the amount of water required for cooling process get limited. On the other hand, water sector needs in many cases electricity for pumping, transport and distribution. Furthermore, increase in electricity price could limit water availability for various consumption sectors.

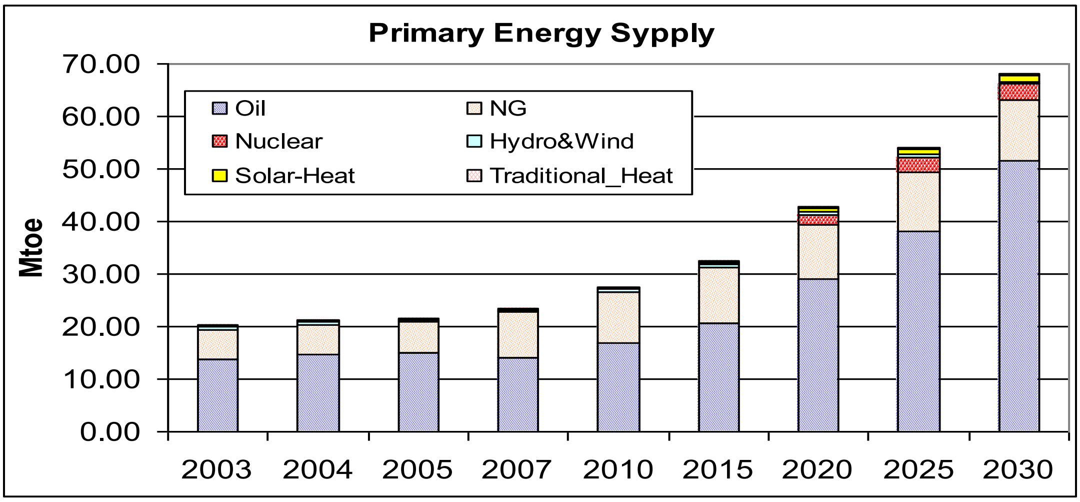
3.5.2. Climate change impact

To evaluate the impact of adaptation measures in the future energy supply policy on the GHG emission, two energy supply scenarios are chosen. These scenarios are the business as usual reference supply scenario and an alternative supply scenario based on enforced future share of the renewable.

3.5.2.1. Reference Energy Supply Scenario

To meet the projected future final energy demand, estimated at 18.235 M toe in 2010 and 48.359 M toe in 2030, a reference supply scenario has been developed that ensures optimal national supply strategy depending mainly upon oil products and natural gas. The result is shown in figure 27.

Fig. (27) Development of future primary energy by fuel type (reference Scenario).



3.5.2.2. Renewable Energy Supply Scenario

This scenario is based on the premise of reducing national dependency on fossil fuel and mitigating the emission of GHGs in the energy sector. Main scenario assumptions are increasing the share of renewable sources in total electricity generation from 1% in 2010 to 10% in 2030, and solar uses achieve share of 10 % of the total thermal uses by 2030. Development trends for the electricity generation for both scenarios are presented in figures 28 and 29.

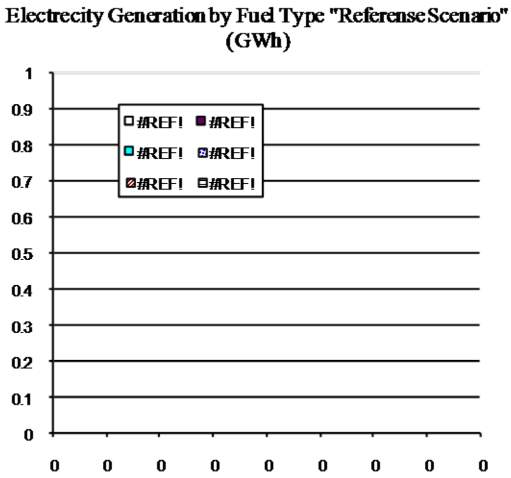


Fig. (28) Electricity generation development by fuel type between 2003 and 2030 in Ref _Sce.

