EUROPEAN COMMISSION
European Research Area
SEVENTH FRAMEWORK PROGRAMME
Funded under Socio-economic Sciences & Humanities

WP 4a - Management of environment and natural resources

Assessment of Socio-Economic and Climate Change Effects on Water Resources and Agriculture in Southern and Eastern Mediterranean countries

Consuelo Varela-Ortega, Paloma Esteve, Irene Blanco, Gema Carmona, Jorge Ruiz and Tamara Rabah

MEDPRO Technical Report No. 28/March 2013

This study aims at assessing the socio-economic and environmental effects of different societal and human development scenarios and climate change in the water-scarce southern and eastern Mediterranean. The study develops a two-stage modelling methodology that includes an econometric analysis for the southern and eastern Mediterranean region as a whole and a detailed, integrated socio-ecological assessment focusing on Jordan, Syria and Morocco. The results show that water resources will be under increasing stress in future years. In spite of country differences, a future path of sustainable development is possible in the region. Water withdrawals could decrease, preserving renewable water resources and reversing the negative effects on agricultural production and rural society. This, however, requires a combination across the region of technical, managerial, economic, social and institutional changes that together foster a substantive structural change. A balanced implementation of water supply-enhancing and demand-management measures along with improved governance are key to attaining a cost-effective sustainable future in which economic growth, a population increase and trade expansion are compatible with the conservation of water resources.

This paper was produced in the context of the MEDPRO (Mediterranean Prospects) project, a three-year project funded under the Socio-economic Sciences & Humanities Programme of DG Research of the European Commission's Seventh Framework Research Programme. MEDPRO Technical Reports give an indication of work being conducted within MEDPRO thematic Work Packages (WPs) and aim at stimulating reactions from other experts and academics in the field.

ISBN 978-94-6138-268-9

Available for free downloading from the MEDPRO (www.MEDPRO-foresight.eu) and CEPS (www.ceps.eu) websites

Contents

List of Figures

List of Tables

Executive Summary

The Mediterranean region is one of the world's climate change hotspots and the heart of dramatic socio-economic transformations. Social and political developments as well as future climate projections have profound implications for the agricultural and water sectors, which might endanger economic development, lead to the degradation of natural resources and provoke social instability. This study aims at assessing the socio-economic and environmental effects of different societal and human development scenarios and climate change in water-scarce southern and eastern Mediterranean countries (SEMCs). To address the complex interactions of human development and water systems, this study develops a two-stage modelling methodology. First, it conducts an econometric analysis using panel data of water use trends and projections to 2030 under four different scenarios (developed by the MEDPRO project) across the selected SEMCs. To cope with the variability of water resources and a changing social environment, assorted scenario-based adaptation measures are analysed for each country. Second, to complement these econometric analyses, the study focuses on three specific case studies (Jordan, Syria and Morocco). For each case-study country an economic, mathematical programming model is integrated with a hydrologic model. This enables a more detailed assessment to be made of the effects on the agricultural sector, taking into account water policies (such as the application of water tariffs and quotas) as well as climate impacts. The modelling integration, on an aggregated national scale, allows an evaluation of the effects on farm income, labour use, cropping strategies and water consumption.

The results concerning water withdrawals show that climate and socio-economic projections in the various scenarios have clear, differential effects across the countries in the area and over time. The analysis illustrates that the most sustainable scenarios, such as Euro-Mediterranean Sustainable Development and Enhanced Cooperation (referred to as QII), mitigate water withdrawal in all the countries in spite of the increase in water demand due to changes in population, GDP and trade. In all the SEMCs, closing the gap between water demand and supply requires a combination of water investments. These range from costly hard measures (dams and reservoirs) to soft and less costly adaptation measures (management, quotas and tariffs). The optimal selection will depend on the country and scenario. In general, under the Sustainable Development and Enhanced Cooperation scenario and to a lesser extent the Fragmented Cooperation (QIII) scenario, most countries will profit from less costly water developments involving the implementation of demand-side water-saving practices. The effectiveness of adaptation measures differs across countries and scenarios, being greater in water-scarce countries (Jordan, the Palestinian territories and Israel) where the cost of overcoming reduced water availability will be highest. The study also points out that in the scenarios where such factors as effective water management, governance and structural change are predominant (QII and QIII), water resources and social stability are more secure.

The results of the three specific case studies (Jordan, Syria and Morocco) reveal that integrating socio-economic and hydrology modelling captures the diversity of the social and environmental realities of irrigated agriculture at present and over time. This has important implications for the vulnerability of the agricultural sector to changes in climate and policies. While water withdrawals are expected to decrease in the sustainable scenarios (QII and QIII) in Syria and Morocco, water consumption may increase in Jordan due to the higher relative weight of industrialisation patterns on a future horizon. In these countries, the use of demand-side water policies (like tariffs and quotas) can be effective for reducing water consumption in the scenario of Euro-Mediterranean Sustainable Development but could be detrimental to farm income and social stability. Cropping changes and technological improvements can counterbalance this effect and allow adaptation to less water availability. Overall, the study supports that this kind of multifaceted analysis is key for supporting current and future policies on water and agriculture, and for improving the preparedness and adaptation capacity to a changing natural and social environment in water-scarce countries.

Assessment of Socio-Economic and Climate Change Effects on Water Resources and Agriculture in Southern and Eastern Mediterranean countries

Consuelo Varela-Ortega, Paloma Esteve, Irene Blanco, Gema Carmona, Jorge Ruiz and Tamara Rabah*

MEDPRO Technical Report No. 28/March 2013

1. Introduction

This report presents the work being conducted by the Universidad Politécnica de Madrid (UPM) for MEDPRO Work Package (WP) 4a (tasks A and B). WP4a aims at analysing the state and management of the environment and natural resources in 11 southern and eastern Mediterranean countries (SEMCs),[1] and the links to economic development and sustainability. More specifically, tasks A and B deal with water and agriculture. The work UPM has undertaken focuses on the past and future trends in water consumption in the SEMCs and their relation to socio-economic, demographic, environmental and technological developments, concentrating on agriculture and irrigation. This report has seven sections and follows a preliminary interim report that included the first phase of the research. Following the introduction, section 2 contains the relevant databases gathered for the analysis of water and agriculture, with a general database (section 2.1) and a specific database compiled from different sources of information (section 2.2). Section 3 analyses the water-use trends from a general comparative perspective for the 11 countries (section 3.1) at the country level (section 3.2) and the trends in water withdrawals in selected countries (section 3.3). The country-level analysis primarily seeks to establish a typology of water-consumption patterns across countries that will serve as the basis of the subsequent econometric analysis. Section 4 includes the analysis of scenarios linking those developed by the MEDPRO project (section 4.1) with the future water scenarios (section 4.2) developed by the EU SCENES project,[2] which will determine the selection of drivers used in the analysis of water use and the agricultural sector (section 4.3). Section 5 is then devoted to the econometric assessment of water consumption in the Mediterranean countries. It includes a spatially-based analysis of water use in the northern and south-eastern Mediterranean sub-regions (section 5.1) and long-term projections at the country level for the four scenarios defined by the MEDPRO project (section 5.2). Summarising future water projections, the last part of this section (section 5.3) includes GIS[3] maps for all the MEDPRO scenarios. Section 6 offers a complex model-based analysis of the MEDPRO scenarios for a selection of SEMCs (Jordan, Syria and Morocco). The modelling integration methodology is explained in section 6.2 and the country-level results of the socio-economic and hydrologic modelling for the selected countries is shown in sections 6.3 to 6.7, with a comparative overview presented in section 6.8. Finally, section 7 summarises the main conclusions of the study.

All databases used in the study are shown in the appendices:

---

* Dr Consuelo Varela-Ortega is a Professor, Paloma Esteve is a PhD Research Assistant, Dr Irene Blanco is an Assistant Professor, Dr Gema Carmona is a Postdoctoral Research Assistant, Jorge Ruiz is a PhD Research Assistant, and Tamara Rabah is a PhD Research Assistant at the Technical University of Madrid (Universidad Politécnica de Madrid).

[1] The 11 countries are Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestinian territories, Syria, Tunisia and Turkey.

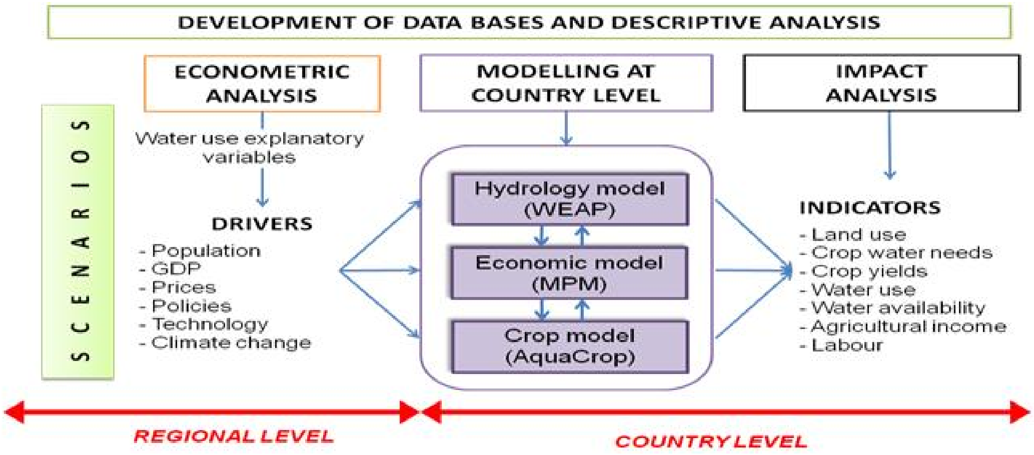
[2] SCENES refers to “Water Scenarios for Europe and for Neighbouring States”, Integrated Project, 2007–2010, European Commission, DG Research, FP6 – Project No. 2005-GLOBAL-4 (OJ C 177/15, 19.7.2005).

[3] GIS refers to geographic information system.

- the general database on water and agriculture elaborated from public databases, such as FAOSTAT, AQUASTAT and the World Bank's public DataBank;
- the specific database with a selection of the most relevant variables related to water and agriculture elaborated from the same public databases (FAOSTAT, AQUASTAT and the World Bank) and refined by other sources of information for specific years and countries (e.g. Plan Bleu for the Mediterranean); and
- a database specifying the different sources used for each of the countries considered, for all the years in the time span covered by the analysis.

The general structure of the study is shown in Figure 1.

Figure 1. Methodological framework



2. The databases of the study

2.1 General database

For the purpose of undertaking the analysis of water withdrawal and agriculture in WP4a, the first step was to compile data and information for a selection of the main variables and indicators related to water, agriculture and development. An initial general database (to be made available on the MEDPRO website) was gathered for the 11 SEMCs for the period 1960–2009, founded on the World Bank and FAO databases. The variables selected for this database are presented in the appendix.

2.2 Specific database for water and agriculture

From the general database, a specific, smaller database has been extracted that includes a selection of the most relevant variables regarding water use and agriculture.

In the MEDPRO project, 2004 is considered the baseline year for analysis. Therefore, the base year of 2004 is used in the specification of the smaller database in this report (Table 1). Yet, given the frequent limitations in data availability about water resources and use, we present a compilation of data for 2004 or the nearest years where data were not available for a given country and year.

According to literature from Plan Bleu (Margat and Vallée, 2000; Margat, 2004; Benoit and Comeau, 2005), the main elements determining water consumption are population, irrigation (here irrigation technology plays a very relevant role) and tourism. Based on this and other relevant literature, we have selected for the analysis a group of variables divided into the following nine clusters:

- Socio-economic variables
- Physical and natural characteristics
- Water resources
- Water use
- Water technology
- Irrigation
- Agriculture
- Agricultural socio-economic
- Agricultural technology and intensification

Table 1. Main indicators considered for the analysis of water use and agriculture in the 11 SEMCs (baseline year 2004)

Cluster	Variable	Country											Source
		Algeria	Egypt	Israel	Jordan	Lebanon	Libya	Morocco	Syria	Tunisia	Turkey	Palestinian Autonomy	
Socio-economic	Total population (1000 inhab.)	32366	75718	6809	5290	4028	5803	30152	18512	9932	70250	3453	World Bank
	Rural population (1000 inhab.)	12105	43462	575	1148	545	1342	13671	8723	3484	23337	981	World Bank
	GDP (constant 2000 million US$)	66190	113666	132024	10660	20581	37771	45835	22733	23213	307968	3553	World Bank
	GDP per capita (current US$)	2627	1041	18629	2157	5410	5753	1863	1322	2832	5595	1045	World Bank
	Total economically active population (1000 inhab.)	11933	22136	2471	1378	1370	1979	10159	5703	3316	24048	1137	AQUASTAT
	Human Development Index (HDI) (-)	0.748	0.716	0.93	0.769	0.796	0.84	0.646	0.736	0.762	0.798	0.731	AQUASTAT
	International tourism (thousand arrivals)	1234	7795	1506	2853	1278	149	5477	3399	5998	16826	56	World Bank
Physical and natural characteristics	Country area (1000 ha)	238174	100145	2207	8878	1045	175954	44655	18518	16361	78356	602	World Bank
	Average precipitation in depth (mm/yr)	89	51	435	111	661	56	346	252	207	593	402	AQUASTAT
	Average precipitation in volume (10^9m^3/yr)	212	51.07	9.6	9.855	6.907	98.53	154.5	46.67	33.87	464.7	2.42	AQUASTAT
Water resources	Water resources: Total renewable per capita (actual)(m^3/inhab./yr)	371.5	786.1	281	183.6	1155	107.7	983.2	963.4	477.5	3123	247.1	AQUASTAT
	Groundwater: Total renewable (natural)(10^9m^3/yr)	1.517	1.3	1.225	0.72	3.2	0.5	10	15.97	1.595	69	0.75	AQUASTAT
	Surface water: Total renewable (natural)(10^9m^3/yr)	10.15	84.5	0.555	1.155	4.138	0.2	22	41.81	3.4	190.7	0.087	AQUASTAT
	Water resources: Total exploitable (10^9m^3/yr)	7.9	49.7	1.64	–	2.08	0.635	20	20.6	3.625	112	0.771	AQUASTAT
	Water resources: Total renewable (natural)(10^9m^3/yr)	11.67	85.8	1.78	1.622	4.838	0.6	29	55.78	4.595	231.7	0.837	AQUASTAT
Water use	Total freshwater withdrawal (surface water + groundwater) (10^9m^3/yr)	6.05	68.2	1.81	0.93	1.26	4.31	12.59	16.69	2.84	40.1	0.42	AQUASTAT
	Total water withdrawal per capita (m^3/inhab./yr)	193.2	937	289.1	158.4	353.9	776.8	427.2	938.2	296.2	614.1	82.37	AQUASTAT
	Reused treated wastewater (10^9m^3/yr)	–	2.971	0.2619	0.0835	–	–	–	0.55	0.021	1	0.01	AQUASTAT
	Agricultural water withdrawal as % of total water withdrawal (%)	64.91	86.38	57.78	64.96	59.54	82.85	87.38	87.9	75.96	73.82	45.22	AQUASTAT
	Industrial water withdrawal as % of total water withdrawal (%)	13.18	5.857	5.783	4.081	11.45	3.051	2.857	3.565	3.86	10.72	6.938	AQUASTAT
	Municipal water withdrawal as % of total withdrawal (%)	21.91	7.76	36.44	30.96	29.01	14.1	9.762	8.544	12.81	15.46	47.85	AQUASTAT

Cluster	Variable	Country											Source
		Algeria	Egypt	Israel	Jordan	Lebanon	Libya	Morocco	Syria	Tunisia	Turkey	Palestinian Autonomy	
Water technology	Improved water source (% of population with access)	85	98	100	96	100	54	80	89	94	97	91	Millennium Development Indicators
	Improved sanitation facilities (% of population with access)	94	93	100	98	98	97	68	93	85	89	89	Millennium Development Indicators
	Desalinated water produced (10^9m^3/yr)	0.017	0.1	0.0256	0.0098	0.0473	0.018	0.007	0	0.013	0.0005	0	AQUASTAT
	Total dam capacity (km^3)	6.005	169	–	0.275	0.2256	0.385	16.09	19.65	2.555	651	–	AQUASTAT
	Wastewater: Produced volume (10^9m^3/yr)	0.82	3.76	0.45	0.082	0.31	–	0.65	1.364	0.187	2.77	–	AQUASTAT
	Wastewater: Treated volume (10^9m^3/yr)	–	2.971	0.283	0.107	0.004	–	0.04	0.55	0.215	1.68	–	AQUASTAT
Irrigation	Irrigation potential (1000 ha)	510.3	4420	–	85	177.5	40	1664	1250	560	8500	–	AQUASTAT
	Total area equipped for irrigation (1000 ha)	569	3422	225	78.86	90	470	1457	1439	410	5215	16	FAOSTAT
	Area equipped for irrigation by surface water (1000 ha)	149.5	2843	–	24.36	40	3	986.7	0	122	3811	0	AQUASTAT
	Area equipped for irrigation by groundwater (1000 ha)	351.9	361.2	–	42	20	464	430	864.7	225	899.2	20.07	AQUASTAT
	Area equipped for irrigation by non-conventional sources of water (1000 ha)	–	217.5	–	12.5	–	–	–	–	7	150.7	–	AQUASTAT
	Area equipped for irrigation: Localised irrigation (1000 ha)	–	221.4	168.8	64	7.7	–	97.97	57.5	62	99.4	–	AQUASTAT
	Area equipped for irrigation: Sprinkler irrigation (1000 ha)	–	171.9	–	1	25.1	–	151.7	130.2	90	298.2	–	AQUASTAT
	Area equipped for irrigation: Surface irrigation (1000 ha)	–	3029	–	13.86	57.2	–	1209	1251	215	4572	–	AQUASTAT
	Area equipped for irrigation: Actually irrigated (1000 ha)	453.3	–	–	–	–	316	1448	–	393	4320	–	AQUASTAT
	Percentage of the cultivated area equipped for irrigation (%)	6.939	99.94	58.89	27.18	33.21	21.86	15.54	23.37	8.028	20.02	9.123	AQUASTAT
Agriculture	Agricultural area irrigated (1000 ha)	793	–	174	76	126.9	–	1291	1439	356	5215	15.8	FAOSTAT
	Permanent crops (1000 ha)	803	513	69.5	86	142	335	831	868	2154	2722	115	FAOSTAT
	Arable land (1000 ha)	7493	2965	313	209	136.3	1750	8210	4757	2791	23871	102	FAOSTAT
	Permanent meadows and pastures (1000 ha)	32849	–	125	742	360	13500	21000	8279	4885	14617	150	FAOSTAT
	Temporary crops (1000 ha)	4110	–	221	185	126.3	–	–	3861	2079	18915	33.5	FAOSTAT
	Land under cereal production (1000 ha)	3000.6	2755.8	89.2	40.8	60.6	350.7	5687.4	3186.2	1657.2	13810.3	32.3	FAOSTAT
	Cereal yield (kg per hectare)	1344.1	7556.1	3064.2	1310.7	2725.6	622.9	1512	1657.5	1305.8	2465.1	1930.2	FAOSTAT
Agricultural	Agriculture, value added to GDP (%)	10	16.46	–	2.546	6.819	–	16.54	26.83	10.29	11.71	–	AQUASTAT

Cluster	Variable	Country											Source
		Algeria	Egypt	Israel	Jordan	Lebanon	Libya	Morocco	Syria	Tunisia	Turkey	Palestinian Autonomy	
socio-economic	Agriculture, value added per worker (constant 2000 US$)	2149.9	2603.7	–	2270.1	29354.9	–	2392.1	4086.0	3607.7	2967.9	–	World Bank
	Economically active population in agriculture (1000 inhab.)	2953	6807	58	119	39	92	3275	1267	776	9172	124	World Bank
	Employment in agriculture (% of total employment)	20.7	31.8	2	3.6	–	–	45.8	27	–	34	15.9	World Bank
	Female economically active population in agriculture (1000 inhab.)	1476	2543	14	62	14	61	1299	750	263	4935	87	AQUASTAT
	Male economically active population in agriculture (1000 inhab.)	1375	4157	46	55	29	38	1845	619	505	4678	40	AQUASTAT
Agricultural technology and intensification	Fertilizer consumption (metric tonnes)	155932	1930819	280114	99595	19398	90399	588094	402727	104733	2644641	–	World Bank
	Agricultural machinery, tractors per 100 sq. km of arable land	130.53	324.67	782.75	287.08	608.95	227.14	52.65	219.85	139.02	416.43	716.92	World Bank

Table legend

	1998
	1999
	2000
	2001
	2002
	2003
	2004
	2005
	2006
	2007
	2008

3. Analysis of water use in 11 SEMCs

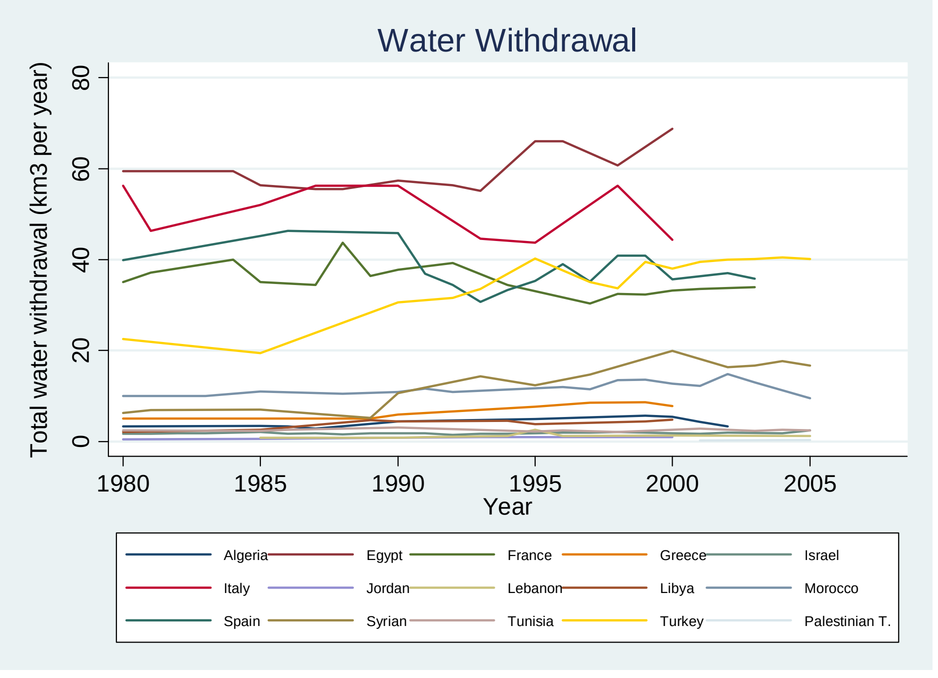
3.1 General comparative analysis

Figures 2 and 3 show the evolution of water withdrawal in the 11 SEMCs plus four EU Mediterranean countries (Spain, France, Italy and Greece). Although data about total water withdrawal are uneven, the trends shown across the Mediterranean countries illustrate how some economies have largely increased their water consumption in the last 20 years. The most notable case is Turkey, which doubled its water withdrawal from 1985 to the year 2005. This fact is explained by the overall development of the Turkish economy and the huge development of its water infrastructure in the past decades.

When looking at water withdrawal per capita (Figure 3), we can distinguish the most 'water-poor' countries: Algeria, Jordan, Lebanon, Tunisia, Israel and Morocco.

Differences across countries are determined by the availability of renewable water resources and by the evolution of demographic and economic trends. Figures 4, 5 and 6 show the trends in total population, GDP and irrigated area (with the area equipped for irrigation used as a proxy for irrigated area).

Figure 2. Total, annual water withdrawal by country



Comparing Figures 3 and 4, the relationship between total water withdrawal and population is noticeable. Turkey and Egypt show the fastest population increases and are simultaneously among those countries that have experienced the fastest increases in total water withdrawal.

Figure 3. Per-capita total, annual water withdrawal by country

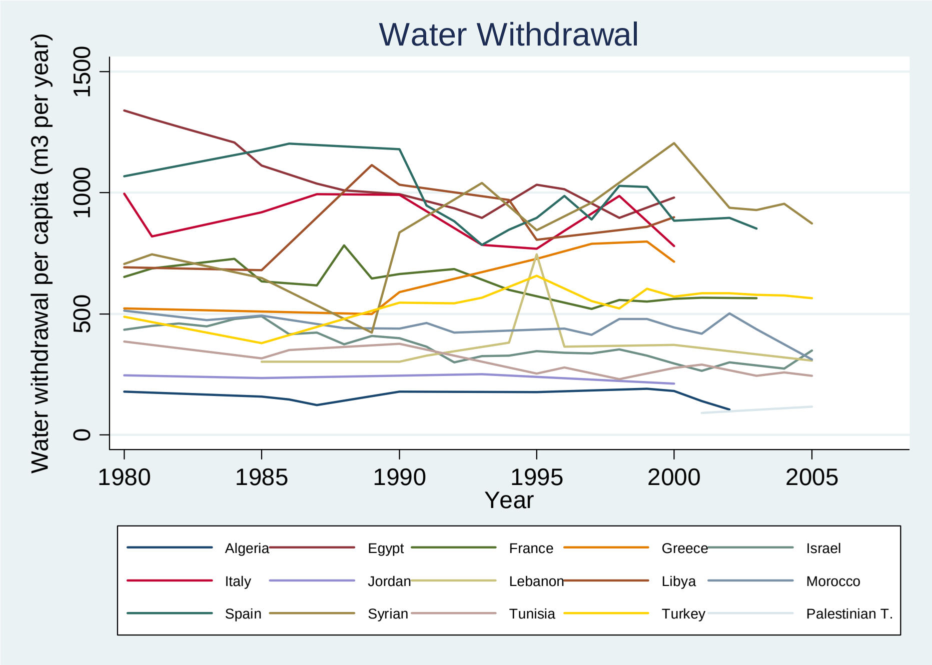
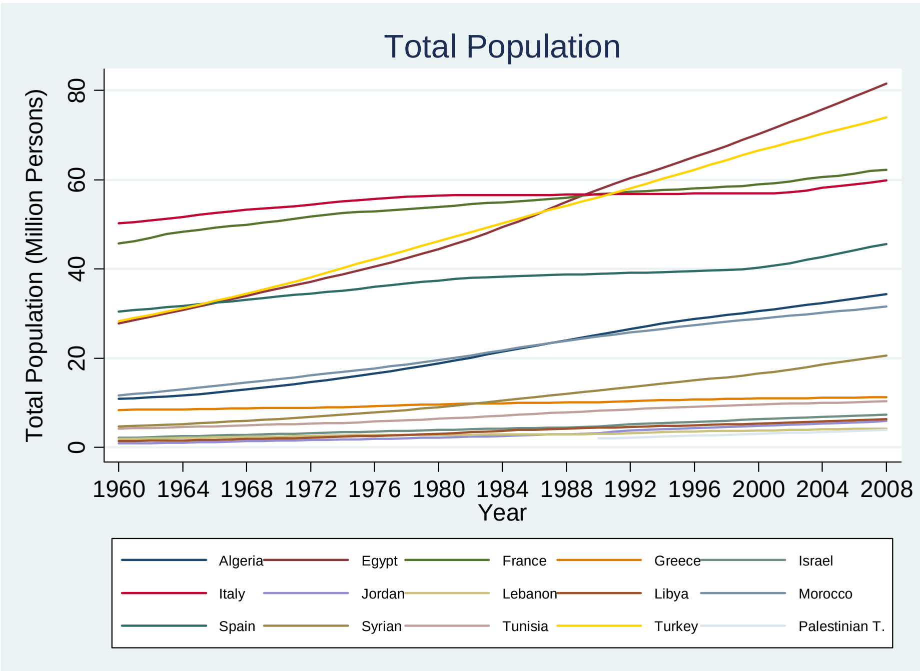
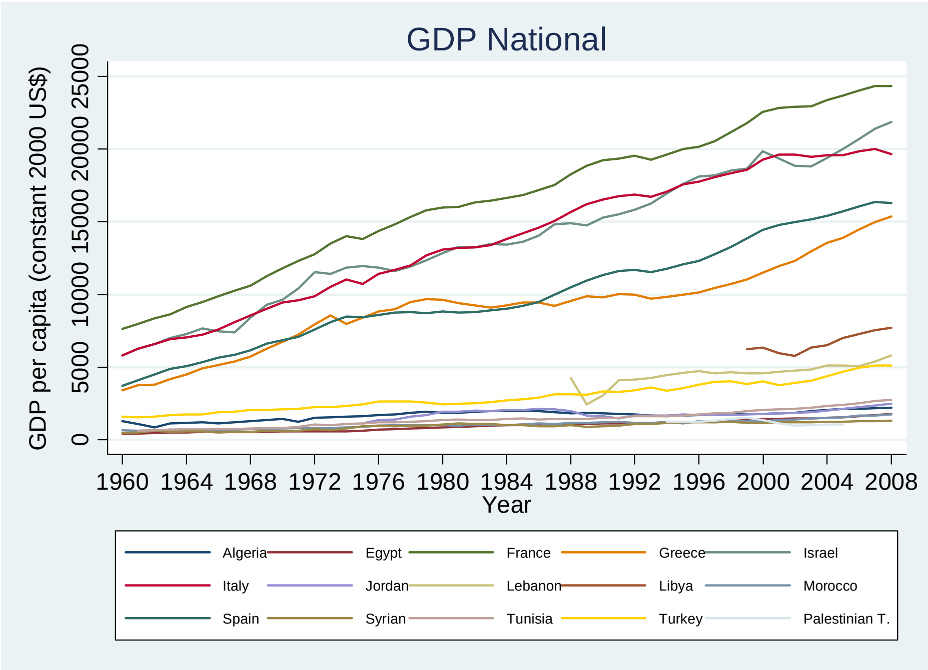


Figure 4. Population trends in Mediterranean countries



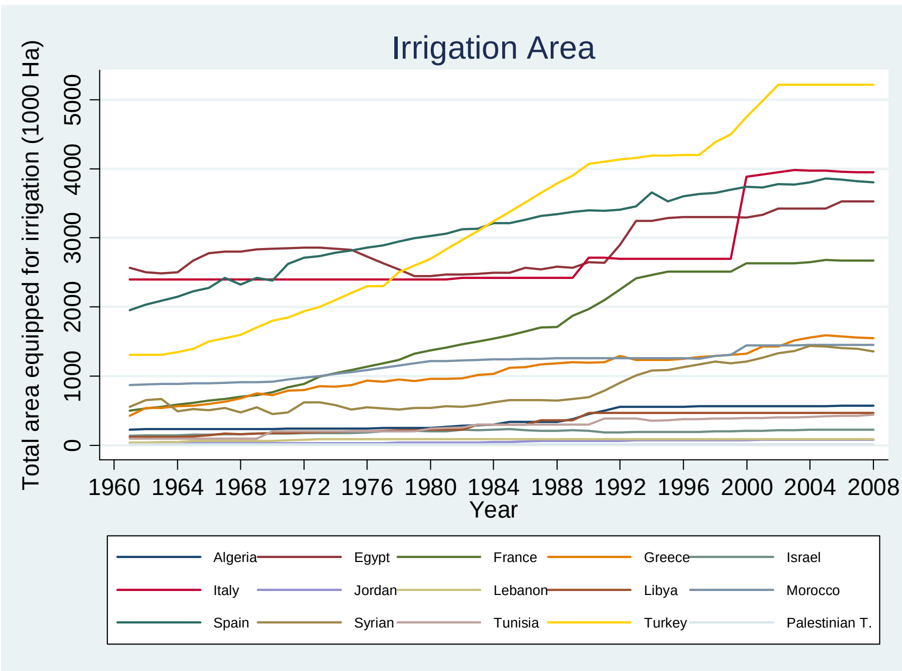
Regarding GDP growth (Figure 5), there is a clear differentiation between the EU Mediterranean countries, plus Israel, and the rest of countries. Among the 11 SEMCs, apart from Israel, the highest growth rates have taken place in Turkey, Libya and Lebanon.

Figure 5. GDP trends in Mediterranean countries



Again, in Figure 6, Turkey stands out as the country in which the irrigation-equipped surface has increased the fastest in the last 50 years. This is necessarily related to the huge development in storage capacity in that country. Among the other 11 SEMCs, Egypt and Syria have also experienced a rapid development of irrigation.

Figure 6. Trends in irrigation in Mediterranean countries



3.2 Country-level analysis

In the Mediterranean region, different countries show different patterns in water consumption, as depicted in Figures 7-39 for the 11 SEMCs. In general, it can be observed that the total water withdrawn per year varies considerably across countries and its relation to other variables is also diverse. The graphs show how, in some cases, the trends in water consumption are clearly linked to the trends in population growth (as in the case of Algeria) or to GDP or irrigated area in some other cases. With this kind of analysis we plan to establish a typology of countries related to their patterns in water consumption as the starting point of the econometric analysis in section 5 of this report.

At the same time, the graphs show that for some countries the data – especially concerning water withdrawal – do not seem very accurate, as there are surprising changes between consecutive years. This happens for example in the case of Algeria in 2002 and in the case of Spain during the 1980s, with water consumption appearing to be overestimated. The lack of data or their quality can be a problem for the analysis in the cases of Italy, Jordan and the Palestinian territories.

The subsequent figures show the trends in water withdrawal, GDP and population for all 11 SEMCs taking 1980 as a reference year. Comparing trends in terms of percentages enables a clearer comparison between GDP, population and the growth of water consumption.

In some cases, for instance Algeria, water withdrawal trends are quite similar to the trends in GDP and population growth. Yet in other countries, such as Israel and Spain, the trends in GDP growth and in water withdrawal or population growth are independent. The case of Turkey is a bit different because there has been a faster increase in water withdrawal.

3.2.1 Algeria

The database for Algeria is generally incomplete; data are missing for some of the years (with a possible outlier for 2001) in the period considered and therefore the time trend does not accurately reflect the relationship between water withdrawal and population growth. The same applies to the relationship with GDP and irrigated area, although population growth seems to have a higher explanatory potential.

Figure 7. Algeria: Population and water withdrawal trends in percentages (1980 = 100%)

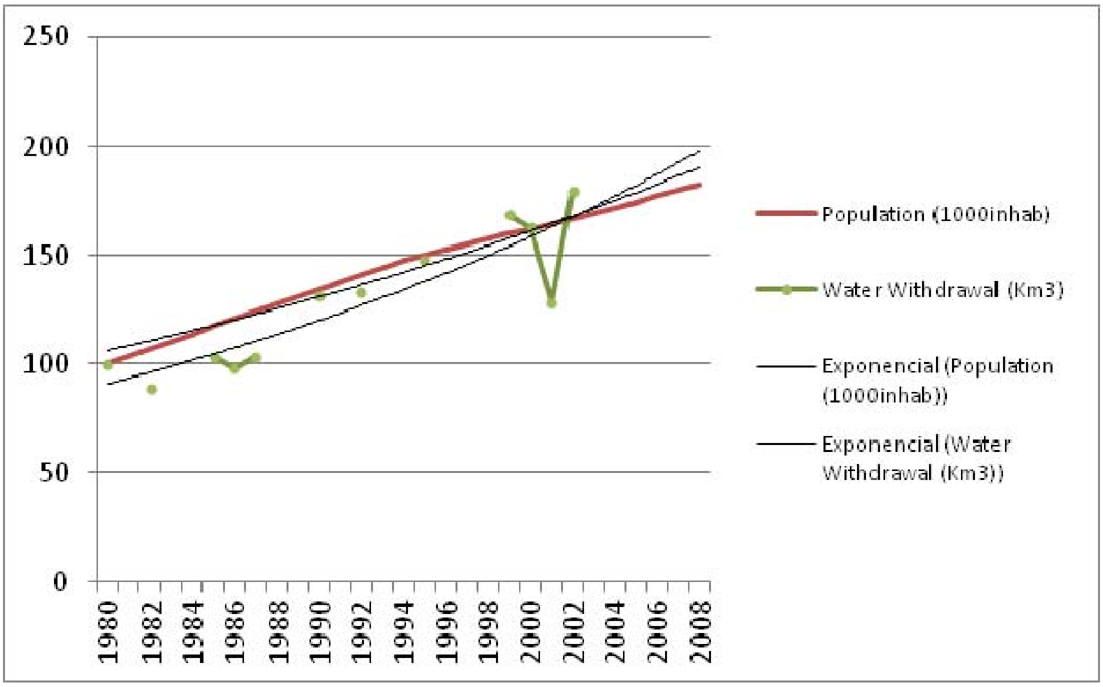


Figure 8. Algeria: GDP and water withdrawal trends in percentages (1980 = 100%)

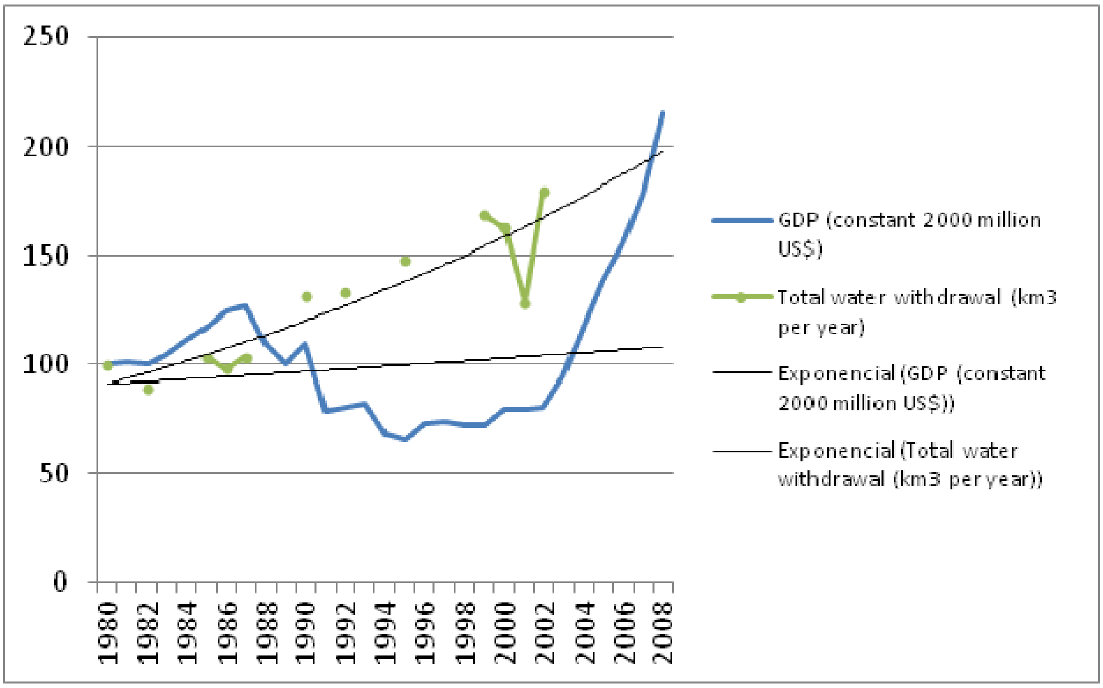
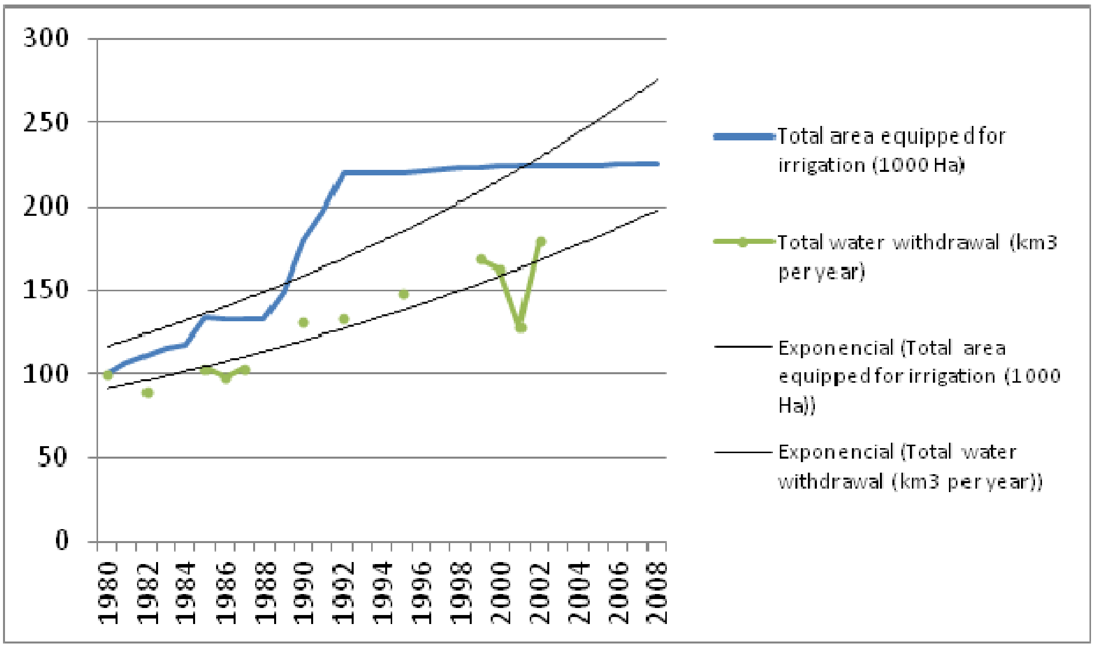


Figure 9. Algeria: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.2 Egypt

For Egypt, the data are more consistent and therefore trends in water withdrawal are more uniform than in the case of Algeria. The irrigated area increased sharply in 1990.

Figure 10. Egypt: Population and water withdrawal trends in percentages (1980 = 100%)

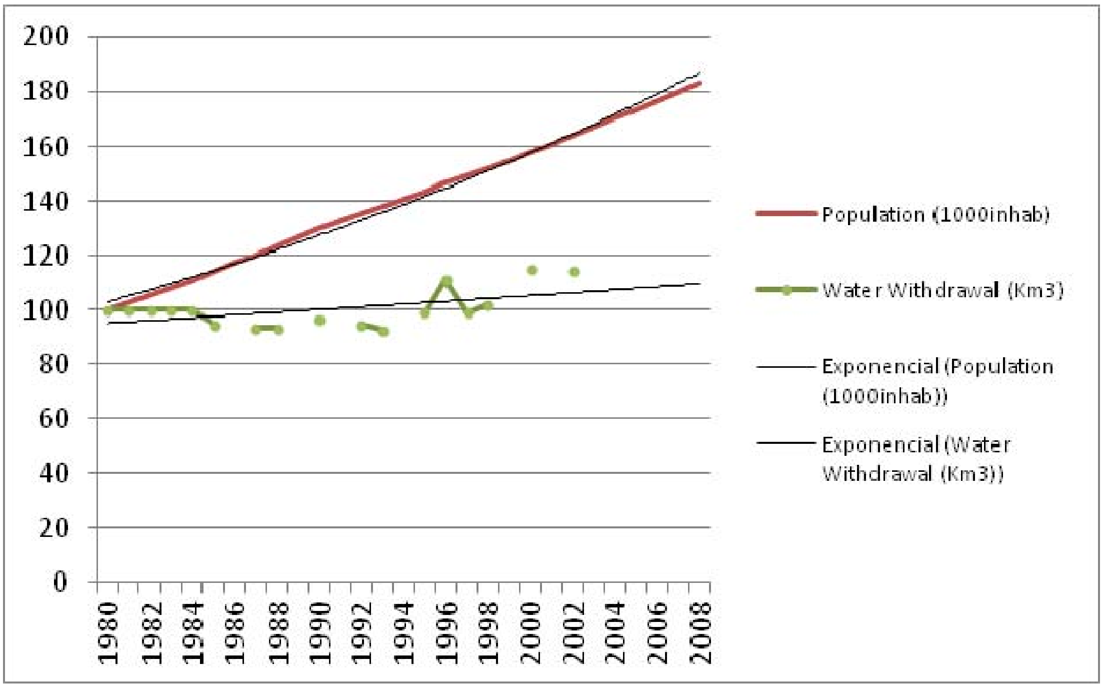


Figure 11. Egypt: GDP and water withdrawal trends in percentages (1980 = 100%)

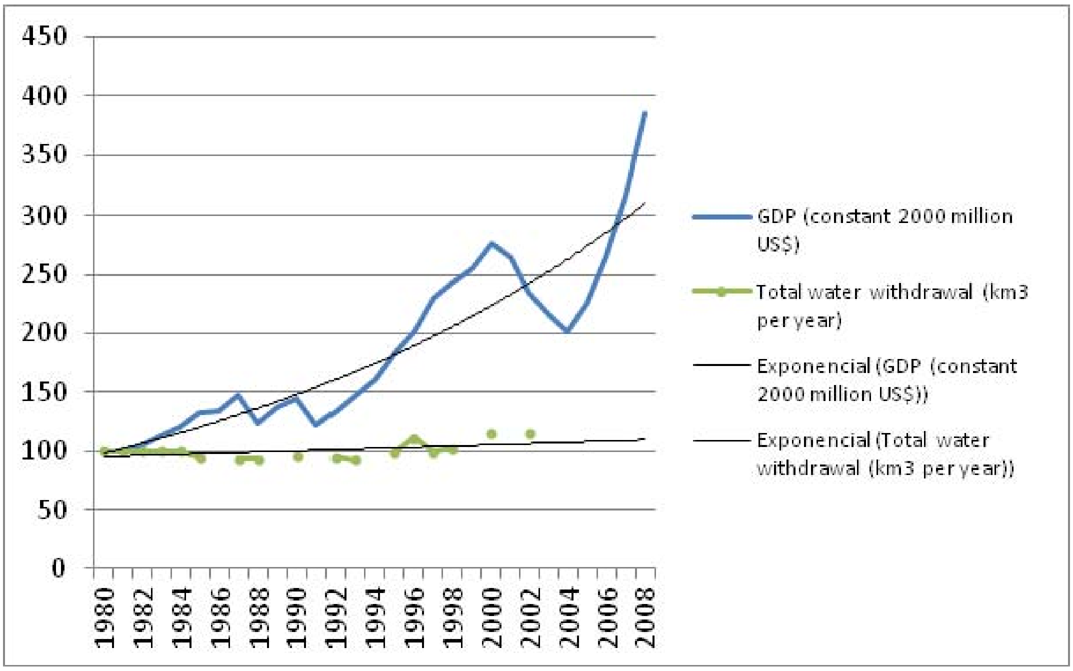
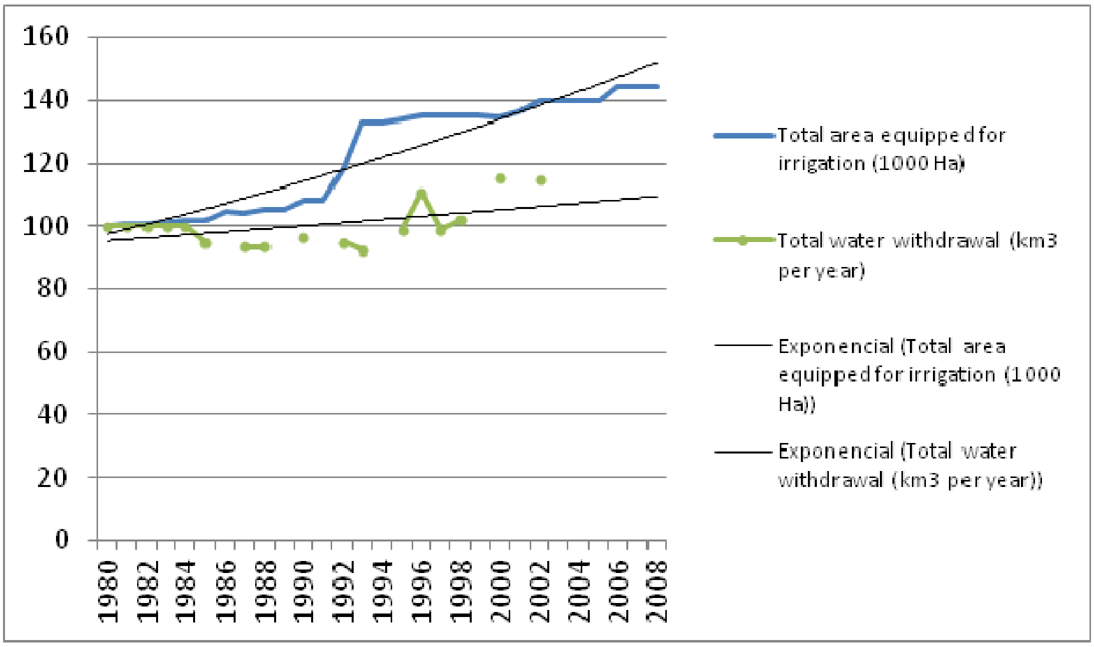


Figure 12. Egypt: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.3 Israel

The data are more complete for Israel than for the other 11 SEMCs, and therefore the time trends for water withdrawal and population growth, GDP and irrigated area are better adjusted.