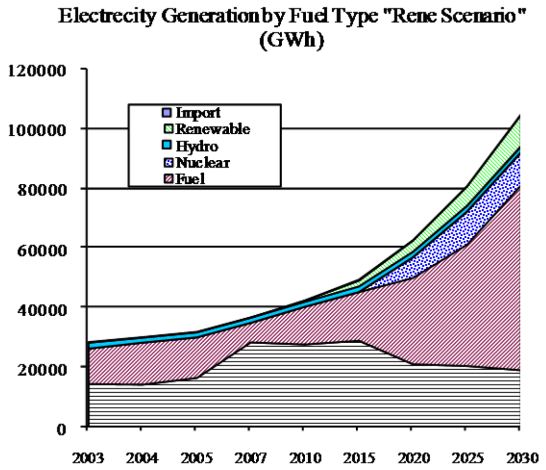


Fig. (28) Electricity generation development by fuel type between 2003 and 2030 in Ref _Sce.

Fig. (29) Electricity generation development by fuel type between 2003 and 2030 in Ren_Sce.

Fig. (29) Ele
by fuel t

The comparison of the output of the two scenarios shows that, the cumulative amount of GHGs emissions in renewable scenario during the period of 2003-2030 is decreased; as the cumulative potential CO_2 emission mitigation in the renewable scenario was about 75 Mt by 2030 which refers to a reduction of 7.7% of total CO_2 emissions. Alone in the year 2030 the expected emission reduction will amount to 7.5 Mt equivalent to 4.4% of CO2 emission in this year. Furthermore, a reduction of non CO_2 emissions (CH_4 and N_2O) is expected too as a result of introducing renewable in energy generation.

3.5.3. Adaptation

Providing energy services to all segments of society at cost effective and affordable prices is a prime policy of energy sector in the country. However, this is faced with three challenges, namely expanding the gas market, sustaining the oil production and developing country's power capacity. The following points present some of the measures to achieve this goal and meet the UNFCCC obligations:

- ✓ Promoting the choice of new and renewable energies, including nuclear energy.
- ✓ Strengthening of the rationalization of energy consumption and improve efficiency.
- ✓ Promoting the introduction of clean technologies in all processes of transformation of energy, especially electricity generation.
- ✓ Gradual removal of subsidies in energy sector in consistence with social and economic conditions.
- ✓ Expansion of the use of public means of transport, including electrified railways.
- ✓ The introduction of the concepts of the rationalization of energy consumption and its use efficiency in the educational curricula.

3.6. Public Health

3.6.1. Overview

People of Syria are relatively enjoying good public health status. Within the last three decades infant mortality rate, mortality rate for children under five, and maternal mortality rate have declined steadily, while life expectancy at birth has increased. This reflects the efforts of health authorities in the country to raise public health standard and maintain it on government agenda.

3.6.2. Climate change impact

It is generally accepted that quantifying the full impacts of climate change on public health is extremely difficult. However, it is well established that the vector borne diseases may extend their range due to warming, floods and other weather phenomena resulted from climate change. The following paragraphs cite two cases on the possible effect of CC on public health in the country.

Leishmaniasis (*Aleppo* boil) has been endemic in Syria since the ninetieth century and found in all regions of the country. Under CC conditions, Leishmaniasis may flourish due to rodents (vector) population outbreaks favored by availability of drought tolerant forage species (*Anabasis articulate*) and declines of natural predators (*hawks*). On the other hand, additive factors like extension of cities into habitats of these rodents would raise the risk of disease spread.

The other case is the malaria. Syria is relatively free of local malaria; however, the World Health Organization (WHO) classified borderline areas of the country with Iraq and Turkey as malarias high risk areas. Possible re-emerging of malaria under conditions of climate change is likely especially with the existence of predisposing factors including the possibility of floods occurrence or dam breakdowns leading to swamps' formation.

No doubt climate change has a negative impact on fundamental determinants of health; namely water, air and food. Thus, it is indirectly impacting human wellbeing as these determinants are affected. Furthermore, CC has a direct impact on the environment itself by increasing risk factors for health. For instance, deterioration of water quantity and quality will lead to an increase in water-borne diseases. Also, incidents of floods, heat waves, drought spells and dust storms have direct impacts on public health. This direct impact may express itself in extreme weather-related mortality, affecting the most vulnerable groups in the society like the poor, the elderly and the chronically sick. Generally speaking, in the events of climate change, as water becomes scarce and food productivity declines, it is expected that current difficulties/problems related to water and food will mount and new challenges will emerge.

Some local predisposing factors may accentuate the impacts of climate change. These include; the concentration of population in big cities leading to increased pressures and competitions for services, and the increasing air pollution from energy generation and transportation. On the other hand, there is a maximum limit for adaptation (with prevention of direct and indirect health impact) from technical, logistic, and physiologic point of view. For instance, there is a clear inverted relationship between water borne diseases and the water per capita. As water quantity and quality deteriorate the incidence of diarrhea, typhoid fever, and waterborne diseases which already exist in some governorates, becomes higher. Therefore significant decrease in national water budget would directly affect water per capita and consequently raising serious health concerns.

3.6.3. Adaptation

The health system needs to be prepared to manage the new risks to public health and the possible emergence of new diseases. A relaxed support of public health programs, poses the greatest threat to effectively combating aliment and death caused by climate change. Adaptation in public health can include the following activities and measures:

- ✓ Secure minimum household water requirements to maintain health.
- ✓ Intensifying water pollution control activities and ensuring safe reuse of wastewater
- ✓ Maintain acceptable standards of medical services.
- ✓ Promotion of health education and community awareness
- ✓ Devising national disaster strategy and management plans to deal; with prospectus risk outcomes.
- ✓ Upgrading and validating routinely collected health records through national information systems.
- ✓ Involving all national parties working in health services in a program aimed at developing strategies to meet the changes in infectious disease patterns caused by climate change.
- ✓ Upgrading ongoing prevention programs regarding climate- related diseases.
- ✓ Capacity building for institutions and staff working in health sector.

3. Adaptation framework: The way forward

Reduction in precipitation and elevation of temperatures will be the two main revealed consequences of climate change in Syria. Presently, drought, heat waves and dust storms are the major present environmental hazards associated with climate variability. These phenomena are expected to intensify under climate change. The consequences of these changes will be immense and pose significant challenges to planners and managers unless measures are taken. Direct effects will be felt on water resources and agricultural production as they represent the most vulnerable sectors to climate change. Other sectors will be affected in a direct or indirect way.

Sound scientific assessment and better understanding of the impacts and associated risk of climate change is the first step towards formulating adaptation policy and measures to deal with likely impact of climate change. This requires capacity building for scientific assessment of vulnerable sectors, ecosystems, as well as providing financial resources to implement this task. Thereafter, based on the socio-economic and political environment of the country, proper adaptation policies can be drawn and mechanism for integrating these policies into national plans is devised.

Generally speaking, adapting to climate change requires a package of responses that include adjustments at various levels starting from community to national level. This includes changes in behavior of individuals and making adjustments in way business is done. The overall aim of adaptation is to promote resilience capacity of natural ecosystems to cope with climate change and to set series of planned actions to enable other sectors to adjust gradually to new outcomes.

Adaptation process requires formulation of national adaptation programs of action. With short, medium and long term prioritized actions; such programs should aim at promoting sustainable development in all sectors and be based on existing coping capacity of the country. Furthermore, the participatory approach and the integration of all sectors measures in a clearly defined national policy embracing these programs are prerequisites for success of proposed measures. The following items are some policy considerations when devising adaptation strategy and measures to mitigate the impact of climate change:

1. Providing enabling environment for legal and institutional changes to set adaptation process in motion. This entails updating laws and making institutional reforms in decision making process and mechanism of work.
2. Adaptation capacity differs among sectors hence; strengthening sectors capacity to cope with climate change is a priority and should be imbedded within the adaptation strategy.
3. Adaptation options, sector or cross-sectors, must be assessed and validated against set of socio-economic and environmental indicators of the country.
4. Financial resources are vital elements in developing a comprehensive adaptation measures and incorporating these measures into national policies as well as implementation of activities.

4.1. Adaptation Action Plan: the policy framework

Adaptation to climate change in Syria requires taking series of mixed strategies and measures. The following items identify the most needed actions at policy level.

1. National policy initiatives

A national policy initiative must be developed to incorporate adaptation in vulnerable sectors into the national development plans. Through this initiative, a national based mechanism for ranking risks and prioritizing actions can be set with special institutional arrangements and effective participation of various stakeholders. The national policy initiative should facilitate the horizontal and vertical integration of sectoral polices across agencies, and reaches out for international assistance. Major elements of national policy include, facilitating access to information and public awareness, reviewing plans for adaptation, setting criteria for measuring achievement, and the implementation of these plans.