Figure 13. Israel: Population and water withdrawal trends in percentages (1980 = 100%)

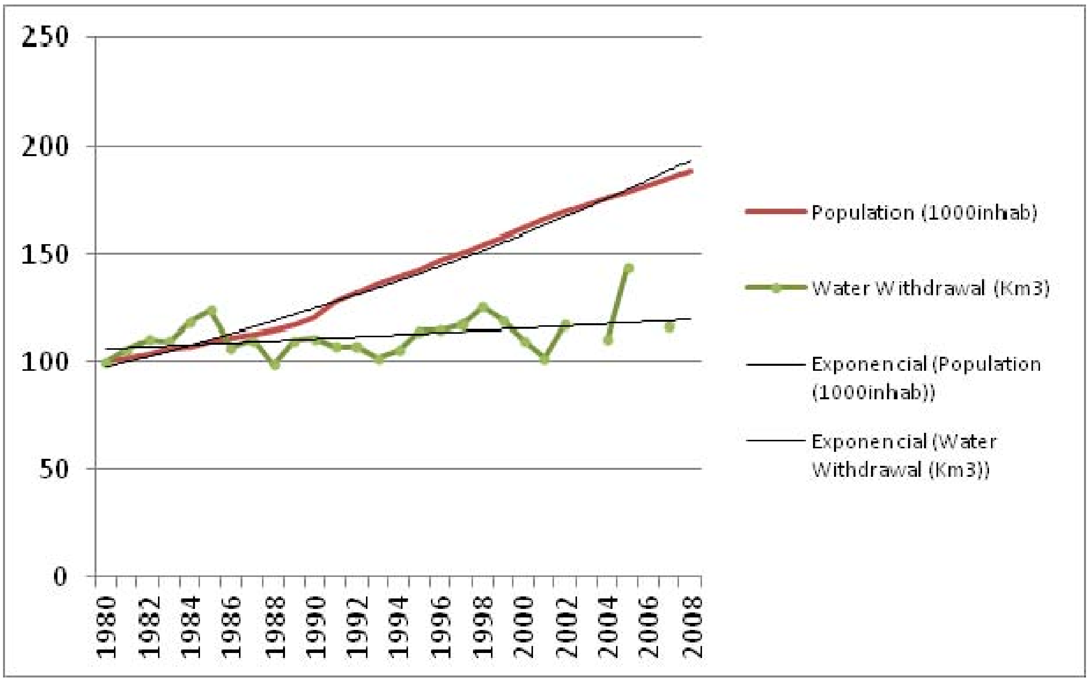


Figure 14. Israel: GDP and water withdrawal trends in percentages (1980 = 100%)

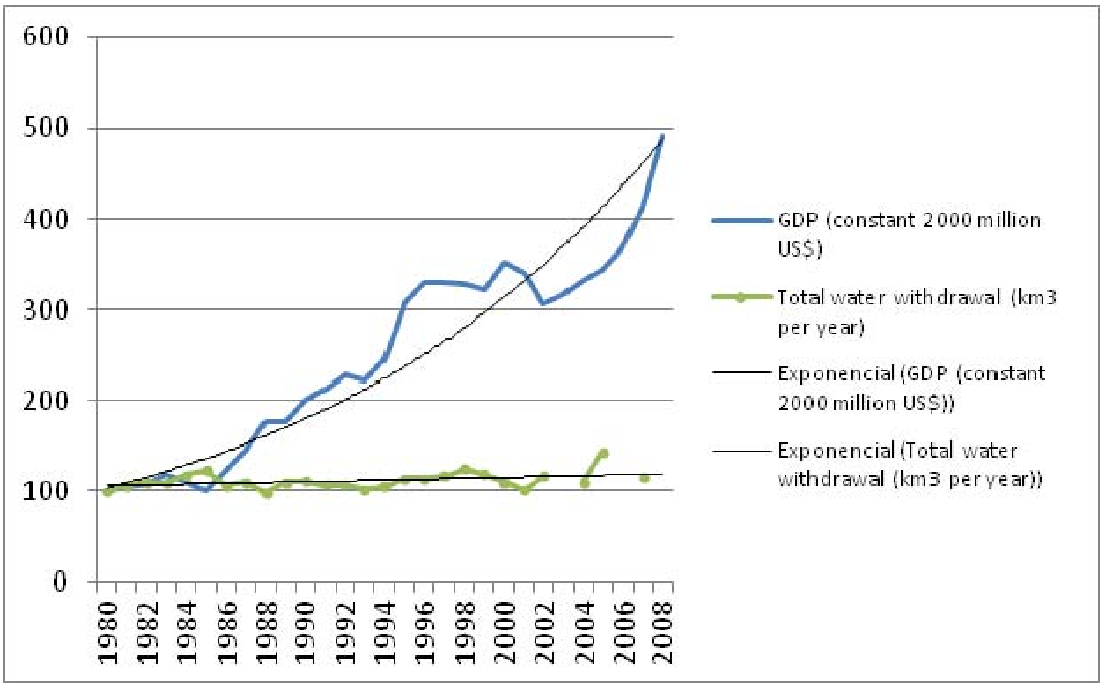
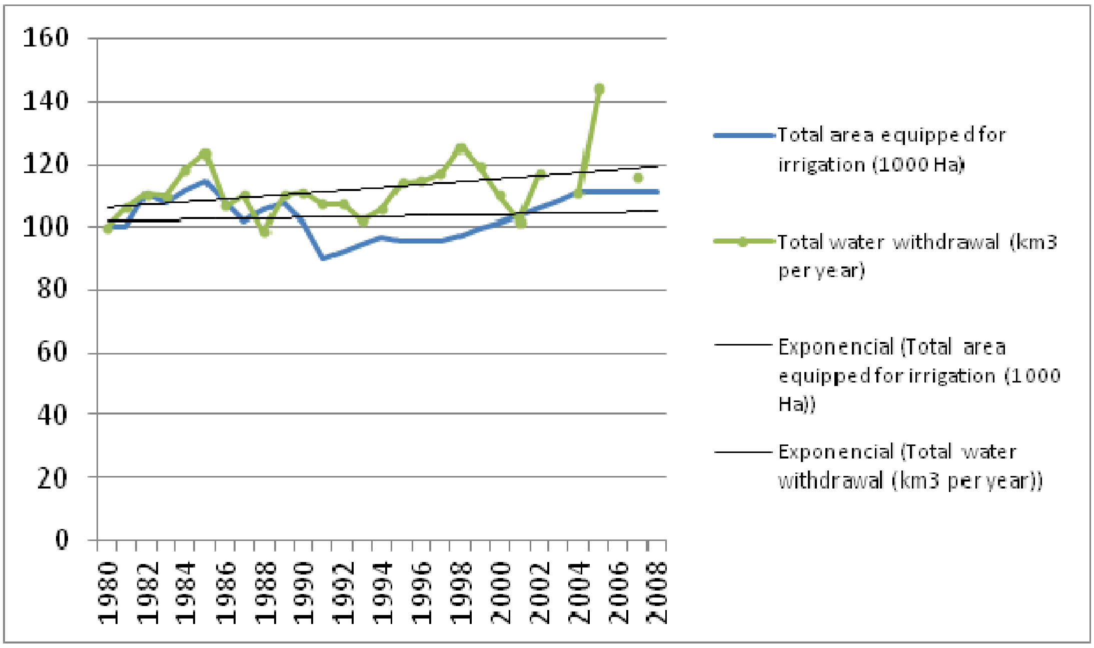


Figure 15. Israel: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.4 Jordan

Data are missing in some years for Jordan and therefore the time trends for the selected variables are not fully accurate.

Figure 16. Jordan: Population and water withdrawal trends in percentages (1980 = 100%)

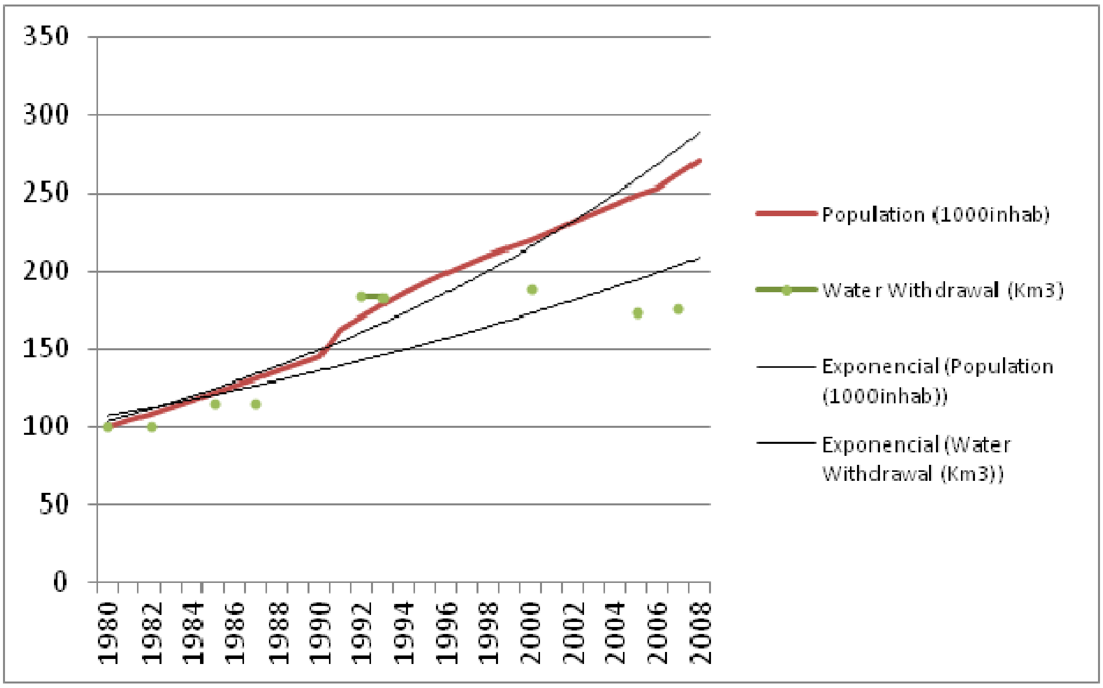


Figure 17. Jordan: GDP and water withdrawal trends in percentages (1980 = 100%)

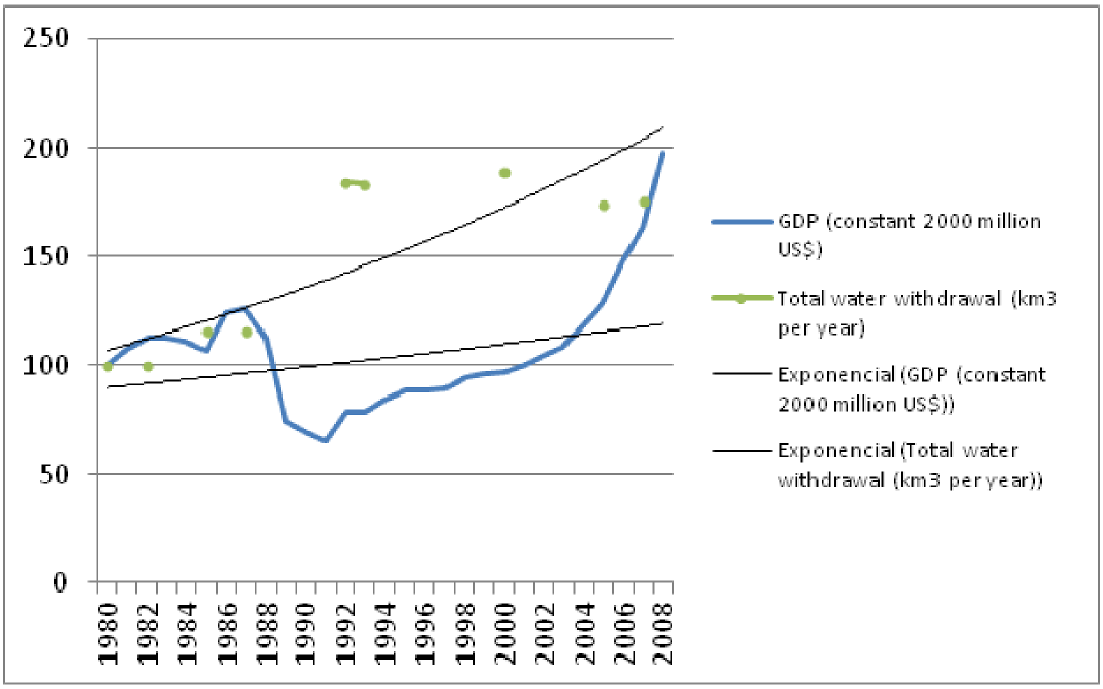
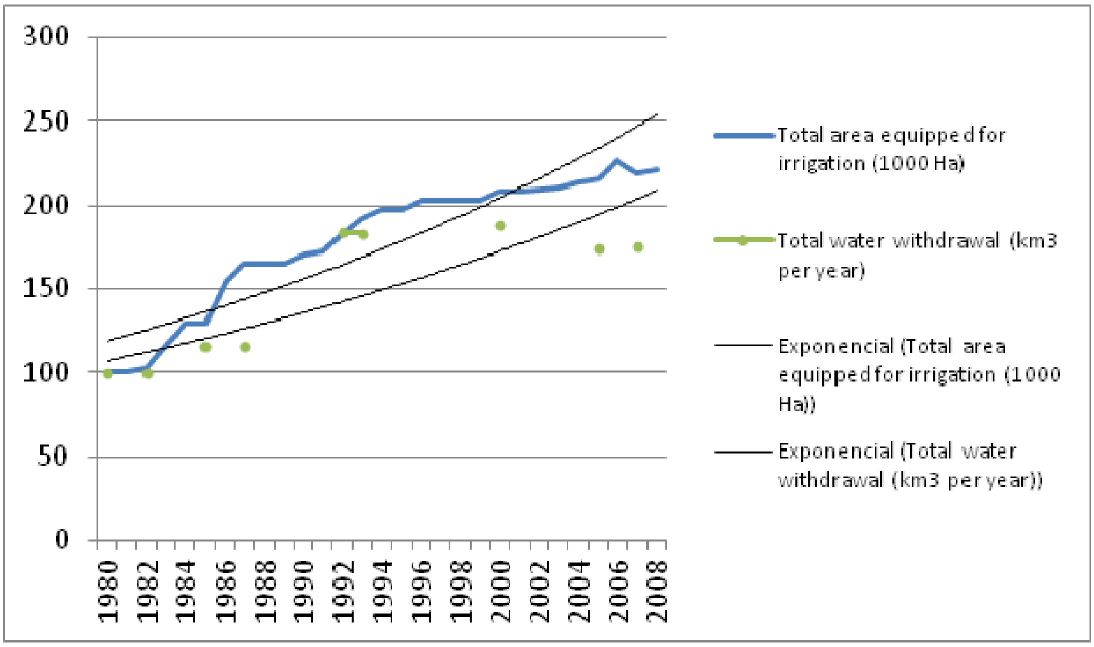


Figure 18. Jordan: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.5 Lebanon

Data are missing in some years for Lebanon and therefore the time trends for the selected variables are not fully accurate.

Figure 19. Lebanon: Population and water withdrawal trends in percentages (1980 = 100%)

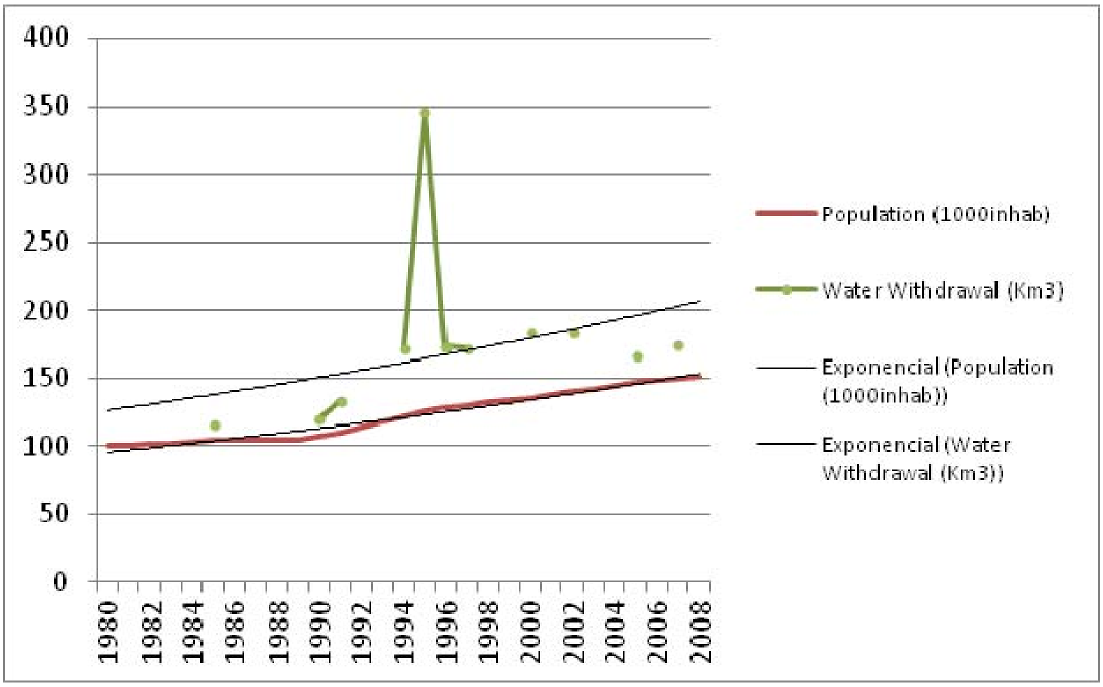


Figure 20. Lebanon: GDP and water withdrawal trends in percentages (1990 = 100%)

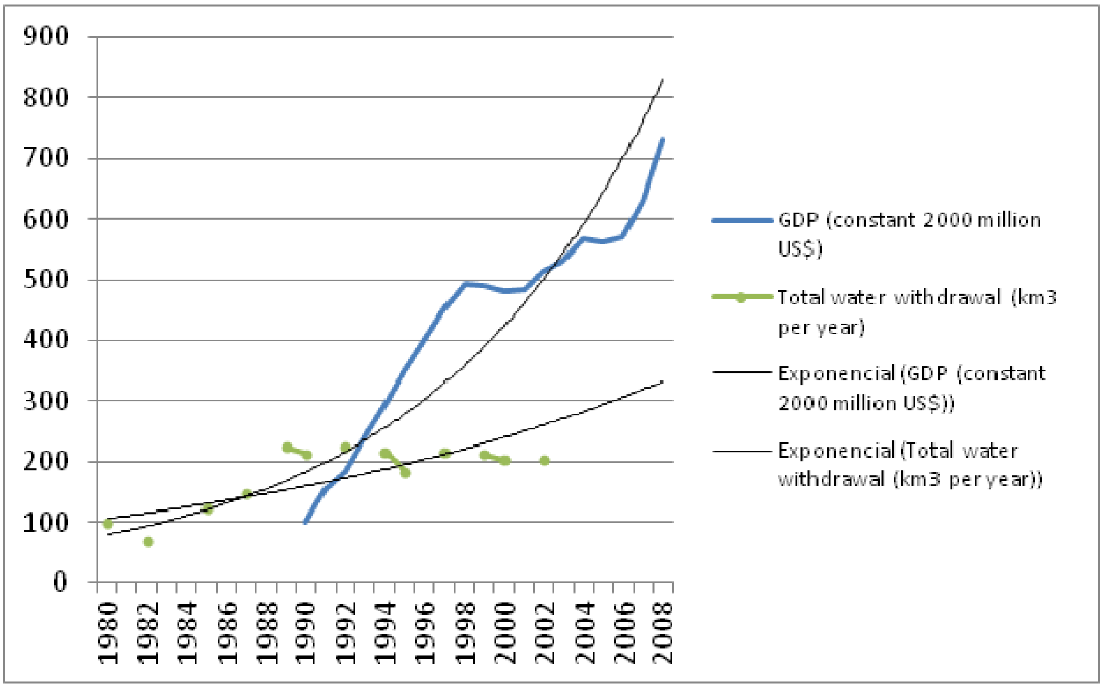
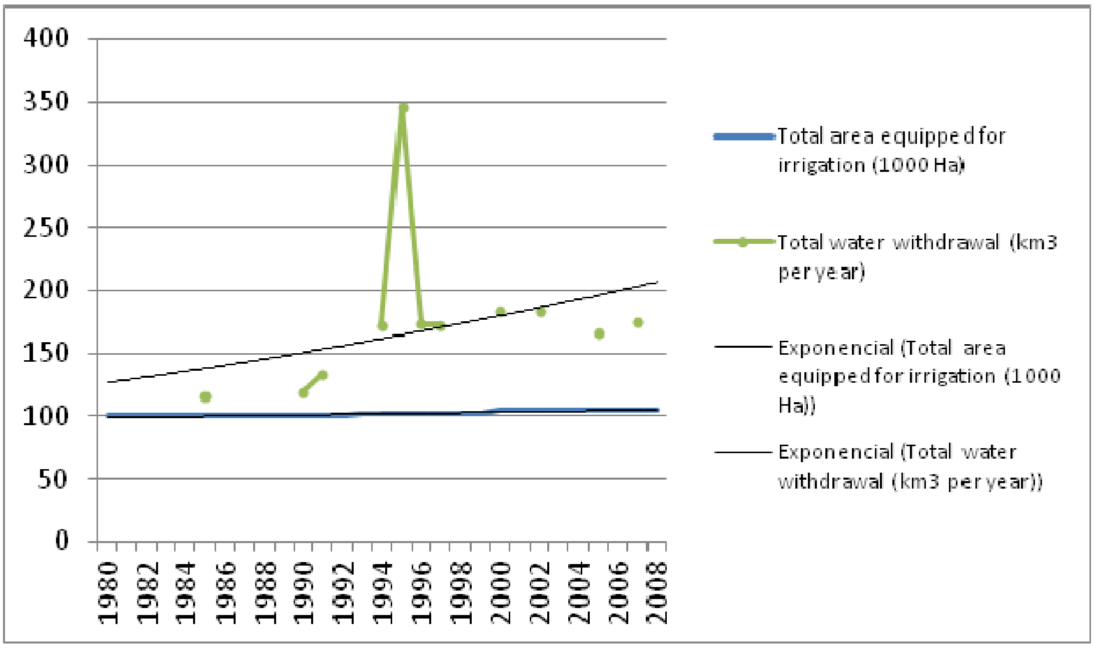


Figure 21. Lebanon: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.6 Libya

Data are missing in some years for Libya and therefore the time trends for the selected variables are not fully accurate.

Figure 22. Libya: Population and water withdrawal trends in percentages (1980 = 100%)

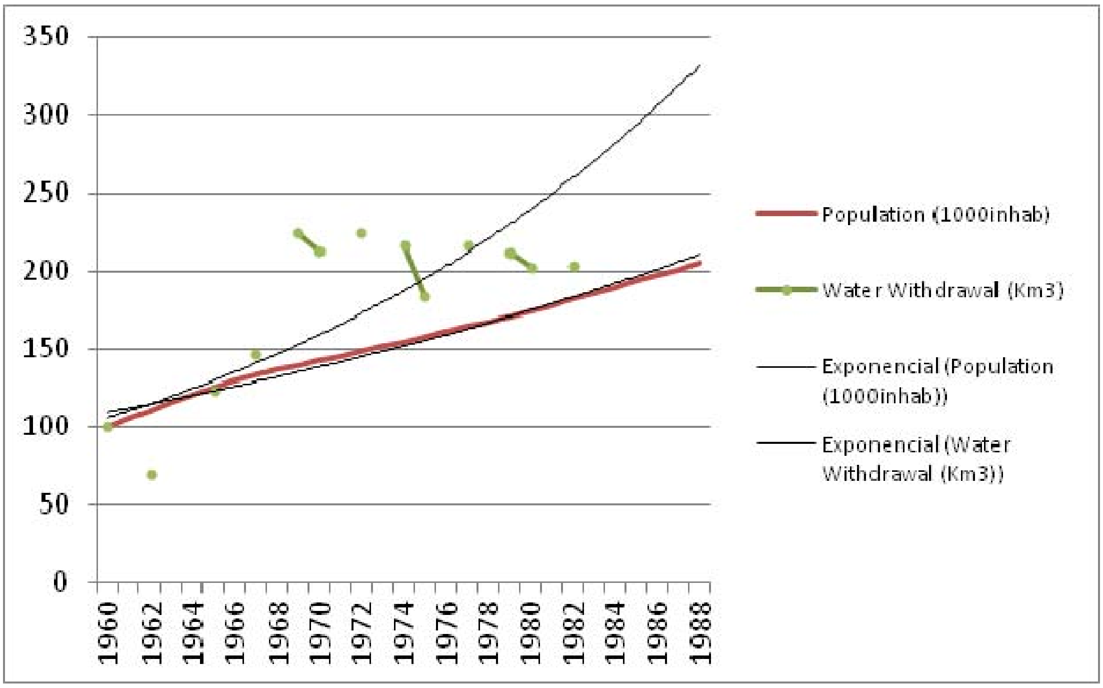


Figure 23. Libya: GDP and water withdrawal trends in percentages (1980 = 100%)

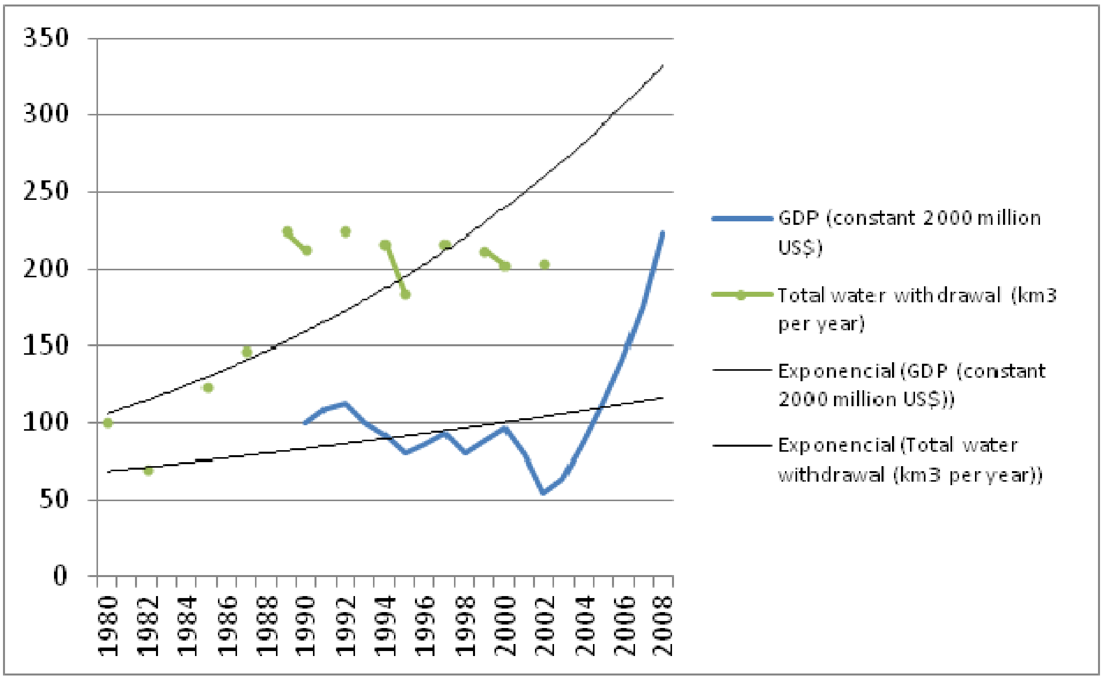
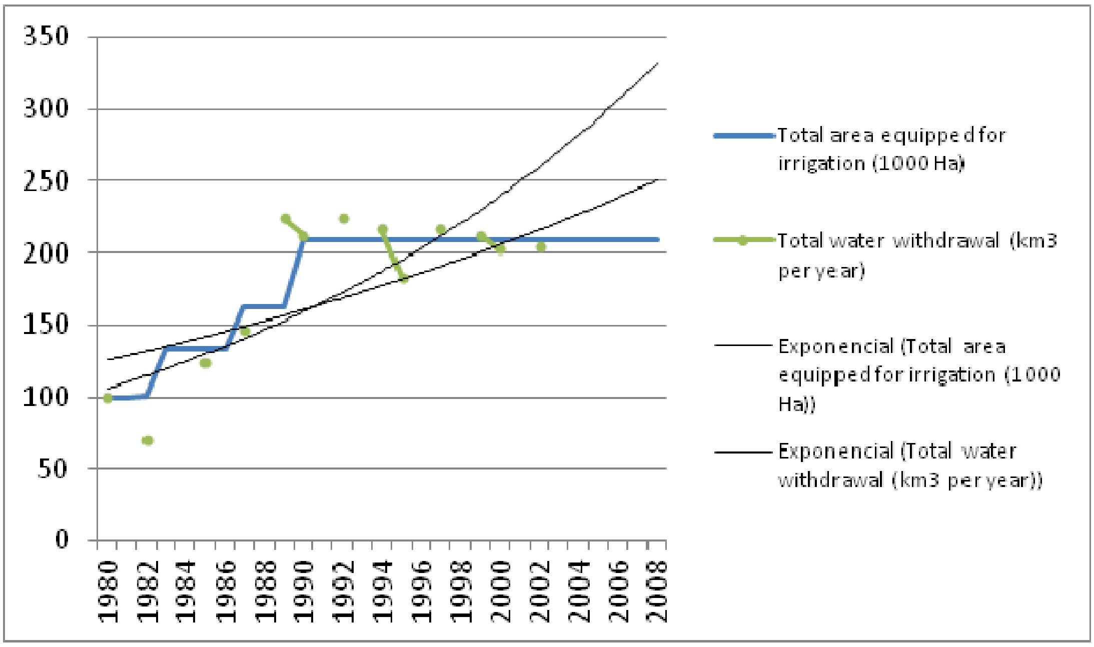


Figure 24. Libya: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.7 Morocco

There is good data availability for Morocco and therefore the time trends for the relationship with the selected variables are more accurate than for some of the other 11 SEMCs.

Figure 25. Morocco: Population and water withdrawal trends in percentages (1980 = 100%)

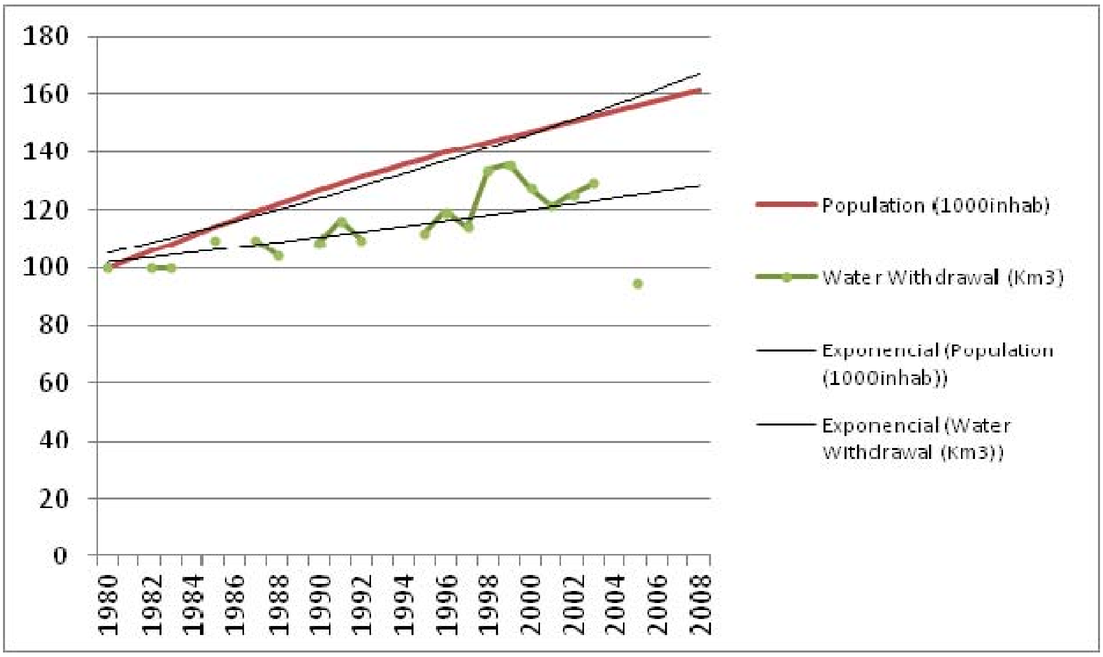


Figure 26. Morocco: GDP and water withdrawal trends in percentages (1980 = 100%)

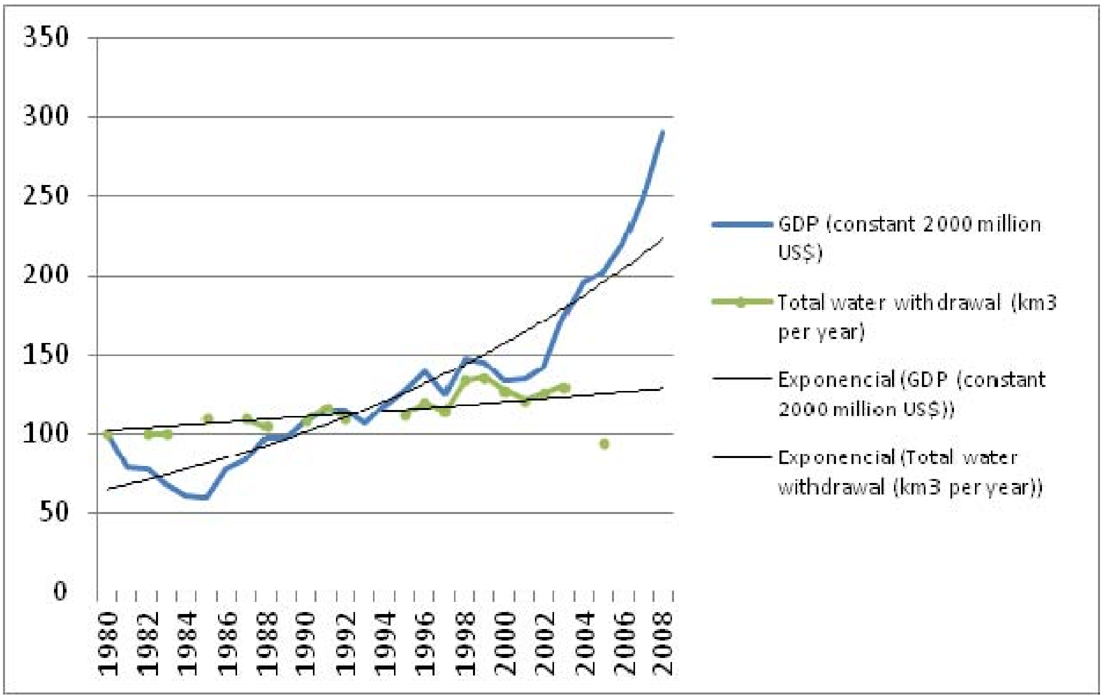
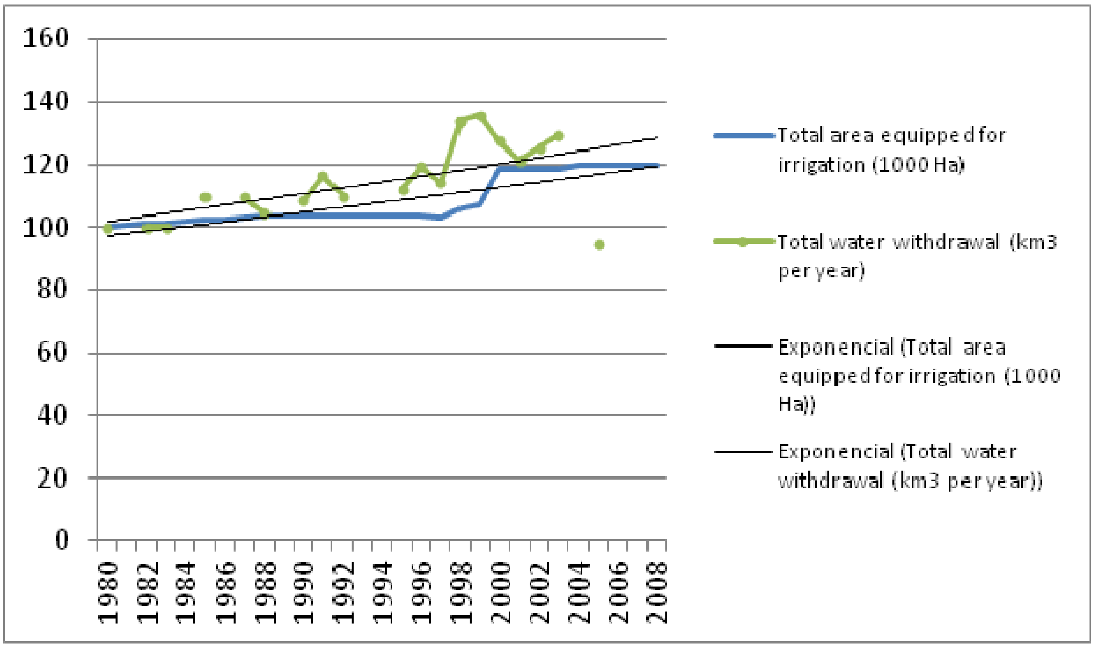


Figure 27. Morocco: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.8 Syria

There is better data availability for Syria than for some of the other countries, although the data series is not very complete. There are sufficient data for observing the trends in water use, however.

Figure 28. Syria: Population and water withdrawal trends in percentages (1980 = 100%)

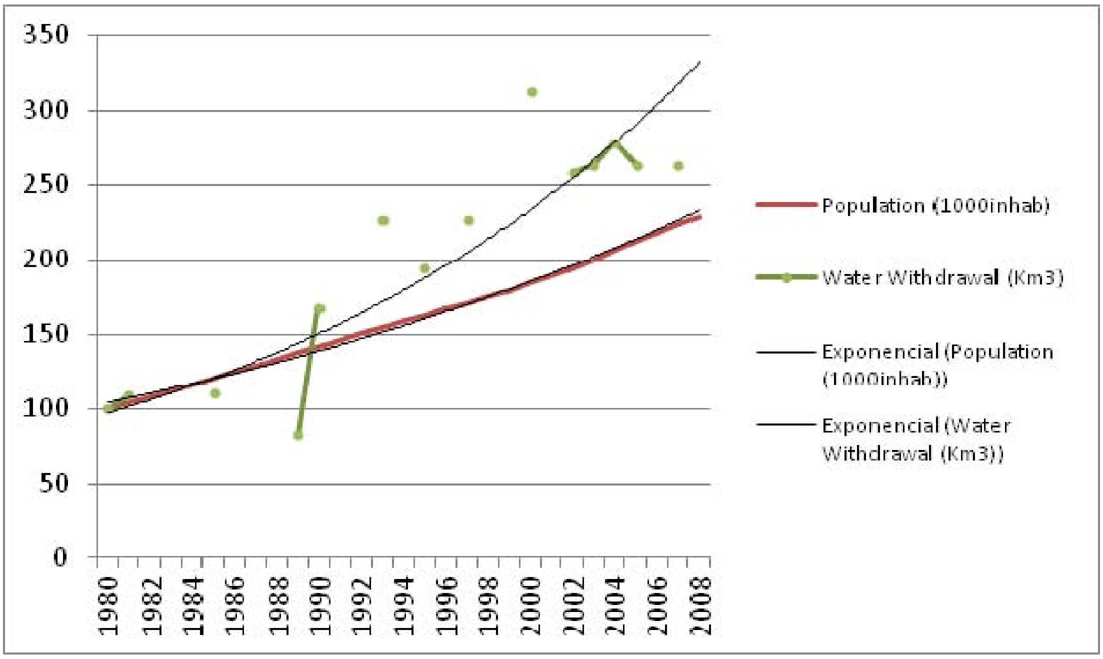


Figure 29. Syria: GDP and water withdrawal trends in percentages (1980 = 100%)

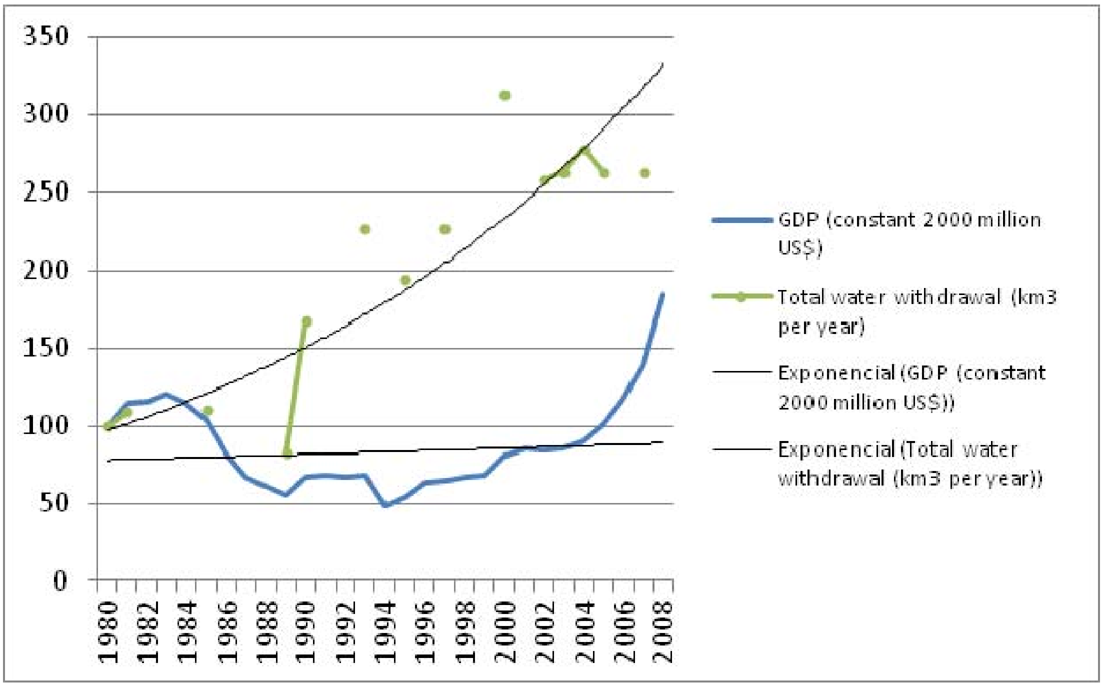
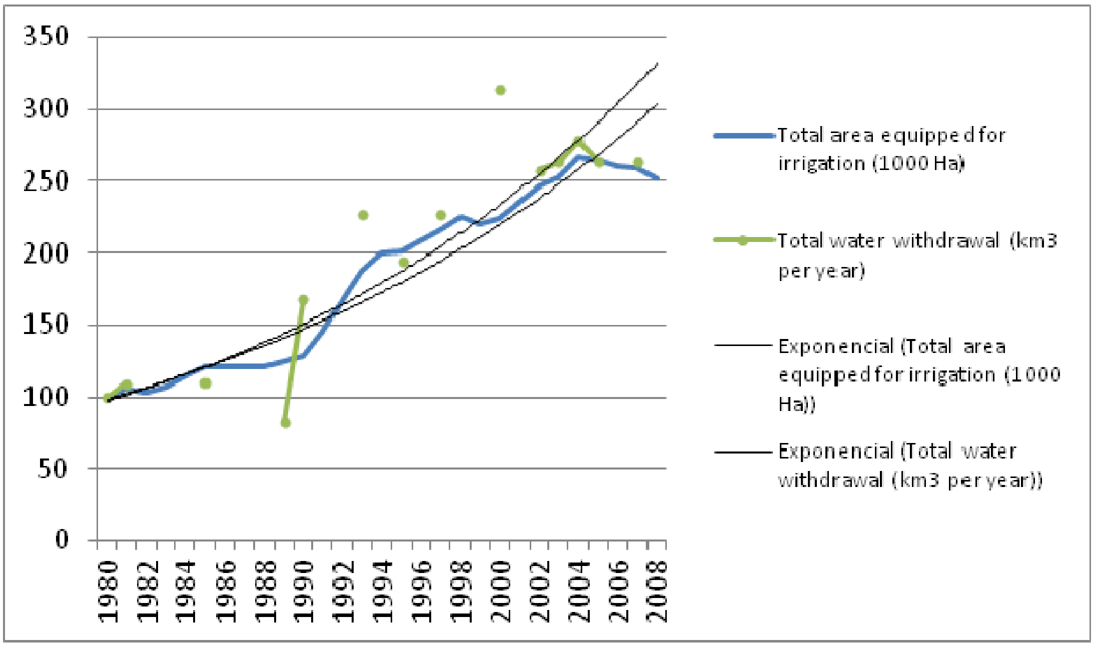


Figure 30. Syria: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.9 Tunisia

The data coverage for Tunisia is good, and the time trends for the selected variables may be more accurate than is the case for other countries.

Figure 31. Tunisia: Population and water withdrawal trends in percentages (1980 = 100%)

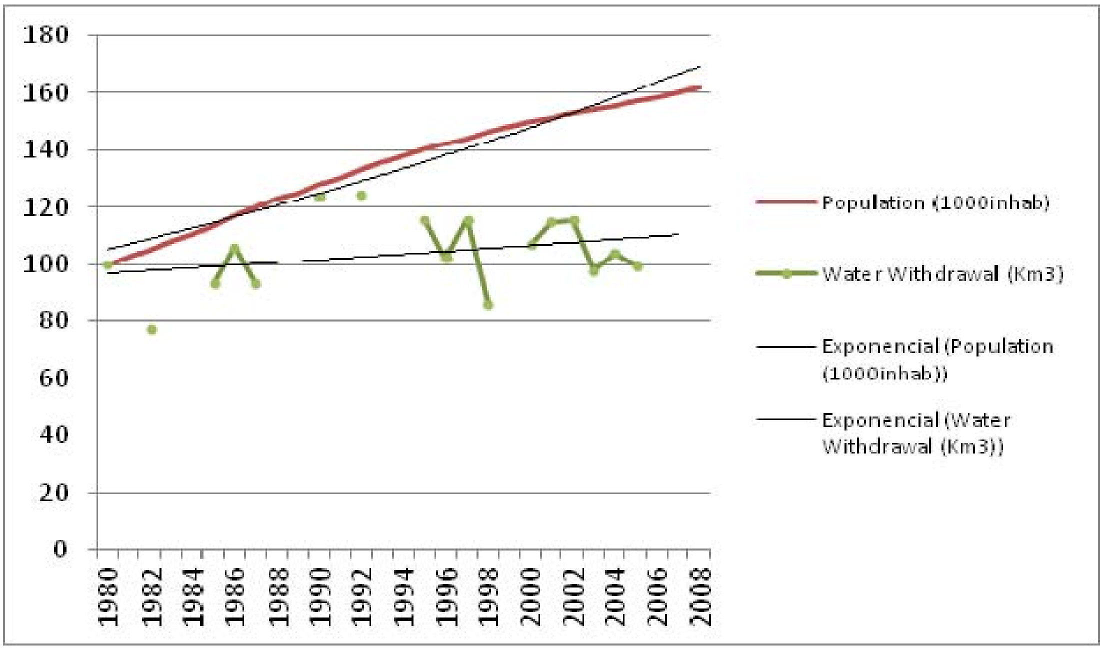


Figure 32. Tunisia: GDP and water withdrawal trends in percentages (1980 = 100%)

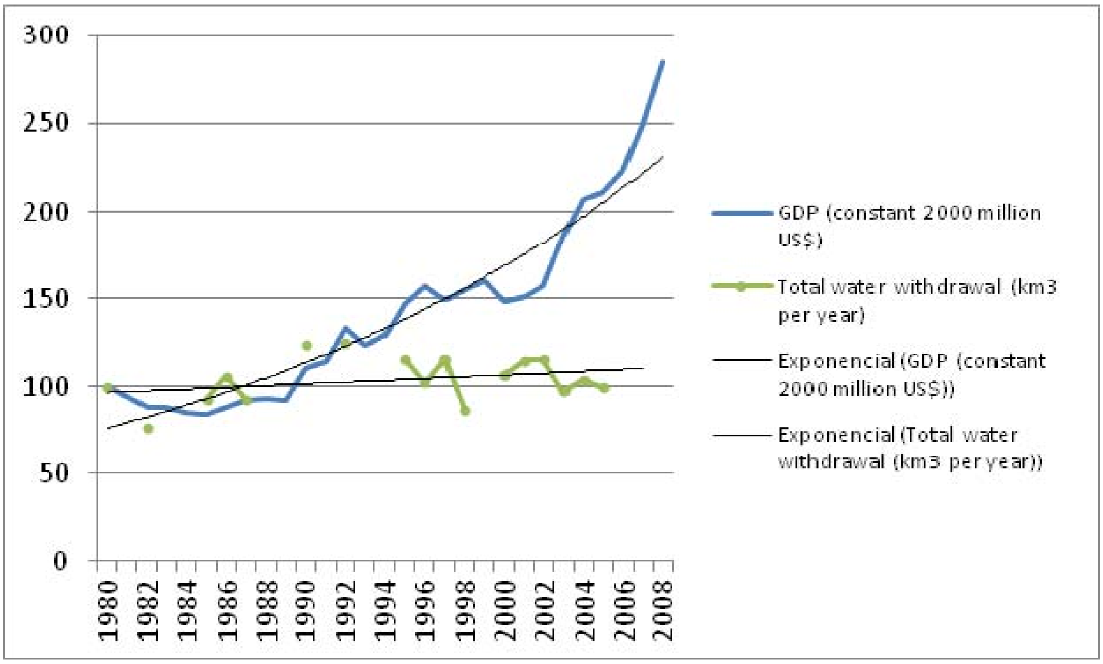
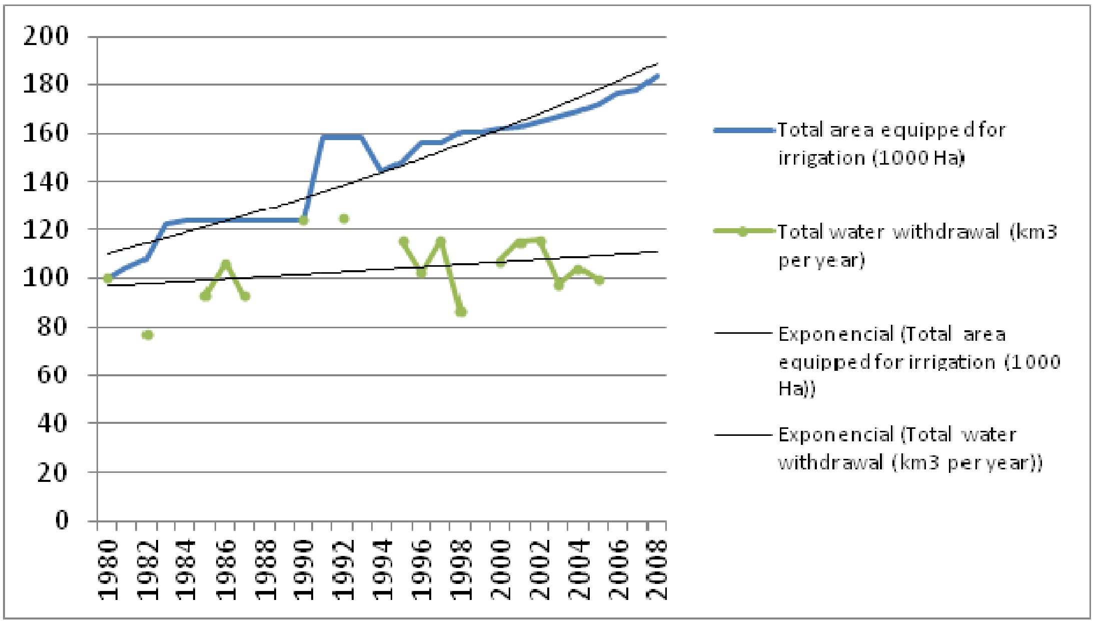


Figure 33. Tunisia: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.10 Turkey

The data coverage for Turkey is also good, and the time trends for the selected variables may be more accurate than is the case for other countries.