2. Ecosystem protection initiatives

Water and land resources are under continuous pressures and require urgent responses. Devising an integrated program for ecosystems protection to ensure their sustainability of products and services should be a priority action in the country. Effective programs for protection and sustainable use of these resources must be developed and implemented with full responsibility and participation of stakeholders.

In this context, the following programs and projects are of priority to the country:

- Strengthening the climate monitoring network and climate data management.
- Integrated management of water resources.
- The development of agricultural technologies.
- Integrated management of land resources.
- Diversification of income sources and enhances the capacity of community residents of the *Badia*.
- Strengthening the conservation and sustainable use of biodiversity components.

- Integrated coastal zone management.
- Strengthening the information systems for the health sector and other relevant sectors.
- The development and deployment of renewable energy technologies.
- Raising public awareness and good environmental behavior.

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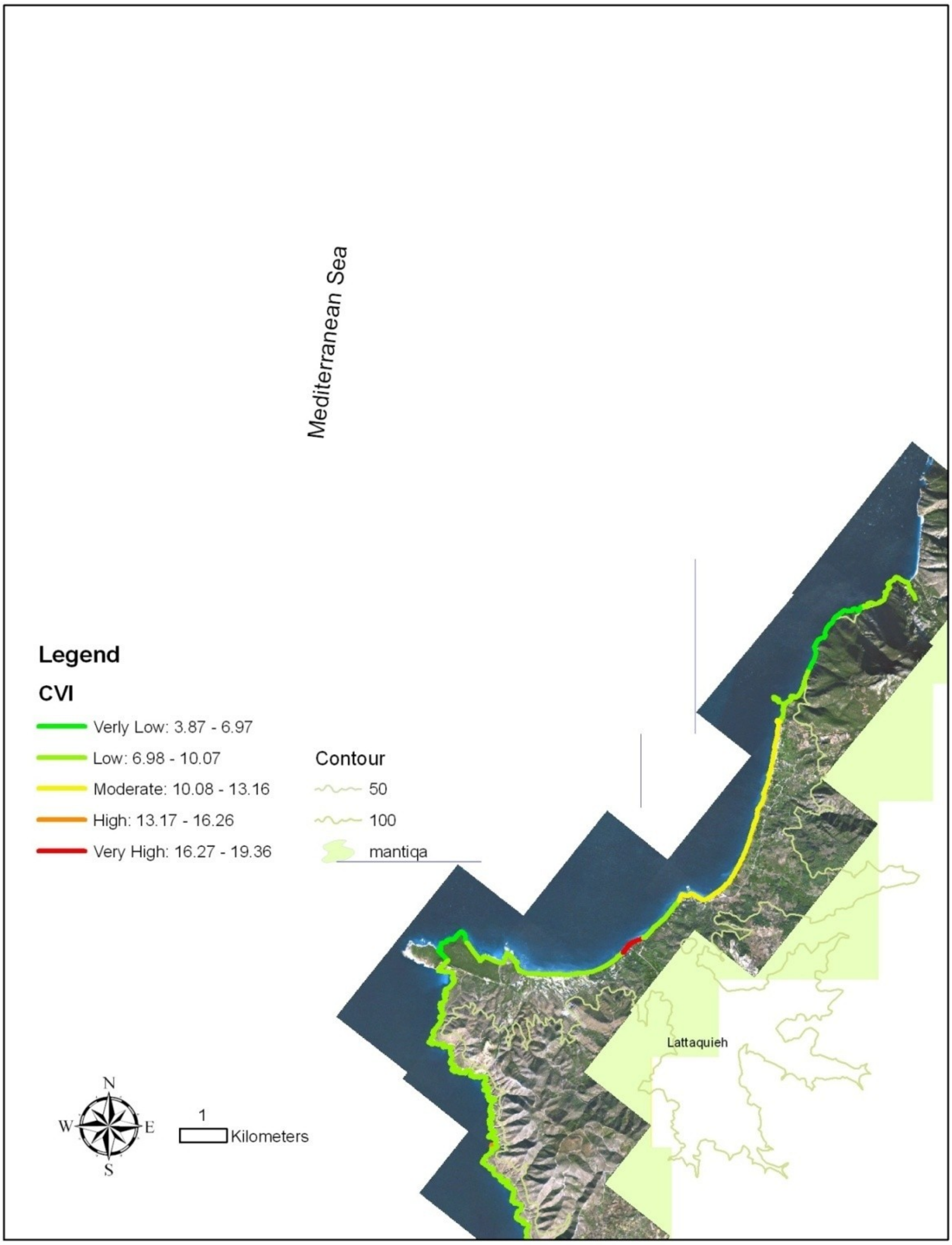
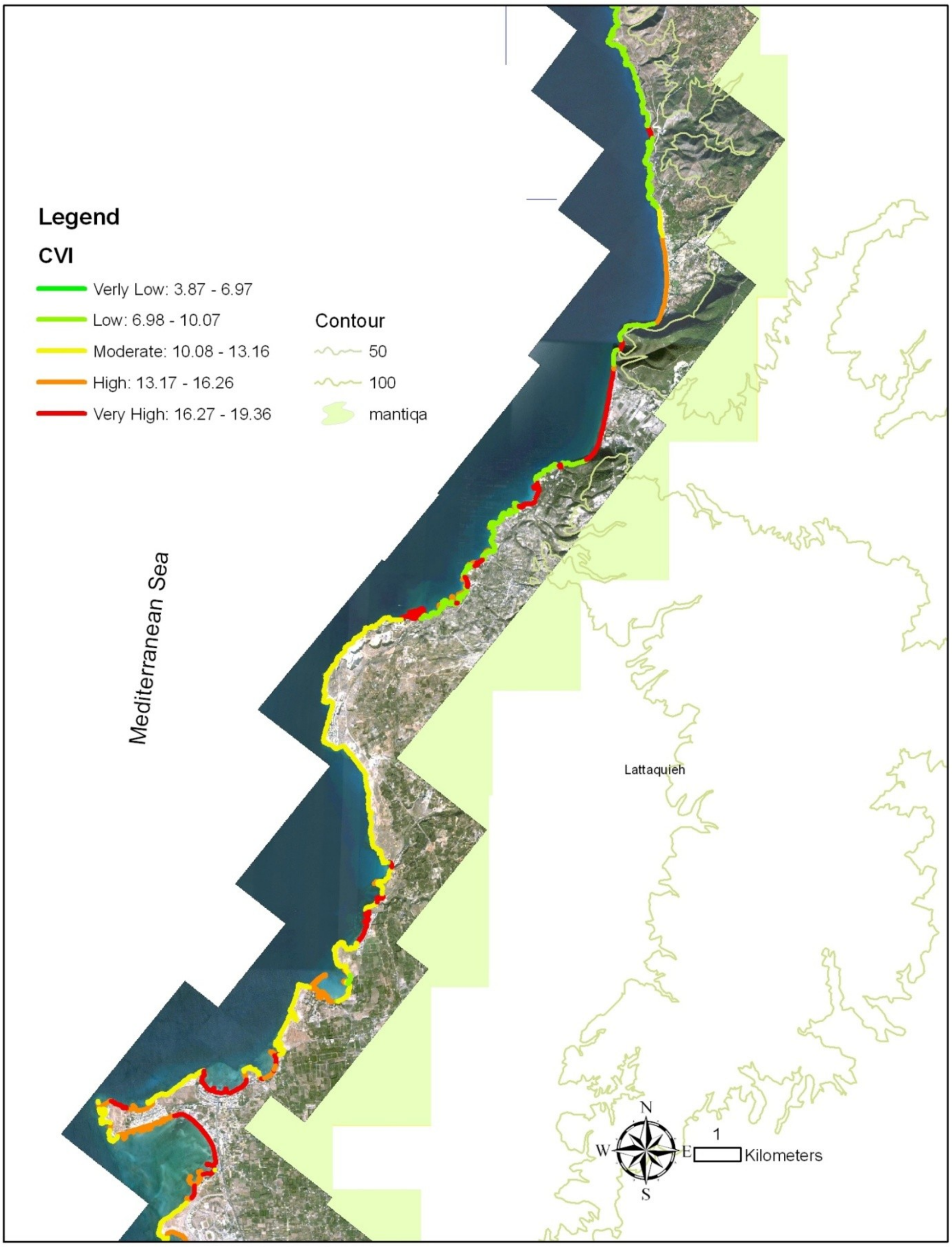
Annex