Figure 34. Turkey: Population and water withdrawal trends in percentages (1980 = 100%)

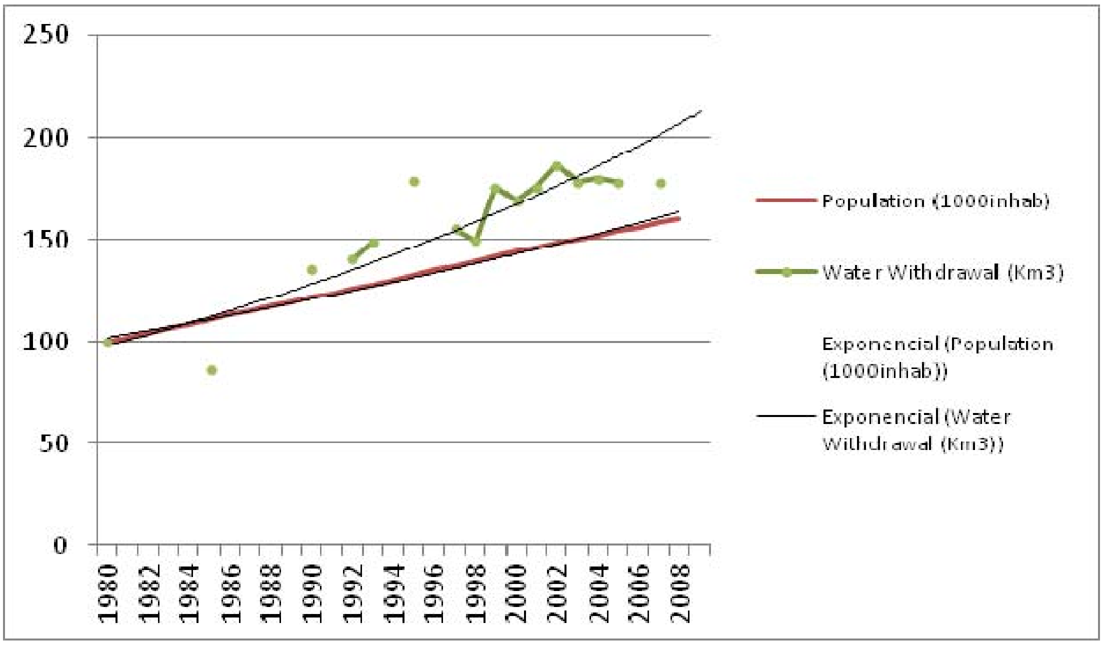


Figure 35. Turkey: GDP and water withdrawal trends in percentages (1980 = 100%)

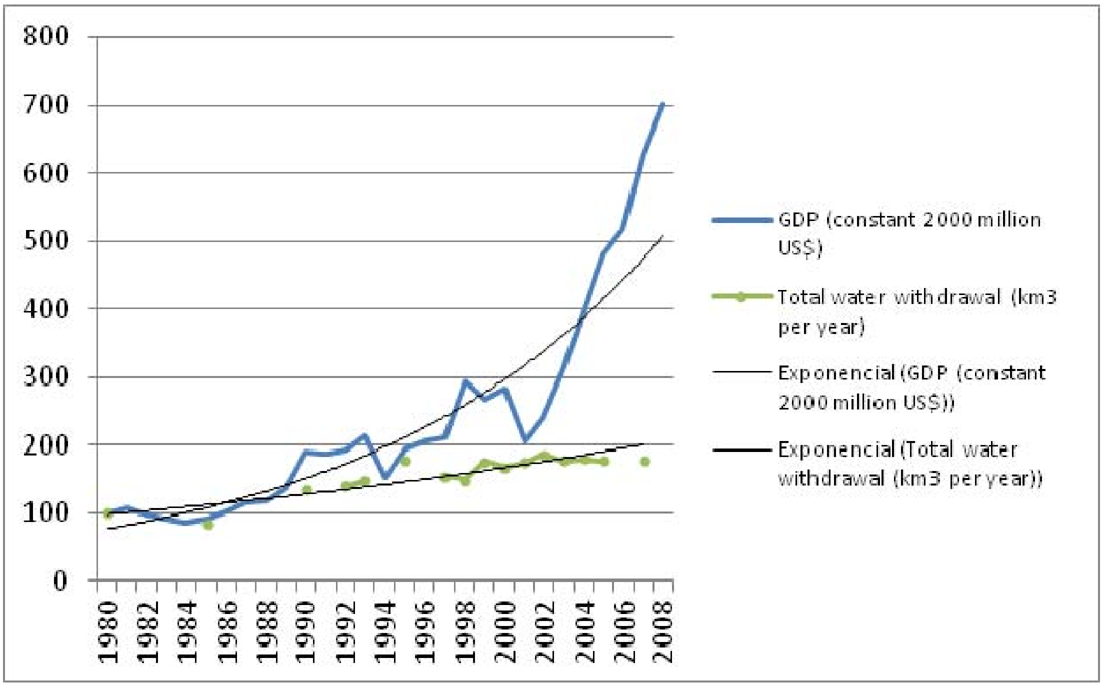
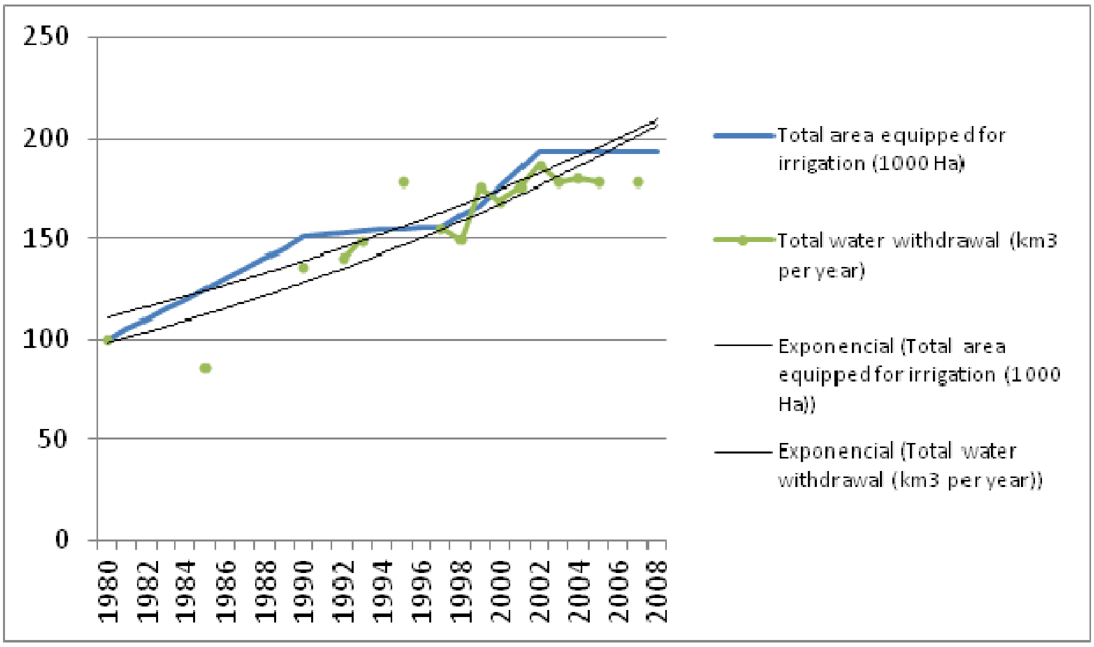


Figure 36. Turkey: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.11 Palestinian territories

The very limited data availability for the Palestinian territories prevents the selected variables from being depicted with accuracy.

Figure 37. Palestinian territories: Population and water withdrawal trends in percentages (1980 = 100%)

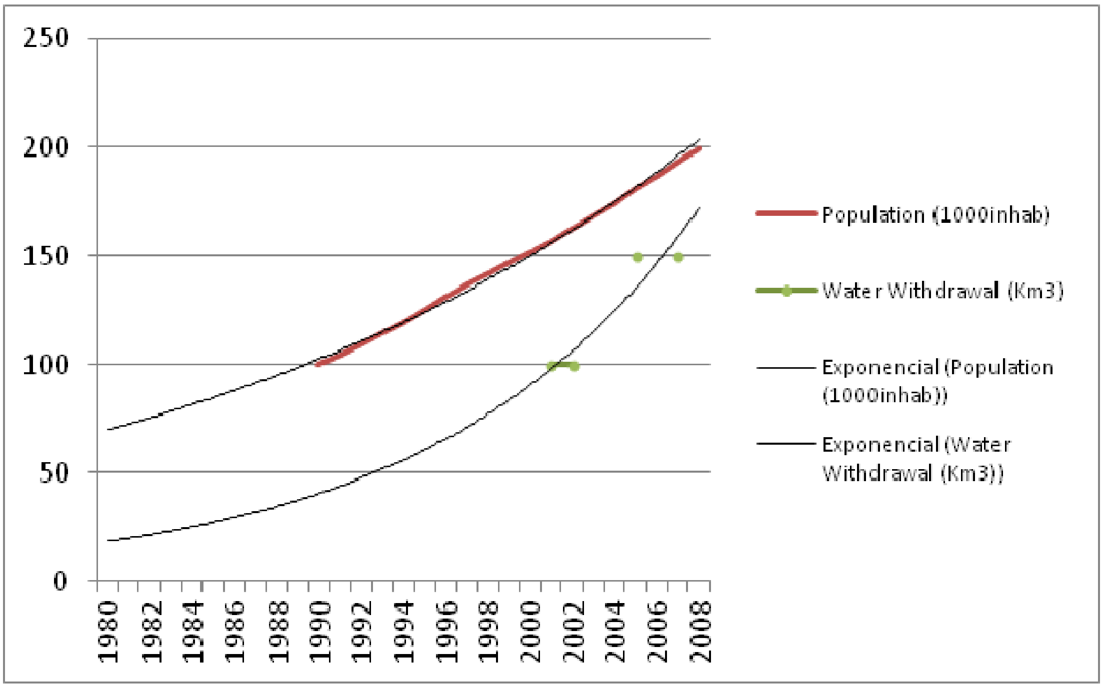


Figure 38. Palestinian territories: GDP and water withdrawal trends in percentages (1980 = 100%)

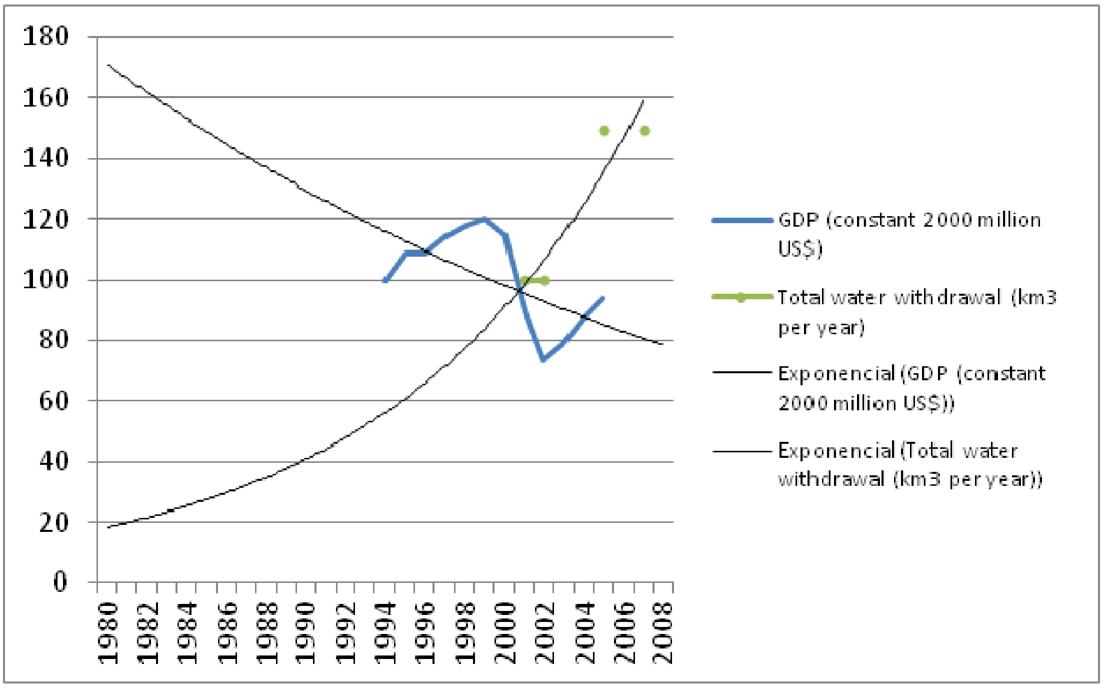
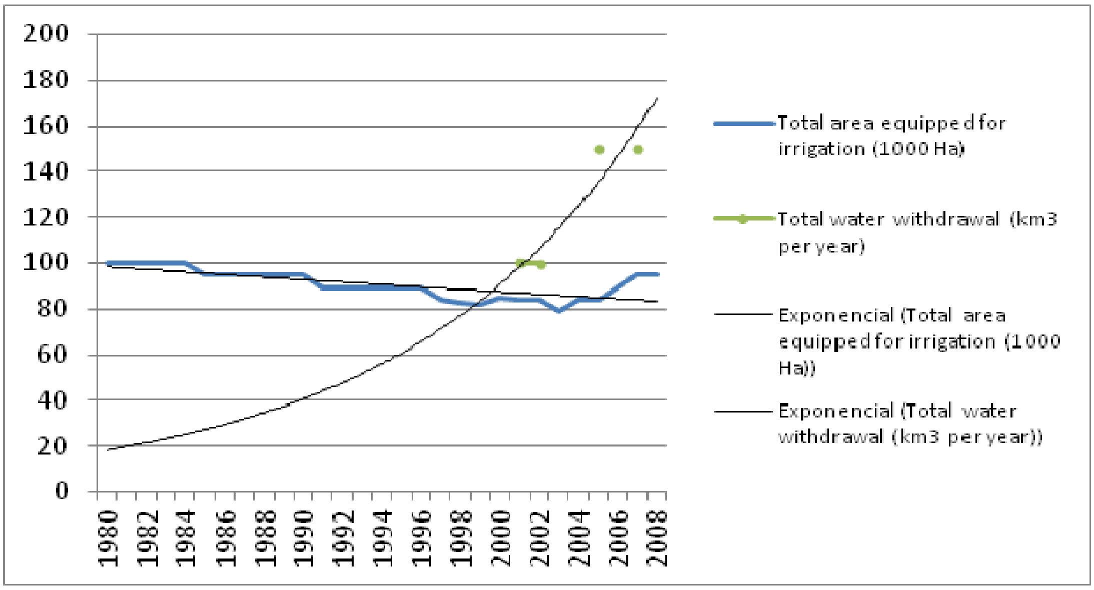


Figure 39. Palestinian territories: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



EU Mediterranean countries

There are ample data for France and Spain, but data are missing for Greece and Italy in some years, making a comparison across the selected variables more difficult (Figures 40-51).

3.2.12 France

Figure 40. France: Population and water withdrawal trends in percentages (1980 = 100%)

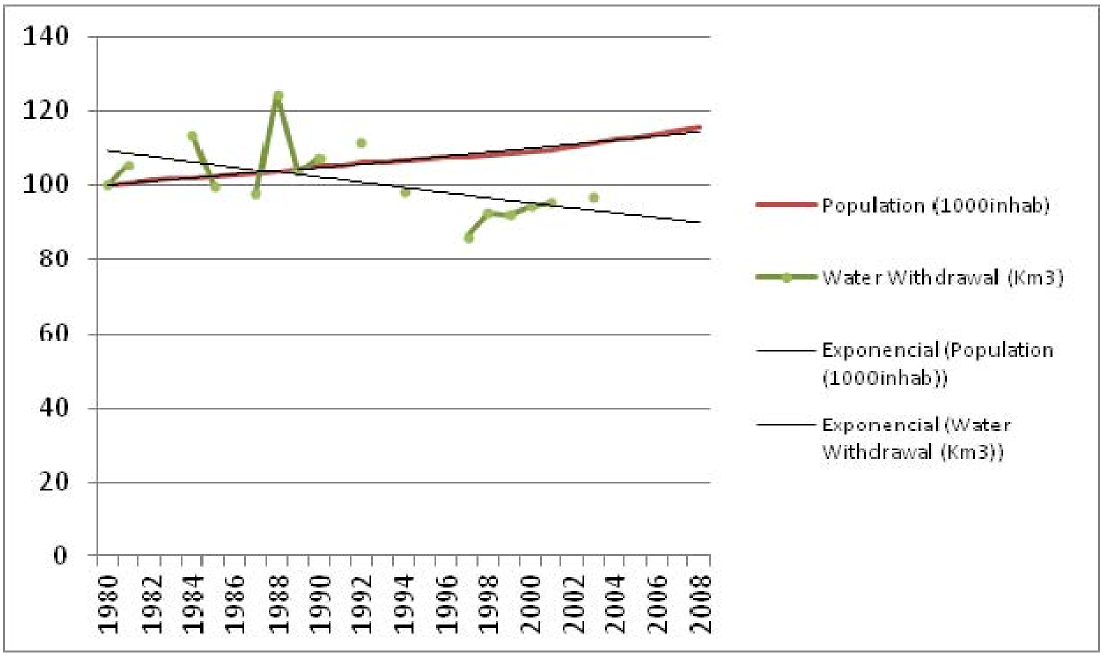


Figure 41. France: GDP and water withdrawal trends in percentages (1980 = 100%)

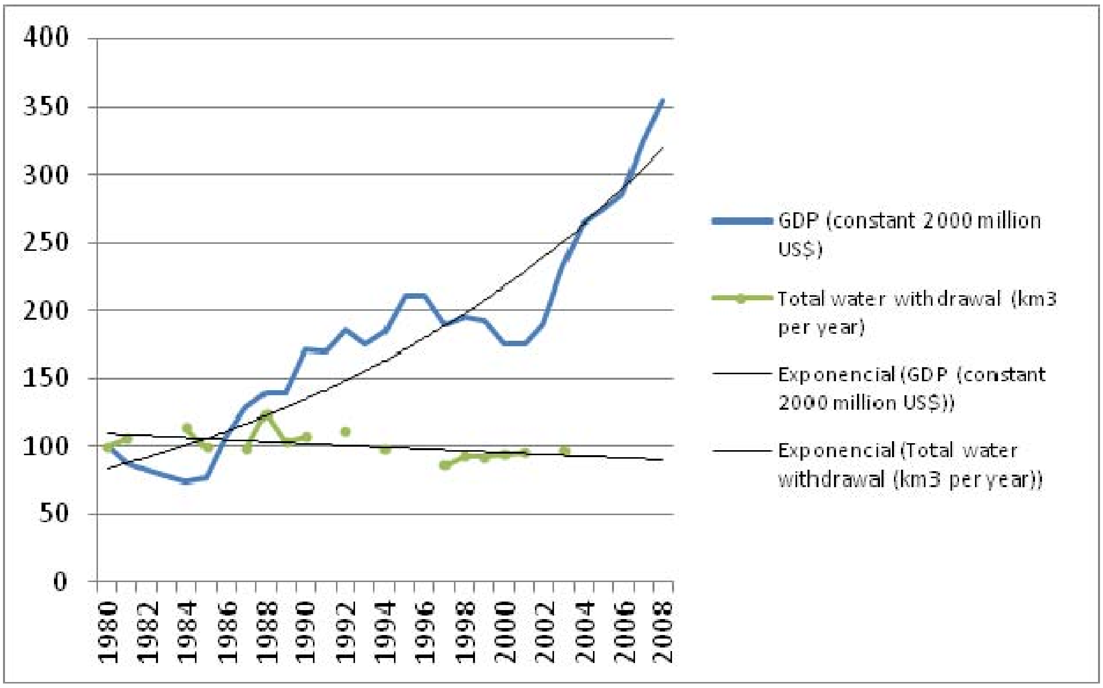
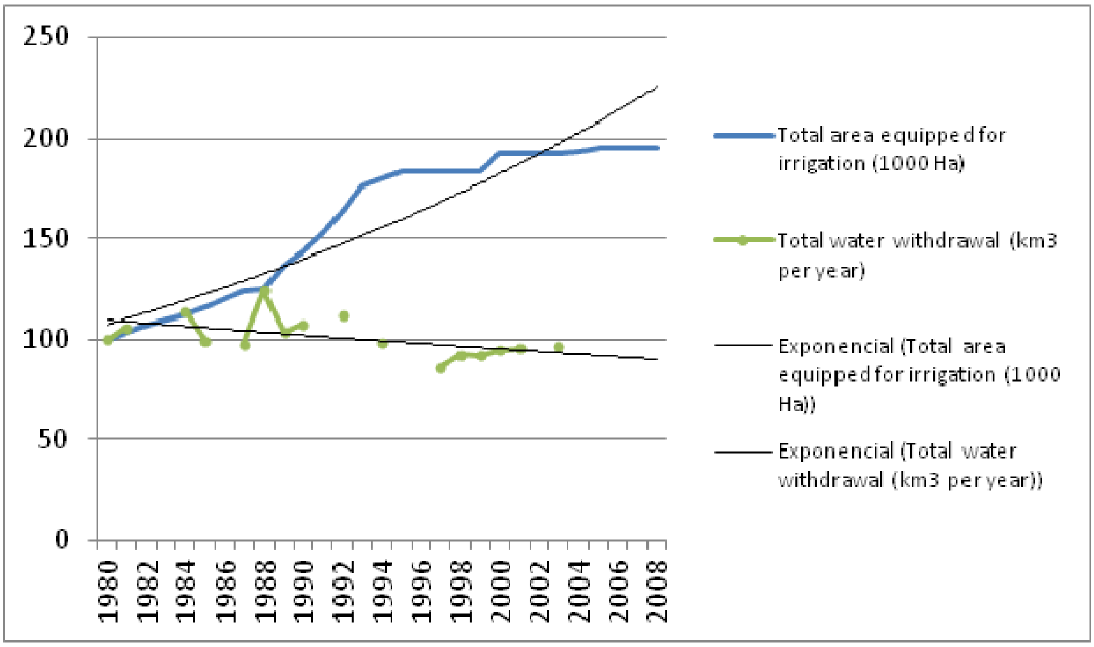


Figure 42. France: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.13 Greece

Figure 43. Greece: Population and water withdrawal trends in percentages (1980 = 100%)

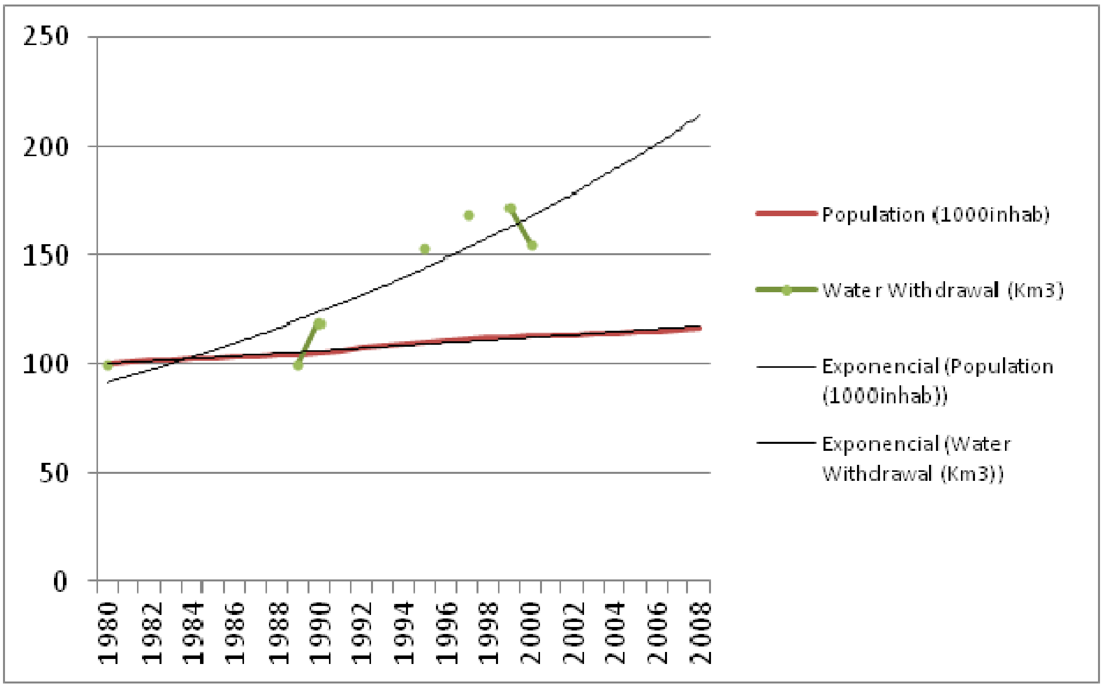


Figure 44. Greece: GDP and water withdrawal trends in percentages (1980 = 100%)

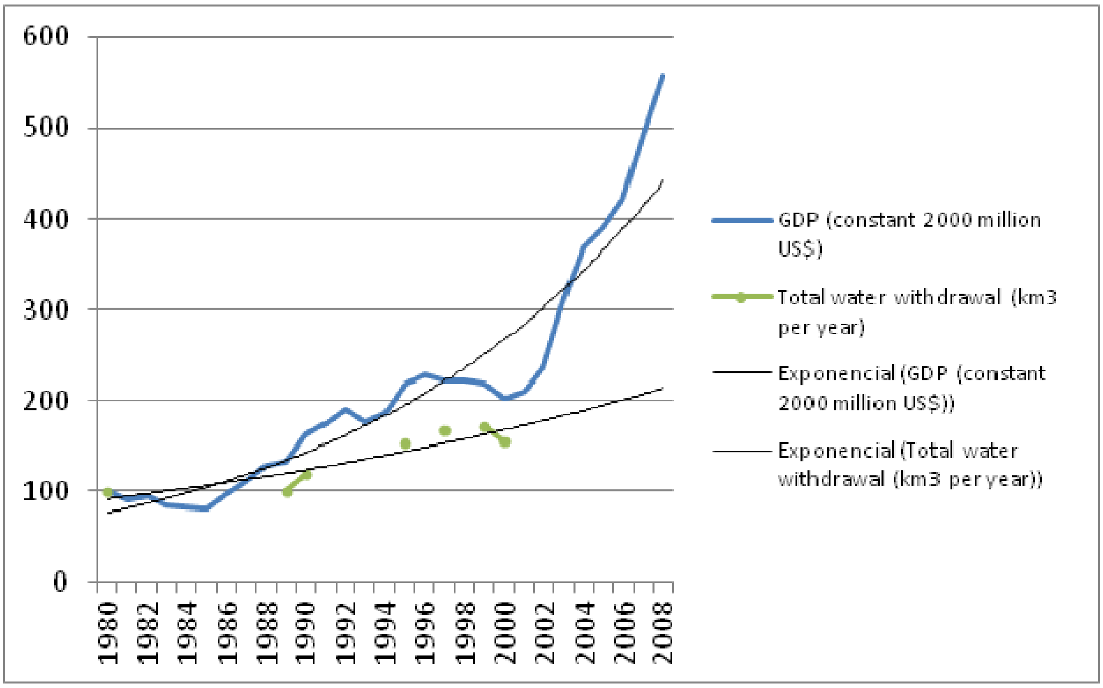
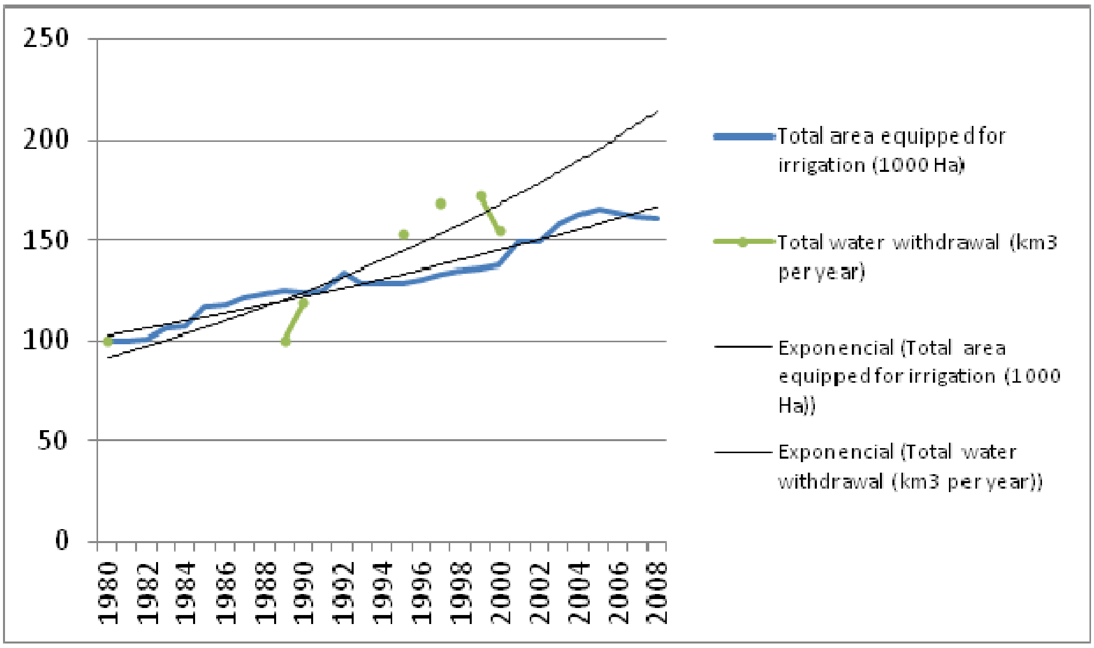


Figure 45. Greece: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.14 Italy

Figure 46. Italy: Population and water withdrawal trends in percentages (1980 = 100%)

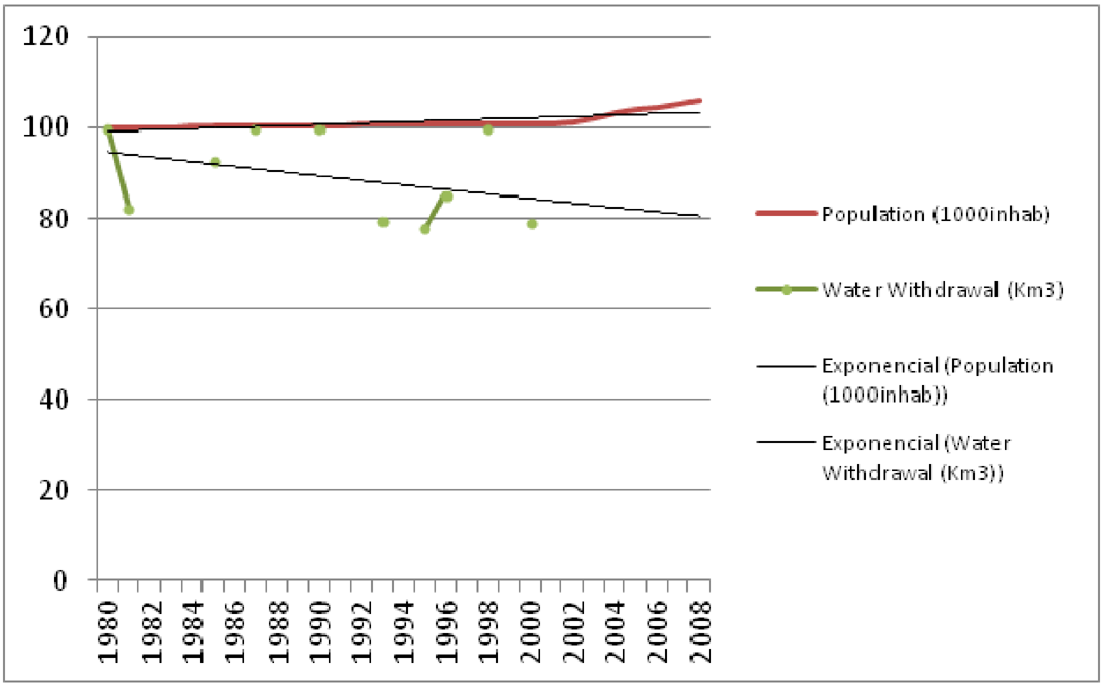


Figure 47. Italy: GDP and water withdrawal trends in percentages (1980 = 100%)

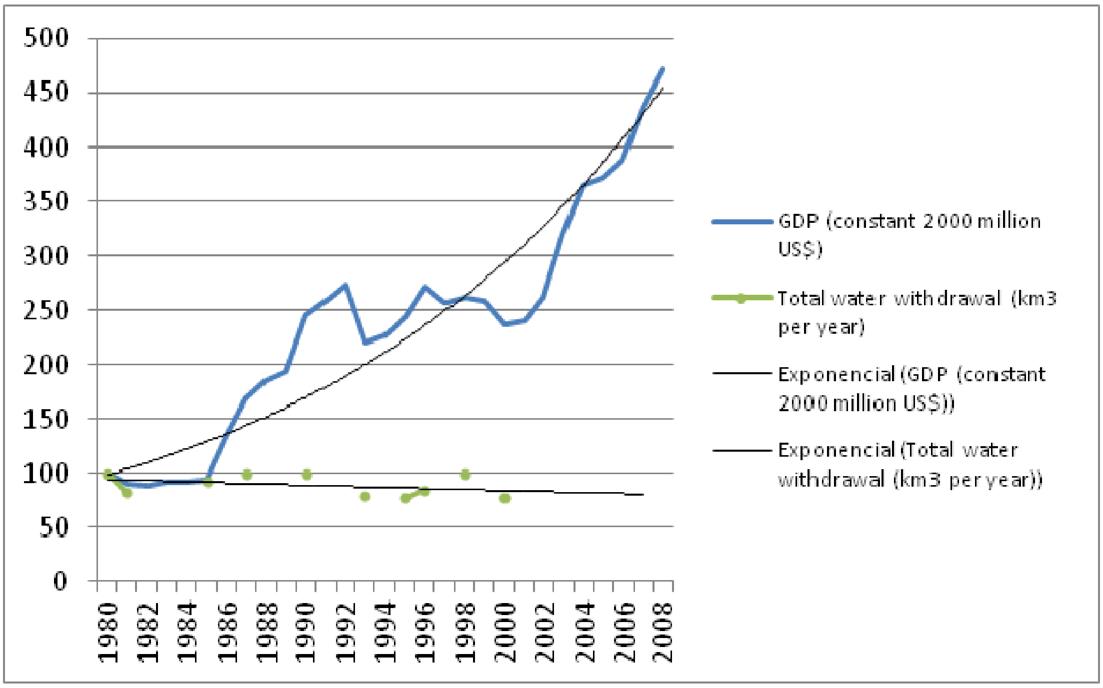
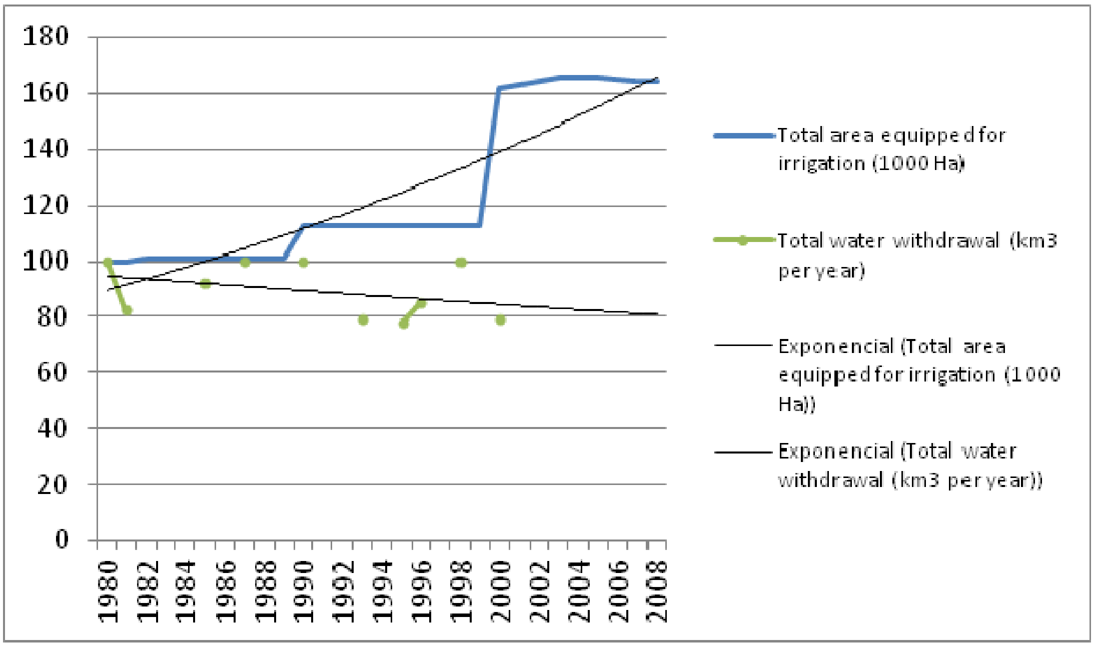


Figure 48. Italy: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



3.2.15 Spain

Figure 49. Spain: Population and water withdrawal trends in percentages (1980 = 100%)

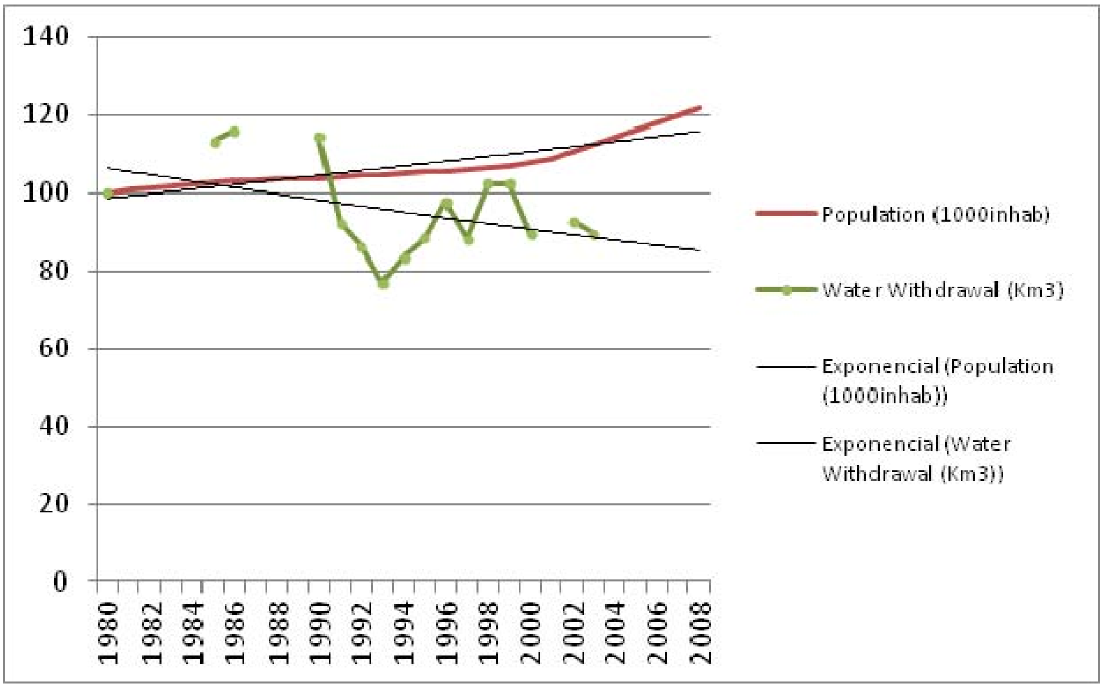


Figure 50. Spain: GDP and water withdrawal trends in percentages (1980 = 100%)

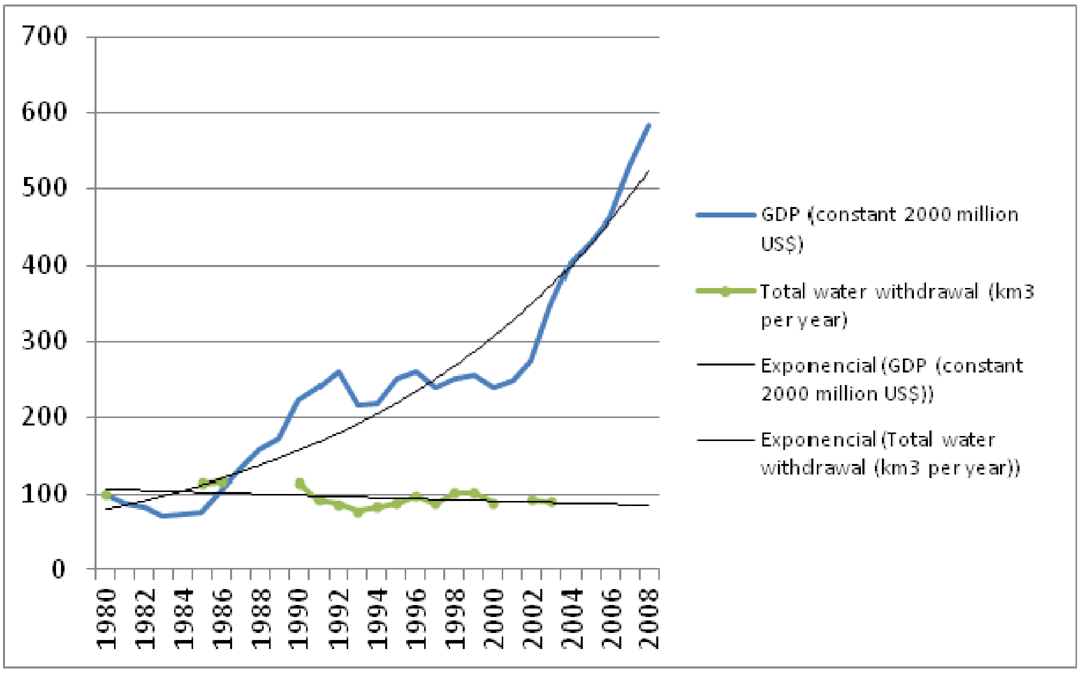
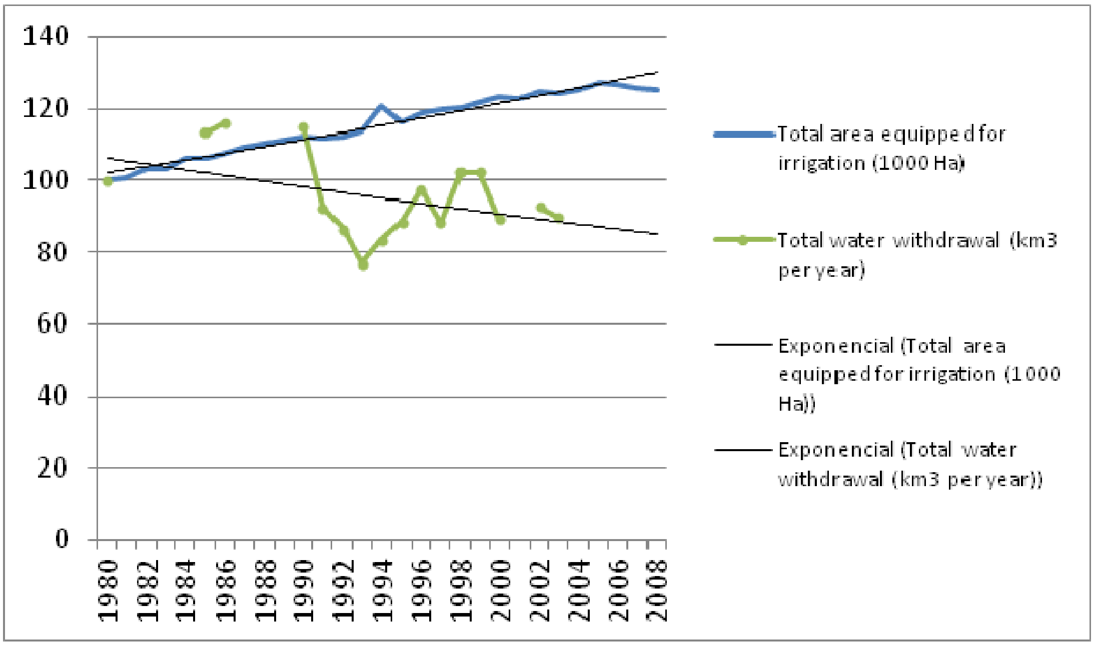


Figure 51. Spain: Irrigation area and water withdrawal trends in percentages (1980 = 100%)



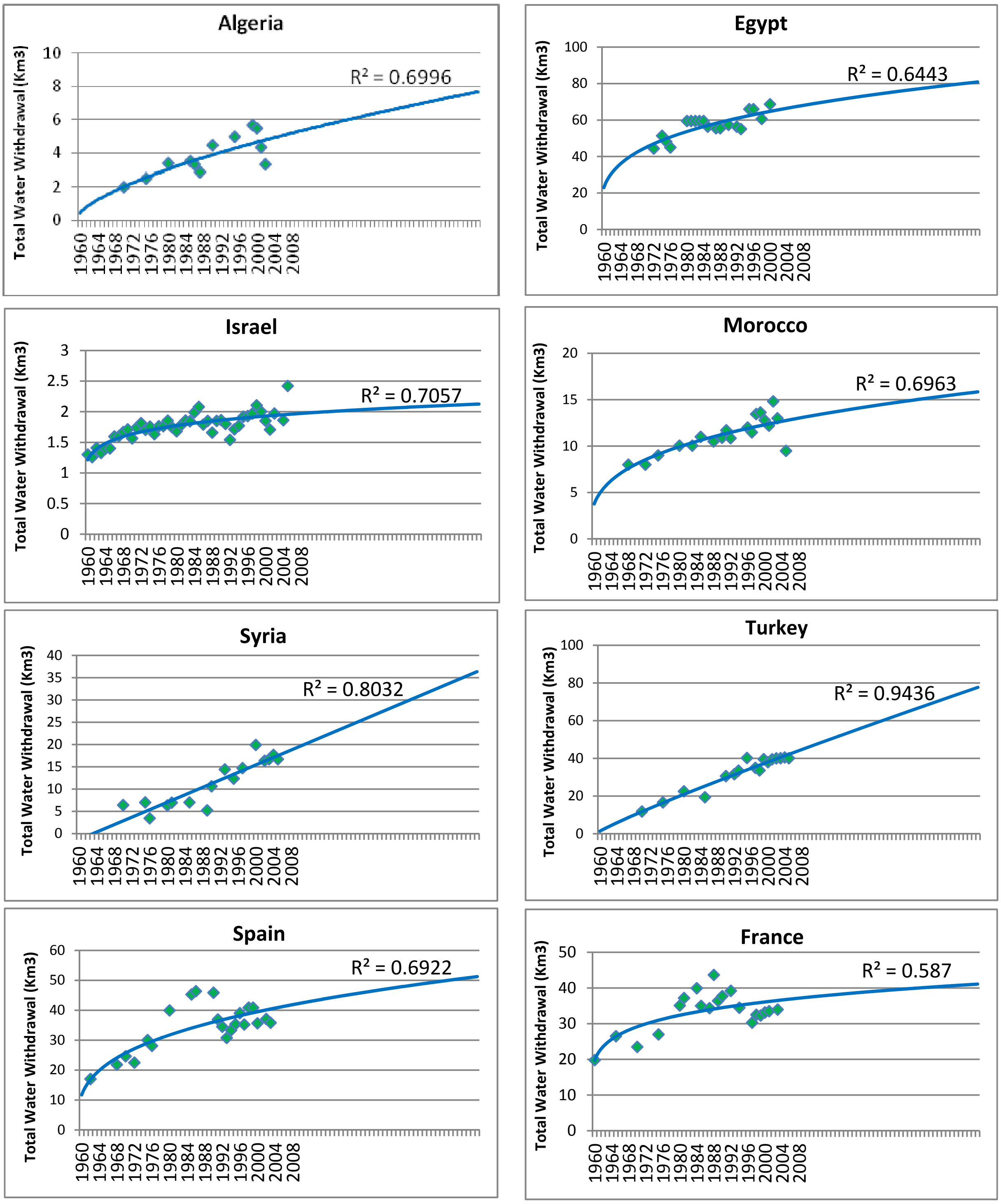
3.3 Trends in water withdrawal

At this stage of analysis, some insights can be gathered about the future of water withdrawal in Mediterranean countries from simple extrapolations. Based on past trends, we selected the trend line that better fitted the time series we have for each country (defined by linear, exponential, logarithmical, polynomial and other functions) and projected it into the future. Figure 52 presents the future trends in water demand up to 2050. While some countries like France or Israel will experience smaller increases in water consumption (around 10–15%), other countries like Syria or Turkey could

almost double their consumption from the present to 2050. Algeria, Morocco and Spain would be in-between those two groups, experiencing increases of about 25–30% for the entire period to 2050.

These projections are just preliminary, simple extrapolations meant to give an overall general idea of the potential, future water withdrawals in order to illustrate, *ceteris paribus*, variations across selected countries. They do not consider the effects of technological changes or the increasing costs of water abstraction in the future.

Figure 52. Trends in water withdrawal for the 11 SEMCs

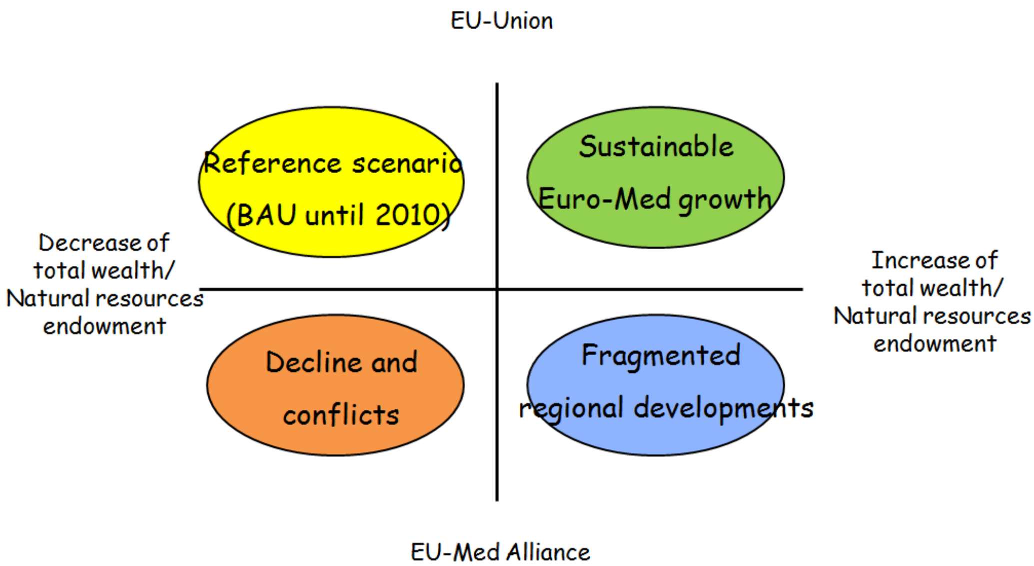


4. Scenario development for foresight in the Mediterranean region

4.1 MEDPRO scenarios of cooperation and development in the Euro-Mediterranean region

After analysing the situation in the 11 SEMCs, the next step is the selection of future socio-economic scenarios for the area, with special attention given to the agricultural sector and water withdrawal. The starting point for scenario selection is the scenarios developed by MEDPRO WP9 (deliverable 9.1), which explores different possibilities for the future development of the Euro-Mediterranean region. Four scenarios are defined, based on the development of two main aspects: the level of cooperation between the EU and SEMCs and the change in total wealth. Figure 53 depicts the four scenarios along two axes, and their position in relation to these two aspects.

Figure 53. Future socio-economic scenarios developed for the MEDPRO project



Sources: Sessa (2011); Ayadi and Sessa (2011).

The location of the MEDPRO scenarios with respect to cooperation and change in wealth carries certain implications in terms of conflicts, the use of resources, the role of institutions, etc., which are summarised in Table 2.

Table 2. Summary of the main features of the MEDPRO socio-economic scenarios

1) Reference Scenario (BAU until year 2010)	**2) Sustainable Euro–Mediterranean Growth**
• Partial EU–Mediterranean cooperation and limited cooperation among Mediterranean countries • Unsustainable growth → towards depletion of natural, human and social capital	• Decrease of conflicts; EU–Mediterranean integration, with a common market, strategies and institutions • Cooperation, research, innovation → sustainable development
4) Decline and Conflicts	**3) Fragmented Regional Developments**
• Increase of conflicts in the region; the Mediterranean sea becomes a border between Christian and Islamic worlds • Failure to achieve sustainable development leads to unmanageable resource scarcity	• Alliance of EU with Mediterranean countries: two blocs in cooperation • Peace and stability • Important role of institutions and laws

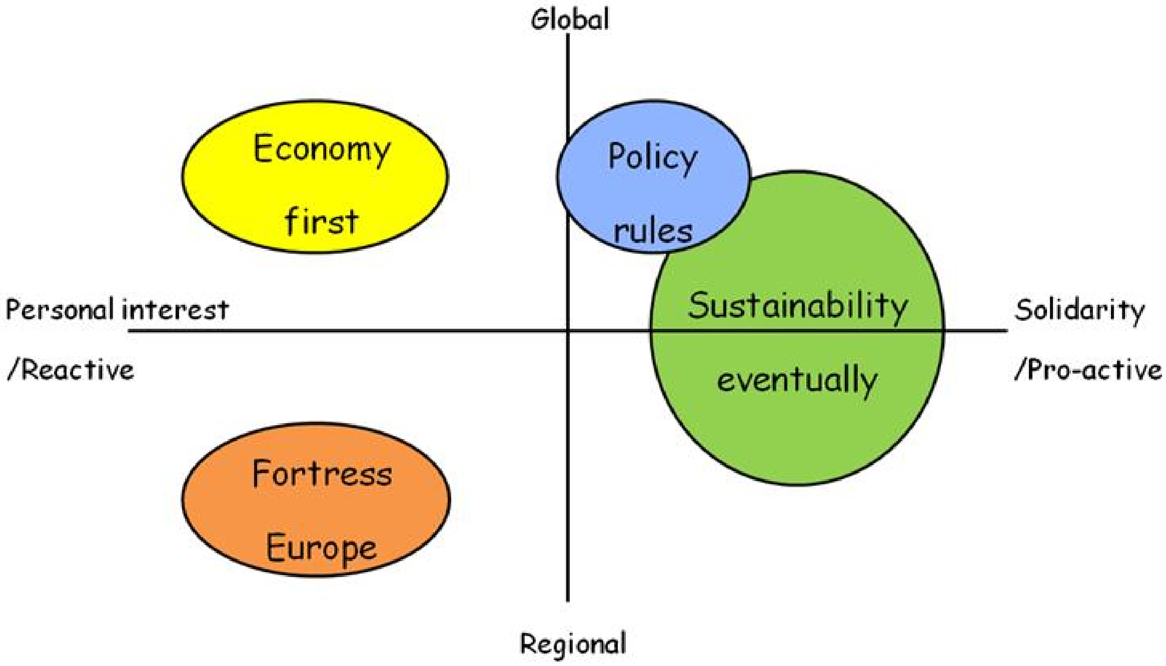
Sources: Own elaboration based on Sessa (2011) and Ayadi and Sessa (2011).

Although the MEDPRO scenarios serve as the basis for exploring the future of water and agriculture in the region, these scenarios do not give much detail about water use. Consequently, we have selected other scenarios to complement the visions developed in the MEDPRO project.

4.2 Future water scenarios: The SCENES project experience

After analysis of the MEDPRO scenarios, we have gone a step further and compared them with another set of scenarios built in the framework of the SCENES project,[4] which were specifically designed for water futures in Europe and neighbouring countries, including those in the Middle East and North Africa. These scenarios build on the Global Environmental Outlook (GEO-4) scenarios (UNEP, 2007) and are the result of interaction between an intensive stakeholder process and a complex modelling process. They seek to reflect possible, future socio-economic developments in Europe and neighbouring countries, with a special focus on water. In this case, the scenarios are located in relation to two axes representing the global/regional dimensions and proactive/reactive behaviour of society. Figure 54 shows the four resulting scenarios and their location along these two axes.

Figure 54. Future scenarios developed in the SCENES project



Sources: Own elaboration based on Kok and Alcamo (2007); Kok et al. (2008).

A summary of the main features of each scenario is shown in Table 3. For each scenario we include the main objective of society, the speed of economic and technological developments, the trends in population growth, the trends in market developments, the state of the environment and climate change.

[4] "Water Scenarios for Europe and for Neighbouring States" (SCENES), European Commission, op. cit.

Table 3. Summary of the main features of the SCENES scenarios, related to water futures

	Economy first	**Fortress Europe**	**Policy rules**	**Sustainability eventually**
Main objective	Economic growth	Security	Economy and environment	Local sustainability
Economic and technological development	Very rapid	Slow	Very rapid	Medium
Population growth	Low	High	Low	Medium
Market	Globalisation	Barriers	Globalisation	Barriers
State of the environment	Very degraded	Degraded	Good	Good
Climate change	Accelerated	Rapidly accelerated	Decreasing	Eventually overcome

Sources: Own elaboration based on Kok and Alcamo (2007); Kok et al. (2008).

Below are more details about the socio-economic developments taken into account in these future scenarios:

1) Economy first

- increase of CO_2 emissions, leading to severe climate change;
- further intensification of agriculture, and as a consequence, an increase of water pollution and a decrease of bio-diversity;
- migrations and urbanisation;
- availability of new technologies, but low motivation to adopt them;

2) Sustainability eventually

- development of clean energy and strategies to mitigate climate change, which implies moderate climate change;
- increase in public participation in northern Mediterranean countries; ruralisation;
- extensification of agriculture, organic production; improvement of the environmental status;
- investments in water-saving technologies;

3) Policy rules

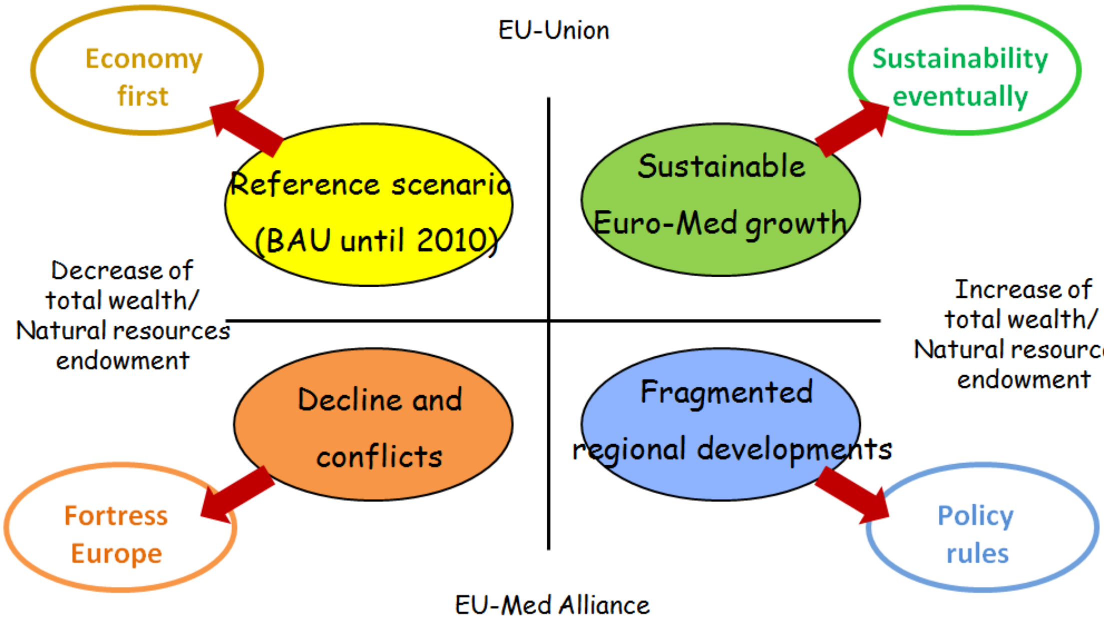
- important negative effects of climate change, which forces policy enforcement in the long term;
- increasing population in the southern Mediterranean, abandonment of rural areas;
- decrease of exports in the southern Mediterranean and pressures from environmental regulations, leading to bilateral agreements;
- EU support of water-saving and recycling technologies;

4) Fortress Europe

- important negative effects of climate change, which include migration from water-poor to water-rich countries in the EU; Frontex strengthens;
- increase of crises (energy, financial and climatic), conflicts and terrorism;
- agricultural intensification, which increases pressure on natural resources; deterioration of water quality; and
- slow development of technology.

Comparing the MEDPRO with the SCENES scenarios, we can deduce equivalence between them, which can help us to add more detail on water withdrawal in the framework of MEDPRO research. Figure 55 shows the correspondence between the two sets of scenarios.

Figure 55. Correspondence between the MEDPRO and the SCENES scenarios



Source: Own elaboration based on the MEDPRO and SCENES scenarios.

Concerning our research related to water and the agricultural sector, the relevant axis is the horizontal one, which primarily considers economic and environmental factors and not explicit political processes. The potential impacts of climate change are estimated for a single climate-change scenario (SRES-A2) according to the *Special Report on Emissions Scenarios* (SRES) by the Intergovernmental Panel on Climate Change (IPCC) (2000 and 2012). Our study solely concerns the Mediterranean region and thus the effects of climate change are treated as being uniform across the different MEDPRO scenarios.

4.3 Application of the MEDPRO scenarios: Selection of drivers and indicators for water and agriculture

For analysing the impacts of future scenarios on water and agriculture, we have selected the main drivers of water use and a set of indicators to show the state of the resource, and explained the qualitative changes in all of them for each scenario. The selected drivers and indicators are consistent with the set of explanatory variables for water withdrawal found in econometric analysis (e.g. water availability, population, GDP and farm income – see Varela-Ortega et al., 2011). Specifically, we have identified the following factors:

Drivers

- climate change (changes in temperature, precipitation, CO_2), water availability, technology and infrastructure, agricultural trade, population and GDP; and

Indicators

- crop yields, crop water requirements, cropping patterns, agricultural income, water availability, water use and unmet demand.

To obtain a clear overview of the situation for water-related variables in the four MEDPRO scenarios, Table 4 presents the most relevant changes experienced by the main drivers and indicators of water resources by 2030, compared with the present situation. Table 4 shows the four MEDPRO storylines, concentrating on the water-relevant aspects.

Table 4. Application of the four MEDPRO storylines to water and the agricultural sector

	Reference (QI)	**Sustainable Development & Enhanced Cooperation (QII)**	**Sustainable Development & Fragmented Cooperation (QIII)**	**Unsustainable Development & Failed Cooperation (QIV)**
1) EU–MED union	Integration, failure	Integration, success	Collaboration, success	Collaboration, failure
2) Natural resources endowment	The state of the environment declines, medium environmental awareness, difficult governance	Very good state of the environment, critical and strong increase in environmental awareness, bottom-up initiatives	Good state of the environment, later increases in environmental awareness, governance is difficult	The state of the environment declines greatly, low environmental awareness, top-bottom initiatives
3) Population	High increase	Medium increase	High increase	Medium-low increase
4) GDP	Medium increase	High increase	High increase	Low increase
5) Surface irrigation	Medium increase (but in some countries, such as Egypt or Libya, limited by the lack of water)	Medium-low increase	Medium-low increase	Medium increase (but in some countries, such as Egypt or Libya, limited by the lack of water)
6) Agricultural trade	Medium-low increase	Medium-high increase	Medium increase	Medium increase
7) Climate change impacts	Water supply decreases due to a decrease in rainfall	Water supply decreases due to a decrease in rainfall	Water supply decreases due to a decrease in rainfall	Water supply decreases due to a decrease in rainfall
8) Net water withdrawals (only considering population, GDP, surface irrigation trends)	Medium increase	Medium-high increase	Medium-high increase	Medium-low increase
9) Water policies (water pricing and quotas, which affect demand)	Water Framework Directive (WFD) fails, water pricing and water quotas are well implemented, but this is not enough to attain the Good Ecological Status (GES) of all water bodies	WFD succeeds (a good combination of water prices and water quotas, watershed restoration)	National policies inspired by WFD objectives, following the Strategy for Water in the Mediterranean; difficult implementation	Reactive measures (basically, emergency plans, adoption of insurance schemes); focused on security
10) Technical water-use efficiency (on farm and off farm)	No change (only renewing obsolete technology)	Medium increase (installing water-saving technologies and practices)	Medium increase (installing water-saving technologies and practices)	Decrease (technologies outdated)
11) Water infrastructure (related to the increase of water supply)	Strong increase in reservoir storage (development of big and small dams); reuse and desalination capacity	Small increase in water reuse and desalination capacity	Development of small dams, small increase in water reuse and desalination capacity	Major development of big dams, strong increase in water reuse and desalination capacity

5. Econometric assessment of the determinants of water consumption in Mediterranean countries

The Mediterranean region is experiencing rapid and profound changes in political, social and economic conditions. These important changes are framed in a context of increasing environmental and water management challenges with implications for sustainable development.

The Mediterranean region is expected to be one of the most adversely affected by climate change in the world. Significant increases in temperature, decreases in precipitation and increased frequency of extreme events are likely to worsen the already existing problems of water scarcity. At the same time, pressures on water resources are expected to increase, leading to an estimated increase in water demand of around 25% (Benoit and Comeau, 2005).

Yet, while climate change impacts and risk projections are clear for some regions, uncertainty plays a key role in the Mediterranean countries, as different models and scenarios show quite different outcomes and levels of risk.

In this context, improved knowledge of the determinants and key components of water consumption is crucial to support a more sound development of future scenarios, to better target current and future policies, and to improve preparedness and adaptation capacity under uncertainty.

Several authors (Margat, 2004; Benoit and Comeau, 2005) highlight population, irrigation and tourism as the main elements shaping water consumption in the Mediterranean region. Other authors (Immerzeel et al., 2011) base their estimations of future water consumption only on population, GDP trends and agricultural development.

Given the remarkable differences among sub-regions in the Mediterranean basin, we have performed an econometric assessment of water consumption to identify the principle elements shaping it in the sub-regions.

5.1 Analysis of key drivers of water consumption in the SEMCs and northern Mediterranean countries

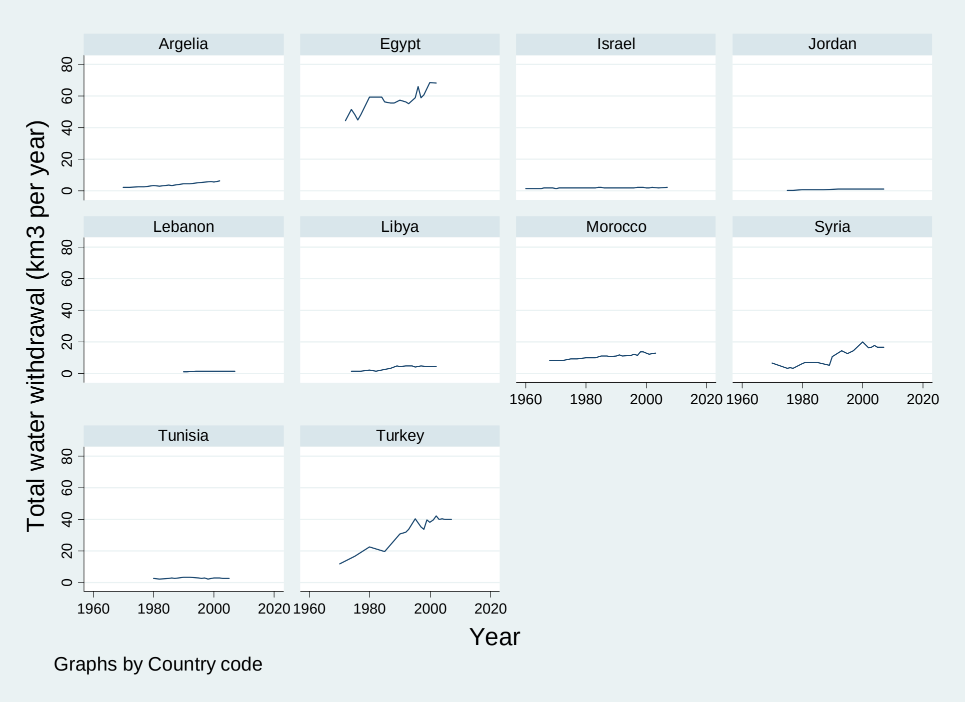
In the econometric assessment we have used the generalised least-squares method to estimate the parameters determining water consumption in the 11 SEMCs, in a linear regression model assuming errors are serially correlated. Specifically, the errors are assumed to follow a first-order autoregressive process (AR1).

For this assessment we have used a panel dataset for 15 countries (all 11 SEMCs plus 4 northern Mediterranean countries (NMCs) of the EU – namely France, Greece, Italy and Spain) over 26 years (1980–2005) extracted from the general database described in section 2.

With water being a key issue for future socio-economic development and sustainability, the lack of data (in terms of quantity and quality) related to water withdrawals, water consumption and its distribution among sectors is contradictory to expectations. This has been the main limitation of this analysis.

The main variable we have used for the study is annual water withdrawals per country (Figure 56). Data for this variable have been collected from different public databases, such as AQUASTAT (FAO) and the World Development Indicators database (World Bank), and from a previous compilation by Plan Bleu for the Mediterranean (Margat, 2004).

Figure 56. Water withdrawal by country



Following several studies in the literature (Benoit and Comeau, 2005 and Bruinsma, 2009 among others), we have based the analysis on the relation between water withdrawals and a set of key indicators, namely, population, economic development, trade, irrigation and technology.

The first hypothesis tested is that water withdrawals do not behave similarly in the NMCs and the SEMCs, and are not determined equally by the same types of variables, such as GDP, population, irrigated area and technology. This stems from the marked differences that exist across countries in the region related to water availability, socio-economic context and structural characteristics.

$$WWithdr = \alpha + \beta_1 \cdot north + \beta_2 \cdot GDP + \beta_3 \cdot pop + \beta_4 \cdot irrig + \varepsilon \quad (1)$$

Adjusted R-squared = 0.8179.

Table 5. Results of the econometric analysis for water withdrawals by country group (NMCs and SEMCs)

WWithdr	**Water withdrawals**	**Coef.**	**Std. err.**	**T**
north***	Dummy north countries (million m^3)	11.17818	3.204796	3.49
GDP***	Gross domestic product (million $)	-0.0000133	$4.62 \cdot 10^{-6}$	-2.87
pop***	Total population (million inhab.	0.8362934	0.0909168	9.20
irrig	Area equipped for irrigation (million ha)	0.0008155	0.001338	0.61
constant		-4.914552	1.304327	-3.77

*** refer to the independent variables being significant at the 99% level.

Therefore, once we assessed the significance of the dummy variable *north* (99% significance level), we estimated a new equation (2) in which we tested the significance of the same variables as in equation 1 specified for each sub-region (NMCs and SEMCs). In this case, each explanatory variable represented each of the two sub-regions considered and therefore both were multiplied by a dummy

variable corresponding to the two areas under study: the 4 northern Mediterranean countries (France, Greece, Italy and Spain) and the 11 southern and eastern Mediterranean countries.

$$WWithdr = \propto + \beta_1 \cdot north \cdot GDP + \beta_2 \cdot south \cdot GDP + \beta_3 \cdot north \cdot pop + \beta_4 \cdot south \cdot pop + \beta_5 \cdot north \cdot irrig + \beta_6 \cdot south \cdot irrig + \beta_7 \cdot agr\_mach + \varepsilon \quad (2)$$

Adjusted R-squared = 0.8698.

This new estimation improves the R^2 of the model, better explaining variations in water withdrawal.

The results show that irrigation is not a key variable in the NMCs, which could be explained by the irrigated area already being quite stable (Table 6). This characteristic stems from two factors: on the one side, from the environmental protection requirements of the EU, which are at the core of water and agricultural policies; and on the other side, from the development of water-saving irrigation technologies, which has permitted the expansion of irrigated lands with almost no increase in overall water consumption. This latter point has been extensively discussed in countries like Spain, where improvements in irrigation technology have not resulted in water savings in some of the water-scarce areas. In some of these areas, modern irrigation technologies have led to increases in irrigated area while keeping water use constant instead of reducing it.

Table 6. Results of the econometric analysis for water withdrawals by country group (NMCs and SEMCs) for each explanatory variable

WWithdr	**Water withdrawals (Km^3)**	**Coef.**	**Std. err.**	**t**
north·GDP***	North countries – GDP (million $)	-0.0000335	$7.90 \cdot 10^{-6}$	-4.24
south·GDP***	South-east countries – GDP (million $)	-0.0001344	0.0000202	-6.65
north·pop***	North countries – Total population (million cap.)	1.188485	0.1831273	6.49
south·pop***	South-east countries – Total population (million inhab.)	0.8104953	0.1001324	8.09
north·irrig	North countries – Area equipped for irrigation (million ha)	0.0018629	0.0015124	1.23
south·irrig***	South-east countries – Area equipped for irrigation (million ha)	0.0051968	0.0018459	2.82
agr_mach***	Agricultural machinery	0.0096485	0.0022732	4.24
constant		-5.961675	1.254163	-4.75

*** refer to the independent variables being significant at the 99% level.

The variable *population*, for both the NMCs and the SEMCs, is 99% significant and positive as expected. Yet, GDP is a significant negative variable, implying that the richer the country the less water it consumes. The relationship between the evolution of GDP and environmental indicators has been widely discussed in the literature, pointing out this apparent contradiction. In fact, a higher income level (GDP) results in more water consumption, but at the same time it is also expected that economic development must bring along improved technologies that would reduce water consumption.

The environmental Kuznets curve (EKC) relates indicators of environmental degradation to income in a way that the natural logarithm of the environmental indicator is a quadratic function of the logarithm of income. Several authors (Perman and Stern, 2003; Stern, 2003) argue that this EKC does not exist when proper econometric methods are used. According to Stern (2003), "most indicators of environmental degradation are monotonically rising in income though the 'income elasticity' is less

than one and is not a simple function of income alone". Yet EKCs usually refer to the production of pollution, and in the case of a natural resource like water, there are some specific characteristics that must be considered, such as the limited availability of the resource and the economic cost involved in the resource exploitation (Katz, 2008).

In line with this reasoning, we tested a new equation that tries to explain the natural logarithm of water withdrawal as a function of the natural logarithm of GDP and the variables included in equation (2) *NorthPOP*, *SouthPOP*, *NorthIRRIG*, *SouthIRRIG* and *Agric_machinery*.

$$\mathrm{Ln(WWithdr)} = \propto + \beta_1 \cdot \ln(\mathrm{GDP}) + \beta_2 \cdot \mathrm{north} \cdot \mathrm{pop} + \beta_3 \cdot \mathrm{south} \cdot \mathrm{pop} + \beta_4 \cdot \mathrm{north} \cdot \mathrm{irrig} + \beta_5 \cdot \mathrm{south} \cdot \mathrm{irrig} + \beta_6 \cdot \mathrm{agr}_{\mathrm{mach}} + \varepsilon \quad (3)$$

Adjusted R-squared = 0.7849.

The results of this new estimate (Table 7) show that GDP is a significant explanatory variable for water use with the correct positive sign, suggesting that the natural logarithm of both water withdrawals and GDP are better proxies for measuring water use and economic growth respectively. Population growth is also a significant variable in the two areas in the Mediterranean, with a similar level of significance and impact coefficient for both areas.

Table 7. Results of the econometric analysis for water withdrawals by country group (log variables for the NMCs and SEMCs)

Ln(WWithdr)	**Log Water withdrawals (Km^3)**	**Coef.**	**Std. err.**	**t**
ln(GDP)**	Log GDP (million $)	0.2822782	0.112337	2.51
north·pop***	North countries – Total population (million cap.)	0.029701	0.0106592	2.79
south·pop**	South-east countries – Total population (million inhab.)	0.028129	0.0108973	2.58
north·irrig**	North countries – Area equipped for irrigation (million ha)	0.0003353	0.0001623	2.07
south·irrig*	South-east countries – Area equipped for irrigation (million ha)	0.0003093	0.0001636	1.89
agr_mach**	Agricultural machinery	-0.000522	0.0002537	-2.06
constant		-2.006614	1.054414	-1.90

*** refer to the independent variables being significant at the 99% level.

** refer to the independent variables being significant at the 95% level.

* refer to the independent variables being significant at the 90% level.

5.2 Long-term projections of water use in the Mediterranean countries according to the four MEDPRO scenarios

In this adjustment, a model with fixed effects has been employed, as was done in the previous section. The adjusted equation now includes the trade variables, as follows:

$$\mathrm{Ln(WW)} = \propto + \beta_1 \mathrm{Year} + \beta_2 \mathrm{GDP} + \beta_3 \ln(\mathrm{Population}) + \beta_4 \mathrm{Ln(I.Area^2)} + \beta_5 \mathrm{Imp.Cereal} + \beta_6 \mathrm{Imp.(Veg\ \&\ Fru)} + \beta_{7-16} \mathrm{Dummy}_{1-10} + \varepsilon \quad (4)$$

Adjusted R-squared = 0.98.

Table 8. Results of the econometric analysis for water withdrawals (dummy variables for each country)

Ln(WW)	**Log water withdrawals (Km^3)**	**Coef.**	**Std. err.**	**t**
Year	Technology proxy	-0.01072	0.004938	-2.170
GDP	GDP (million $)	8.93E-07	4.87E-07	1.830
Ln(Population)	Log population (million inhab.)	0.47202	0.230921	2.040
Ln(I.Area^2)	Log square irrigated area (10^3 ha)	0.37894	0.035031	10.820
Imp.Cereal	Imports of cereals (tonnes)	1.80E-07	5.85E-08	3.080
Imp.(Veg&Fru)	Imports of vegetables & fruit (tonnes)	-2.68E-07	1.99E-07	-1.350
Dummy2 (Egypt)	Dummy	0.44449	0.188700	2.360
Dummy3 (Israel)	Dummy	0.67916	0.315098	2.160
Dummy4 (Jordan)	Dummy	1.37476	0.378397	3.630
Dummy5 (Lebanon)	Dummy	1.34488	0.401725	3.350
Dummy6 (Libya)	Dummy	0.74857	0.366288	2.040
Dummy7 (Morocco)	Dummy	0.03110	0.093822	0.330
Dummy8 (Syria)	Dummy	0.54806	0.183348	2.990
Dummy9 (Tunisia)	Dummy	0.27790	0.243100	1.140
Dummy10 (Turkey)	Dummy	-0.38327	0.223519	-1.710
Constant	Constant Term	16.77451	9.195276	1.820

Figure 57 shows the comparison between the observed and fitted values of the dependent variable, water withdrawals, evidencing an overall good adjustment in the country-level sample.

Figure 57. Comparison of the observed and fitted values of water withdrawals across the 11 SEMCs

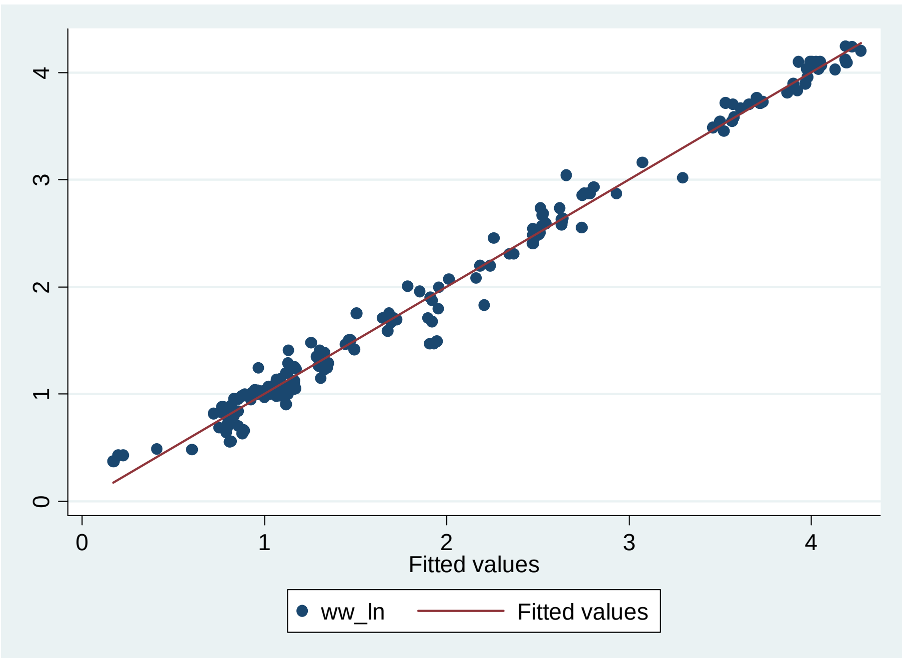
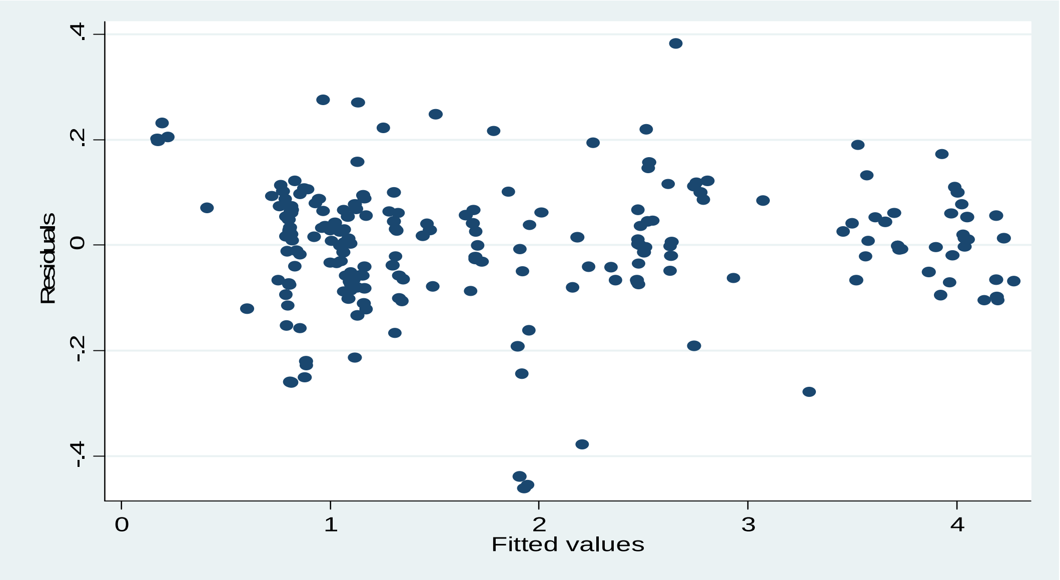


Figure 57 shows that the fixed effects model substantially improves the quality of the adjustment, and evidences a good fit between the observed and fitted values of water withdrawals per country. In addition, the analysis of residuals (Figure 58) shows that there is no evidence of heteroscedasticity or autocorrelation.

Figure 58. Distribution of the residuals of the econometric adjustment of water withdrawal projections



Using the coefficients estimated in the above equation and the projected values of GDP (Paroussos et al., 2012), population (Groenewold et al., 2012), imports of cereals, fruit and vegetables (Belghazi, 2012) and changes in irrigated area (Bruinsma, 2009), water withdrawals have been projected up to 2030. Subsequently, the values obtained for the water withdrawals in the sustainability scenarios have been adjusted using coefficients representing a structural change in the policies and the population's mindset. Structural change implies a decrease in water withdrawal driven by increased awareness and a change in political will, leading to better water conservation and management policies and more sustainable water use. These coefficients were obtained from the water scenarios of the SCENES project, and have been applied progressively starting from 2012 to the projected values in 2030.

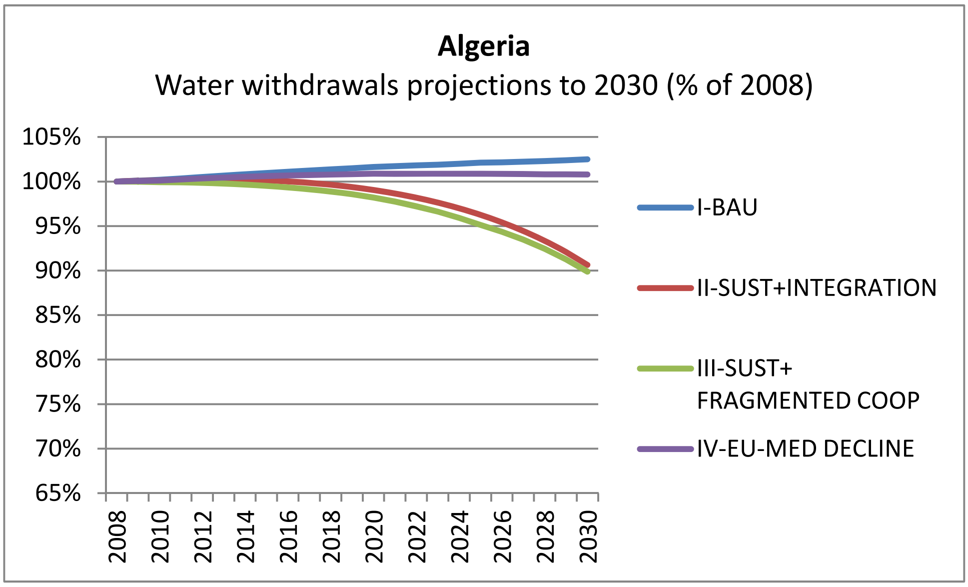
The results obtained, which are depicted graphically and separately for each country, compare the evolution of the scenarios. For all the countries collectively the results are shown in maps illustrating the evolution of the scenarios in the different countries.

The graphs represent percentage changes in the water withdrawal projections with respect to 2008, in the four proposed scenarios.

5.2.1 Algeria

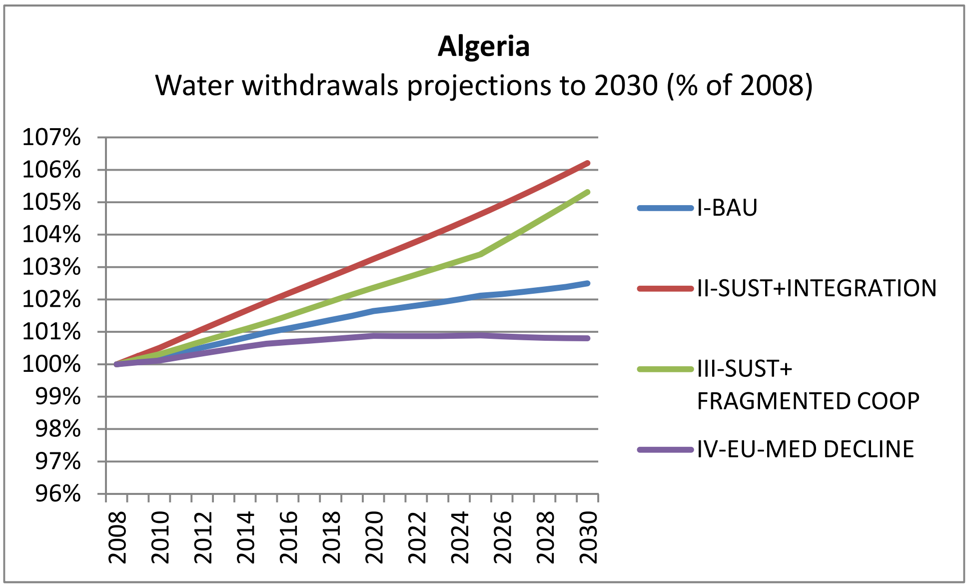
In Figure 59, we can see the differences among the projections of the different scenarios when structural change is taken into consideration. In the scenarios of sustainability, there is a decrease of about 10% in water withdrawal in 2030 with respect to 2008, despite a predicted increase in population and GDP. This result is explained, however, by the better use of resources, as more technological investments are applied. The QI scenario produces a slight increase in water withdrawal in 2030, and in the last scenario, water withdrawals remain practically constant from 2008 onwards.

Figure 59. Long-term projections of water withdrawal in Algeria in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change



The water withdrawal projections in Figure 60 do not take into account structural change to decrease water consumption and thus reflect different results from those illustrated above. As can be noted, water withdrawals increase in all the scenarios, especially in the sustainability scenarios where greater increases in GDP and more technological and infrastructural developments take place in the absence of policies to limit the withdrawals. As a result, growing economies consume more water.

Figure 60. Long-term projections of water withdrawal in Algeria in the four MEDPRO scenarios (% of the reference year 2008) without structural change

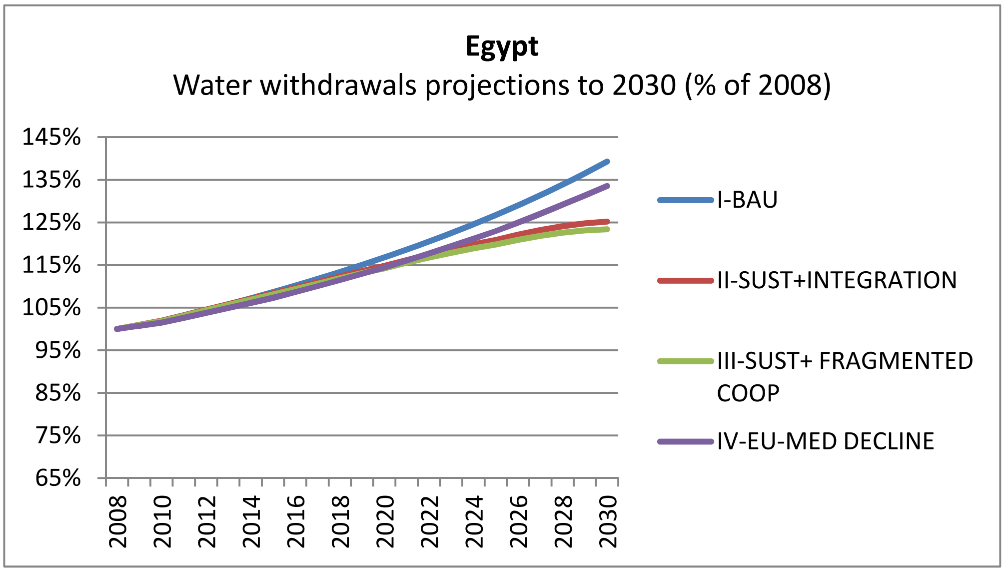


5.2.2 Egypt

In the case of Egypt, the evolution of the trend for water withdrawal is very similar for all the scenarios, but like Algeria, the sustainability scenarios produce lower water withdrawals than the other scenarios do when structural change is incorporated into the calculations (Figure 61). While water increases by about 40% in the QI scenario, it only increases by about 35% in the last scenario because

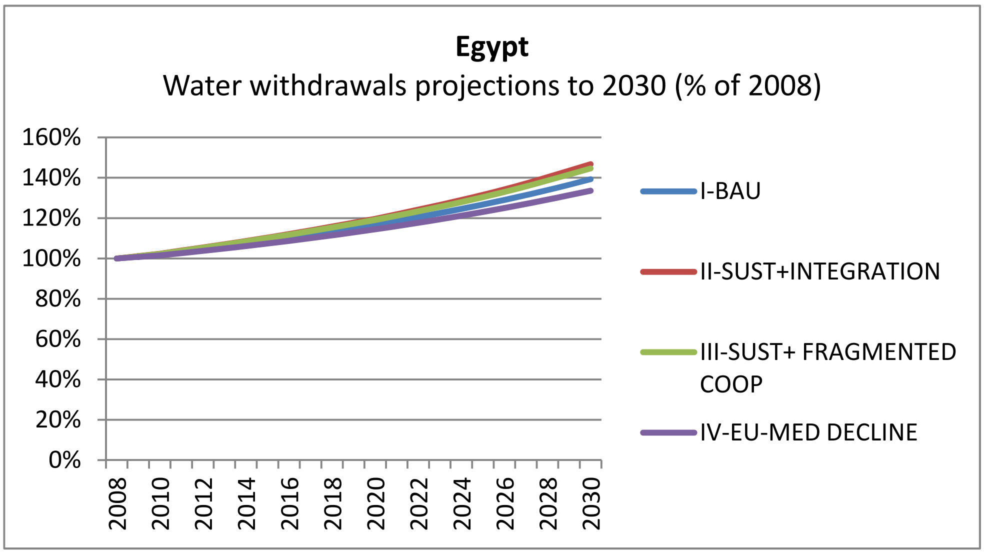
of a lower level of development. In the sustainability scenarios, owing to the expanded use of technology, water withdrawals increase by about 25%.

Figure 61. Long-term projections of water withdrawal in Egypt in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change



When structural change is not taken into account (Figure 62), water withdrawals increase in all the scenarios by 2030; however, water withdrawals in the two sustainability scenarios increase more than the other scenarios – by around 45% with respect to 2008. This result clearly stems from the absence of policies regulating water consumption in combination with economic development.

Figure 62. Long-term projections of water withdrawal in Egypt in the four MEDPRO scenarios (% of the reference year 2008) without structural change

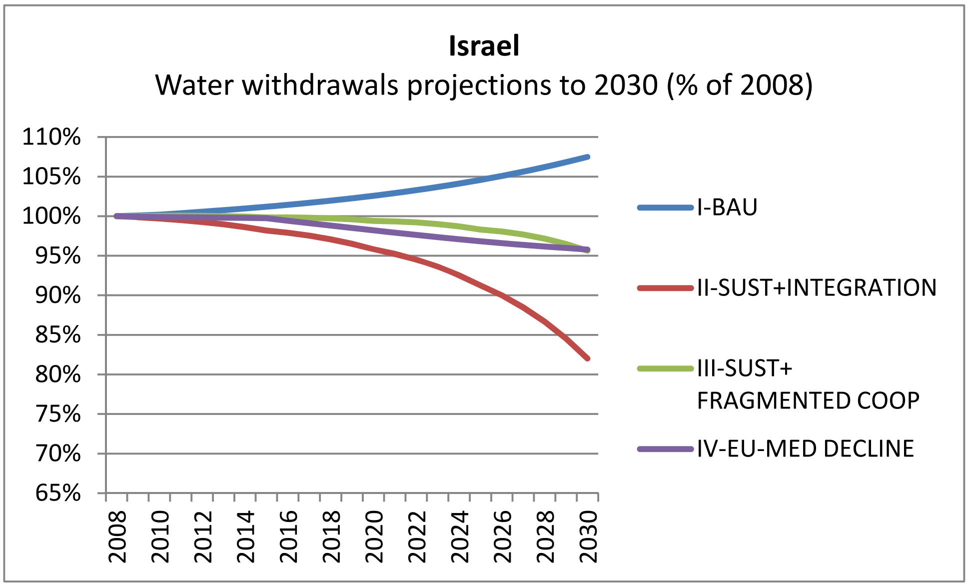


5.2.3 Israel

In Israel, the projected water withdrawal behaviour in the different scenarios is remarkably different under structural change (Figure 63). The only scenario in which an increase occurs is the first one, with a rise of about 6% in 2030. In the more sustainable scenarios, the water withdrawals decrease sharply, falling to just over 80% of the level for 2008. In the last scenario (because of declining levels

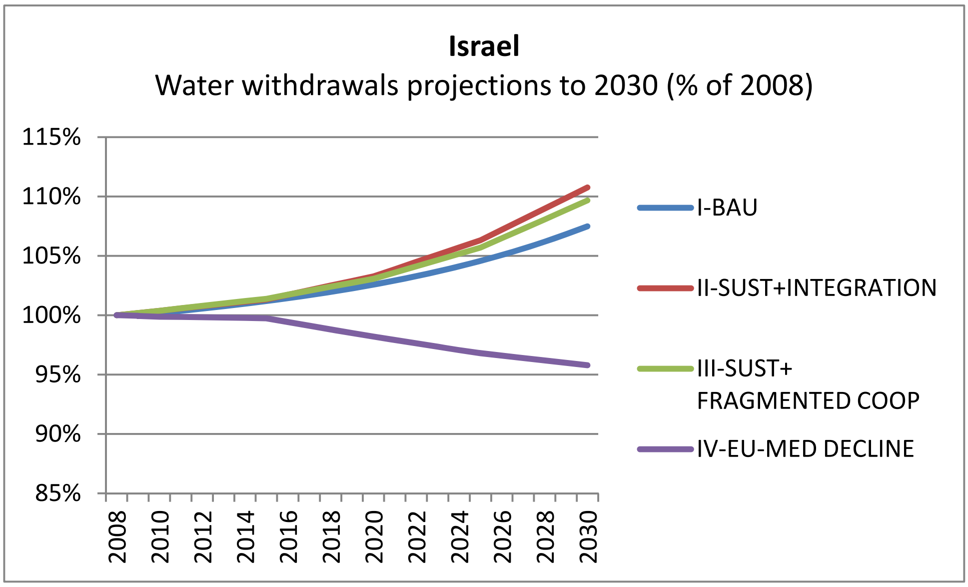
of development) and in the scenario of sustainability with fragmented cooperation (because of better management of water resources), water withdrawals decrease by nearly 5%.

Figure 63. Long-term projections of water withdrawal in Israel in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change



Without structural change, an increase in water withdrawals is witnessed in all the scenarios but the last one (Figure 64). Those of the sustainability scenarios increase as more development calls for more water consumption in the absence of policies. Still, the water withdrawal level in the last scenario decreases by 2030 as much as it would with structural change – by around 4% with respect to 2008. That is also mainly due to a lower level of overall economic growth.

Figure 64. Long-term projections of water withdrawal in Israel in the four MEDPRO scenarios (% of the reference year 2008) without structural change

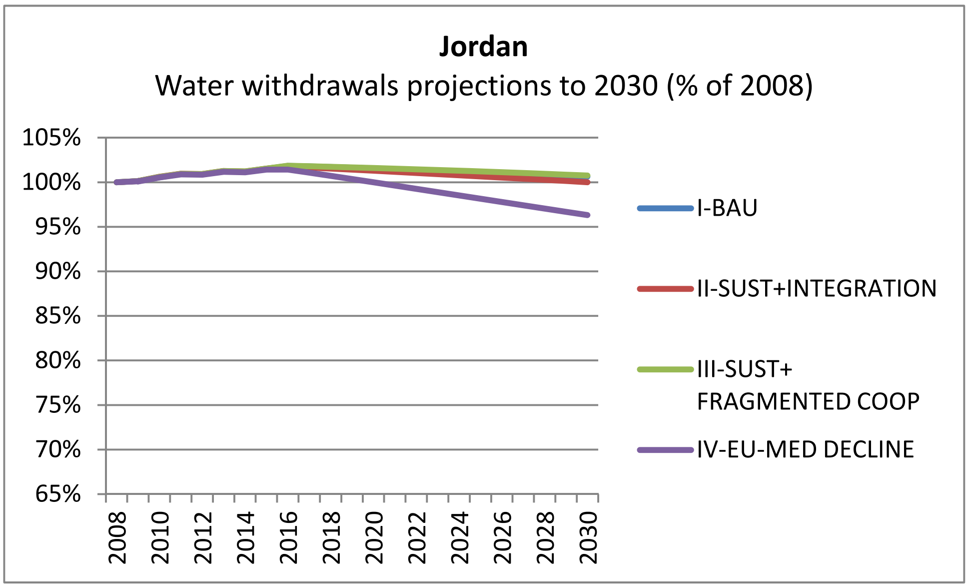


5.2.4 Jordan

Water withdrawals in Jordan reach a turning point in 2016 (Figure 65). In all the scenarios, from 2008 to 2016, water withdrawals are expected to increase by around 1.5% and then decrease to approximately the same initial level as in 2008, except in the last scenario, in which it falls by around

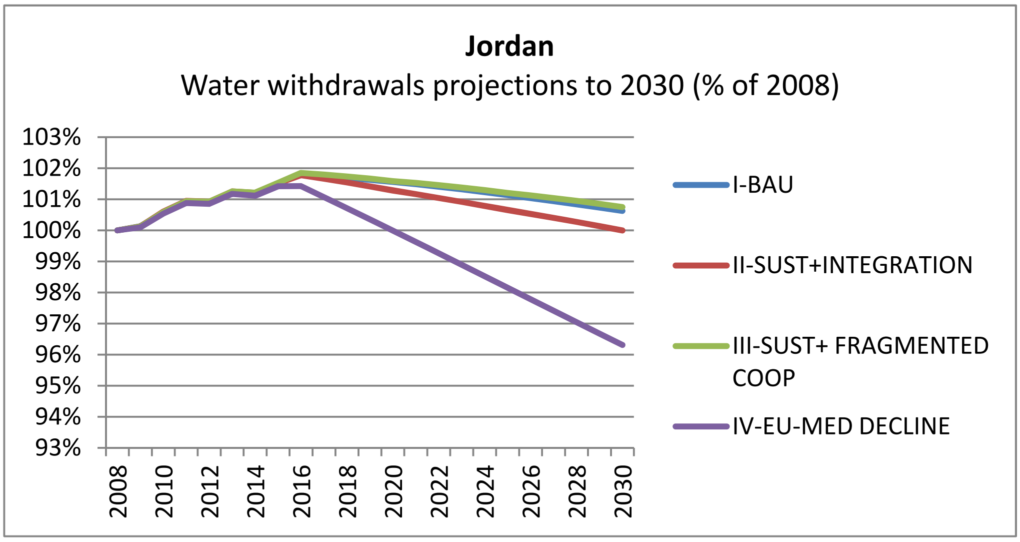
4% with respect to the initial level. This turning point is a result of an assumption that in 2016 the maximum potential for the irrigated area will have been realised and therefore it is considered constant thereafter. It is also worth mentioning that due to the lack of reliable observations of water withdrawals in Jordan, the projections are not as robust as in the case of other countries.

Figure 65. Long-term projections of water withdrawal in Jordan in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change



Moreover, we can see that the projected water withdrawal in 2030 when no structural change is taken into account has the same trend as when structural change is applied (Figure 66). It increases in all the scenarios (as no policy inhibits water consumption), then in 2016 when the maximum potential for the irrigated area has been realised, it decreases gradually through the years in all the scenarios but the last, until it reaches approximately the same level as in 2008. In the last scenario, water withdrawals decrease the most, as no further potential surface is irrigated and there is a lack of development and external cooperation.

Figure 66. Long-term projections of water withdrawal in Jordan in the four MEDPRO scenarios (% of the reference year 2008) without structural change



5.2.5 Lebanon

As in previous projections, simulated trends in the case of Lebanon do not have a good statistical fit; therefore, despite the water withdrawal decrease in all the scenarios when structural change is applied, these results cannot be taken as robust. Setting aside the bad fit, the decrease is consistent for all the scenarios because, as in most countries, the water withdrawals decrease the most in the two sustainability scenarios (Figure 67).

Figure 67. Long-term projections of water withdrawal in Lebanon in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change

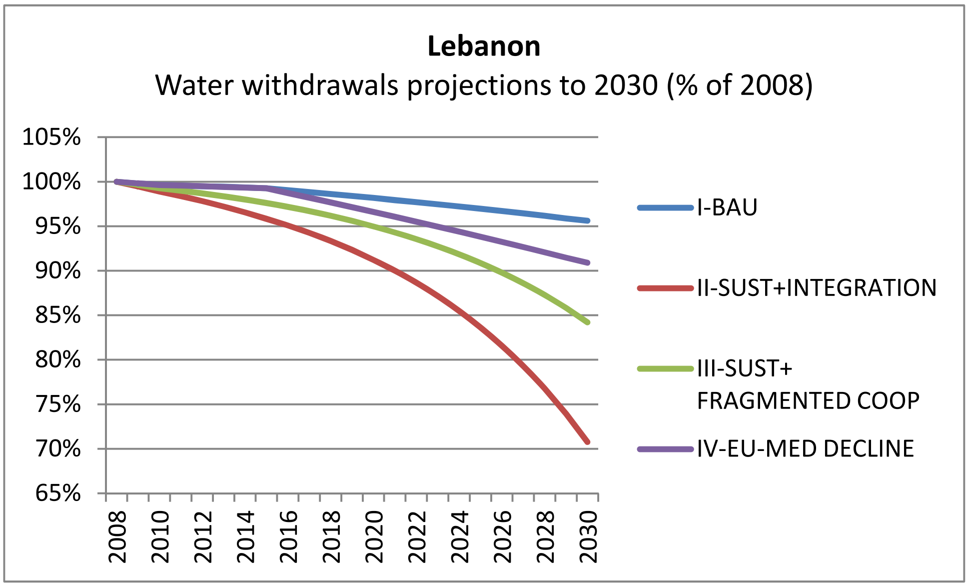
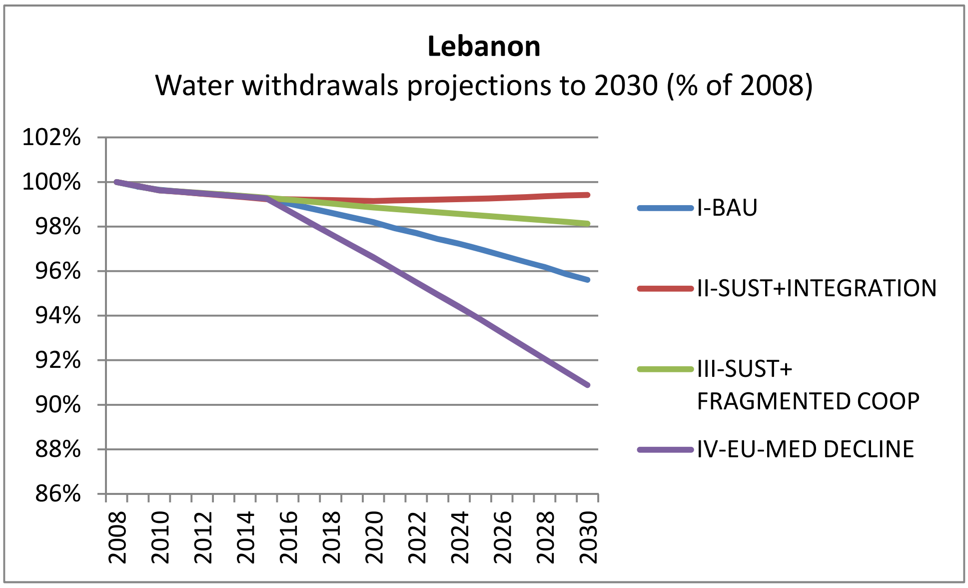


Figure 68 shows that the water withdrawals in Lebanon in 2030 also decrease in all the scenarios when no structural change is applied. Still, we can see that the scenario that experiences the smallest decrease in water withdrawal in 2030 is the Sustainability + Integration scenario, whereas it experiences a larger decrease when structural change is effective. The last scenario records the sharpest decrease in water withdrawal levels, due to a lack of development.