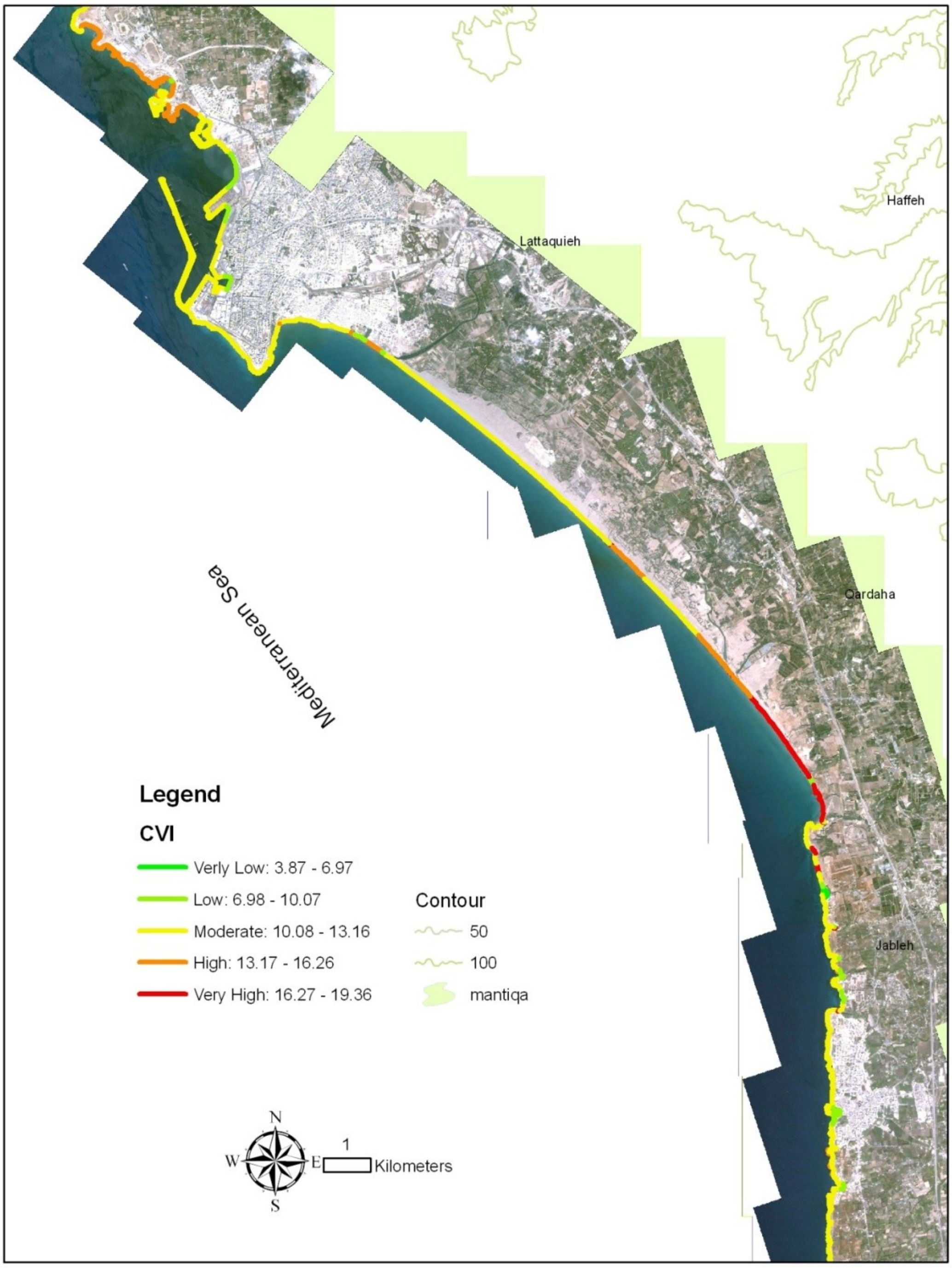
Coastal Vulnerability Index (CVI)