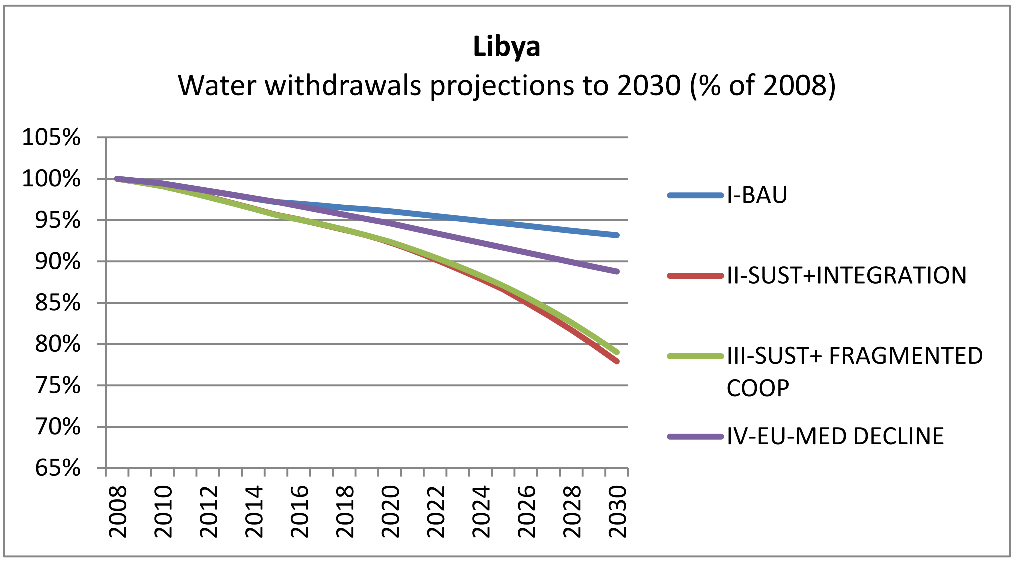
Figure 68. Long-term projections of water withdrawal in Lebanon in the four MEDPRO scenarios (% of the reference year 2008) without gradual structural change



5.2.6 Libya

Like Lebanon, in Libya water withdrawal also decreases when structural change is applied, but with a greater magnitude in the sustainability scenarios – i.e. a decrease of over 20% in 2030 (Figure 69). In the first and last scenarios, water withdrawals decrease by 6% and 12% respectively.

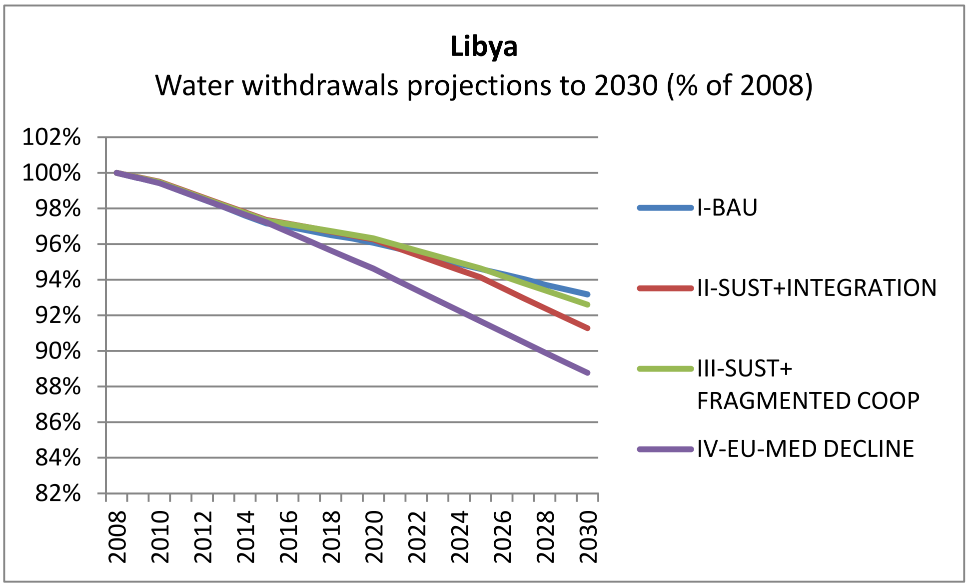
Figure 69. Long-term projections of water withdrawal in Libya in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change



The trend of decreasing water withdrawals continues in all the scenarios, just like the case of Lebanon, when no structural change is applied (Figure 70). In 2030, the last scenario experiences the largest decrease in water withdrawal, like most of the country cases. It is assumed that in both Lebanon and Libya, the weight of technological advancement is larger than the growth of population and GDP, and so efficiency increases and water withdrawals decrease.

It is important to note, however, that because of the paucity of data for both Lebanon and Libya the adjustment of the trend lacks accuracy and thus the results lack precision.

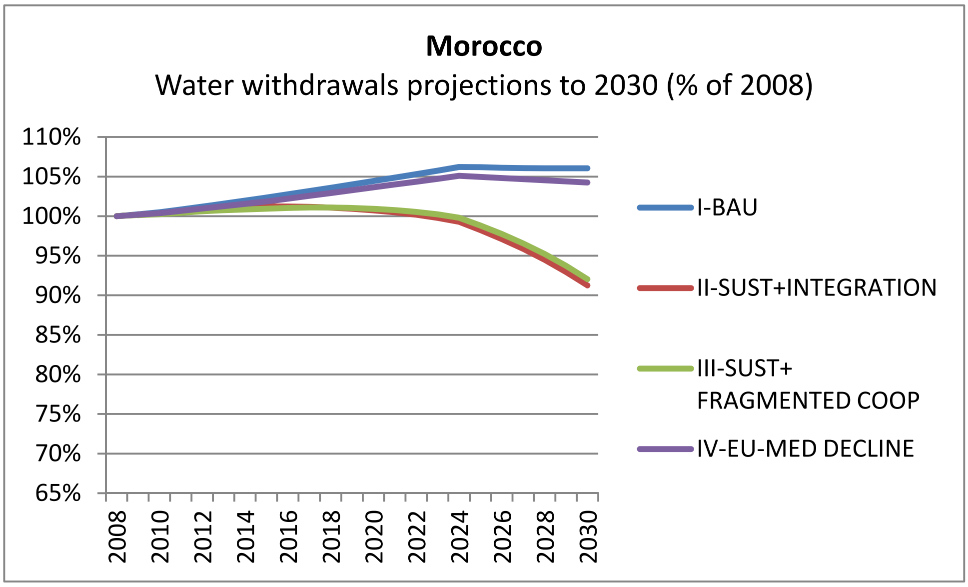
Figure 70. Long-term projections of water withdrawal in Libya in the four MEDPRO scenarios (% of the reference year 2008) without structural change



5.2.7 Morocco

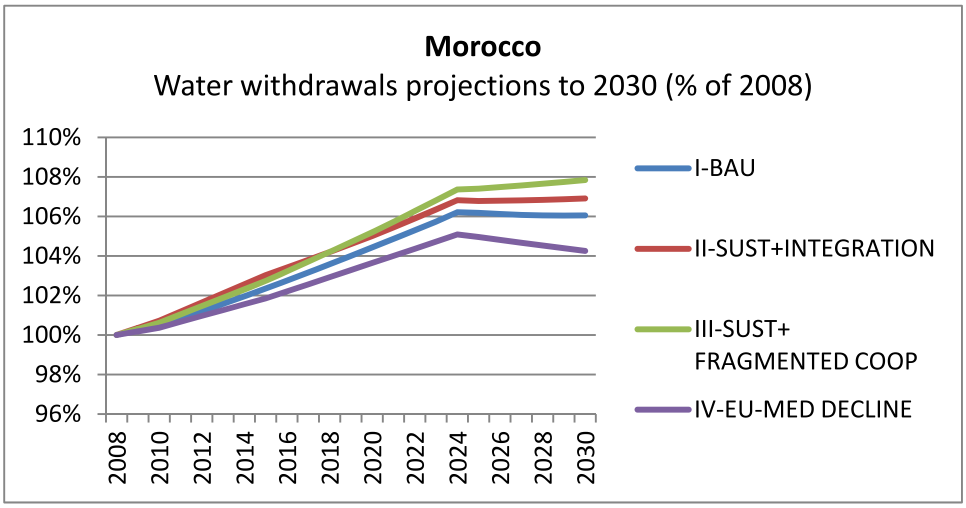
In Morocco, the projected water withdrawals under structural change are similar to the cases of Algeria and Egypt, where in the sustainability scenarios they decrease by almost 10% (Figure 71). In the first and last scenarios, they increase by around 5%. As noted for the case of Jordan in 2016, it is estimated that in Morocco in 2023, the maximum potential for the irrigated area will be realised, which is reflected in a turning point in the trends of projected water withdrawal in all the scenarios. In the first and the last scenarios, water withdrawals decrease slightly, while for the two sustainability scenarios it decreases to a greater degree.

Figure 71. Long-term projections of water withdrawal in Morocco in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change



When structural change is not taken into account, water withdrawals in Morocco increase under all the scenarios until 2023, when the maximum potential for the irrigated area is realised and the tendency changes in all the scenarios (Figure 72). In the first and last scenarios, which record lower increases in water withdrawals, this tendency peaks and then falls slightly until 2030. The trend for the Sustainability + Fragmented Cooperation scenario continues to increase, but at a slower rate, while the trend for the Sustainability + Integration scenario does not change.

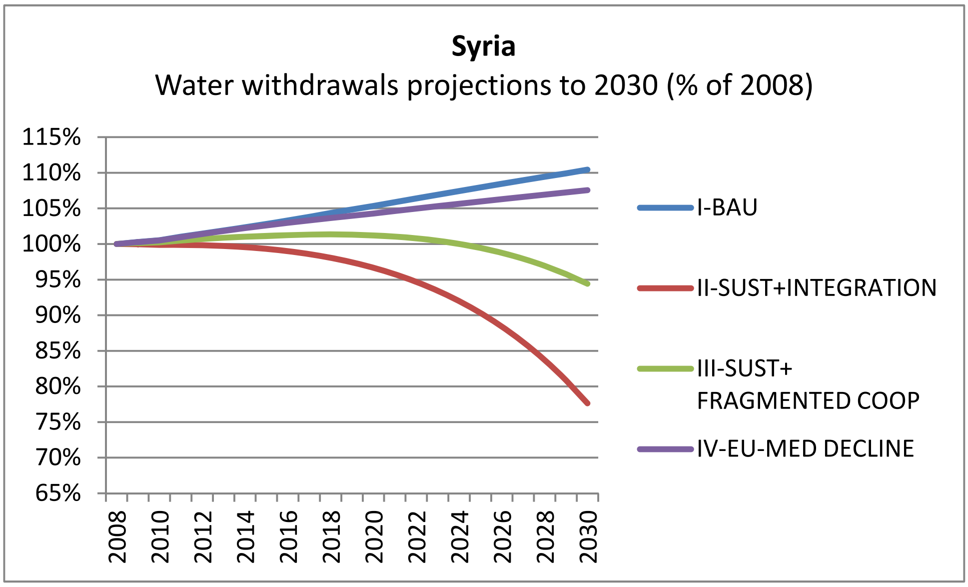
Figure 72. Long-term projections of water withdrawal in Morocco in the four MEDPRO scenarios (% of the reference year 2008) without structural change



5.2.8 Syria

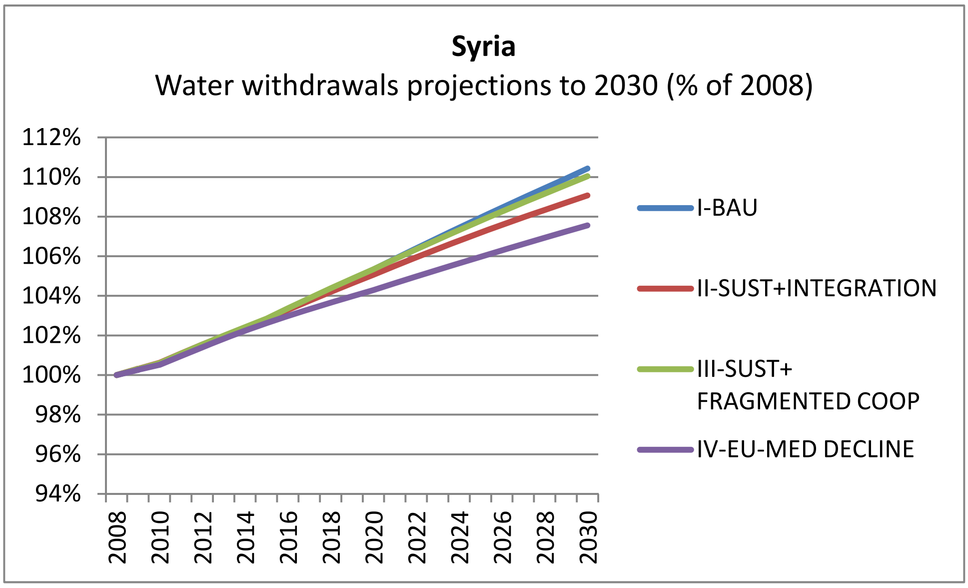
Much like the case of Algeria, in Syria the first and last scenarios reflect increases in water withdrawal under structural change, while the sustainability scenarios witness a decline by almost 25% with respect to the baseline year of 2008 (Figure 73). In the first and last scenarios in the Mediterranean area, water withdrawals increase by 10% and 7.5% respectively, due to the growth of GDP and the population.

Figure 73. Long-term projections of water withdrawal in Syria in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change



In the case of Syria, water withdrawals increase when no structural change is taken into account in 2030 under all the scenarios (Figure 74). Unlike the simulations when structural change is included in the calculations, water withdrawals in the sustainability scenarios also increase, as more technological development and investment in infrastructure and the economy in general require more water withdrawal.

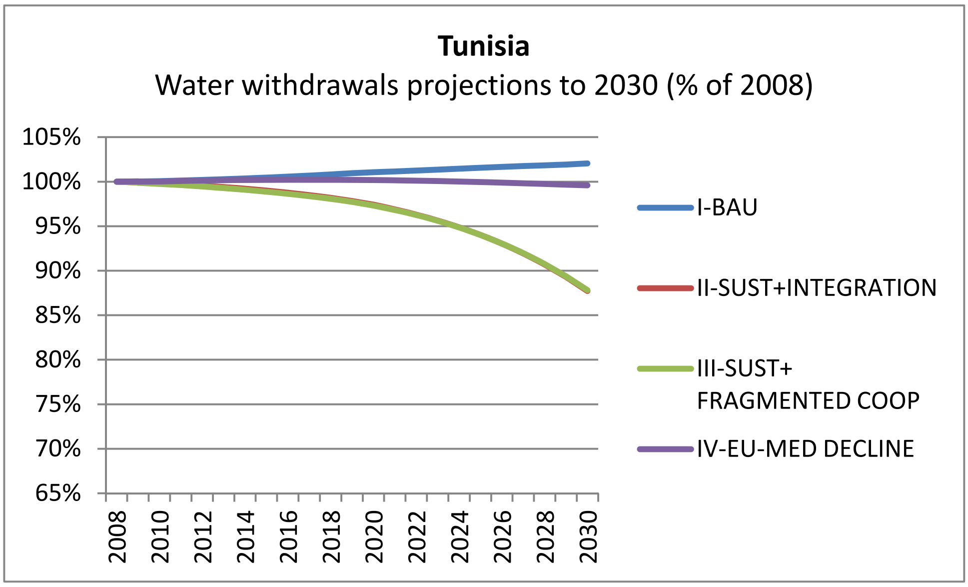
Figure 74. Long-term projections of water withdrawal in Syria in the four MEDPRO scenarios (% of the reference year 2008) without structural change



5.2.9 Tunisia

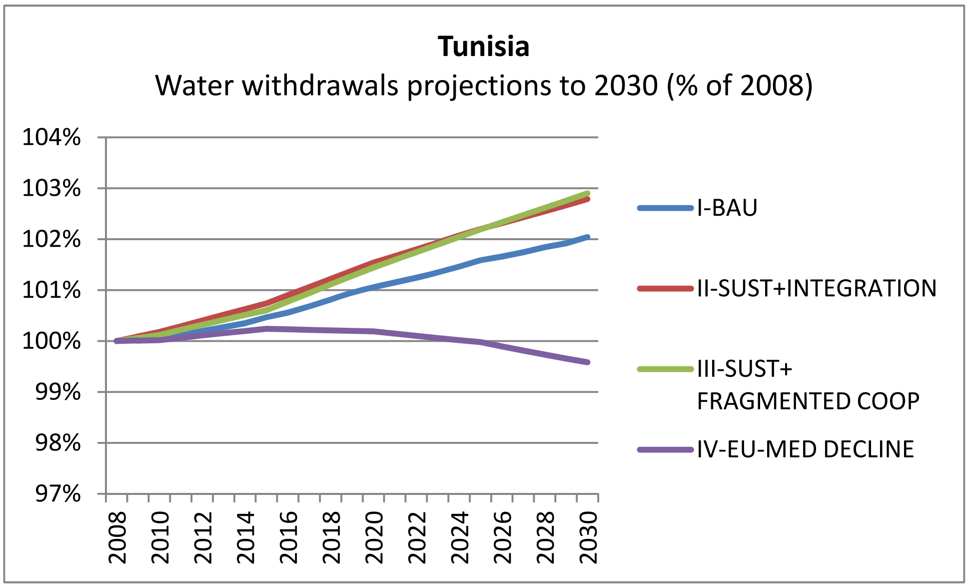
The projections for Tunisia are very similar to those for Syria when structural change is applied, where water withdrawals decrease by around 12% in the two sustainability scenarios but increase in the QI scenario by 2% and remain constant in the last scenario (Figure 75).

Figure 75. Long-term projections of water withdrawal in Tunisia in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change



The case of Tunisia is similar to most countries in that water withdrawals under the sustainability scenarios increase as more development and cooperation takes place (Figure 76). Yet, it decreases in the last scenario, in the absence of development and cooperation with the EU or among the SEMCs.

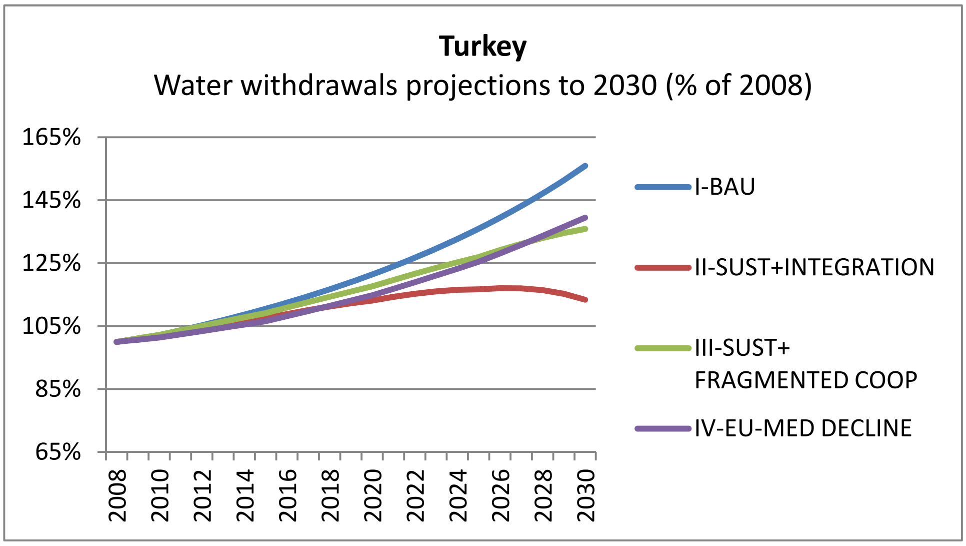
Figure 76. Long-term projections of water withdrawal in Tunisia in the four MEDPRO scenarios (% of the reference year 2008) without structural change



5.2.10 Turkey

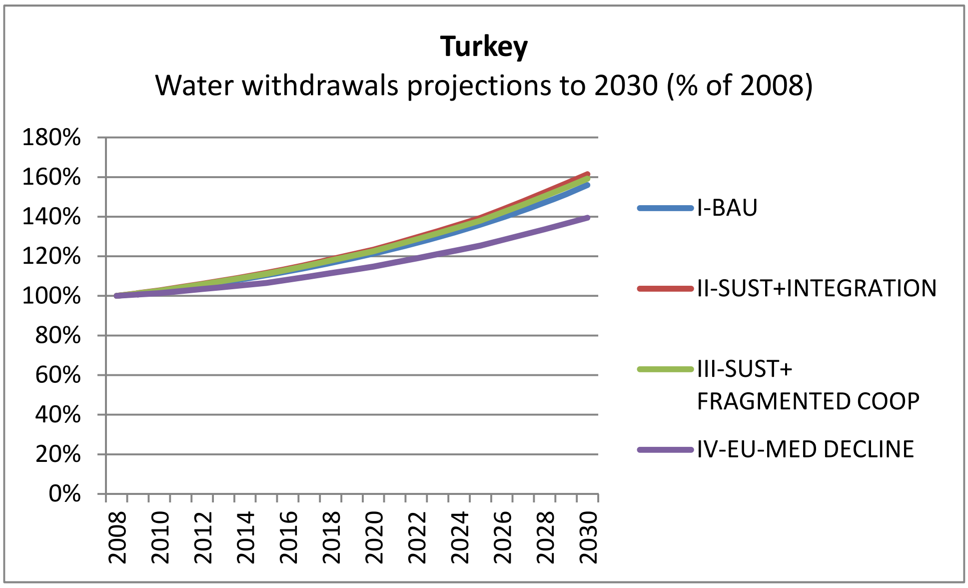
Due to the expected population growth in Turkey, water withdrawals are estimated to increase in all the scenarios under structural change (Figure 77). This increase is greatest in the QI scenario (55%). In the last and the Sustainability + Fragmented Cooperation scenarios, water withdrawals increase by 35%, while in the Sustainability + Integration scenario it increases by only 15% with a tendency to decline, owing to the implementation of structural change.

Figure 77. Long-term projections of water withdrawal in Turkey in the four MEDPRO scenarios (% of the reference year 2008) with gradual structural change



Water withdrawals increase under all the scenarios in 2030 when no structural change is applied (Figure 78). Since Turkey's large area allows it to increase investments in agriculture, water withdrawal increases as there no policies to limit it.

Figure 78. Long-term projections of water withdrawal in Turkey in the four MEDPRO scenarios (% of the reference year 2008) without structural change



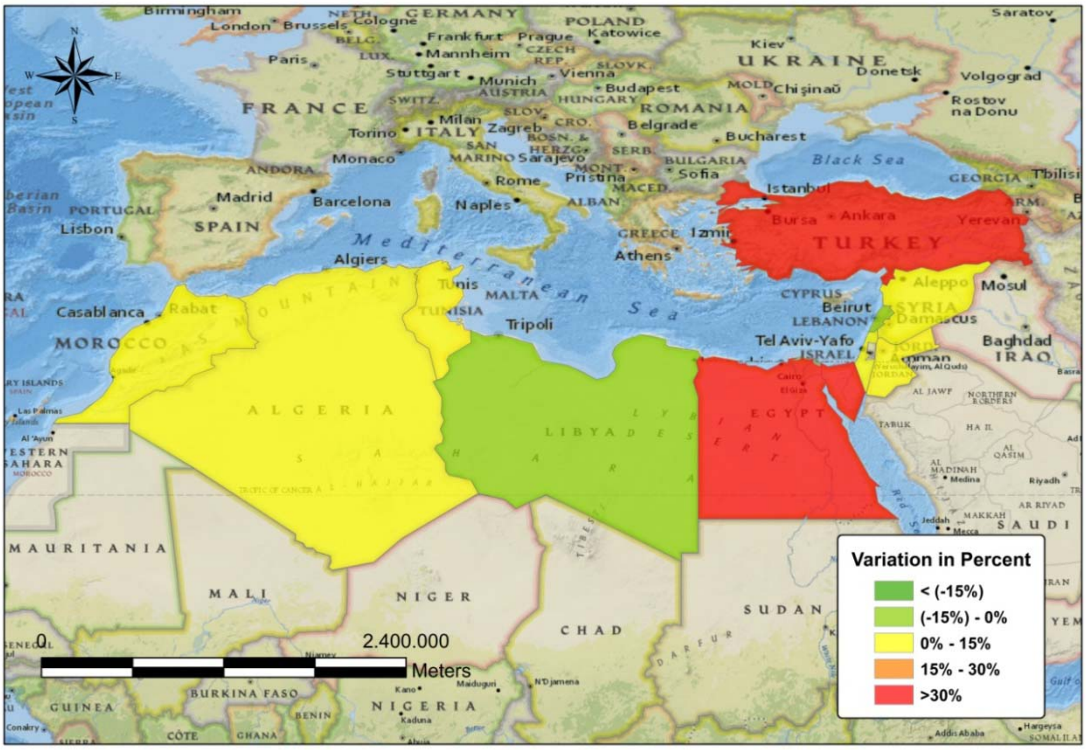
5.3 Summary maps of water projections under the four scenarios in 2030 with gradual structural change

5.3.1 Scenario 1: Business as usual

In Figure 79, water withdrawal projections are represented in the different countries under the QI scenario. In this scenario, the assumption is that no policy changes are made with respect to water resource exploitation, and therefore, the water withdrawal projections represent a continuation of the past trends. We can see that countries experiencing increases in water withdrawal in the past, as in the cases of Algeria, Egypt and Turkey, continue to have the same tendency in 2030.

Yet owing to improved technology or limits to irrigation expansion (or both), Libya and Lebanon's water withdrawals are expected to decrease by 15% in 2030 with respect to 2008.

Figure 79. Evolution of water withdrawals between 2008 and 2030 – Scenario 1

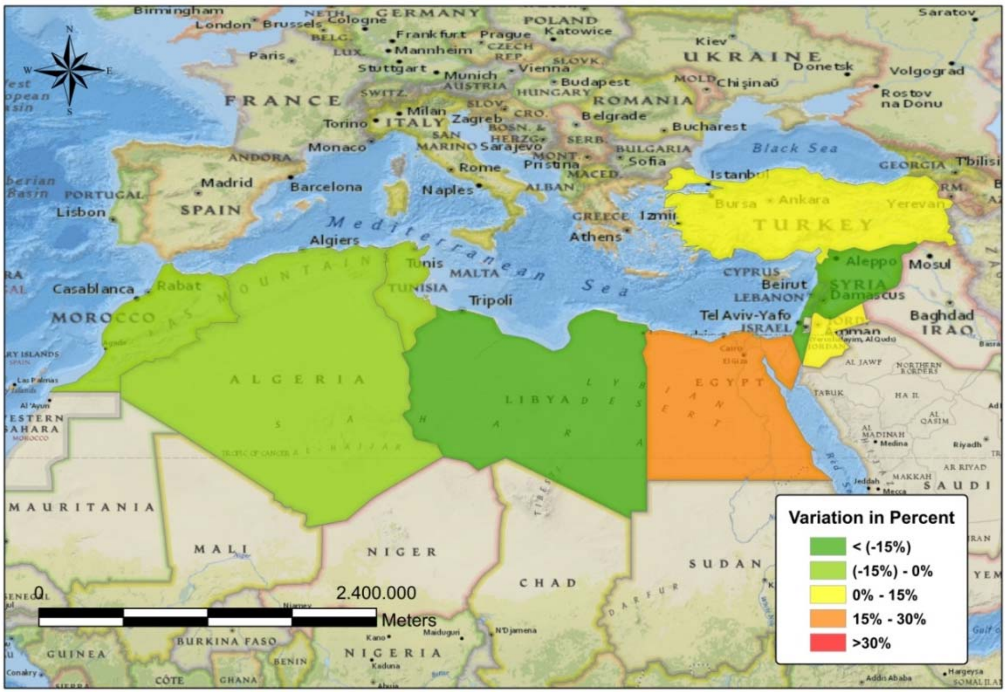


5.3.2 Scenario 2: Sustainability + Integration

Figure 80 represents the water withdrawal projections under the 'one global player' scenario (Sustainability + Integration), which is considered the most sustainable scenario. In this scenario, the EU and SEMCs are expected to form an integrated region with a common market and common policy goals, such as those of the Water Framework Directive, which would lead to sustainable growth by 2030.

As expected, the performance of the countries as a single integrated entity promotes sustainable development and growth, which is reflected in a general decrease in water withdrawals in all the countries except for Egypt, Turkey and Jordan, where increases are expected.

Figure 80. Evolution of water withdrawals between 2008 and 2030 – Scenario 2



5.3.3 Scenario 3: Sustainability + Fragmented Cooperation

Figure 81 represents the water withdrawal projections under the ‘regional player’ scenario (Sustainability + Fragmented Cooperation), which assumes that the Mediterranean region will be separated into two sub-regions: the northern European countries and the SEMCs. The expected relations between the two sub-regions would involve cooperative and development initiatives that would lead to increased sustainability in the fields of agriculture, water and food security, and would include programmes for mitigation and adaptation to climate change.

Figure 81. Evolution of water withdrawals between 2008 and 2030 – Scenario 3

In this new scenario of sustainability, the lowest degree of convergence among countries is accompanied by a slightly smaller decrease in water withdrawals compared with the previous sustainability scenario in the cases of Israel and Syria, and a large increase in water withdrawals in Turkey compared with scenario 2.

5.3.4 Scenario 4: Decline and Conflicts

Figure 82 represents the last scenario considered, 'Euro-Mediterranean area under threat' (Decline and Conflicts), which assumes that the current conflicts in the Middle East are not resolved, thus exacerbating tensions in the area. The lack of agreement among the countries would also result in weak authority that is unable to promote cooperation; tensions could lead to wars in some parts of the study area.

In this scenario, in which GDP growth is assumed to be lower than in the other scenarios, water withdrawals increase in most of the countries. This increase is a consequence of the lack of structural change and slower technological improvements than in the other scenarios, along with less irrigation efficiency.

Figure 82. Evolution of water withdrawals between 2008 and 2030 – Scenario 4

6. Analysis of selected countries

This section includes a detailed model-based analysis of selected case-study countries that allows an assessment of the socio-economic, agronomic and climate impacts at the aggregate country level. For this analysis we have developed a modelling integration framework that includes an economic, mathematical programming model of constrained optimisation, a crop-based agronomic model and a hydrologic model for the entire water system in the country. Given the complexity of this modelling exercise as well as the outsized data requirements, this analysis has been preformed solely for four countries: Spain (as a baseline comparative reference), Syria, Jordan and Morocco. The subsequent sections discuss the selection of the countries and the modelling framework.

6.1 Selection of countries

For the selection of 3 of the 11 SEMCs, we have used different indicators related to the availability of water resources in the present situation, future climate projections and other social and economic factors. According to the total, annual, renewable water resources (Figure 83), Syria represents a country that relies extensively on external surface water resources, while Jordan is almost exclusively dependent on internal groundwater sources and is considered one of the most water-scarce areas in the world. Future projections of the availability of water resources expect that Syria will see reductions of its renewable water resources by about 20% from 2010 to 2050, while Jordan will suffer a reduction of 50% – the highest in the region together with the Palestinian territories and Libya (Figure 84). Future water demand in Jordan under average climate projections will more than double in the period considered, especially in 2040–50, with unmet demand set to increase almost threefold (Table 9). Projections of future water demand for Syria, for the same average climate scenario, show a lower increase than for Jordan, passing from 16 to 24 Mm^3 over the period 2010–50. As Syria relies on external surface water resources, however, it is less resilient to future climate variations. Thus, unmet demand will be much higher in Syria and rise more than tenfold by the end of the period (from 873 to 9,500 Mm^3) (Table 9). For the dry climate projections, Syria will be more severely affected relative to current water demand than Jordan (Table 10).

The third country studied is Morocco, because, unlike Syria and Jordan, it is located on the north-western corner of the African continent and on the south-western side of the Mediterranean. The selection of Morocco is based on the distinct climate-change effects that apply to the western Mediterranean area, the importance of its agriculture for the Mediterranean region and its renewable water structure.

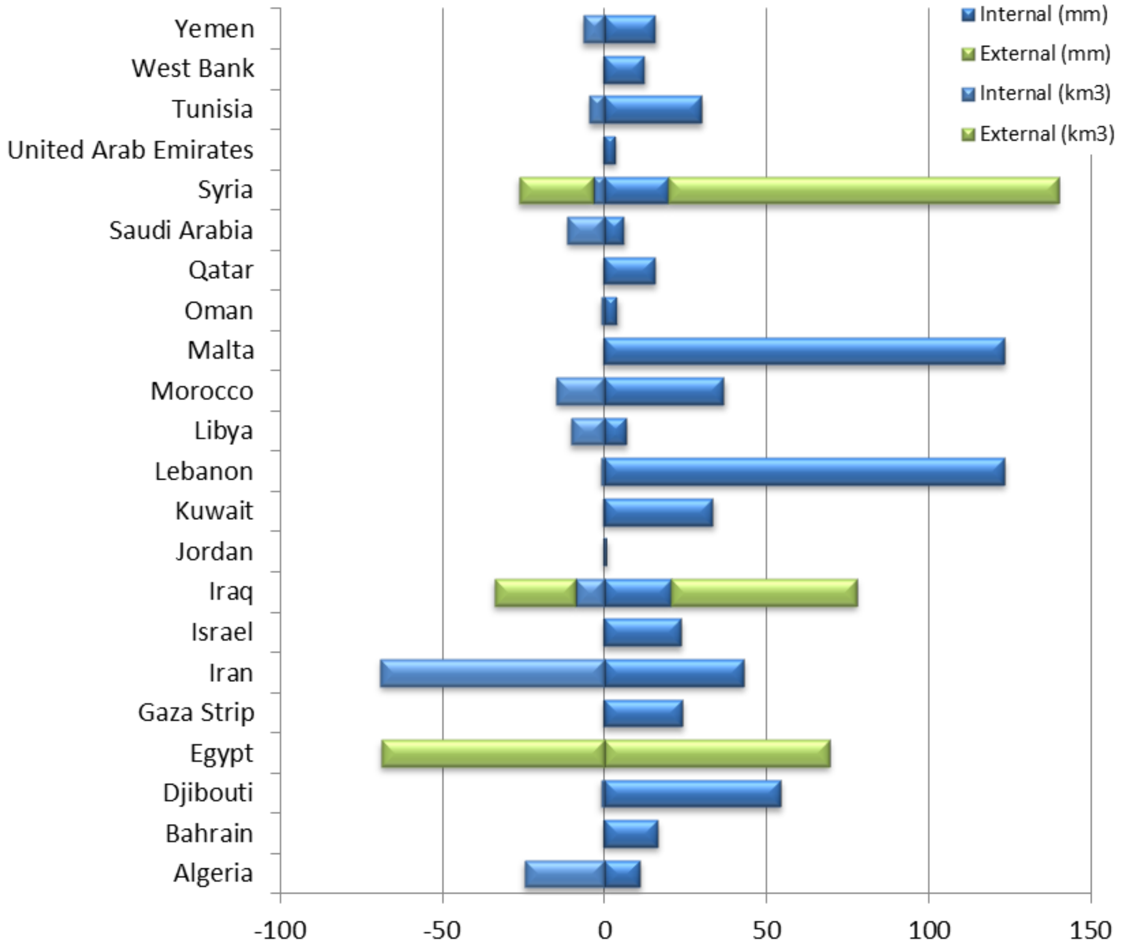
Morocco's agricultural sector represents 19% of the country's GDP and employs about 40% of the labour force.[5] Moreover, it is the third largest producer of cereals after Turkey and Egypt, occupying 5,688,222 ha of its arable land (Figure 85). It is also important to note that Morocco's agricultural area is the third largest among the 11 SEMCs after Turkey and Algeria, and its arable land makes up 30% of the total agricultural area.

In addition, according to the indicators used for the other cases, Morocco relies exclusively on its internal, surface water renewable resources (Figure 83). After Turkey and Lebanon, Morocco has the highest level of renewable water resources per capita, of about 935m^3/person/year. Also, it has the third largest area equipped for irrigation, of 1,485 ha (Figure 86).

Future projections for Morocco show reductions of water resources by around 50% from 2010 to 2050 (Figure 84). That will lead to a widening of the gap between the water demand and the water available under all the assumed climate projections. For average climate projections, the unmet demand in Morocco in 2050 will increase by as much as seven times the quantity unmet in 2009 (Table 9). Morocco will be even more greatly affected under the dry climate projections, as the unmet demand will increase from 2,092 Mm^3 to 19,554 Mm^3 from 2009 to 2050, rising almost tenfold.

[5] Data obtained from FAOSTAT 2009 (see the appendix for further details).

Figure 83. Average, annual, total renewable water resources per country in the Middle East and North Africa, in mm (right) and km³ (left)



Source: Immerzeel et al. (2011).

Figure 84. Total change from 2010 to 2050 in total renewable water resources (in %)

Source: Immerzeel et al. (2011).

Table 9. Water demand and unmet demand for the current situation and future in the average climate projection (AVG) (in Mm^3)

(MCM)	Demand 2000-2009	Demand 2020-2030	Demand 2040-2050	Unmet 2000-2009	Unmet 2020-2030	Unmet 2040-2050
Algeria	6,356	8,786	12,336	0	8	3,925
Bahrain	226	321	391	195	304	377
Djibouti	28	46	84	0	0	0
Egypt	55,837	70,408	87,681	2,858	22,267	32,085
Gaza Strip	162	299	527	140	283	505
Iran	79,703	92,310	110,081	11,325	29,721	51,753
Iraq	43,968	57,130	71,113	7,272	26,907	43,096
Israel	3,140	4,619	6,081	2,118	3,733	5,130
Jordan	1,113	1,528	2,276	853	1,338	2,061
Kuwait	508	867	1,216	0	310	788
Lebanon	1,202	1,525	1,869	141	471	876
Libya	4,125	4,974	5,982	0	1,399	3,625
Malta	88	122	148	34	80	107
Morocco	15,739	19,357	24,223	2,092	9,175	15,381
Oman	891	1,544	2,807	0	663	2,194
Qatar	489	602	641	234	418	481
Saudi Arabia	21,733	26,667	35,257	10,572	18,146	28,535
Syria	16,183	19,446	24,418	873	4,539	9,498
Tunisia	2,772	3,985	5,916	0	17	2,853
U.A. Emirates	3,370	3,495	3,389	3,036	3,203	3,173
West Bank	403	652	1,061	256	555	957
Yemen	5,819	8,162	19,065	1,262	3,540	14,289
MENA	263,853	326,842	416,562	43,265	127,078	221,691

Source: Immerzeel et al. (2011).

Table 10. Water demand and unmet demand for the current situation and future in the dry climate projection (DRY) (in Mm^3)

(MCM)	Demand 2000-2009	Demand 2020-2030	Demand 2040-2050	Unmet 2000-2009	Unmet 2020-2030	Unmet 2040-2050
Algeria	6,356	9,250	12,818	0	0	675
Bahrain	226	322	392	195	313	389
Djibouti	28	47	85	0	0	0
Egypt	55,837	72,643	90,381	2,858	48,590	61,867
Gaza Strip	162	304	533	140	294	524
Iran	79,703	98,331	116,435	11,325	56,782	78,207
Iraq	43,968	59,788	74,725	7,272	38,657	56,070
Israel	3,140	4,756	6,240	2,118	4,138	5,637
Jordan	1,113	1,587	2,349	853	1,510	2,286
Kuwait	508	870	1,219	0	501	977
Lebanon	1,202	1,627	1,994	141	817	1,259
Libya	4,125	5,241	6,241	0	404	3,931
Malta	88	123	150	34	95	125
Morocco	15,739	20,957	25,939	2,092	13,169	19,554
Oman	891	1,573	2,831	0	971	2,434
Qatar	489	612	650	234	494	558
Saudi Arabia	21,733	27,427	36,048	10,572	20,190	31,321
Syria	16,183	20,548	25,606	873	9,056	14,512
Tunisia	2,772	4,325	6,271	0	1,320	4,153
U.A. Emirates	3,370	3,605	3,491	3,036	3,448	3,403
West Bank	403	678	1,093	256	625	1,048
Yemen	5,819	8,692	19,732	1,262	5,241	16,575
MENA	263,853	343,306	435,223	43,265	206,615	305,503

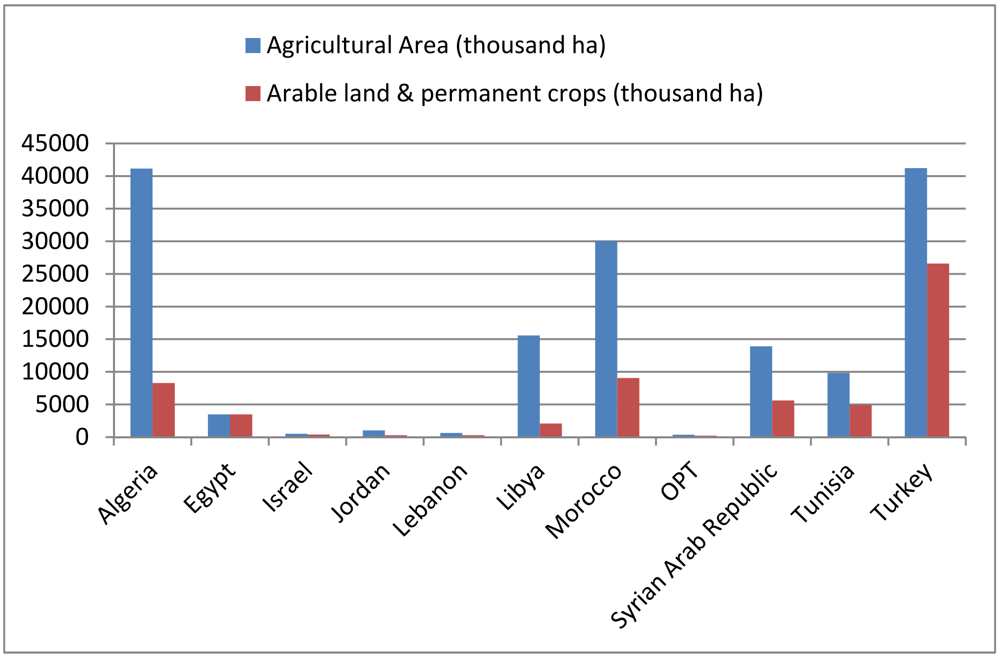
Source: Immerzeel et al. (2011).

Table 11. Water demand and unmet demand for the current situation and future in the wet climate projection (WET) (in Mm^3)

(MCM)	Demand 2000-2009	Demand 2020-2030	Demand 2040-2050	Unmet 2000-2009	Unmet 2020-2030	Unmet 2040-2050
Algeria	6,356	8,351	11,878	0	0	0
Bahrain	226	319	390	195	299	361
Djibouti	28	44	82	0	0	0
Egypt	55,837	68,489	85,235	2,858	0	0
Gaza Strip	162	294	520	140	274	486
Iran	79,703	87,965	103,924	11,325	2,096	14,793
Iraq	43,968	53,748	67,646	7,272	14,685	28,511
Israel	3,140	4,470	5,916	2,118	3,209	4,437
Jordan	1,113	1,471	2,207	853	1,117	1,777
Kuwait	508	863	1,212	0	6	491
Lebanon	1,202	1,433	1,746	141	272	499
Libya	4,125	4,715	5,727	0	4	130
Malta	88	121	148	34	57	83
Morocco	15,739	17,623	22,443	2,092	475	8,669
Oman	891	1,507	2,766	0	121	1,756
Qatar	489	587	627	234	299	342
Saudi Arabia	21,733	25,757	34,481	10,572	15,701	25,010
Syria	16,183	18,375	23,109	873	0	2,588
Tunisia	2,772	3,635	5,464	0	0	18
U.A. Emirates	3,370	3,341	3,212	3,036	2,961	2,771
West Bank	403	627	1,032	256	482	847
Yemen	5,819	7,416	18,178	1,262	873	10,478
MENA	263,853	311,153	397,942	43,265	42,930	104,046

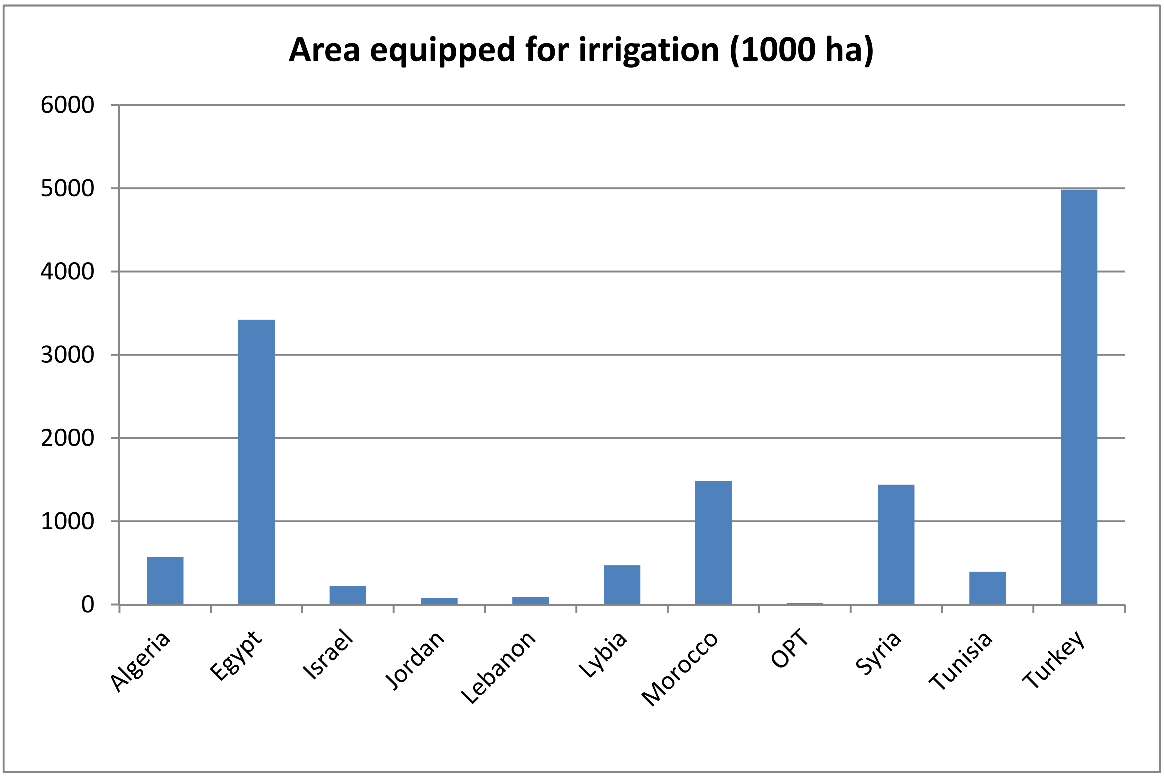
Source: Immerzeel et al. (2011).

Figure 85. Agricultural area and arable land in the 11 SEMCs (thousand ha)



Source: Own elaboration based on FAOSTAT.

Figure 86. Area equipped for irrigation in the 11 SEMCs (thousand ha)



Source: Own elaboration based on FAOSTAT.

6.2 Methodological framework

The analysis of future developments of water and agriculture in the 11 SEMCs has been performed for the case-study countries, based on the simulation of future scenarios with a group of connected models. The models can reproduce changes in the main drivers and provide the expected values for the selected indicators.

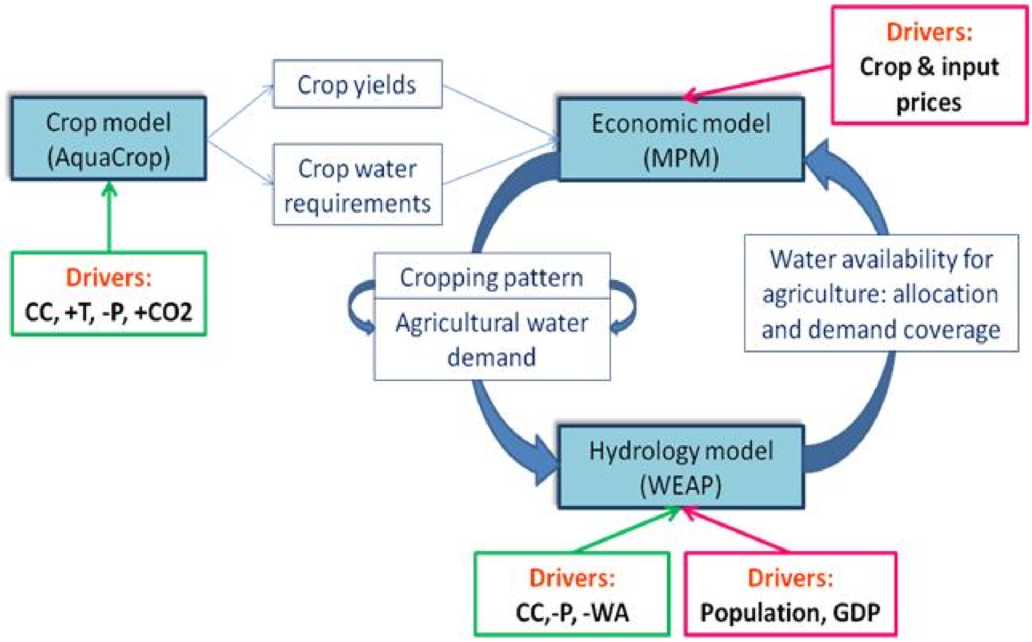
6.2.1 An integrated agronomic, economic and hydrologic model

The modelling framework contains three models:

- a crop model (AquaCrop), which represents the crops and provides yields and water requirements under different conditions;
- an economic model (mathematical programming model, MPM), which reproduces decision-making at the farm level, providing farm income, employment, cropping pattern and the use of resources for the different scenarios; and
- a hydrologic model (‘Water Evaluation and Planning’ system, WEAP), which represents the hydrologic system and provides water allocation and demand coverage for a given cropping pattern and crop water needs.

Further details of each model are given in the following sub-sections. Figure 87 shows the modelling framework applied.

Figure 87. Modelling structure for the country-level analysis



The crop model, AquaCrop

The crop model used in this research, AquaCrop, has been recently developed by the FAO (Steduto et al., 2009). It is a water-driven growth model, where biomass and yield are calculated as a function of transpiration. These calculations are based on the FAO paper, *Yield response to water* (Doorenbos and Kassam, 1979), which gives the relationship between yield and evapotranspiration:

$$\left(\frac{Y_x - Y_a}{Y_x}\right) = k_y \left(\frac{ET_x - ET_a}{ET_x}\right) \quad (5)$$

where Y_x = potential yield, Y_a = actual yield, ET_x = potential evapotranspiration, ET_a = actual evapotranspiration, and k_x = the proportionality factor between relative yield loss and relative evapotranspiration reduction. The model is structured in several modules, which represent the soil–crop–atmosphere continuum. A set of data has to be introduced for each module, from which the model calculates the daily accumulation of biomass and the final yield, as well as the crop water requirements. Table 12 summarises the modules of the model and the main variables included in each module.

Table 12. AquaCrop modules and main input variables

Modules	**Main variables included**
Climate	Rainfall, temperature, solar radiation, relative humidity, wind speed
Soil	Soil layers: depth, texture
Crop	Planting date, density, phenology, canopy cover, root depth, actual yield
Management	Irrigation method, dates and amount of irrigation, fertilisation level

These model modules have to be filled with real data, followed by a calibration stage based on experimental data. In our case, we simulated wheat, barley, sunflower, maize, tomatoes, potatoes and rice. Calibration was carried out using field experiments from a research centre in central Spain, and based on the 'water productivity' and 'harvest index' crop coefficients.

The impacts of climate change on crop yields and crop water requirements were introduced as inputs into the economic model when simulating climate change scenarios.

The agro-economic model

The economic model is a mathematical programming model of constrained optimisation specified for the irrigated agricultural sector at the country level and represented by an aggregated farm type. It is non-linear and stochastic, including climate and market price variations. The objective function is a utility function, which contains two addends: farm income and a risk component, representing the amount of income that the farmer is willing to lose in order to avoid the risk of income losses stemming from market and climate variations.

$$\text{Objective function: } \max U = Z - \varphi \cdot \sigma(Z) \tag{6}$$

where U = utility, Z = gross margin, φ = risk aversion coefficient and σ(Z) = the sum of standard deviations of the gross margin as a result of the variability of crop prices and yields.

The maximisation of the utility function is subject to land, water, and labour and technology constraints.

$$\text{Constraints } g(x) \text{ € } S_1,\ x\text{€ } S_2 \tag{7}$$

where *x* is the vector of the decision-making variables (activities) defined by a given crop, with an associated production technique and irrigation method.

The model reproduces the farmer’s decisions in terms of cropping patterns, techniques and use of resources given a certain situation and allows the simulation of scenarios, providing the impact of such scenarios on cropping patterns, farm income and agricultural employment, among other aspects.

A model has been built for the selected case-study countries (Spain, Syria, Jordan and Morocco), considering an aggregated representative farm and accounting for the distribution of crops, techniques and resources of those countries. After a calibration stage, based on statistical data, several scenarios have been simulated.

The hydrologic model

The water-resource simulation model used to replicate the functioning of the hydrologic system at the country level is the user-friendly Decision Support System tool WEAP, which is short for Water Evaluation and Planning system. The WEAP model was developed by the Stockholm Environment Institute in 1988. Since then, it has been successfully applied in many world regions, from single catchments to complex transboundary river systems, to support the integrated management of water resources and policy analysis (Raskin et al., 1992).

WEAP integrates the biophysical processes and the engineered hydrologic components of water systems into a common modelling platform, allowing for a more comprehensive view of the key factors that affect water management and water use (Groves et al., 2008). It determines the optimal allocation of limited water resources according to demand priorities (e.g. agriculture and industry), supply preferences (e.g. groundwater, rivers and creeks), ecosystem requirements and other physical and regulatory constraints (e.g. the capacity of reservoirs, irrigation channels and transmission links).[6] WEAP usually operates on a monthly time step, with each month being independent of the previous one, except for reservoir and aquifer storage. Therefore, all the groundwater or surface water entering the system is either stored in an aquifer or reservoir, or disappears from the system by the end of the month owing to transmission losses, evaporation or consumption.

[6] For details, see Yates, Purkey, Sieber, Huber-Lee and Galbraith (2005), and Yates, Sieber, Purkey and Huber-Lee (2005).

Following Immerzeel et al. (2011), the management of the water system at the country level has been represented in WEAP by means of aggregated water supply and water demand elements: streams, aquifers, reservoirs and water-use sectors. Immerzeel et al. (2011) use this type of approach to analyse water stress and water management strategies with and without climate change impacts in the Middle East and North Africa. Among others, Droogers and Perry (2008), Sandoval-Solis and McKinney (2010), Varela et al. (2011) and Yates et al. (2009) have also used a stylised replica of the water system in scenario analysis related to climate change.

Using WEAP, the potential impacts on water resources of future changes were assessed in Spain, Syria, Jordan and Morocco. The hydrologic model allows the up-scaling of the crop-based and farm-based results of the agronomic model and the economic model to the country level.

6.3 Preliminary simulated scenario for water and agriculture (Spain)

This section covers the simulated scenario for the case of Spain, as a test to check the sensitivity of the models and to validate preliminary results.

A set of scenarios has been selected for simulation in the economic model, to find out the impacts of market prices, climate and technological changes on the agricultural sector. Table 13 summarises the characteristics of the selected scenarios.

Five scenarios are simulated, which correspond to a sequence of different changes that would occur within the BAU general scenario. The first scenario is the reference situation, i.e. the current agricultural, environmental and economic characteristics that affect farming activity. *BAU-P* represents a business-as-usual scenario in which the only projected change in the future is the price of inputs and agricultural products (this means no climate change at all). Price projections are taken from MARM (2010) for input prices and from the OECD (OECD–FAO, 2010) for agricultural product prices. The *BAU-P-CC crop* scenario is similar to *BAU-P* regarding input and crop prices, but includes the changes in crop water requirements and crop yields due to severe climate change (SRES-A2). These data come from the results of the crop model AquaCrop (see section 6.3.1). The *BAU-P-CC crop & WR* scenario is similar to *BAU-P-CC crop*, but also considers the reduction in the availability of water resources due to climate change. In this case, data on the reduction of water availability come from the WEAP model. Finally, in the 'technological improvements' scenario, we have simulated an improvement in irrigation technology, as an example of an adaptation strategy, by increasing the surface of irrigated crops under pressurised irrigation systems by 10%.

Table 13. Preliminary simulated scenarios for Spain

Scenarios	**Crop prices (%)**	**Input prices (%)**	**Yields**	**Crop water req.**	**Water availability (%)**	**Press. irrig.**
Baseline						
BAU – P	+7	+5				
BAU – P – CC crop	+7	+5	+	+		
BAU – P – CC crop & WR	+7	+5	+	+	-25	
Technical improvements	+7	+5	+	+	-25	+10

In the case of crop prices, an increase of 7% has been simulated for Spain (using OECD projections for cereals as a proxy for crop prices). Following simulations with the economic model, we next outline respective changes in crop distribution, farm income and agricultural employment.

For the hydrologic model, first, following business-as-usual trends from 2004 to 2030 for population growth, GDP development and agricultural production we have obtained monthly estimates of the amount of fresh water available and the level of water used per economic sector (domestic, industrial and agricultural) and per water source (surface water and groundwater systems). This scenario

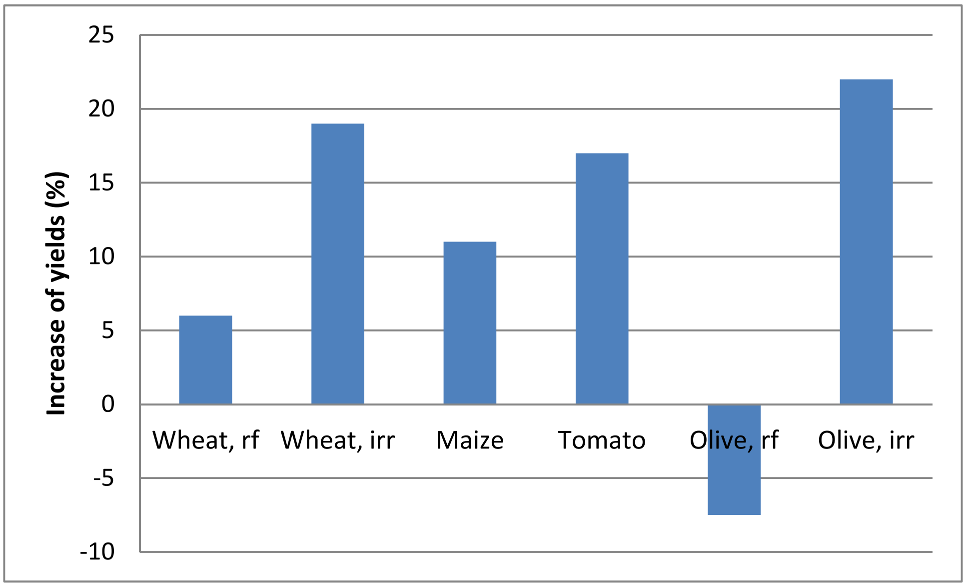
coincides with the BAU scenario of the MEDPRO project, defined in WP9 (Sessa, 2011; Ayadi and Sessa, 2011). Long-term growth projections for population and GDP are exogenous to the model. Active population and population growth have been obtained from the UN's *World Population Prospects*, assuming a medium scenario (UN, 2009). Future GDP estimates have been obtained from MEDPRO WP5 (see Coutinho, 2011). These projections for population and GDP have also been used in MEDPRO WP8 to evaluate the impact of the BAU scenario in the 11 SEMCs, using the GEM-E3 model (Kouvaritakis et al., 2011). Changes in agricultural production and land use are provided by the economic model.

Then, we simulated a BAU scenario with severe climate change (SRES-A2) by taking into account forecasted changes in water inflows, an increase in crop water requirements and cropping mix adjustments. Variations in crop water requirements and cropping patterns are obtained from the agronomic model and the economic model, respectively. Similar to the BAU scenario, the WEAP model provides updated information on water supply and water demand coverage, and informs the economic model about the total amount of water available for agricultural use.

6.3.1 Results of the crop model

The AquaCrop model has been used to represent the main crops in the country and to perform simulations of moderate (SRES-B2) and severe (SRES-A2) climate change scenarios. As a result of the simulations, we have obtained yields and the water consumption of crops under each scenario under Spanish conditions. Figure 88 shows some of these outputs: the changes in crop yields for a severe climate change scenario (SRES-A2), as a percentage of change compared with current yields, for a selection of crops in Spain.

Figure 88. Increase in crop yields in a severe climate change scenario, compared with the present, for a selection of crops in Spain (%)



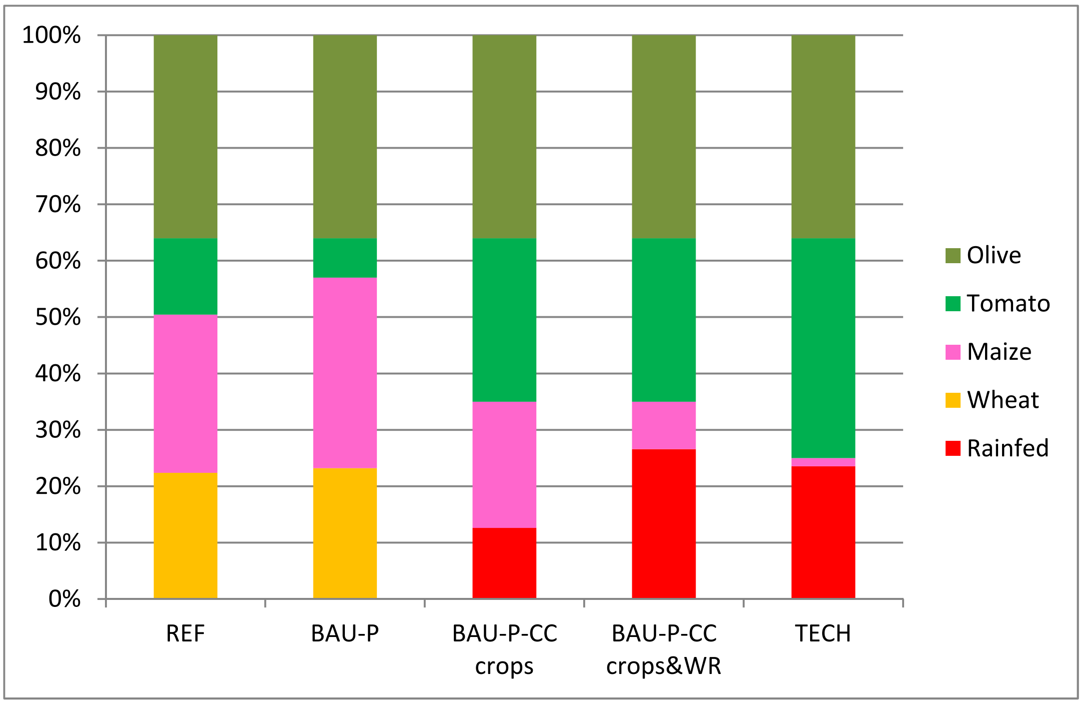
We can see that, in general terms and given no water restrictions at the crop level, climate change results in an increase in yields. The same type of output was obtained for a moderate climate change scenario and for crop water needs. These results are the consequence of the new climatic conditions (changes in temperature and precipitation) and the atmospheric CO_2 concentration for each scenario. Under Spanish conditions, it seems that the positive impact of CO_2 on yields dominates the possible negative effects of temperature changes. Except for rain-fed olive trees, yields increase for all the simulated crops.

The changes in yields and water needs obtained with AquaCrop are then introduced into the economic model as an input, to be considered part of the data for future scenarios, for which there is a lack of statistical data.

6.3.2 Results of the economic model

One of the elements analysed in the simulation scenarios is the resulting cropping pattern. A set of representative crops has been selected and incorporated into the economic model as the possible crop options and the model gives the optimum selection that maximises the utility function in each scenario. Figure 89 shows the results, in percentages, of each crop over the total irrigable surface (that is, the total surface currently under irrigation) for the present situation and for the simulation scenarios.

Figure 89. Spain: Cropping pattern under different simulated scenarios (% of irrigated land)

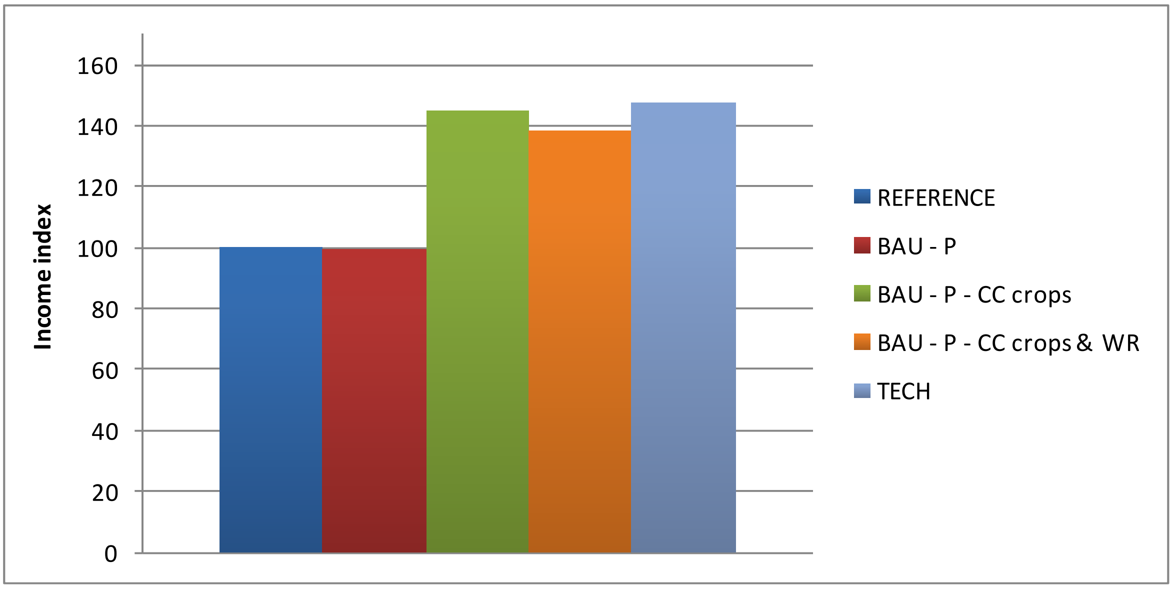


The results show that some of the irrigated surface changes to rain-fed under climate change scenarios, with both current and additional restrictions on farm water, although this figure can be reduced when technological improvements are undertaken. We also note that maize is progressively replaced by tomato and rain-fed crops as we go towards scenarios with lower water availability.

Another important output variable provided by the economic model is farm income. Figure 90 shows the change in the income obtained by a representative farm under the different simulation scenarios, expressed as a percentage of current farm income. In the reference scenario, 100% corresponds to €1,450/ha income for an average farm.

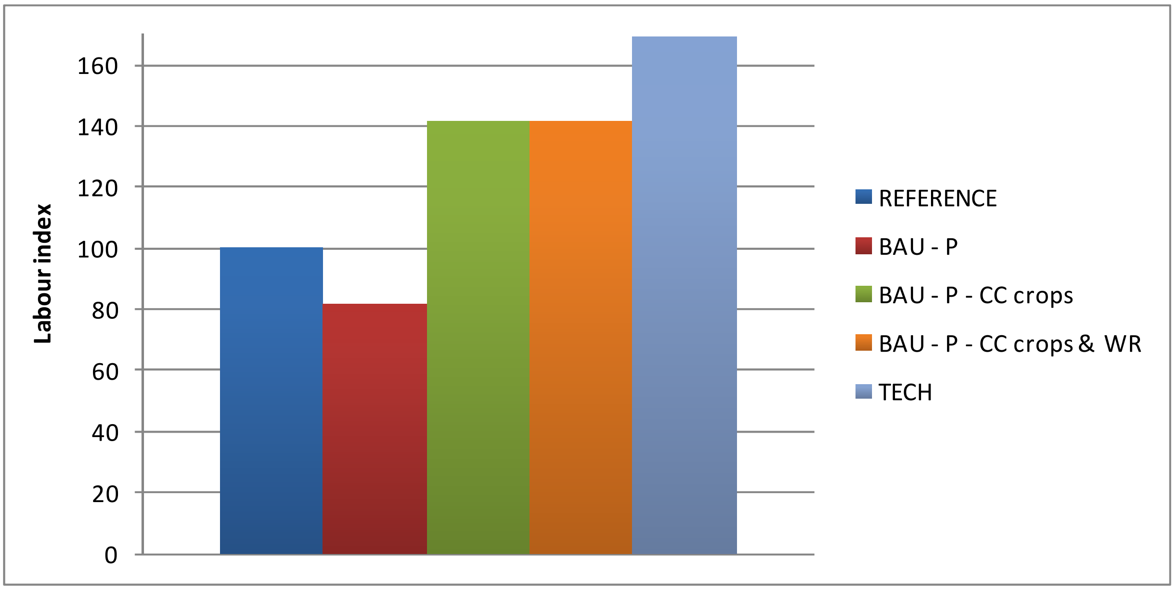
The results show that the simulated change in market prices does not have a noticeable impact on farm income. Regarding the climate change scenarios, the general increase in crop yields and the shift to more profitable crops under those scenarios implies an increase in farm income, which is lower when additional water restrictions are applied at the farm level. Nevertheless, this income loss can be compensated by technological improvements.

Figure 90. Spain: Farm income under the different scenarios (% with respect to the reference)



Finally, we show the impact of simulation scenarios on agricultural employment (Figure 91). Total employment is presented for each simulation scenario as a percentage of the current employment at a representative farm, with 100% corresponding to 760 h/year.

Figure 91. Spain: Agricultural employment under the different scenarios (% with respect to the reference)

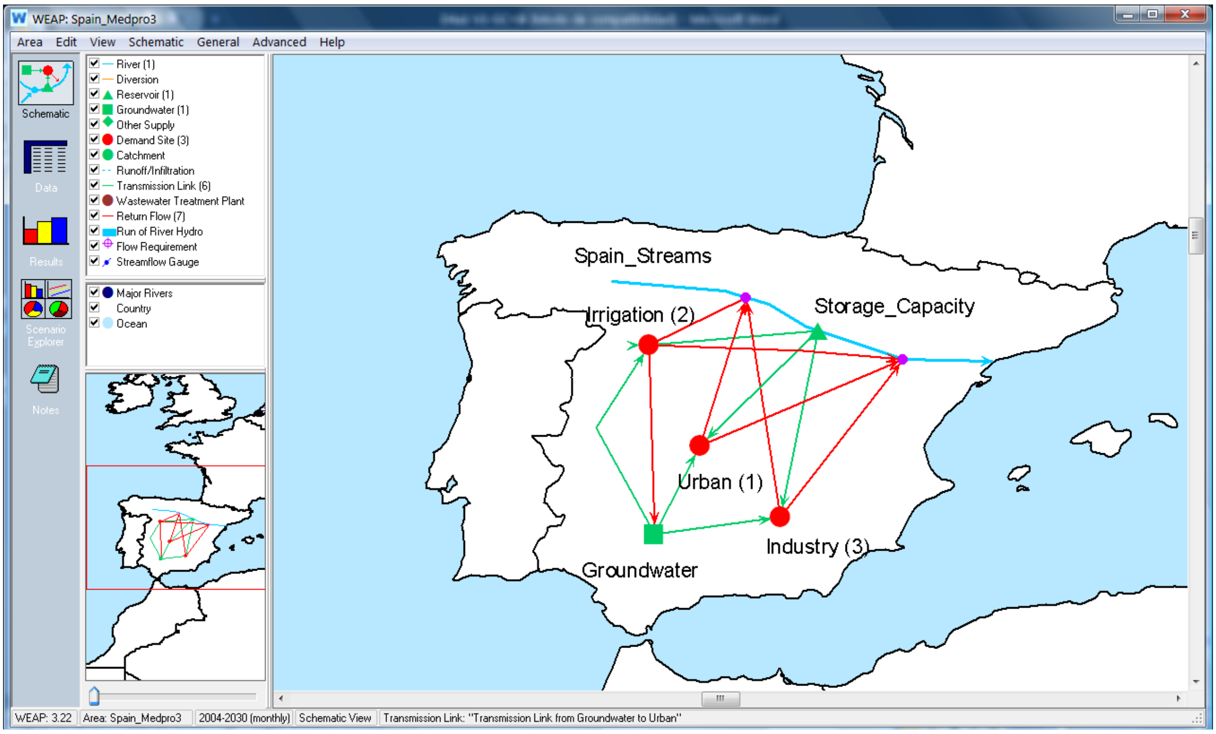


From these results, we can deduce that the simulated price scenario has a negative impact on employment, while climate change scenarios lead to an increase of employment due to the increase of tomato cultivation, which is a highly labour-intensive crop.

6.3.3 Results of the hydrologic model

The WEAP model has been applied to Spain. Figure 92 presents the WEAP layout for Spain, which shows the main hydrologic elements of the water system and their linkages as depicted in the WEAP platform. Data have been mainly obtained from the country profiles of the FAO database on water and agriculture, AQUASTAT (see the appendix). Additional information has been obtained from literature and other national statistics.

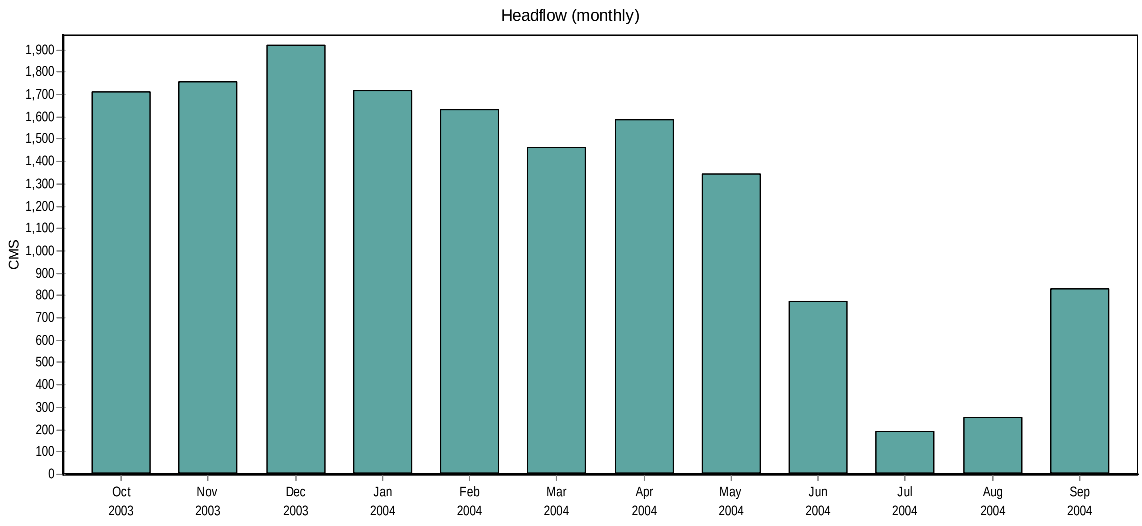
Figure 92. Schematic of the WEAP model for Spain



The water supply is characterised by the following features:

- one river, drawn as a blue line in WEAP, which comprises all surface renewable water in the country. The major Mediterranean river in Spain is the Ebro River. Thus, this virtual river replicates the shape of the Ebro River and flows out to the Mediterranean Sea. Figure 93 shows the headflow of the aggregated Spanish river. Return flows, depicted in WEAP using red arrows, make their way back to the system upstream and downstream in the river;
- one aquifer, represented in WEAP by a green square, which accounts for all groundwater storage within the country (about 150,000 Mm^3 in Spain). Water can be pumped from the aquifer for agricultural, domestic or industrial uses, but only irrigation return flows go back to the aquifer; and
- one reservoir, characterised in WEAP by a green triangle, which groups all the dams and reservoirs spread all over the country. It represents the total capacity for surface water storage in the country (56,000 Mm^3 in Spain). Water can be extracted from the reservoir for agricultural, urban or industrial purposes.

Figure 93. Headflow of the river in Spain for the baseline hydrologic year 2003–04



The WEAP representation of water demand nodes is symbolised by red dots in Figure 92 above, which depict three demand nodes (irrigation, domestic and industry). Water can be obtained from surface water or groundwater. According to the Spanish Water Law, water must be diverted first to domestic uses, second to agriculture and third to industry.

- ‘Domestic’ represents all the water required for urban purposes. It depends on the total population in the country and the water use rate per capita. It has been assumed that domestic demand uses 20% of the inflow received from the river or the aquifer. The remainder is returned to the system through return flow connections (20% is returned upstream in the river, while 80% goes downstream in the river).

- ‘Irrigation’ represents all the water requirements for irrigation in the country. It includes the area distribution of the most representative crops, crop water requirements and irrigation schedule. Irrigation water withdrawal exceeds the consumptive use of irrigation because of water lost in water-supply distribution systems (irrigation canals and on-farm irrigation systems). The average on-farm irrigation efficiency in Spain is about 0.74. Therefore, irrigation water use was increased by 36%. Additional water requirements due to efficiency losses in irrigation canals have been assumed to be 40%. It has been assumed that 65% of the inflow is used on site (lost from the system). Of the remainder, 20% is returned to the aquifer, 20% upstream in the river and 60% downstream in the river.

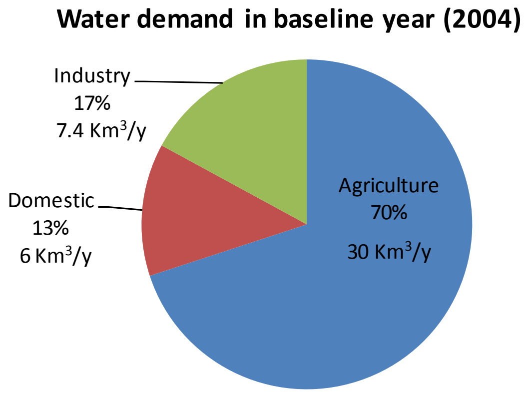
- ‘Industry’ represents all the water required for industrial supply. It depends on the level of GDP and GDP per capita (GDPP) in the country, and on the water use rate per production unit. According to AQUASTAT, as countries produce more GDP they use more water, but as the country grows richer per person it is more inclined to save water. Following this rationale, future industrial water withdrawals have been defined as follows:

$$IWC_t = \frac{IWC_{t-1} \times GDP_t}{\left(GDP_{t-1} * GDPP_{t-1}\right) / GDPP_t} \tag{8}$$

where IWC_t is the industrial water consumption in the year t; IWC_{t-1} is the industrial water consumption in the previous year t-1; GDP_t, $GDPP_t$, GDP_{t-1}, $GDPP_{t-1}$ are the gross domestic product and the gross domestic product per capita in the year t and in the previous year t-1.

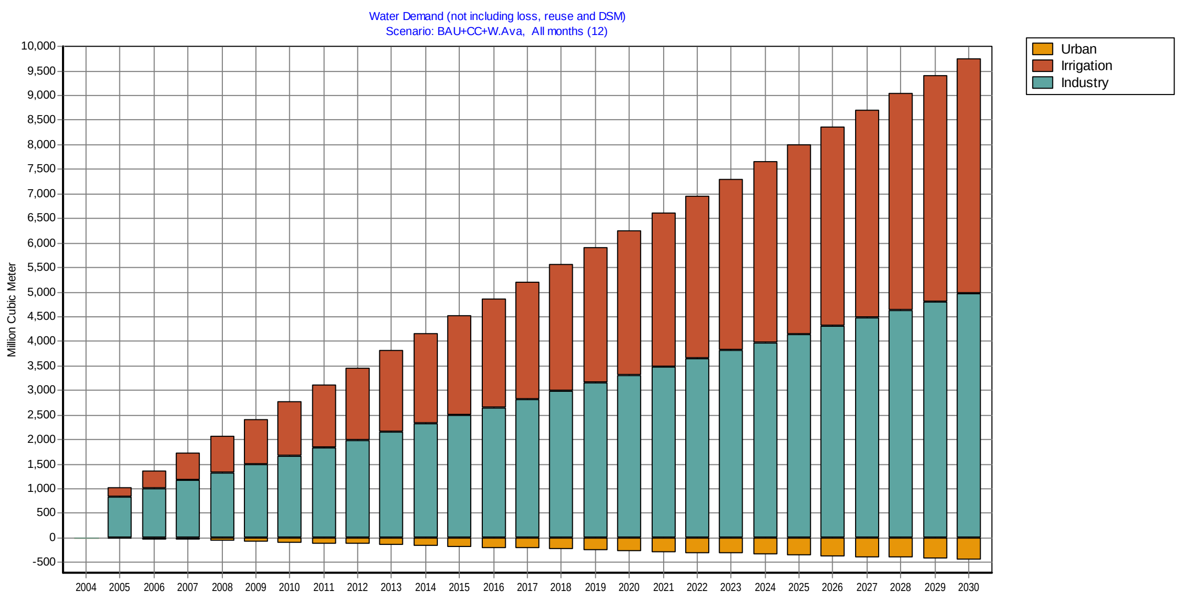
Return flows can discharge upstream in the river (so can be reused) and downstream in the river (so no reuse). Similar to domestic demands, it has been assumed that the industrial sector uses 20% of the inflow received from the river or the aquifer. The remainder is returned to the system through return flow connections (20% is returned upstream in the river, while 80% goes downstream in the river). Figure 94 shows the total amount of water used by each sector in the baseline year 2004.

Figure 94. Urban, agricultural and industrial water use in Spain (2004)



For each scenario, we obtain the changes in water demand, surface water supply and groundwater storage, compared with the reference situation (year 2004). From these data, the model compares water supply with water consumption, and also calculates the extent to which demand is fulfilled in each scenario (unmet demand or demand coverage). To simplify this section, here we present the results obtained for the scenario of BAU with climate change, in relation to the reference situation. Figure 95 shows long-term forecasts for water demand for each of the main water uses in Spain (urban, industrial and agricultural).

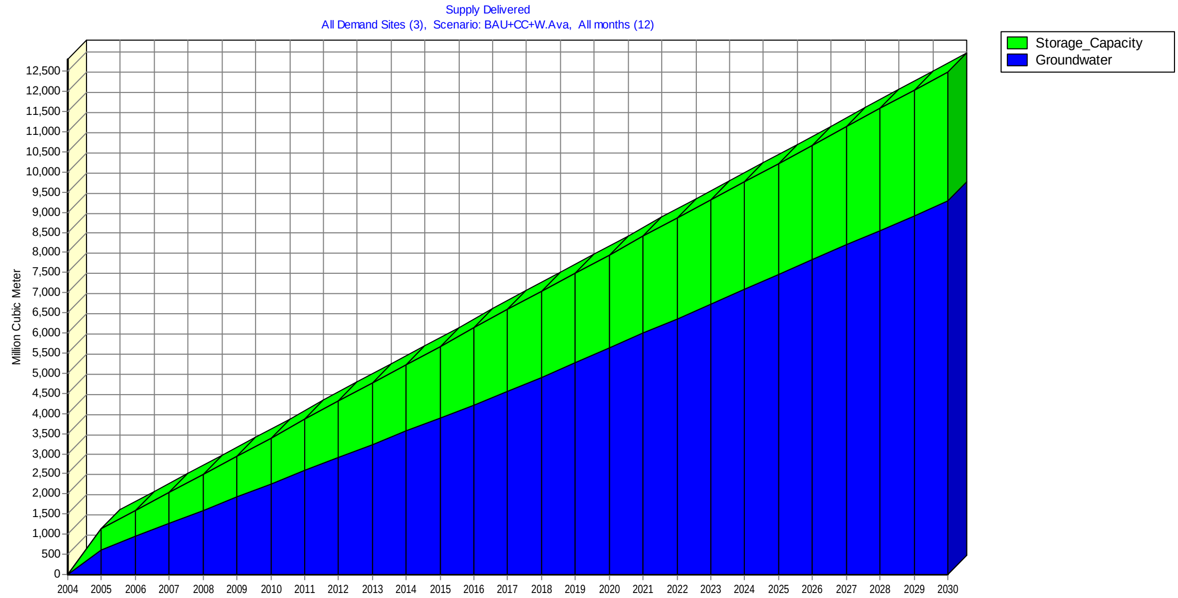
Figure 95. Water demand in Spain: BAU scenario, including climate change, relative to the baseline



As shown in Figure 95, water use in Spain is predicted to increase by almost 9,500 Mm^3 by 2030 due to the development of the industrial sector and the rise of irrigation water needs as a result of climate change. Although agriculture will continue to be the main water user from 2004 to 2030, the contribution of industry to Spanish economic growth will play a major role in the use of water resources in the near future. Notably, in the short term, water demand increases will be caused by the expansion of industry. Climate change impacts will be hardly noticeable before 2020; that is why the increase in irrigation water demand will be more pronounced at the end of the period studied. While an increase in industrial and agricultural water demand is observed, domestic water use is expected to decrease by 500 Mm^3 (about 8%) by 2030. In the coming years, Spanish demographic growth will follow a slightly descending trend. Over the period 2004–30, life expectancy will increase, but the number of deaths will also rise due to the progressive ageing of the population structure. As a result, the number of births and the number of deaths will be almost the same at the end of the period. Yet, the tendency of the Spanish population to emigrate abroad will increase while simultaneously the immigration flows will decrease, because of the economic crisis and the poor employment situation in Spain.

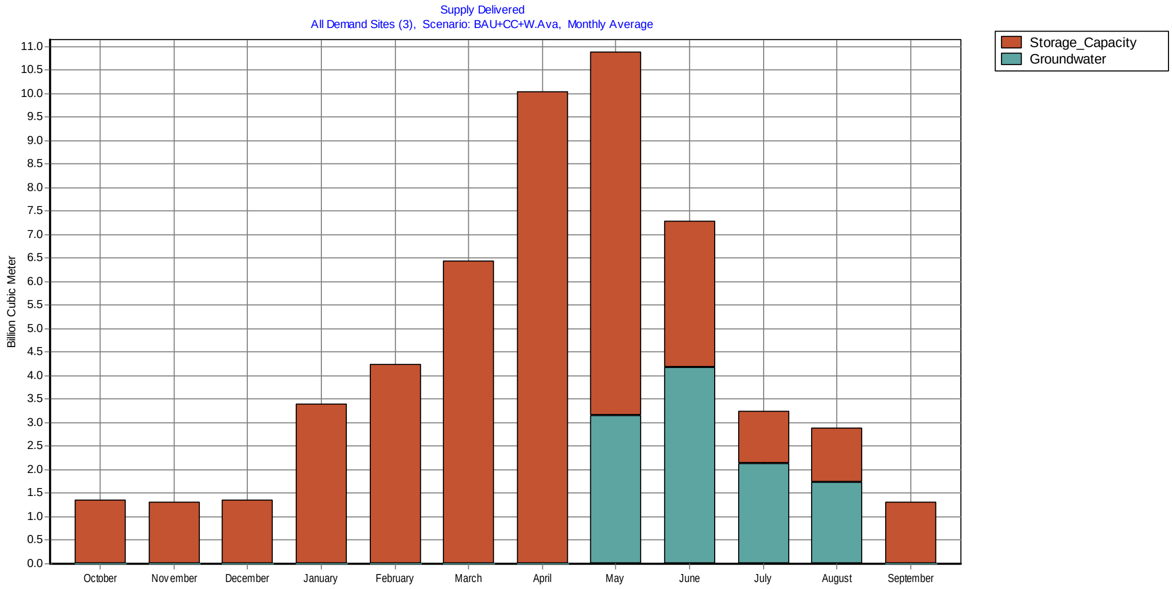
Our findings indicate that an increase in water supply will be required to meet projected water demands. Figure 96 shows the water supply delivered in Spain during the period 2004–30, compared with the reference situation in 2004, from each of the main water supply structures: the reservoir and the aquifer.

Figure 96. Water supply delivered in Spain (annual average): BAU scenario, including climate change, relative to the baseline



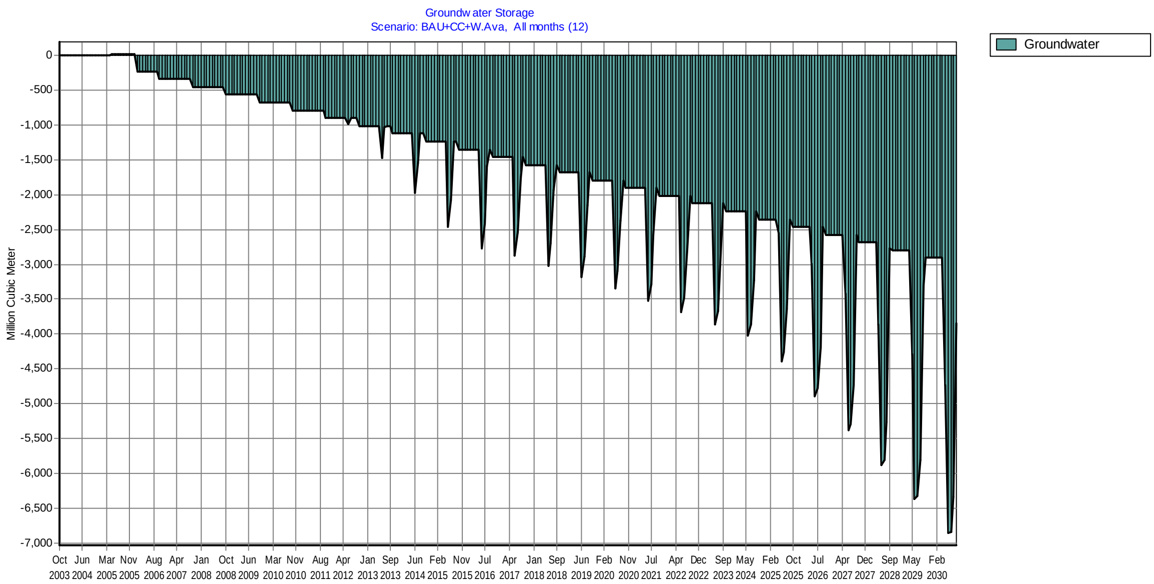
As depicted in Figure 96, water users can take water directly from the reservoir or the aquifer. The results obtained reveal that to satisfy water demand by 2030, the amount of water delivered should increase by 4,000 Mm^3 from the reservoir and by 8,500 Mm^3 from the aquifer, which means that current supply will be inadequate to meet the water requirements in the future. In Spain, surface water is the main source of water. Groundwater, however, is key for urban and agricultural uses. Groundwater is mainly used at the beginning of the crop-growing season, buffering the production risk for farmers (see Figure 97).

Figure 97. Water supply delivered in Spain (monthly average): BAU scenario, including climate change



Climate change will have a significant impact on the sustainability of water supplies. According to the literature, it is expected that the current, mean annual flow in Spain will be reduced by 11% (Garrote et al., 2004). Although groundwater is less vulnerable to climate change than surface water, it is foreseen that stored groundwater will decrease by 7,000 Mm^3 by 2030, especially in the summer months, coinciding with periods of high water demand (see Figure 98). Additional efforts should be made to save water and close the gap between water supply and water demand.

Figure 98. Groundwater storage in Spain: BAU scenario, including climate change, relative to the baseline



6.4 Application of the MEDPRO storylines

A set of scenarios has been selected for simulation in the economic model, to find out the impacts of market prices, climate and technological changes on the agricultural sector. Tables 14 and 15 summarise the characteristics of the selected scenarios for the three countries – Jordan, Syria and Morocco – for 2030 under climate change. After simulating the case of Spain (representing a northern Mediterranean country), Jordan and Syria are taken as examples of two south-eastern Mediterranean countries and Morocco as a south-western one.

Four scenarios have been applied that correspond to the different changes that are more likely to occur depending on the future situation of the EU–Mediterranean region with respect to the reference year 2004.

In the QI (reference) scenario (until 2010), intergovermentalisation in EU–Mediterranean relations is achieved through bilateral agreements among EU member states and the 11 SEMCs. It is more based on an 'economy first' approach, where a severe climate change is forecasted, agriculture is intensified and new technologies are adopted, however poorly.

In the second scenario, QII (which is one of two sustainability scenarios), northern Mediterranean countries increase their public transportation and produce strategies to mitigate climate change, concentrating on sustainable extensification of agriculture and investments in water-saving technologies.

The third scenario, QIII, which also promotes sustainability, forecasts long-term policy enforcement accompanied by a population increase in the SEMCs and a decrease in their exports. Bilateral agreements are concluded between the EU and the 11 SEMCs, and water-saving and recycling technologies are adopted.

As can also be seen in Table 14, two simulations have been run on the second and the third scenarios representing sustainability: the tariff and the quota assumptions. The tariff simulation assumes that on-farm water consumption will be decreased as a result of applying a tariff that will adjust the amount consumed by the projected effect of climate change. The second simulation assumes that a fixed quota is implemented through a policy measure, which would adjust the on-farm water consumption by the projected amount.

The last scenario, QIV, reflects the negative effects of climate change and an increase of migration to the EU. This scenario eventually leads to crises, conflicts and terrorism. Agricultural intensification increases, sustainability deteriorates and the development of technology is constrained.

As Tables 14 and 15 show, the following variables have been adjusted under climate change: product prices, input prices, yields and crop water requirements, water availability, improvements in pressurised irrigation systems and a structural change entailing a decrease in water consumption.

According to OECD projections for cereals, an increase of 9% for the three countries corresponds to the general world price increase (with cereals used as a proxy for crop prices). The increase in product prices in the case of Morocco corresponds to better export opportunities in the sustainability scenarios.

Price projections have been taken from MARM (2010) for input prices and from the OECD (OECD–FAO, 2010) for agricultural product prices. The changes in crop water requirements and crop yields due to severe climate change (Carmona, 2011; Giannakopoulos et al., 2009) come from the results of the crop model AquaCrop (see section 6.3.1) and the literature review. The data on the reduction of water availability comes from the WEAP model. Finally, in the 'technological improvements' scenario we have simulated an improvement in irrigation technology, by increasing the surface of irrigated crops under pressurised irrigation systems, as an example of an adaptation strategy.

Table 14. Simulated assumptions for climate change under the four MEDPRO scenarios

<table>
<tr><th></th><th>Jordan</th><th>Syria</th><th>Morocco</th></tr>
<tr><td>QI</td><td>Cereal prices decrease by 9%
Input prices increase by 5%
Water availability decreases by 20%
No improvements in pressurised systems apply
No structural change applies</td><td>Cereal prices decrease by 9%
Input prices increase by 5%
Water availability decreases by 20%
Pressurised systems improve by 5%
No structural change applies</td><td>Cereal prices decrease by 9%
Input prices increase by 5%
Water availability decreases by 15%
Pressurised systems improve by 15%
No structural change applies</td></tr>
<tr><td>QII – Tariff
QII – Quota</td><td rowspan="2">Cereal prices decrease by 9%
Input prices increase by 5%
Water availability decreases by 20%
Pressurised systems are improved by 8%</td><td>Cereal prices decrease by 9%
Input prices increase by 5%
Water availability decreases by 20%
Pressurised systems improve by 16%
Water consumption decreases by 31%</td><td>All product prices increase by 10%
Input prices increase by 5%
Water availability decreases by 15%
Pressurised systems improve by 25%
Water consumption decreases by 16%</td></tr>
<tr><td>QIII – Tariff
QIII – Quota</td><td>Cereal prices decrease by 9%
Input prices increase by 5%
Water availability decreases by 20%
Pressurised systems improve by 16%
Water consumption decreases by 15%</td><td>All product prices increase by 5%
Input prices increase by 5%
Water availability decreases by 15%
Pressurised systems improve by 25%
Water consumption decreases by 16%</td></tr>
<tr><td>QIV</td><td>Cereal prices decrease by 9%
Input prices increase by 5%
Water availability decreases by 20%
No improvements in pressurised systems apply
No structural change applies</td><td>Cereal prices decrease by 9%
Input prices increase by 5%
Water availability decreases by 20%
Pressurised systems improve by 2%
No structural change applies</td><td>Cereal prices decrease by 9%
Input prices increase by 5%
Water availability decreases by 15%
Pressurised systems improve by 15%
No structural change applies</td></tr>
</table>

Table 15. Percentage change in yields of the selected crops under climate change

	In all the scenarios
Jordan	Yields for { *rainfed wheat increases by* 20% *other irrigated wheat increases by* 9% *potato increases by* 23% *tomato increases by* 9% *rainfed olives decreases by* 7% *other irrigated olives increases by* 9%
Syria	Yields for { *rainfed wheat increases by* 20% *other irrigated wheat increases by* 9% *cotton increases by* 8% *tomato increases by* 9%
Morocco	Yields for { *rainfed cereals increase by* 20% *other irrigated cereals increases by* 9% *tomato increases by* 9% *sugar beet increase by* 23% *citrus increase by* 20%

For the hydrologic model, different trends from 2004 to 2030 on population growth, GDP development and irrigation expansion have been considered to estimate the level of water used per economic sector (domestic, industrial and agricultural). Long-term growth projections for population, GDP and irrigated land area are exogenous to the model. Active population and population growth have been obtained from the UN's *World Population Prospects*, assuming a medium scenario (UN, 2009) and from MEDPRO WP3 (Groenewold et al., 2012). Assumptions on economic growth in the 11 SEMCs are based on MEDPRO WP5 (see Coutinho, 2011). These assumptions have also been used by MEDPRO WP8 to calculate GDP and GDPP projections for the four MEDPRO scenarios using the GEM-E3 model (Kouvaritakis et al., 2011; Paroussos et al., 2012). Changes in irrigated land areas have been obtained from the SCENES project.[7]

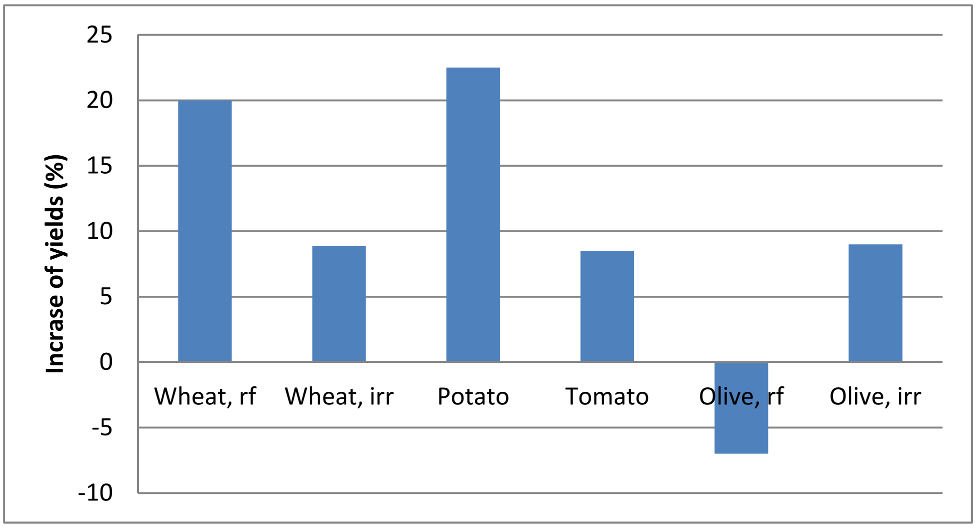
Water availability has been simulated under a severe climate change scenario (SRES-A2) by taking into account the foreseen changes in water inflows, an increase in crop water requirements and cropping mix adjustments. Variations in crop water requirements and cropping patterns have been obtained from the agronomic model and the economic model, respectively. In turn, the hydrologic model provides updated information on water supply and water demand coverage, and informs the economic model about the total amount of water available for agricultural use.

6.5 Jordan

6.5.1 Results of the crop model

In this case, no specific simulations have been performed for Jordanian conditions, but crop yields and water needs have been estimated based on the results of simulations performed for Spain and the literature (see, e.g. Giannakoupoulos et al., 2009). Similarly, changes have been estimated (in percentages) for the moderate climate change scenario, for both variables: yields and crop water needs. Like the case of Spain, given no water restrictions, crop yields experience an increase as a consequence of climate change for all the crops considered. At the same time, we have considered different crops, selecting those that are representative of Jordanian agriculture. Figure 99 shows the expected changes in crop yields for a severe climate change scenario (SRES-A2), expressed as a percentage of change compared with current yields.

Figure 99. Increase in crop yields in a severe climate change scenario, compared with the present, for a selection of crops in Jordan (%)



Sources: Own elaboration based on Giannakoupoulos (2009) and Carmona (2011).

[7] The web-based interface is at http://www.1stcellmedia.de/customer/uni/cms/.

The changes have been estimated for the moderate climate change scenario as well, for both variables: yields and crop water needs. In this case the positive effects of climate change outdo the negative ones when no water restrictions are imposed. Only in the case of rain-fed olive groves, where irrigation does not mitigate the adverse effects of climate change, are yields reduced under climate change.

Estimations of yields and water needs for the two climate change scenarios are finally introduced as an input into the economic model.

6.5.2 Results of the economic model

The economic model used for Jordan to simulate the scenarios is outlined in Table 16. The results of these simulations are displayed in Figures 100, 101 and 102. These figures show, respectively, the percentage of each crop that has been chosen as optimal by the economic model in each scenario, the changes in farm income compared with current figures and the changes in agricultural employment compared with the present situation.

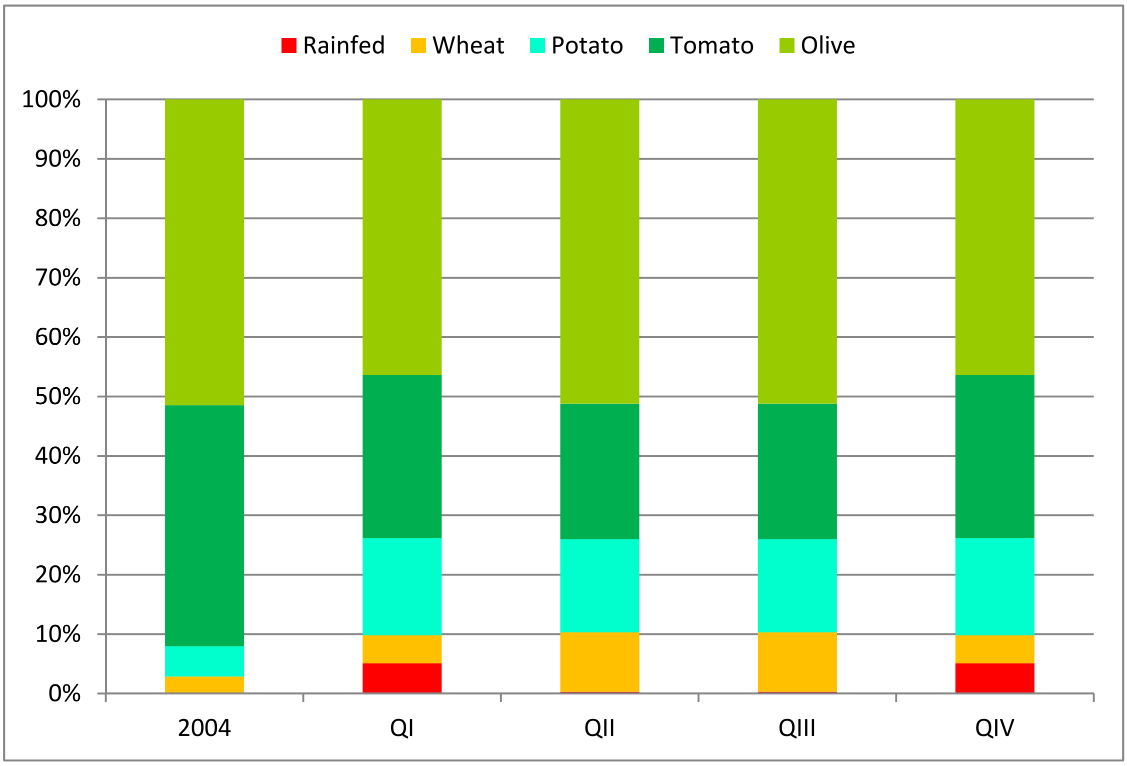
As can be seen from Table 16, a structural change related to the water consumption on farms does not take place against the background of climate change. Also note that pressurised irrigation in scenarios QII and QIII experiences a small improvement of 8% of the actual (based on 2004) pressurised system coverage in Jordan.