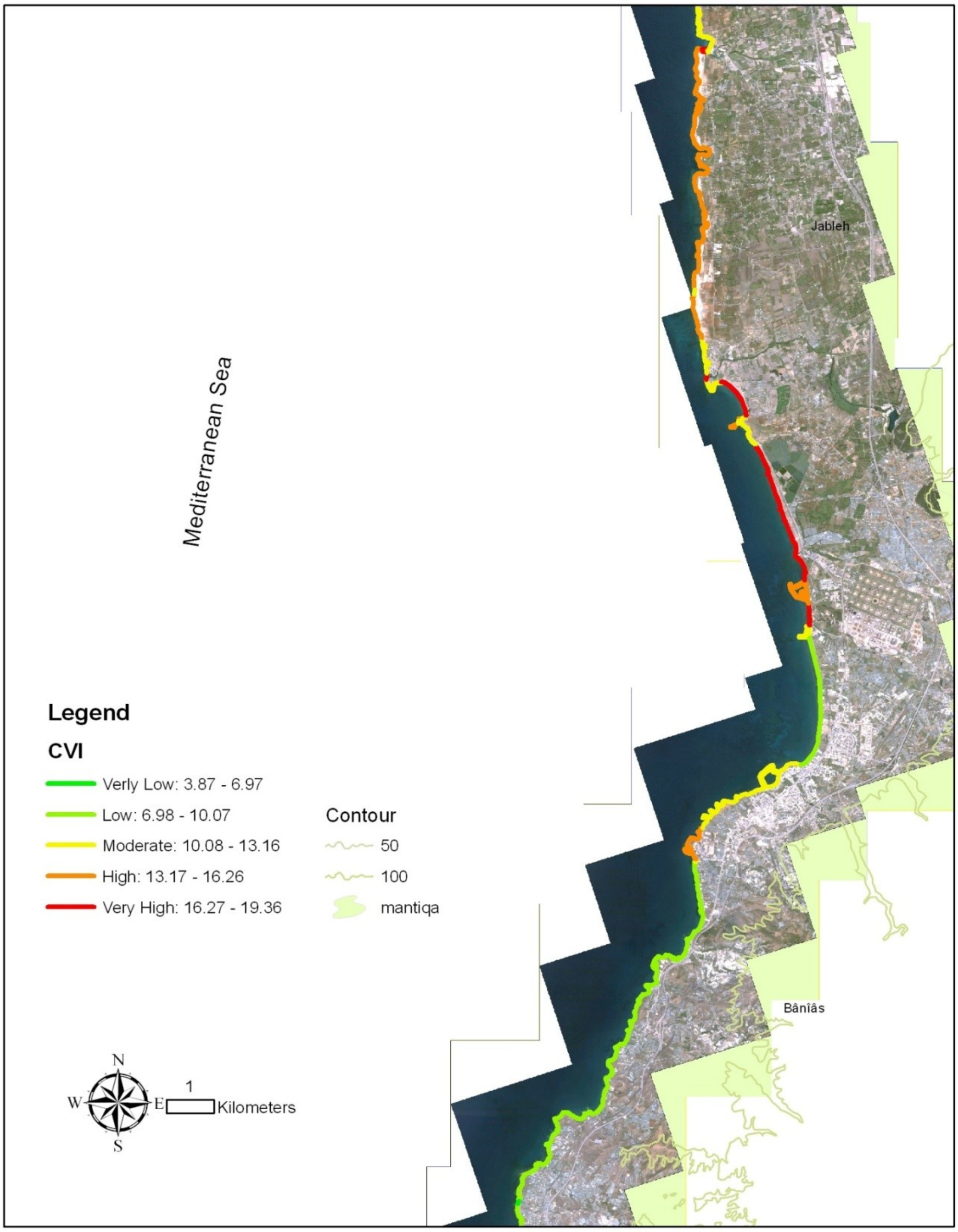
Coastal Vulnerability Index (CVI)