Table 16. Simulated scenarios of climate change for Jordan

	Jordan			
	QI	QII	QIII	QIV
Product prices	-9% cereal prices			
Input prices	+5%			
Yields & crop water requirements	Same climate change impact: variation according to Carmona (2011) and Giannakopoulos et al. (2009)			
Water availability	Same climate change impact: 20% decrease, only affecting availability at the global level and simulated in WEAP; we consider that this reduction in water resources is not reflected in water quotas			
Improvement in pressurised irrigation	0	8%	8%	0
Structural change (water consumption decrease)	0	0	0	0

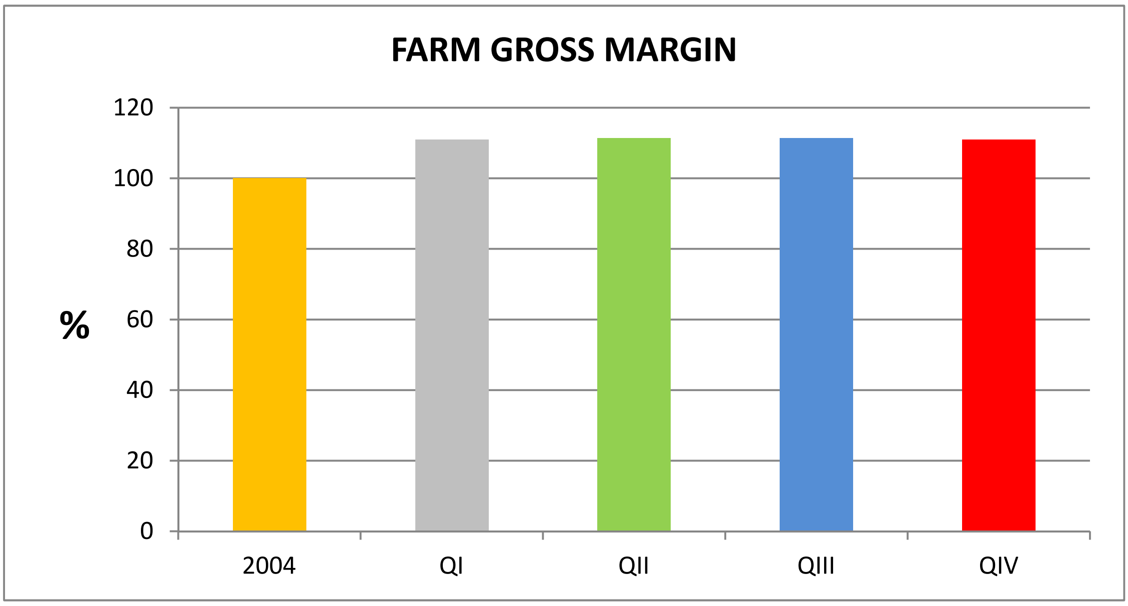
Like in the Spanish case study, a set of representative crops has been provided to enable the model to choose the crop combination that maximises utility. In the Jordanian model, the set of crops is composed of wheat, potatoes, tomatoes and olives. The case of Jordan differs significantly from that of Spain, as in Jordan permanent crops are much more relevant, covering around 55% of the total irrigated area. The inclusion of olives among the selected representative crops implies, given that the economic model is an annual model, that the surface of olive trees is considered constant in the future, and the only possibility for this crop is to switch from irrigated to rain-fed olive groves.

Figure 100. Jordan: Cropping pattern under different simulated scenarios (% of irrigated land)



Changes in cropping patterns are accompanied by a change in farm income, as displayed in Figure 101. These changes are given as a percentage of the current income for the specified, representative farm type, with 100% corresponding to €1,243/ha.

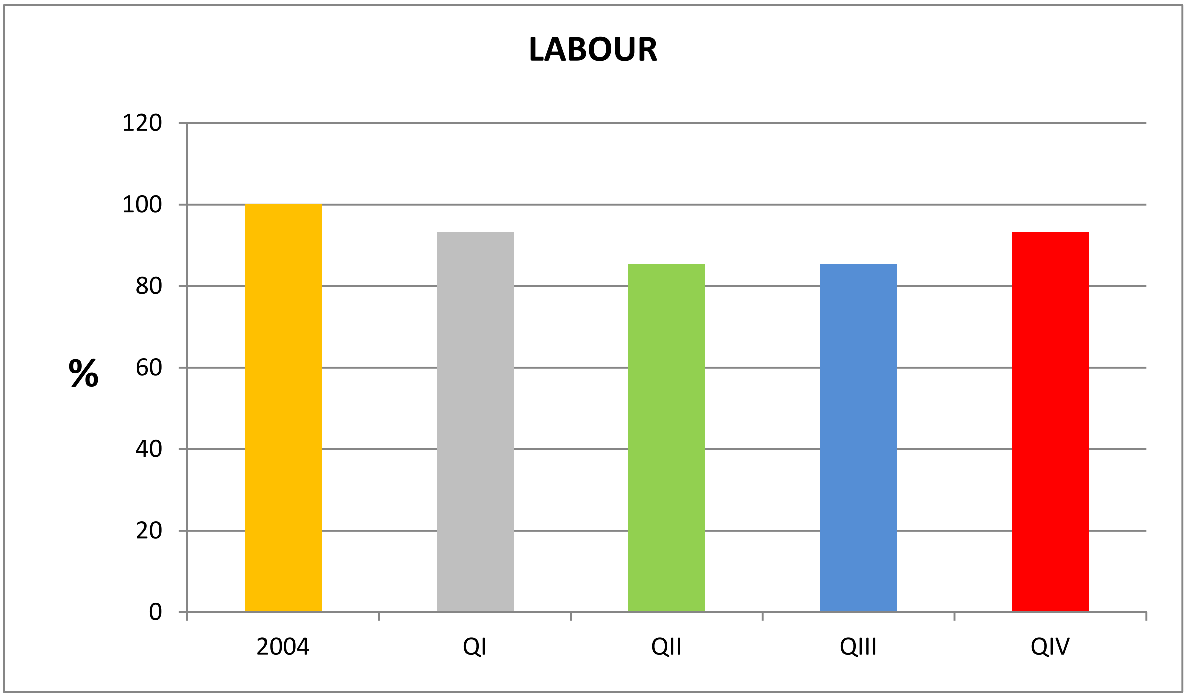
Figure 101. Jordan: Farm income under the different scenarios (% with respect to the reference)



According to these results, the impacts of simulation scenarios on farm income show that climate change and an improvement of pressurised irrigation are important drivers of income changes. Yet, the overall impact of climate change on farm income is not remarkable (an income gain of around 11%). Nevertheless, it is important to notice here that as Jordan's irrigation systems are already quite technologically advanced, there is little room for technology to soften the negative economic impacts that may arise when larger constraints are imposed on water. In this case, with Jordan being such a water-scarce country, awareness is already high and no structural change is expected even in the sustainability scenarios, and therefore projections for the different scenarios are quite similar.

Changes in cropping patterns also imply changes in labour use. Figure 102 shows the impact of the simulation scenarios on agricultural employment as a percentage of current labour use, with 100% corresponding to 4,865 h/year.

Figure 102. Jordan: Agricultural employment under the different scenarios (% with respect to the reference)

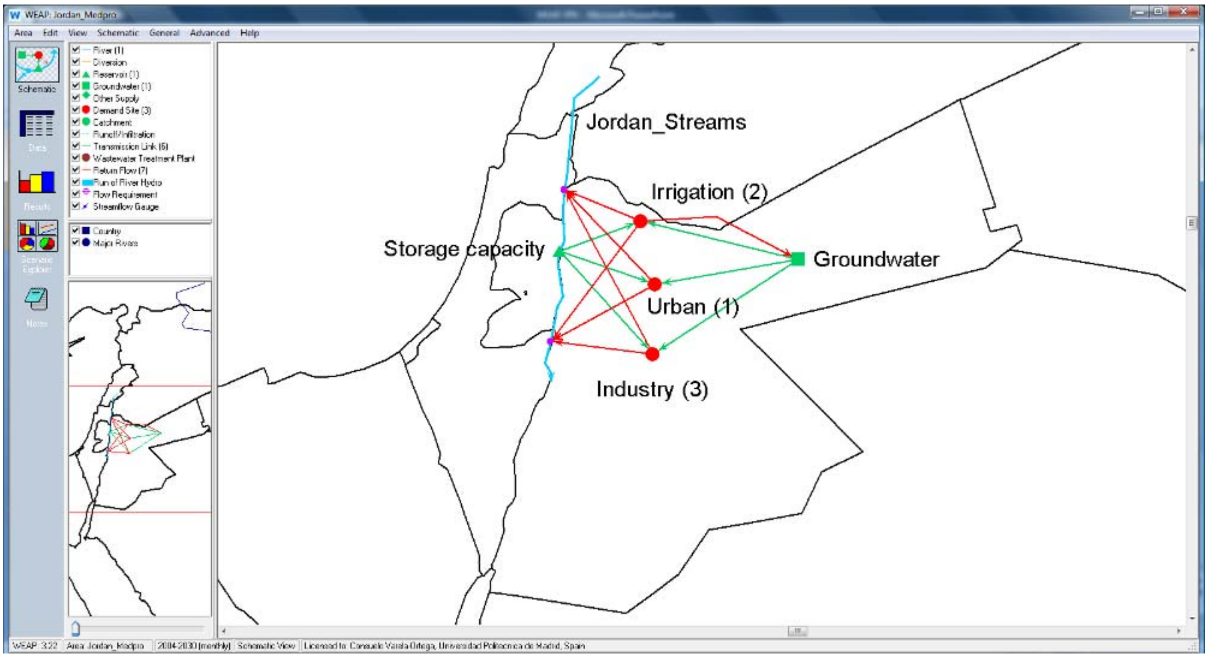


From Figure 102 we can see that climate change scenarios involve a reduction in agricultural employment, especially when farm water allotments are reduced. This is due to the replacement of highly labour-intensive crops, such as tomatoes or irrigated olives, by more extensive crops (wheat and rain-fed cropland), for which the labour demands are lower. Technological improvements in this case have some impact on labour, as crop substitution leads to an even lower tomato crop surface in favour of irrigated olive groves.

6.5.3 Results of the hydrologic model

Following the steps and rationale used to develop the WEAP model for Spain, the WEAP hydrology model has been applied to Jordan. Figure 103 presents the WEAP layout for Jordan, which shows the main hydrologic elements of the water system and their linkages as depicted in the WEAP platform.

Figure 103. Schematic of the WEAP model for Jordan



Water supply in Jordan is characterised by the following features:

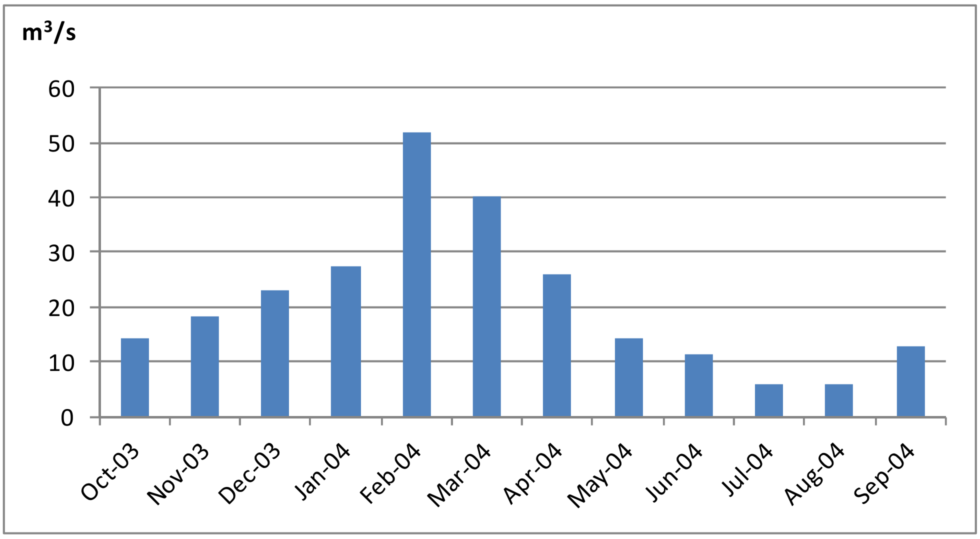
- one river, drawn as a blue line in WEAP, which comprises all surface renewable water in the country. The most important river in Jordan is the Jordan River, which comes from Lebanon and flows to the Dead Sea. Thus, the virtual river in the Jordan WEAP application replicates the shape of the Jordan River. As shown in Figure 103, the river serves as the eastern border of Israel and the West Bank. Precipitation varies greatly with location (from 50 mm in the eastern and southern desert regions to 650 mm in the northern highlands), but it usually occurs between October and April. River flows are of a flash-flood nature, with large seasonal and annual variations. Figure 104 shows the monthly headflow of the aggregated Jordan River. Return flows, depicted in WEAP using red arrows, make their way back to the system upstream and downstream in the river;

- one aquifer, represented in WEAP by a green square, which accounts for all groundwater storage within the country. In Jordan, the total capacity for groundwater storage capacity is about 540 Mm^3. The most important aquifers are located in the Yarmouk, Amman-Zarqa and the Dead Sea basins. Water can be pumped from the aquifer for agricultural, domestic or industrial uses, but only irrigation return flows go back to the aquifer. In 2004, about 60% of the total water withdrawal came from groundwater;

- one reservoir, characterised in WEAP by a green triangle, which groups all the dams and reservoirs spread all over the country. In Jordan, the construction of dams has been strongly promoted over the last five decades. In 2004, Jordan had ten dams with a total storage capacity of 275 Mm^3. The main dam is the King Talal Dam on the Zarqa River with a total capacity of 80 Mm^3. Water can be extracted from the reservoir for agricultural, urban or industrial purposes; and

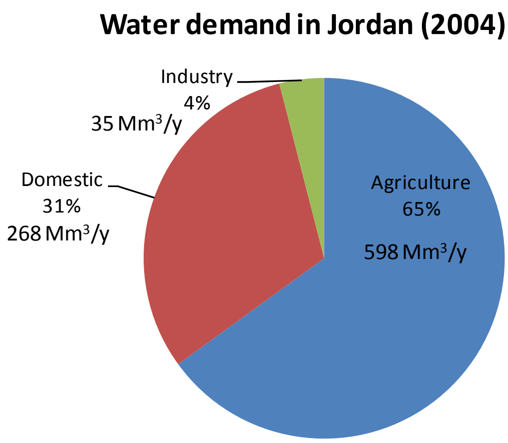
- reused treated wastewater and desalinated water, which are important non-conventional sources of water in Jordan. The study is still in progress. In this report, these sources have been considered part of surface water.

Figure 104. Headflow of the river in Jordan for the baseline hydrologic year 2003–04



The WEAP representation of water demand nodes is symbolised by red dots in Figure 103 above, which depict three demand nodes (irrigation, domestic and industry). Figure 105 illustrates the water used by each of the economic sectors in the baseline year (2004).

Figure 105. Urban, agricultural and industrial water use in Jordan (2004)



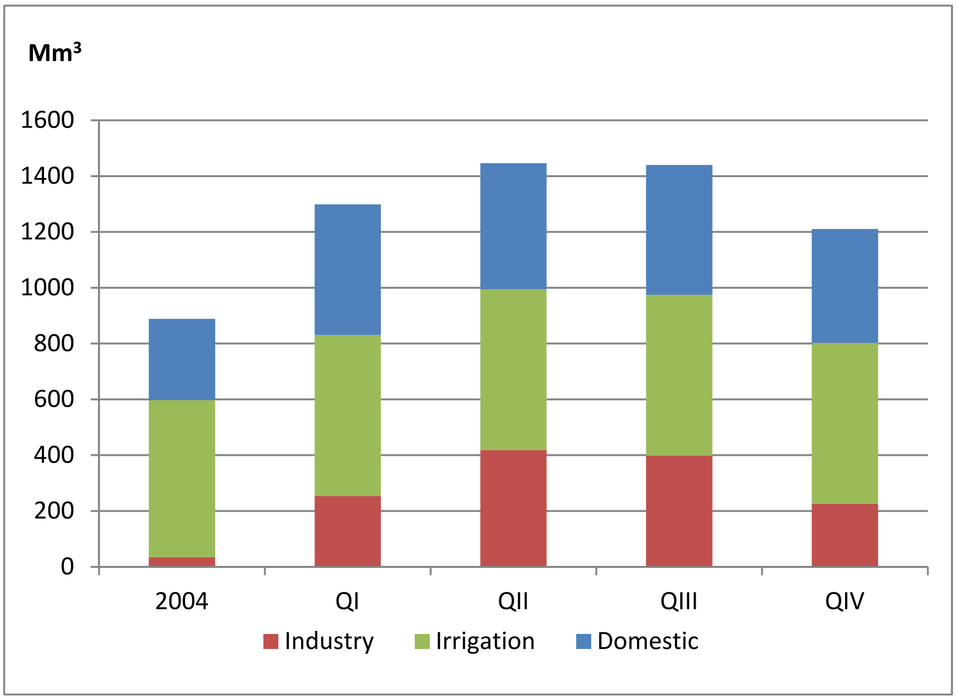
- ‘Domestic’ represents all the water required for urban purposes. It depends on the total population in the country and the water use rate per capita. In 2004, Jordan had 5.7 million inhabitants and a population growth rate of 2.5%. About 70% of Jordan’s population is urban, mostly concentrated in the north-west quadrant of the country where rainfall is highest. Domestic water use was about 268 Mm^3 (31% of the total water consumption) and 47 m^3/person. It has been assumed that domestic demand calls for 20% of the inflow received from the river or the aquifer. The remaining volume is returned to the system through return flow connections (20% is returned upstream in the river, while 80% goes downstream in the river).
- ‘Irrigation’ represents all water requirements for irrigation in the country. It includes the area distribution of the most representative crops (already defined in the agro-economic model), crop water requirements and irrigation schedule. Traditional irrigated lands (by gravity) cover only 18% of the total irrigated land. The remaining area, 82% of the total irrigated land, is irrigated almost totally with drip irrigation. Sprinkler irrigation almost does not exist due to water quality problems. Additional water requirements stemming from efficiency losses in irrigation canals

have been assumed to be 50%. The agricultural sector is the main water user. Many irrigation projects, such as the King Abdullah Canal (the most important irrigation canal in Jordan), were developed along the Lower Jordan River, in the Jordan Valley, which concentrated most of the irrigated crops (mainly vegetables). In 2004, about 598 Mm^3 of water (65% of the total water consumption) was used to irrigate 76,000 ha. Therefore, average water use for irrigation for the baseline year was about 8,304 m^3/ha. It has been assumed that 65% of the inflow is used on site (lost from the system). Of the remaining water, 20% is returned to the aquifer, 20% upstream in the river and 60% downstream in the river.

- ‘Industry’ represents all the water required for industrial supply. It depends on the level of GDP and on GDP per capita (GDPP) in the country, and on the water use rate per production unit. Industry only used 34 Mm^3 in 2004 (4% of the total water consumption). Return flows can discharge upstream in the river (so they can be reused) and downstream in the river (with no reuse). Similar to domestic demands, it has been assumed that the industrial sector uses 20% of the inflow received from the river or from the aquifer. The remaining volume is returned to the system through return flow connections (20% is returned upstream, while 80% goes downstream).

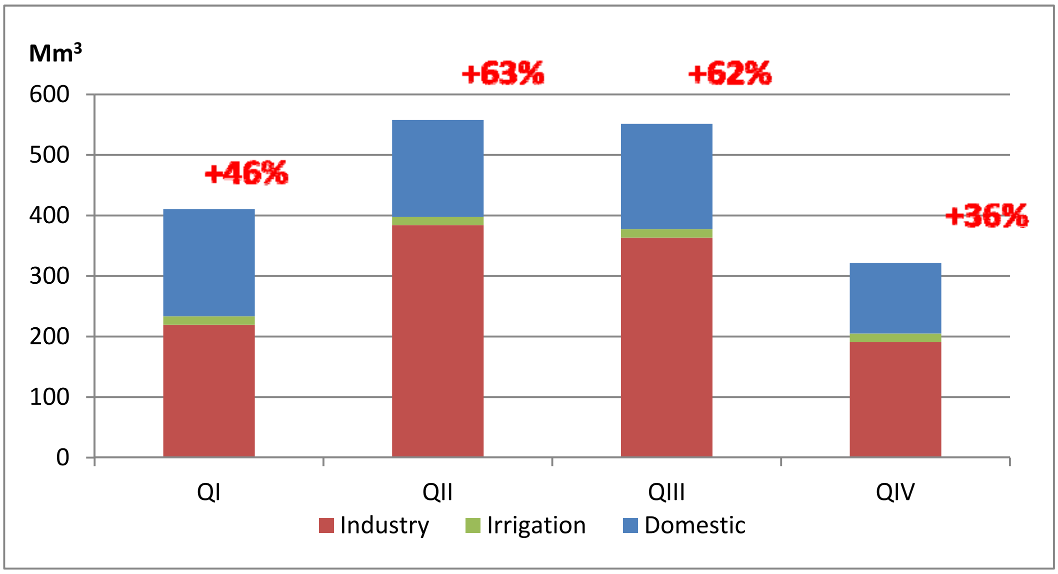
In the same way as in the previous section, with the aim of simplifying this report, here we only present the results obtained under the different MEDPRO scenarios in relation to the reference situation in 2004. Figure 106 shows the forecasts for long-term water demand for each of the main water uses in Jordan (urban, industrial and agricultural). Figure 107 shows changes in water demand with respect to the reference situation (2004).

Figure 106. Jordan: Water demand under the different scenarios



Figures 106 and 107 show that socio-economic and demographic pressures will further increase future water demand in Jordan, particularly in scenarios QII and QIII. Significant changes in water demand will mainly occur in the industrial sector owing to the rapid economic growth expected for 2030 in Jordan. Because irrigation systems are already technologically advanced, irrigation demands for water will not change considerably, which leaves no room for technology to allow for increases in consumption. It is likely that industrial and domestic demands will increase in the future and that a threshold limit to irrigation expansion will be promptly reached.

Figure 107. Jordan: Changes in water demand, relative to the reference situation (2004)



As can be seen in Figure 107, water demand in scenario QI increases by 46% in 2030 to a total of 1,299 Mm^3. Water demand increases sevenfold in the industrial sector with respect to 2004, while domestic demand almost doubles.

Moving to scenario QII, water demand in the industrial sector increases much more than in the previous scenario, by 384 Mm^3 by 2030. And that of the domestic sector increases also, by 160 Mm^3, but less than in scenario QI. Although the agricultural sector will continue to be the main water user, total water demand is almost equally divided among the agricultural, domestic and industrial sectors (40%, 31% and 29% respectively).

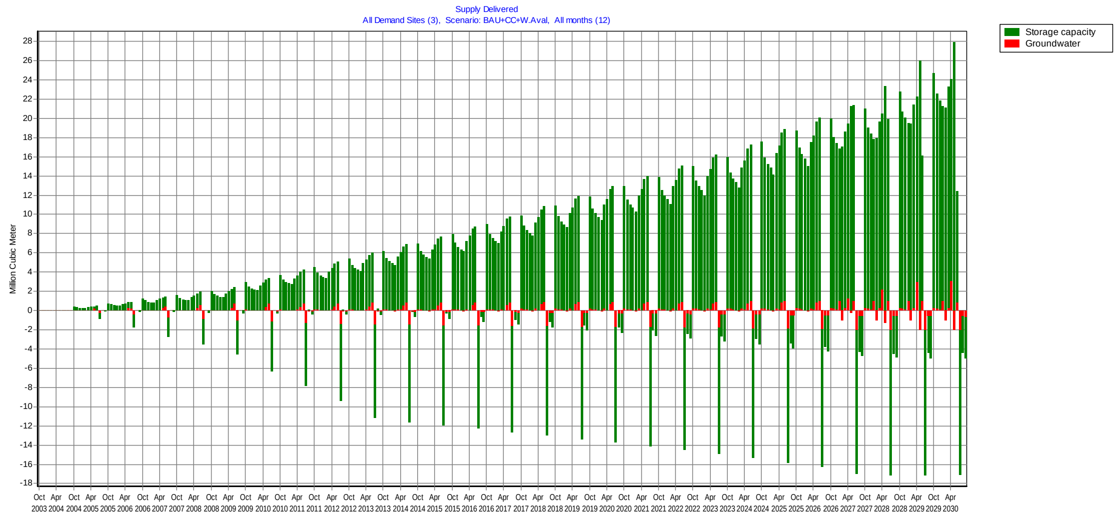
Similarly, in scenario QIII, total water demand in Jordan increases by 62% with respect to 2004, with the largest share of this increase attributable to the industrial sector. Its water demand increases by 363 Mm^3 in 2030 with respect to 2004, to a total of 398 Mm^3. Nevertheless, industrial water use in QIII is lower than in QII. The economy will grow at a slightly slower rate in QIII than in QII because of the lack of a common EU–Mediterranean market and only fragmented cooperation between the EU and the SEMCs. Water demand in QIV follows a similar pattern. Yet, under the QIV scenario, water consumption will increase to 1,210 Mm^3 in 2030, which represents a lower level than in the other scenarios and an average general increase of 36% with respect to 2004. Population growth and economic development in Jordan are not particularly expected in this QIV scenario of a Euro-Mediterranean area under threat.

On the top of that, climate change threatens to reduce water supply. As noted by Melsmani (2010), the Middle East is one of the most vulnerable regions to climate change. Regional modelling studies foresee a reduction of 10% of the average rainfall in Jordan by 2030; a 10% reduction in rainfall is well reflected by the 10–11% reduction in daily mean base flow for all the rivers (Samuels et al., 2010).

A decrease in water availability and an increase in water demands will accentuate water stress in Jordan by 2030. As many parts of Jordan rely on groundwater, however, the impact of climate change on water availability will not be as dramatic as in other countries. This outcome stems from the higher resilience of groundwater with respect to surface water. The effects of climate change are assumed to be uniform across the different MEDPRO scenarios, and thus projections of water supply will be the same for QI, QII QIII and QIV.

Figure 108 illustrates the water supply delivered in Jordan during the period 2004–30 compared with the reference situation in 2004, from each of the main water supply structures: the reservoir and the aquifer.

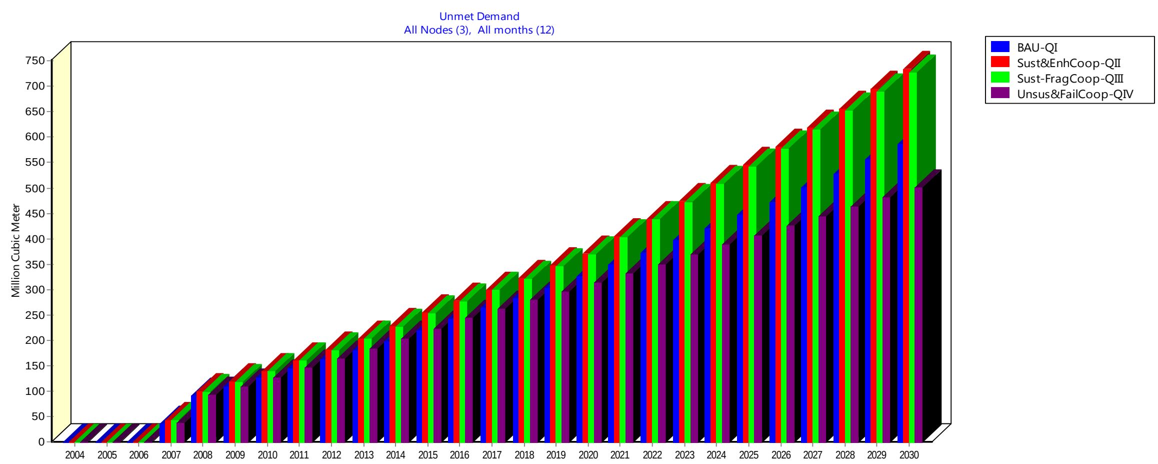
Figure 108. Water supply delivered in Jordan (monthly average), relative to the reference situation (2004)



In the period considered, the high storage capacity of reservoirs in Jordan will allow the country to partially cope with increasing water demands. Surface water delivery will increase by 150 Mm^3 from 2004 to 2030, while groundwater supplies will slightly decrease. Renewable groundwater resources are already exploited to their maximum capacity. In 2004, 6 of the 12 groundwater basins in Jordan were overexploited, 4 were balanced and 2 were underexploited. Therefore, surface water will be used to satisfy future water demands more than groundwater resources. Yet, as shown in Figure 108, the surface water supply (and to a lesser extent, the groundwater supply) decreases sharply in summer months (from July to September), which will constrain future irrigation developments in the country.

Finally, water stress has been assessed by comparing water supply with water demand. Figure 109 shows the unmet water demand in the baseline situation (2004, projected to 2030) under the different MEDPRO scenarios.

Figure 109. Unmet demand in Jordan under the different scenarios



In line with previous work (Immerzeel, 2011), our findings indicate that water resources in Jordan are very limited compared with the needs of the country. Figure 109 shows that unmet water demand could increase greatly by 2030 in all the scenarios and particularly in scenarios QII and QIII, in which economic growth is supposed to be stronger. In these scenarios (QII and QIII), the level of unmet

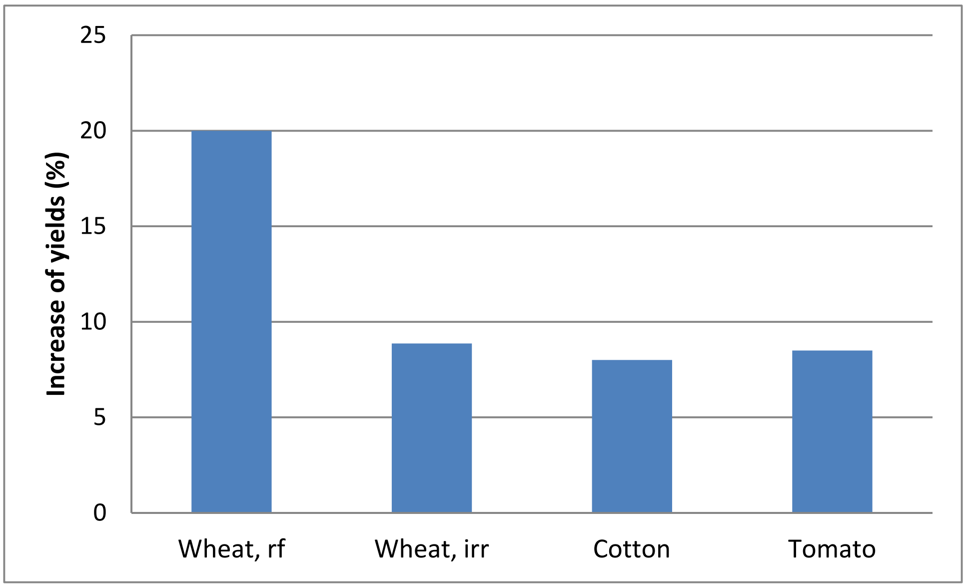
demand will increase from 0 Mm^3 to 734 Mm^3 and 727 Mm^3, respectively, from 2004 until 2030. The construction of new dams and reservoirs does not seem a feasible option to deal with future water shortages in Jordan, at least in the short term. Closing the gap between water supply and water demand by 2030 will require a combination of technical and management options, such as the application of water-saving techniques to manufacturing processes (water recycling and reuse), improvement of canal irrigation systems, implementation of water conservation policies (appropriate tariffs and quotas) and the development of water-efficiency education and awareness programmes.

6.6 Syria

6.6.1 Results of the crop model

In this case, no specific simulations have been performed for Syrian conditions. An estimation of crop water requirements and crop yield changes for the two climate change scenarios simulated, severe and moderate climate change (SRES-A2 and SRES-B2, respectively), has been made based on the differences between Spain and the Middle East found in the literature (Giannakoupoulos et al., 2009). Figure 110 shows the changes in crop yields for a severe climate change scenario for a selection of crops in Syria.

Figure 110. Increase in crop yields in a severe climate change scenario, compared with the present, for a selection of crops in Syria (%)



Sources: Own elaboration based on Giannakoupoulos (2009) and Carmona (2011).

Similarly, changes have been estimated (in percentages) for the moderate climate change scenario, for both variables: yields and crop water needs. Like in the case of Spain, given no water restrictions, crop yields experience an increase as a consequence of climate change for all the crops considered.

The results of scenario simulations have been introduced into the economic model for the simulation of climate change scenarios.

6.6.2 Results of the economic model

Table 17 presents the scenarios simulated for Syria. The results of these simulations are discussed below.

Table 17. Simulated scenarios of climate change for Syria

	Syria			
	QI	QII	QIII	QIV
Product prices	-9% cereal prices			
Input prices	+5%			
Yields & crop water requirements	Same climate change impact: variation according to Carmona (2011) and Giannakopoulos et al. (2009)			
Water availability	Same climate change impact: 20% decrease, only affecting availability at the global level and simulated in WEAP; we consider that this reduction in water resources is not reflected in water quotas			
Improvement in pressurised irrigation	5%	16%	16%	2%
Structural change (water consumption decrease)	0	-31%	-15%	0

Figure 111 shows the percentage of each crop chosen as optimal by the economic model in each scenario. A set of representative crops has been provided for the model in order to select the crop combination that maximises utility.

Figure 111. Syria: Cropping pattern under different simulated scenarios (% of irrigated land)

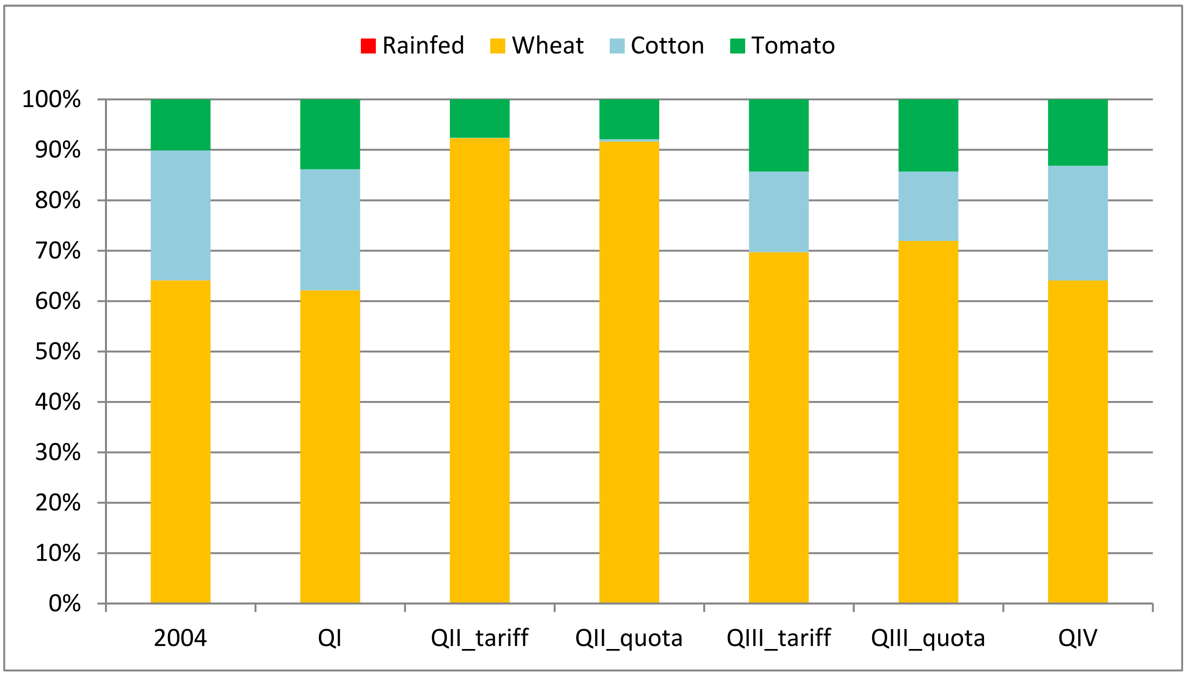
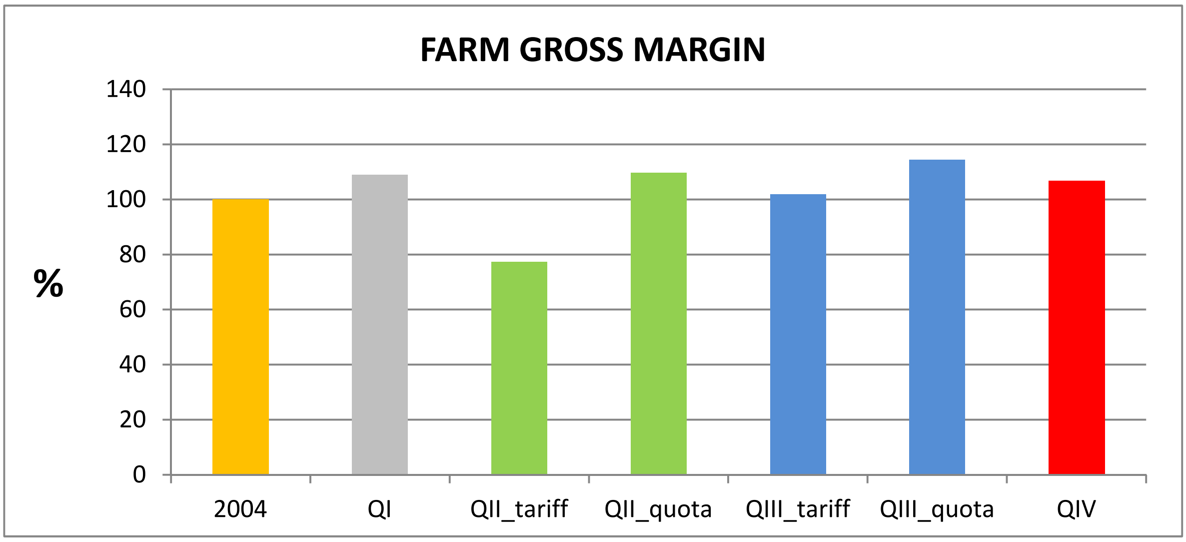


Figure 111 represents the cropping pattern in Syria under climate change. As can be noted, in QII where water consumption decreases by 31% accompanied by a 16% improvement in pressurised irrigation, cotton cultivation disappears and is substituted by wheat, while tomato cultivation decreases as well.

Changes in cropping patterns for the different scenarios are accompanied by a change in farm income, as shown in Figure 112. These results are given as a percentage of the current income of a representative farm, with 100% corresponding to €899/ha.

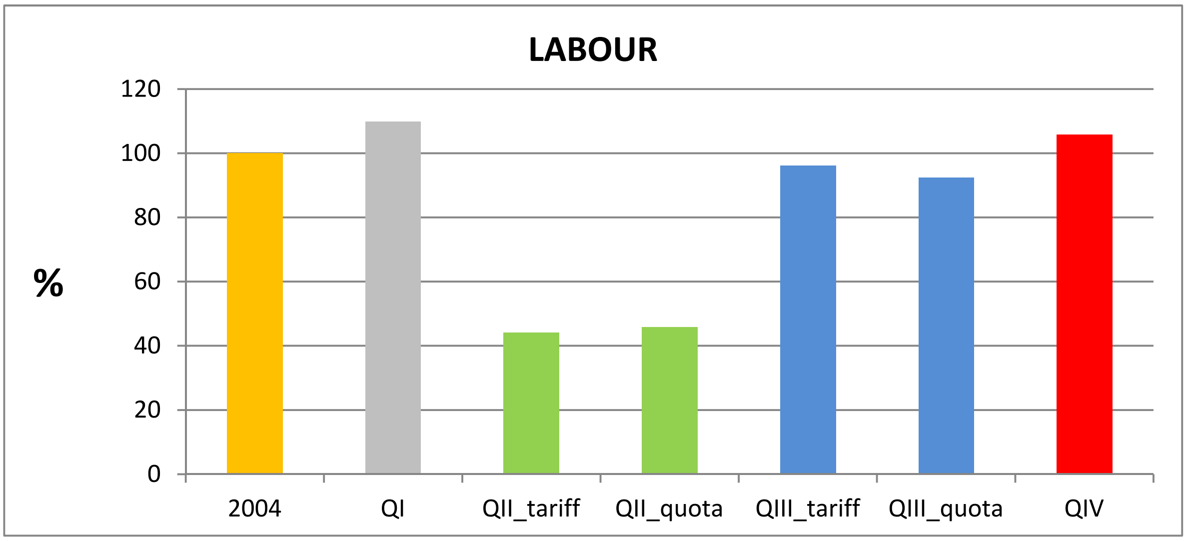
Figure 112. Syria: Farm income under the different scenarios (% with respect to the reference)



Climate change may lead to an increase in farm income in all the simulated scenarios because of higher yields when water is not constrained. Yet when there is a decrease in the availability of water for farms and a water tariff is implemented, it negatively affects farm income. Compared with the same scenario where water consumption is restricted by a direct water quota, with a water tariff (scenario QII) income decreases by 32%. When the water quota applies, even if the farm water consumption decreases, increase in yields and improved technology can overcome the effect of a restriction in water use.

Finally, Figure 113 shows the impact of simulation scenarios on agricultural employment as a percentage of current labour use, with 100% corresponding to 1,923 h/year.

Figure 113. Syria: Agricultural employment under the different scenarios (% with respect to the reference)

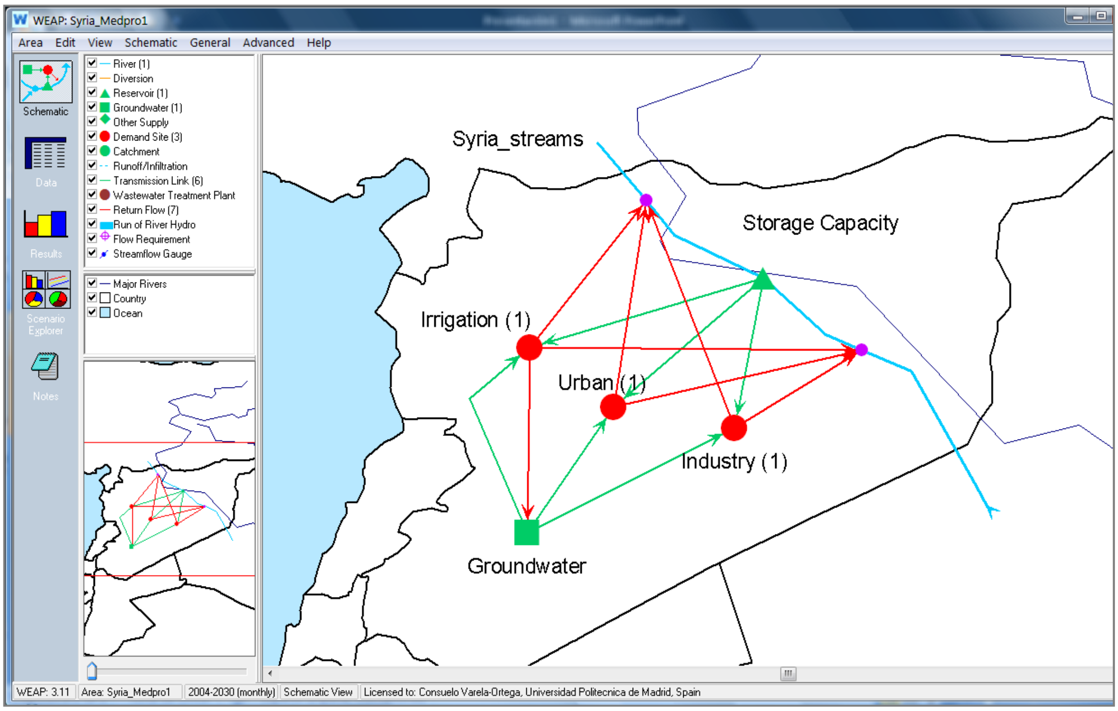


Climate change scenarios involve a reduction in labour, especially when farm water allotments are reduced, because of the replacement of cotton (a highly labour-intensive crop) by wheat (which does not require much labour). Technological improvements, however, have a positive impact on labour.

6.6.3 Results of the hydrologic model

Following the steps and rationale used to develop the WEAP model for Spain and Jordan, the hydrology model WEAP was applied to Syria. Figure 114 presents the WEAP layout for Syria, which shows the main hydrologic elements of the water system and their linkages as depicted in the WEAP platform.

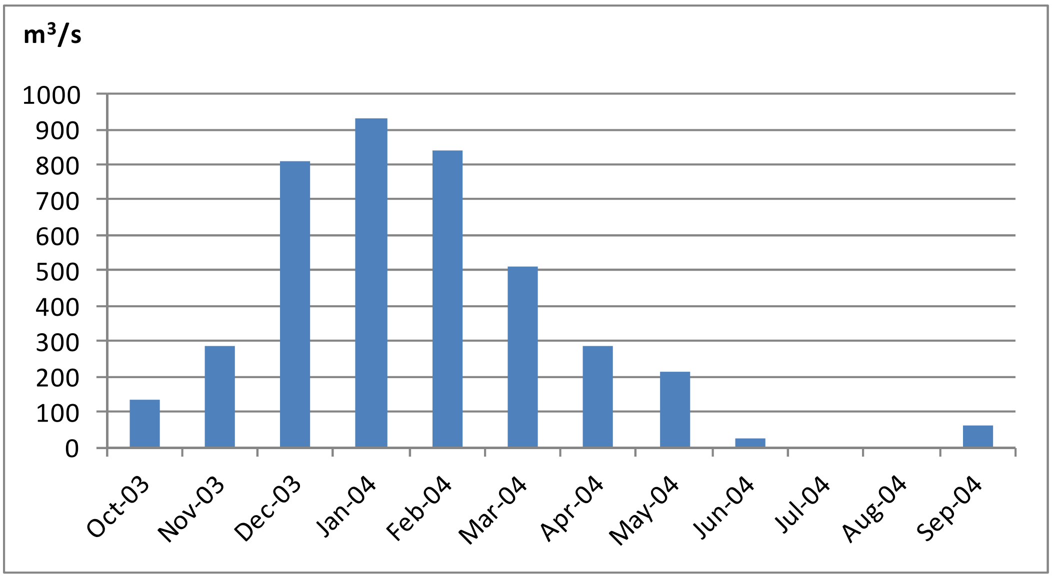
Figure 114. Schematic of the WEAP model for Syria



Water supply in Syria is characterised by the following features:

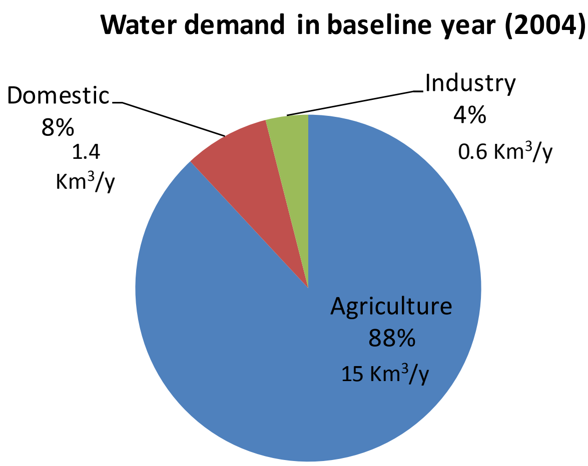
- one river, drawn as a blue line in WEAP, which comprises all surface renewable water in the country. The most important river in Syria is the Euphrates River (Al Furat), which comes from Turkey and flows to Iraq. Thus, the virtual river in the Syria WEAP application replicates the shape of the Euphrates River. Precipitation varies from one region to another, but it usually occurs between October and May, providing surface runoffs and facilitating groundwater recharge. Figure 115 shows the monthly headflow of the aggregated Syrian river. Return flows, depicted in WEAP using red arrows, make their way back to the system upstream and downstream in the river;
- one aquifer, represented in WEAP by a green square, which accounts for all groundwater storage in the country and corresponds predominantly to the aquifers situated in the Anti-Lebanon and the Alawite Mountains. In Syria, groundwater resources total around 6,174 Mm^3 and represent 37% of the estimated total water resources of the country. Water can be pumped from the aquifer for agricultural, domestic or industrial uses, but only irrigation return flows go back to the aquifer; and
- one reservoir, characterised in WEAP by a green triangle, which groups all the dams and reservoirs spread all over the country. As water resources are very limited in Syria the construction of dams has been strongly promoted in the last decades. In 2004, Syria had 159 dams with a total storage capacity of 19,654 Mm^3. The Al Tabka dam, on the Euphrates River, stores 14,000 Mm^3 (74% of the total storage capacity in Syria). Water can be extracted from the reservoir for agricultural, urban or industrial purposes.

Figure 115. Headflow of the river in Syria for the baseline hydrologic year 2003–04



The WEAP representation of water demand nodes is symbolised by red dots in Figure 114 above, which depict three demand nodes (irrigation, domestic and industry). Figure 116 illustrates the water used by each of the economic sectors in the baseline year (2004).