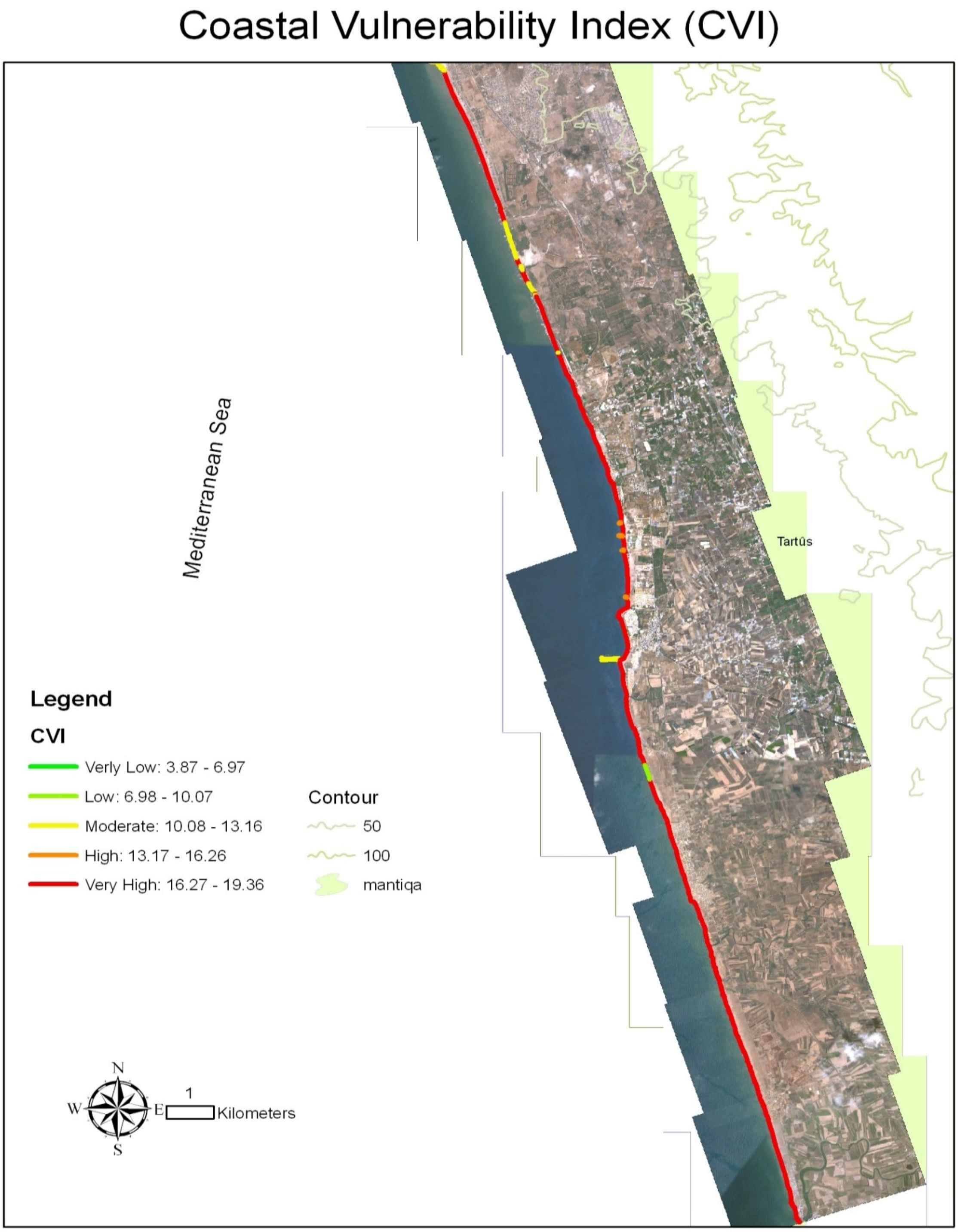


Coastal Vulnerability Index (CVI)



Coastal Vulnerability Index (CVI)




Coastal Vulnerability Index (CVI)
Mediterranean Sea
Tartûs
Legend
CVI
Verly Low: 3.87 - 6.97
Low: 6.98 - 10.07
Moderate: 10.08 - 13.16
High: 13.17 - 16.26
Very High: 16.27 - 19.36
Contour
50
100
mantiqa
N
W
E
S
1
Kilometers

Coastal Vulnerability Index (CVI)