Figure 116. Urban, agricultural and industrial water use in Syria (2004)



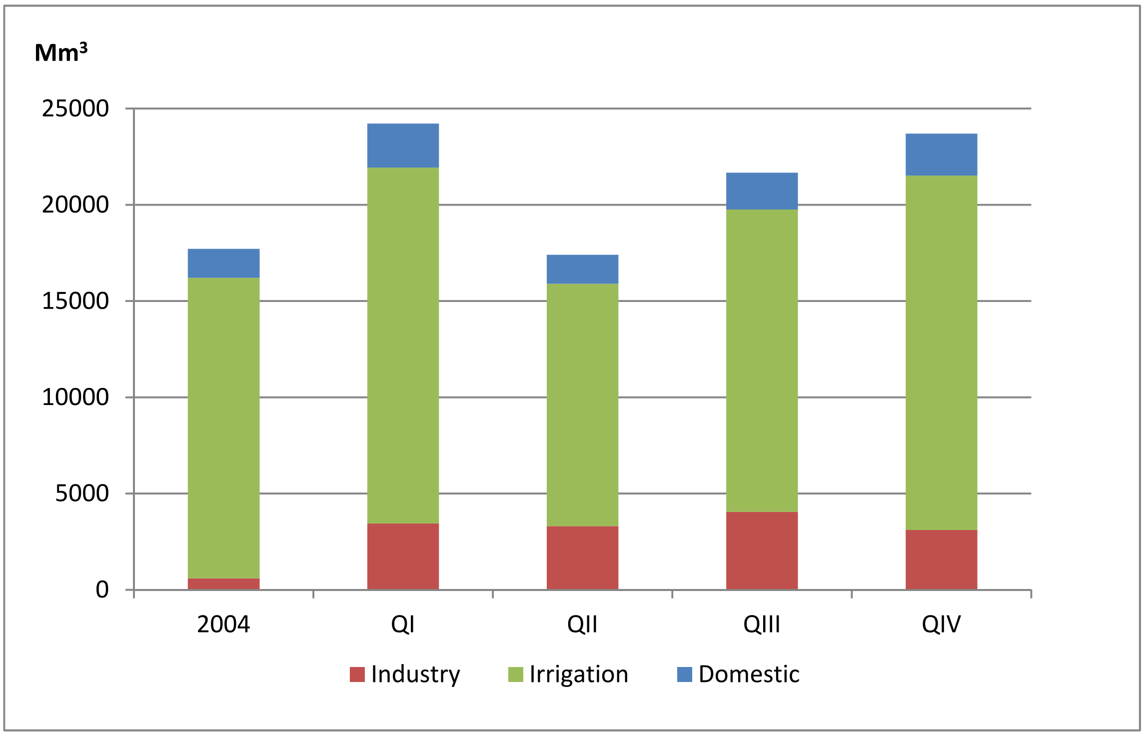
- 'Domestic' represents all the water required for urban purposes. It depends on the total population in the country and the water use rate per capita. Syria is among the more populous countries. In 2004, Syria had 19.5 million inhabitants and a population growth rate ranging between 2.45 and 2.7%. Domestic water use was about 1.4 Km^3 (8% of the total water consumption). It has been assumed that domestic demands use 20% of the inflow received from the river or the aquifer. The remainder is returned to the system through return flow connections (20% is returned upstream in the river, while 80% goes downstream in the river).
- 'Irrigation' represents all the water requirements for irrigation in the country. It includes the area distribution of the most representative crops (already defined in the agro-economic model), crop water requirements and irrigation schedule. Irrigation water withdrawal exceeds the consumptive use of irrigation because of water lost in water-supply distribution systems (irrigation canals and on-farm irrigation systems). Traditional irrigated lands (by gravity) cover

almost 87% of the total irrigated land, which results in the low application efficiency of field irrigation (of about 40-60%) (Kaissi et al., 2005; Varela-Ortega and Sagardoy, 2001). Additional water requirements due to efficiency losses in irrigation canals have been assumed to be 40%. The agricultural sector is the main water user. In 2004, about 15 Km^3 of water (88% of the total water consumption) was used to irrigate 1,439,000 ha. Therefore, average water use in irrigation for the baseline year was about 10,806 m^3/ha. It has been assumed that 65% of the inflow is used on site (lost from the system). Of the remainder, 20% is returned to the aquifer, 20% upstream in the river and 60% downstream in the river.

- 'Industry' represents all the water required for industrial supply. It depends on the level of GDP and GDP per capita (GDPP) in the country, and on the water use rate per production unit. Industry only used 0.6 Km^3 in 2004 (4% of the total water consumption). Return flows can discharge upstream in the river (so can be reused) and downstream in the river (so no reuse). Similar to domestic demands, it has been assumed that the industrial sector uses 20% of the inflow received from the river or the aquifer. The remainder is returned to the system through return flow connections (20% is returned upstream in the river, while 80% goes downstream in the river).

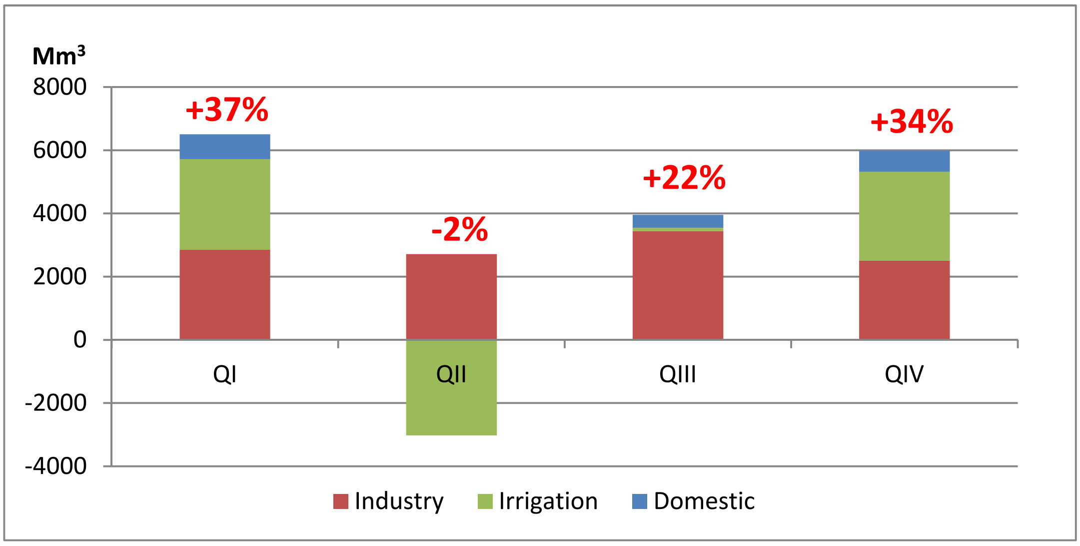
Similar to the previous section, with the aim of simplifying this report, here we present the results obtained in the different MEDPRO scenarios in relation to the reference or baseline situation (2004). Figure 117 shows the forecasts for long-term water demand for each of the main water uses in Syria (domestic, industrial and agricultural). Figure 118 shows changes in water demand with respect to the reference situation (2004).

Figure 117. Syria: Water demand under the different scenarios



As can be seen in Figures 117 and 118, water demand will grow significantly in all the scenarios in the period studied, and particularly in scenarios QI and QIV. In 2004, the total amount of water withdrawn was 17,712 Mm^3, of which 15,611 (88%) was used for agriculture. By 2030, water consumption in the QI scenario will increase by 37% to a level of 24,219 Mm^3, owing to the combination of a moderate population increase, improving living standards, the growth of business activities, the expansion of irrigated areas and the rise in crop water needs driven by climate change. Projections of population growth estimate an average annual increase of 1.5% between 2004 and 2030. GDP and GDPP will also increase, about threefold and twofold, respectively, by 2030. As a consequence, industrial water use will increase by more than a proportional amount. Industrial water consumption will increase by 2,851 Mm^3 by 2030 (which is almost 6 times the amount of water used in 2004), while agricultural demand will rise by 2,871 Mm^3 (only 1.2 times) and domestic water use will increase by 785 Mm^3 (that is, 1.5 times).

Figure 118. Syria: Changes in water demand, relative to the reference situation (2004)



As shown in Figures 117 and 118, water demand in scenario QII decreases by 2% in 2030 to a total of 17,407 Mm^3. Water demand increases by 2,709 Mm^3 in the industrial sector while the irrigation demand decreases greatly, by 3,022 Mm^3, and domestic demand increases by only 7 Mm^3. In this scenario of sustainable development and successful EU–Mediterranean integration, it has been assumed that Syria undergoes a major structural change in water management because of growing social concerns about water conservation, the implementation of policy measures for water demand management (water tariffs and water quotas) and the establishment of highly efficient technologies and practices for water savings in irrigation.

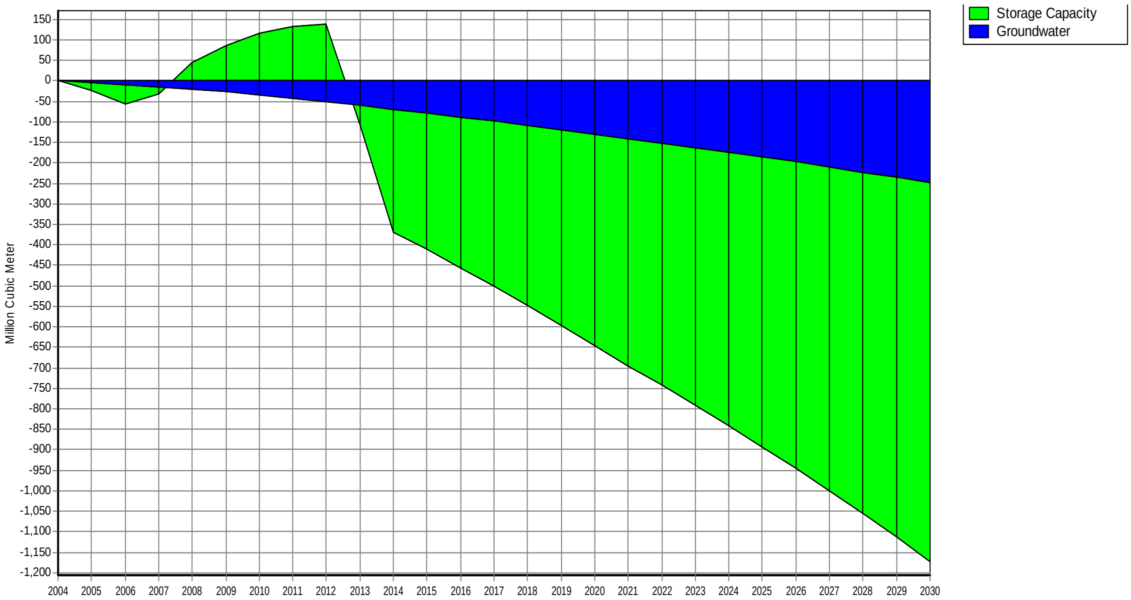
In scenario QIII, total water demand in Syria increases by 22% with respect to 2004 and, as in QII, the largest share of this increase is attributable to the industrial sector. Its water demand increases six times in 2030 with respect to 2004, to a total of 4,047 Mm^3. Meanwhile, irrigation and domestic demand increase by 97 and 410 Mm^3 respectively. In the QIII scenario, the structural changes that affect water supply and water demand are moderate, and apparently not sufficient for reducing water consumption in Syria. In a scenario of fragmented EU–Mediterranean cooperation, water policies and conservation agreements are difficult to implement and therefore less efficient than those applied under the scenario of an EU–MED union.

In scenario QIV, water consumption increases to a level of 23,697 Mm^3, with the largest share (18,418 Mm^3 or 78%) attributable to irrigation, as a result of a rapid expansion of irrigation in the absence of structural changes.

Climate change will also affect water supply. Regional modelling studies foresee a reduction of 7% of the average rainfall in the Upper Euphrates and Tigris basin by 2030. Such a reduction is expected to reduce the annual water discharge into the Euphrates River by 11% (Evans, 2008). Other studies are more pessimistic and predict a reduction of approximately 10-25% in the river runoff of the Euphrates by 2070 (EEA, 2004).

These reductions in flow discharge will affect several sectors that rely on the river flow of the Euphrates, but especially agricultural water uses, which consume the largest portion of the water. The decrease in water availability and increase in water demand will accentuate water stress in Syria by 2030. Most of the aquifers are already overexploited and the construction of new dams is not an easy task because the Euphrates River is subject to international agreements with Syria's neighbour countries, Turkey and Iraq. Figure 119 shows the water supply delivered in Syria during the period 2004–30, compared with the reference situation in 2004, from each of the main water supply structures: the reservoir and the aquifer. The effects of climate change are assumed to be uniform across the different MEDPRO scenarios, and thus projections of water supply will be the same for QI, QII, QIII and QIV.

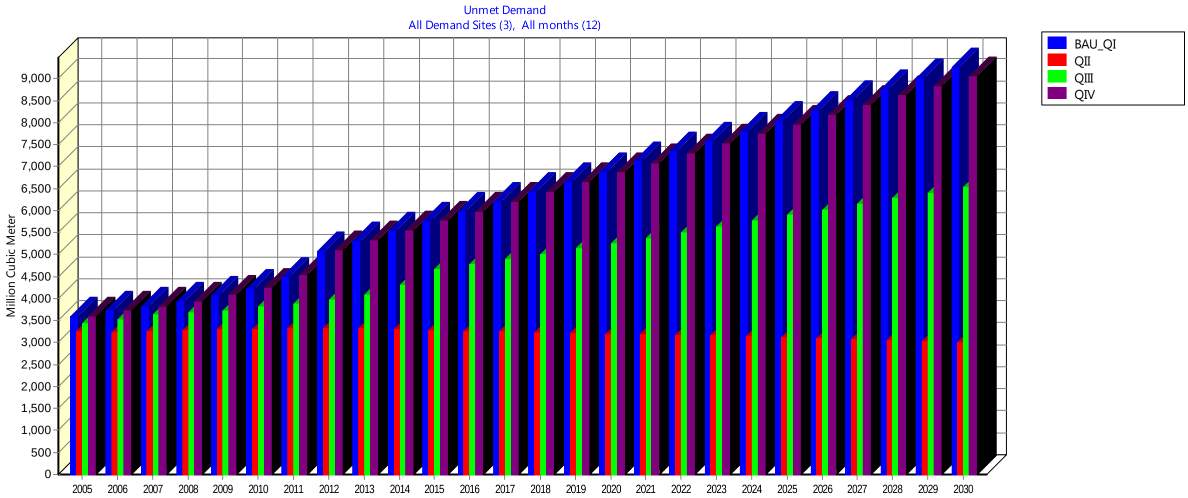
Figure 119. Water supply delivered in Syria (annual average), relative to the reference situation



As shown in Figure 119, in the short term (from 2004 to 2013), the high storage capacity of reservoirs in Syria will allow the country to cope with increasing water demands. Still, this storage capacity will be insufficient to deal with growing water uses after 2014. In other words, although the current supply of water can meet most of the demand, this supply definitely would not meet the accelerating water demand in the long run, exacerbating the problem of water scarcity in the future. As observed in the Jordan case study, the adverse effects of climate change on water use and water availability will be more pronounced as we get closer to the end of the period (2030).

Finally, water stress has been assessed by comparing water supply with water demand. Figure 120 shows the unmet water demand in the baseline situation (2004, projected to 2030), for the different MEDPRO scenarios.

Figure 120. Unmet demand in Syria under the different scenarios



In line with other previous work (Varela-Ortega and Sagardoy, 2001), our findings indicate that water resources in Syria are very limited compared with the needs of the country. In the reference situation, total, available water resources amount to 14.67 Km^3 and total water uses reach 17.67 Km^3, which results in a negative water balance of 3,000 Mm^3 (see Figure 120, reference situation). Only in scenario QII, where water consumption by agriculture is reduced, does the unmet water demand in Syria decrease slightly by 2030. In scenarios QI and QIV, however, unmet demand could triple by 2030, mounting to 9,250 Mm^3 (around 6,000 Mm^3 more of unmet demand than in the reference situation). In the remaining scenario of QIII, unmet water demand in 2030 could double with respect to 2004. Assuming that new water-supply sources cannot be easily developed in the near future, improving irrigation efficiency and promoting water conservation measures will be crucial to dealing with increasing water demand and mitigating the impacts of climate change in Syria.

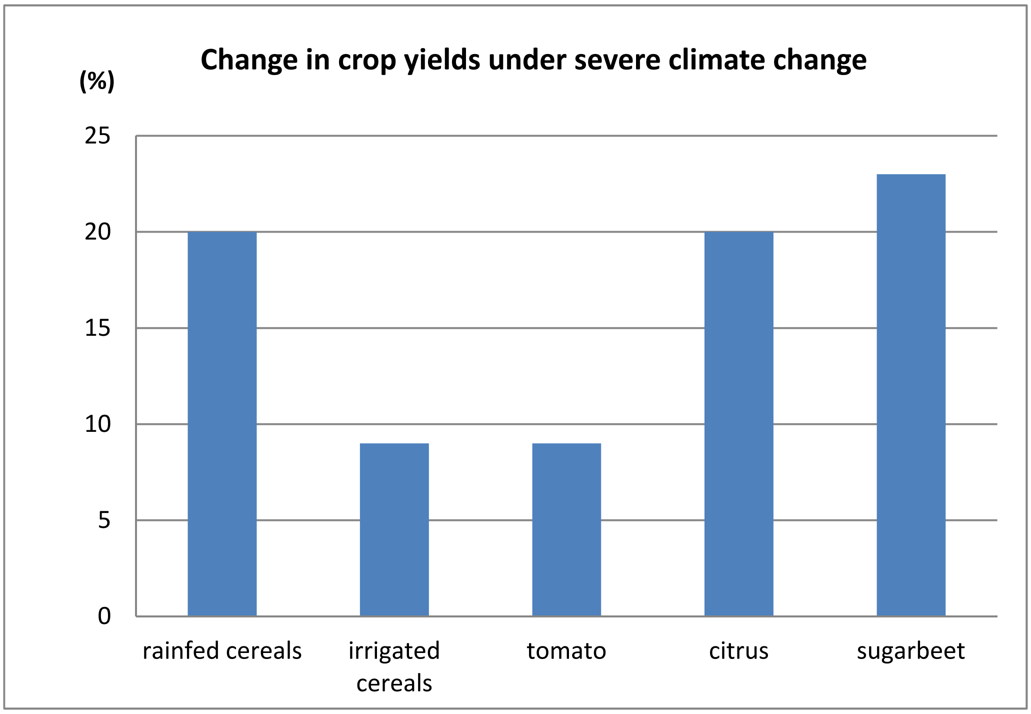
6.7 Morocco

6.7.1 Results of the crop model

Like the cases of Syria and Jordan, no specific simulations have been performed for Moroccan conditions, but crop yields and water needs have been estimated based on the results of simulations performed for Spain and the literature. According to the information found on these issues (Giannakoupoulos et al., 2009), changes in yields and water would be similar to those taking place in Syria. At the same time, we have considered different crops, selecting those that are representative of Moroccan agriculture. Figure 121 shows the expected changes in crop yields for a severe climate change scenario (SRES-A2), expressed as a percentage of change compared with current yields.

Changes have been estimated (in percentages) for the moderate climate change scenario as well, for both variables: yields and crop water needs. Again in this case, the positive effects of climate change outdo the negative ones when no water restrictions are imposed. Yield and water needs estimations for the two climate change scenarios have been introduced as an input into the economic model.

Figure 121. Increase in crop yields (%) in a severe climate change scenario, compared with the present, for a selection of crops in Morocco



Source: Own elaboration based on Giannakoupoulos (2009) and Carmona (2011).

6.7.2 Results of the economic model

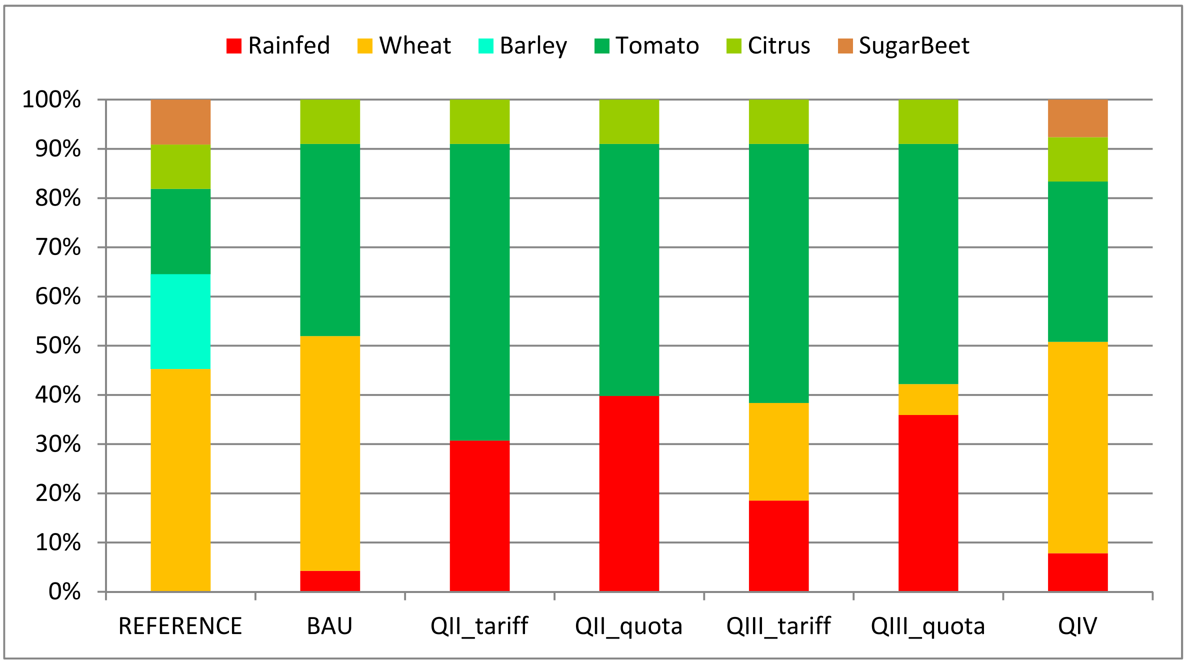
The economic model used to simulate the scenarios is outlined in Table 18.

Table 18. Simulated scenarios of climate change for Morocco

	Morocco			
	QI	QII	QIII	QIV
Product prices	-9% cereal prices	+10%	+5%	-9% cereal prices
Input prices	+5%			
Yields & crop water requirements	Same climate change impact: variation according to Carmona (2011) and Giannakopoulos et al. (2009)			
Water availability	Same climate change impact: 20% decrease, only affecting availability at the global level and simulated in WEAP; we consider that this reduction in water resources is not reflected in water quotas			
Improvement in pressurised irrigation	15%	25%	25%	10%
Structural change (water consumption decrease)	0	-16%	-16%	0

The cropping pattern of the selected crops (wheat, barley, tomatoes, citrus and sugar beets) has been obtained from the economic model, which has produced the optimum selection by which the utility function is at its maximum in every scenario. Figure 122 shows the results (in percentages) of each crop with respect to the total irrigated area for the current actual situation and for the simulated scenarios.

Figure 122. Cropping pattern under different simulated scenarios (% of irrigated land)



The results show that some of the irrigated surface changes to rain-fed under climate change scenarios, with both current (QI and QIV) and additional (QII and QIII) farm water restrictions, although technological improvements are undertaken to improve the efficiency of on-farm water irrigation. We also note that barley is completely replaced by tomato cultivation under climate change conditions, whereas the cropping pattern of wheat also decreases because of price changes and technology. Sugar beet cultivation also disappears in the different scenarios, except in the last simulation where water consumption remains the same along with a small improvement in pressurised systems, making way for an increase in the wheat crop surface again. Another important factor shown in Figure 122 is that when a specific quota reduction of 16% is applied to on-farm water availability, the cropping surface of rain-fed crops increases more than when a water tariff is added, which decreases water consumption by 16%.

Another important output variable provided by the economic model is farm income. Figure 123 shows the change in the income obtained by a representative farm under the different simulation scenarios, expressed as a percentage of current farm income. In the reference scenario, 100% corresponds to €862/ha for an average farm.

Figure 123. Morocco: Farm income under the different scenarios (% with respect to the reference)

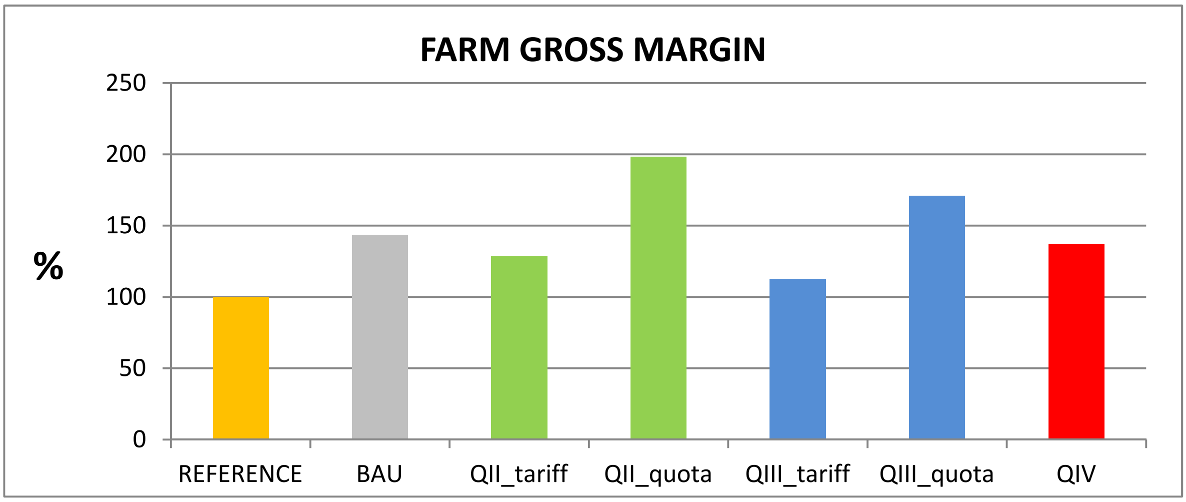


Figure 123 shows that an increase in crop yields resulting from climate change (Carmona, 2011; Giannakopoulos et al., 2009) together with an improvement in pressurised irrigation may compensate for the decrease in water availability resulting from the implementation of a water conservation policy (through water tariffs or quotas). In fact, for scenarios QII and QIII, in the case of the water quota reduction, when farmers do not have to pay the increased costs of water tariffs, the increase in yield and improvements in technology together with better market conditions (i.e. increase in product prices) lead to higher farm income than in the baseline situation (2004).

Finally, we look at the impact of the simulation scenarios on agricultural employment (Figure 124). We show the total employment for each simulation scenario, as a percentage of the current employment at a representative farm, with 100% corresponding to 2,086 h/year.

Figure 124. Morocco: Agricultural employment under the different scenarios (% with respect to the reference)

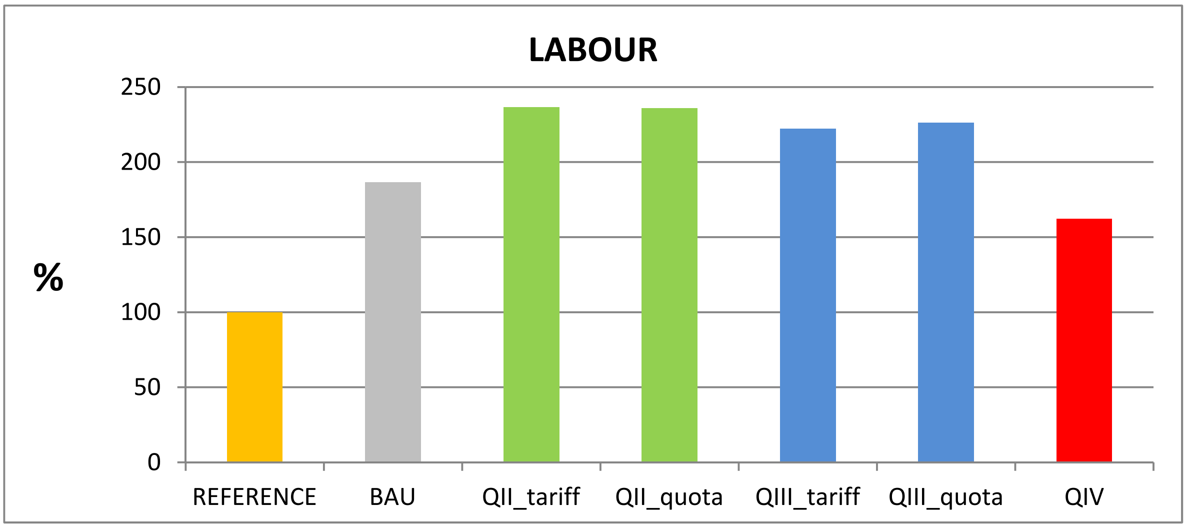
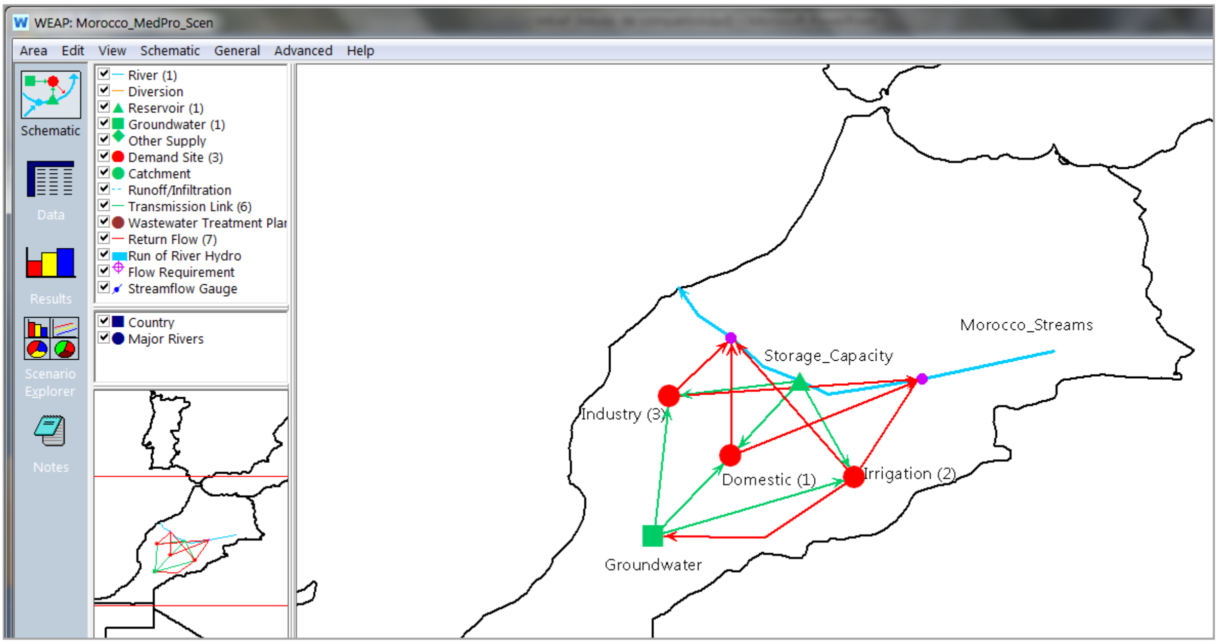


Figure 124 clearly shows that all the simulated scenarios increase employment as a result of the model's selection of the most profitable crops, among which tomato cultivation is highly labour-intensive. The scenario QII scores the highest employment level of the scenarios, since its tomato crop makes up around 50% of the total pattern.

6.7.3 Results of the hydrologic model

Following the steps and rationale used to develop the WEAP model for Syria and for Jordan, the hydrology model WEAP was applied to Morocco. Figure 125 presents the WEAP layout for Morocco, which shows the main hydrologic elements of the water system and their linkages as depicted in the WEAP platform.

Figure 125. Schematic of the WEAP model for Morocco



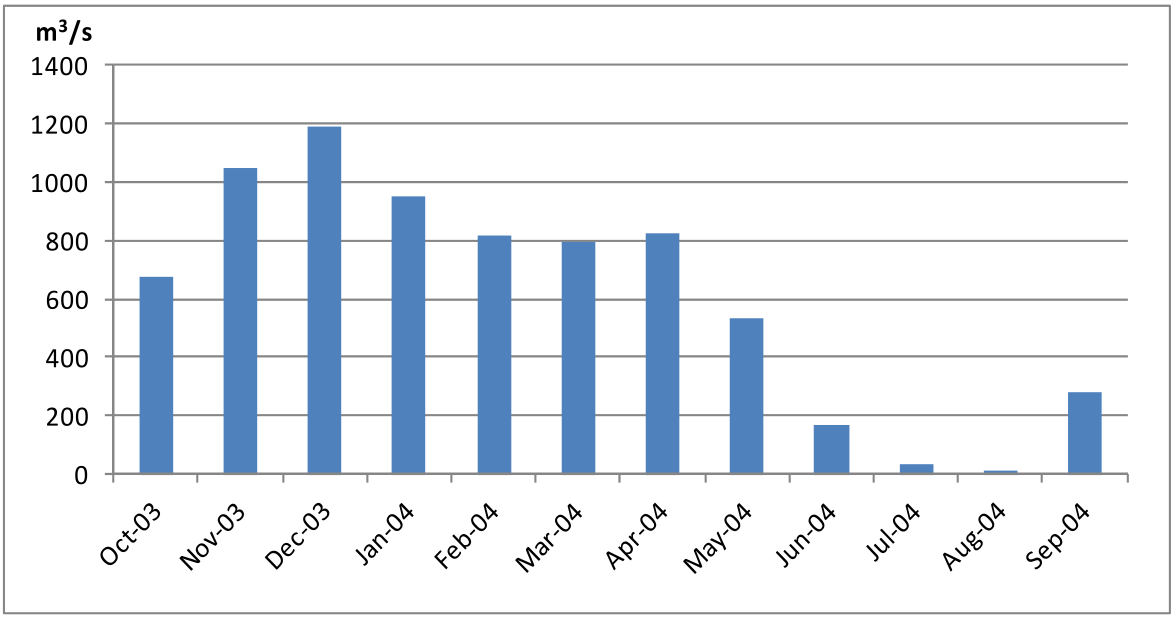
Water supply in Morocco is characterised by the following features:

- one river, drawn as a blue line in WEAP, which comprises all surface renewable water in the country. Surface renewable water is estimated to be 19 km^3. The resources are unevenly distributed, with the basins of Loukkos, Sebou and Oum Er-Rbia gathering 71.5% of national resources.[8] The average rainfall of 346 mm/year varies by more than 750 mm in the extreme north-west and less than 150 mm/year to the south-east. Oum Er-Rbia is the most important basin in Morocco in terms of renewable water resources and agricultural production. It contains half of Morocco's large-scale irrigated areas and produces 60% of the country's sugar beet crop and 40% of its olives. Thus, the virtual river in the Morocco WEAP application replicates the shape of the Oum Er-Rbia River. It flows 555 km from its source in the Middle Atlas Mountains to the Atlantic coast, where it empties near the town of Azemmour. Figure 126 shows the monthly headflow of the aggregated Morocco river. Return flows, depicted in WEAP using red arrows, make their way back to the system upstream and downstream in the river;
- one aquifer, represented in WEAP by a green square, which accounts for all groundwater storage within the country. In Morocco, groundwater resources are about 3,166 Mm^3 and represent around 29% of the estimated total water resources of the country. Water can be pumped from the aquifer for agricultural, domestic or industrial uses, but only irrigation return flows go back to the aquifer; and
- one reservoir, characterised in WEAP by a green triangle, which groups all the dams and reservoirs spread all over the country. In 2005, Morocco had 104 large dams with a total storage

[8] Data for 2005 derived from AQUASTAT (country profiles) – see the appendix for further details.

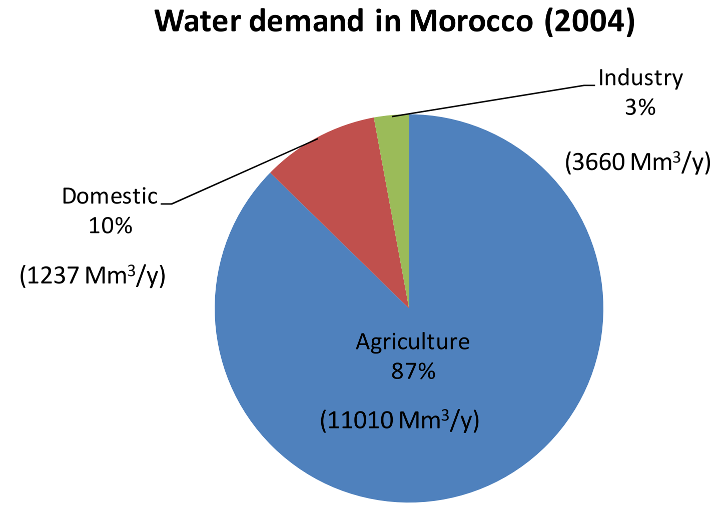
capacity of 16,904 Mm^3, 17 small to medium-sized dams and 67 hill reservoirs with a total storage capacity of 9.9 Mm^3. Water can be extracted from the reservoir for agricultural, urban or industrial purposes.

Figure 126. Headflow of the river in Morocco for the baseline hydrologic year 2003–04



The WEAP representation of water demand nodes is symbolised by red dots in Figure 125 above, which depict three demand nodes (irrigation, domestic and industry). Figure 127 illustrates the water used by each of the economic sectors in the baseline year (2004).

Figure 127. Urban, agricultural and industrial water use in Morocco (2004)



- 'Domestic' represents all the water required for urban purposes. It depends on the total population in the country and the water use rate per capita. Morocco, like Syria, is among the more populous countries. In 2004, Morocco had over 31 million inhabitants and a population

growth rate ranging between 1.7 and 2%. Domestic water use was about 1,237 Mm^3/year (10% of the total water consumption). It has been assumed that domestic demand uses 20% of the inflow received from the river or the aquifer. The remainder is returned to the system through return flow connections (20% is returned upstream in the river, while 80% is lost in the sea).

- ‘Irrigation’ represents all the water requirements for irrigation in the country. It includes the area distribution of the most representative crops (already defined in the agro-economic model), crop water requirements and irrigation schedule. Irrigation water withdrawal exceeds the consumptive use of irrigation because of water lost in water-supply distribution systems (irrigation canals and on-farm irrigation systems). Traditional irrigated lands (by gravity) cover almost 83% of the total irrigated land, which results in the low application efficiency of field irrigation (of about 60%). Additional water requirements due to efficiency losses in irrigation canals have been assumed to be 20% (losses of farm canals). The agricultural sector is the main water user. In 2004, about 11,010 Mm^3/year of water (87% of the total water consumption) was used to irrigate 1,520,200 ha. Therefore, average water use in irrigation for the baseline year was about 7,242.5 m^3/ha. It has been assumed that 60% of the inflow is used on site (lost from the system). Of the remainder, 20% is returned to the aquifer, 20% upstream in the river and 60% downstream in the sea.

- ‘Industry’ represents all the water required for industrial supply. It depends on the level of GDP and on GDP per capita (GDPP) in the country, and on the water use rate per production unit. Industry only used 360 Mm^3/year in 2004 (3% of the total water consumption). Return flows can discharge upstream in the river (so can be reused) and downstream in the river (so no reuse). Similar to domestic demands, it has been assumed that the industrial sector uses 20% of the inflow received from the river or the aquifer. The remainder is returned to the system through return flow connections (20% is returned upstream in the river, while 80% goes downstream in the sea).

In the same way as in the previous section, with the aim of simplifying this report, here we only present the results obtained under the different MEDPRO scenarios in relation to the reference situation. Figure 128 shows the forecasts for long-term water demand for each of the main water uses in Morocco (domestic, industrial and agricultural). Figure 129 shows changes in water demand with respect to the baseline situation (2004). Figure 130 shows the water supply in the baseline situation (2004, projected to 2030) under the different MEDPRO scenarios.

As shown in Figures 128 and 129, water demand will grow significantly during the period studied in all the scenarios, and particularly in scenarios QI and QIV. By 2030, water consumption in QI will increase by almost 4,000 Mm^3, mainly owing to a combination of industrial development as an engine of economic growth, improving living standards, the expansion of irrigated land (about 13%) and the rise in crop water needs driven by climate change. Agriculture and industry will consume the larger amount of this water, while the domestic sector will only demand 306 Mm^3.

Figure 128. Morocco: Water demand under the different scenarios

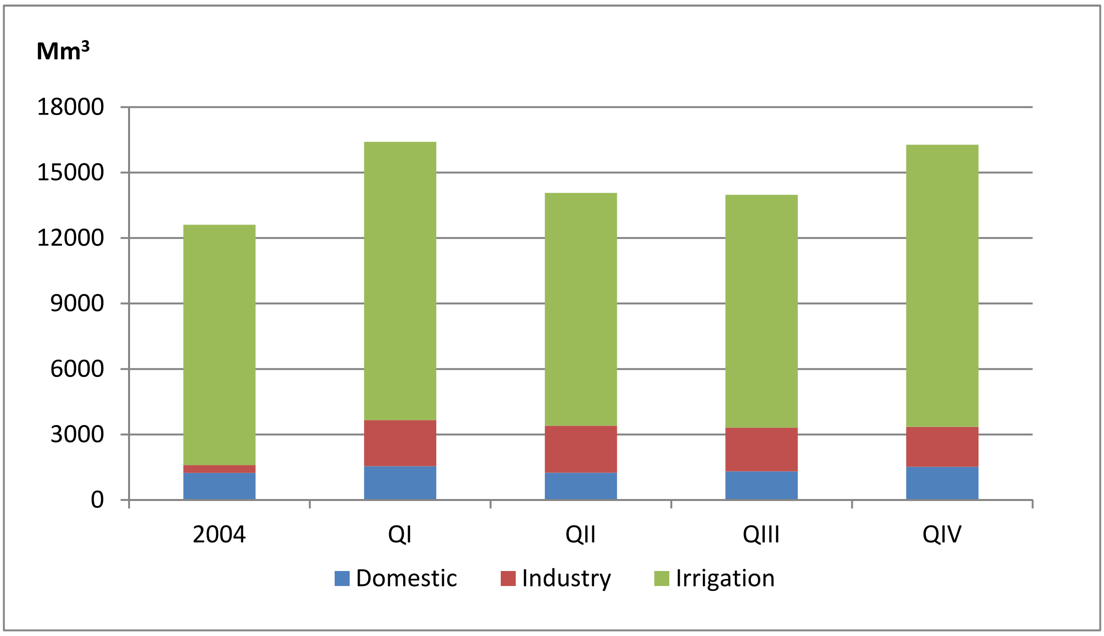
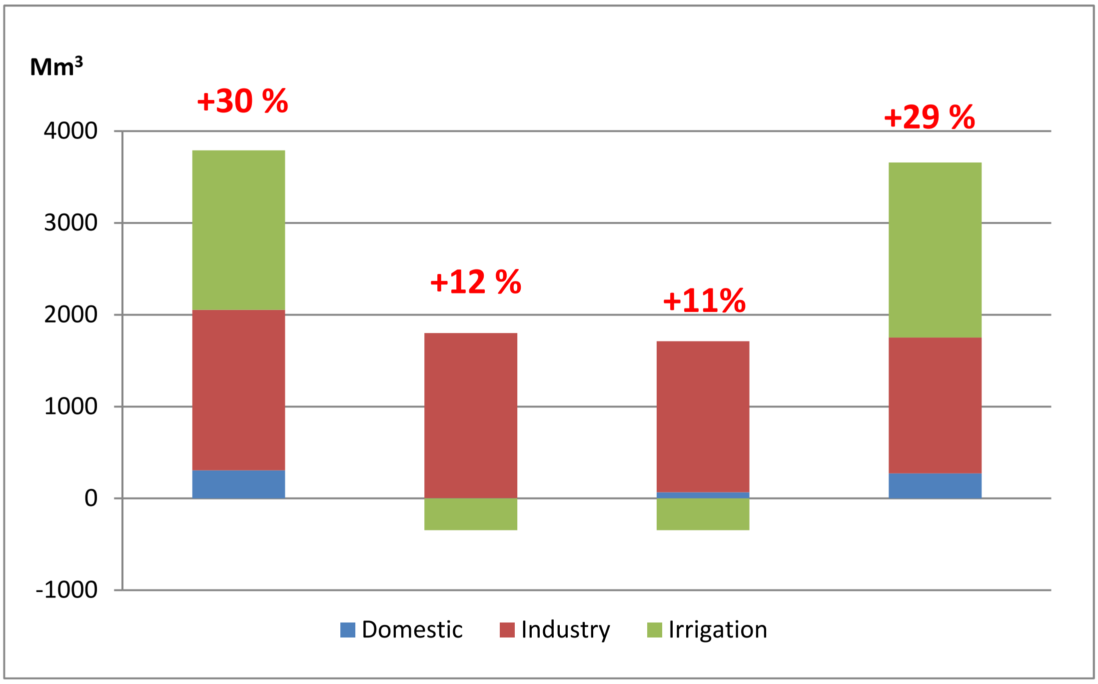


Figure 129. Morocco: Changes in water demand, relative to the reference situation (2004)

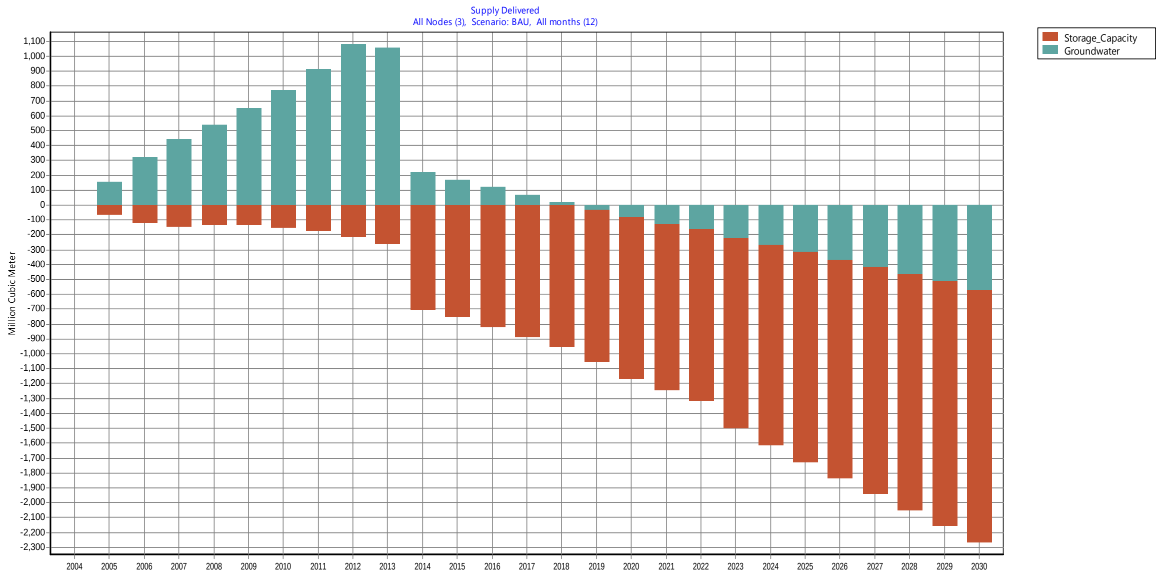


As observed for Syria, however, in scenarios QII and QIII, irrigation water demand decreases by 347 Mm^3 by 2030, as a result of moderate structural changes gradually implemented to support water conservation in Morocco. It is assumed that modern irrigation for high-value farming has been put in place together with policy instruments to achieve water conservation goals. By 2030, in scenarios QII and QIII the industrial sector will respectively demand 1,798 Mm^3 and 1,644 Mm^3 more water than it did in 2004, because of the expected GDP growth throughout 2010–30.

Finally, water demand in 2030 in the last scenario QIV will increase by 29% with respect to 2004. Irrigation will consume the largest share, 12,917 Mm^3, which is 1,907 Mm^3 more than its demand in 2004. Following that is the industrial sector, with an increase in water demand by 1,479 Mm^3. As in scenario QI, noticeable changes in water management regimes are not expected.

As shown in Figure 130, in the short term (from 2004 to 2013), the high level of groundwater in Morocco will allow the country to cope with increasing water demands. The total volume of water supply delivered from the storage capacity of reservoirs and groundwater continues to be positive until 2013. After 2014, this storage capacity will be insufficient to deal with growing water uses. In other words, although the current supply of water can meet most of the demand, this supply definitely will not meet the accelerating water demand in the long run, exacerbating the problem of water scarcity in the future.

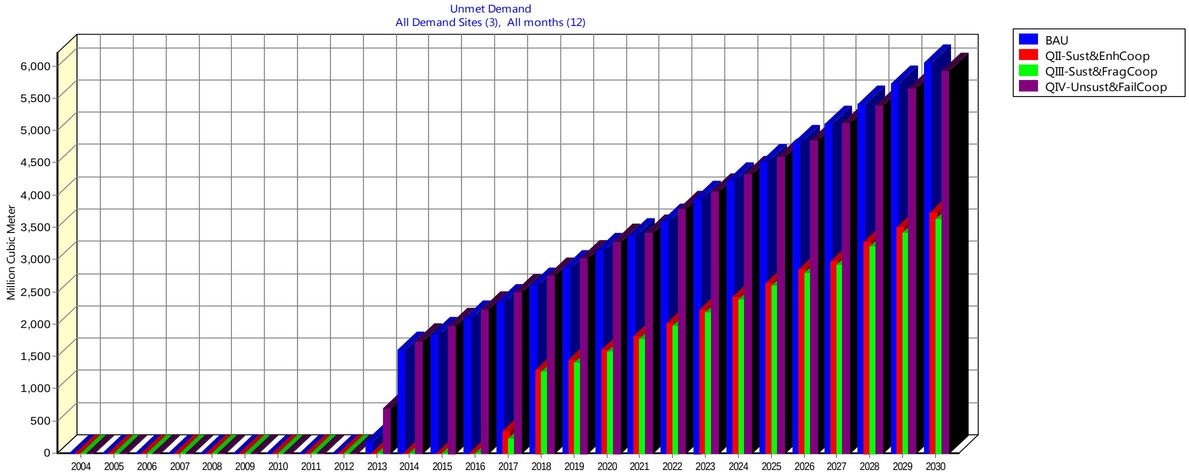
Figure 130. Water supply delivered in Morocco (annual average), relative to the reference situation



In line with previous work (Immerzeel, 2011), our findings indicate that the water supply is adequate to meet the current water requirements in Morocco, but it will be insufficient to satisfy future human, commercial and agricultural needs in 2030.

As Figure 131 shows, in the reference year 2004 the unmet water demand was zero, indicating no gap between the water supplied and that demanded. Yet from 2013 until 2030, the unmet demand will gradually increase, reaching a maximum of 6,056 Mm^3 under the QIV scenario. Data show that the increase in unmet demand is higher in scenarios QI and QIV, with gaps of 6,056 and 5,928 Mm^3 respectively, than in the other two scenarios (QII and QIII), which record unmet demand of 3,722 and 3,634 Mm^3, respectively. That is mainly because of the modernisation of irrigation systems and the structural changes that are emphasised in both the QII and QIII scenarios, which imply a reduction of water consumption by 16% of its actual rate. Developing modern farming while ensuring effective, sustainable management of water resources is one of the major tasks facing decision-makers in Morocco, and as discussed in this study, it will be key to saving water and protecting the environment in coming years.

Figure 131. Unmet demand in Morocco under the different scenarios



6.8 Comparative overview

Table 19 represents a comparative summary of the results of the economic model applied to the three countries.

As can be seen, each of the scenarios simulated has different effects on the case study countries. In the QI scenario, income and water demand increases in all three countries in 2030, but unlike the other two countries, in Jordan agricultural employment decreases as the cropping pattern employs more rain-fed cultivations than labour-intensive crops like tomatoes. Also, while water consumption slightly increases in Syria and Morocco, no structural change occurs in Jordan in any of the scenarios because its water technology is already very modern.

When a tariff is applied to reduce water consumption in the QII scenario, it is important to note that income and agricultural employment decrease in Syria yet increase in the case of Morocco. That is because the resulting cropping pattern employs more wheat cultivation in Syria and more tomato cultivation in Morocco. It is also notable that the only decrease in water demand that occurs in scenario QII in Syria is a result of a drastic structural change, as water-saving policies are encouraged in the long run.

In the QII scenario, when a water quota is applied, income in Syria and Morocco increases greatly in comparison with water consumption being limited by a water tariff. Farms with the same cropping pattern based on water supply do not have to pay the high water costs associated with a tariff.

In the QIII scenario, two simulations are also applied: water consumption is restricted by a water tariff and by a water quota. The different results of each simulation are shown in Table 19. The same impacts are recorded for Jordan and Syria: income increases and agricultural employment decreases as the cropping pattern moves to a more optimal state and as more technology is employed. In the case study of Morocco, however, income and agricultural employment both increase, as its cropping area employs more labour-intensive cultivations (tomatoes). Yet, when a water quota is applied, income increases in Syria and Morocco much more than in the tariff simulation, as no additional water costs are being paid.

In the last scenario simulated, income increases and agricultural employment decreases in Jordan, while both increase in Syria and Morocco, as does water consumption. This final scenario simulates the failure of any EU–Mediterranean cooperation and no sustainability measures being taken to control or reduce water use or to improve efficiency.

Table 19. Comparative table of the simulation results for the four scenarios

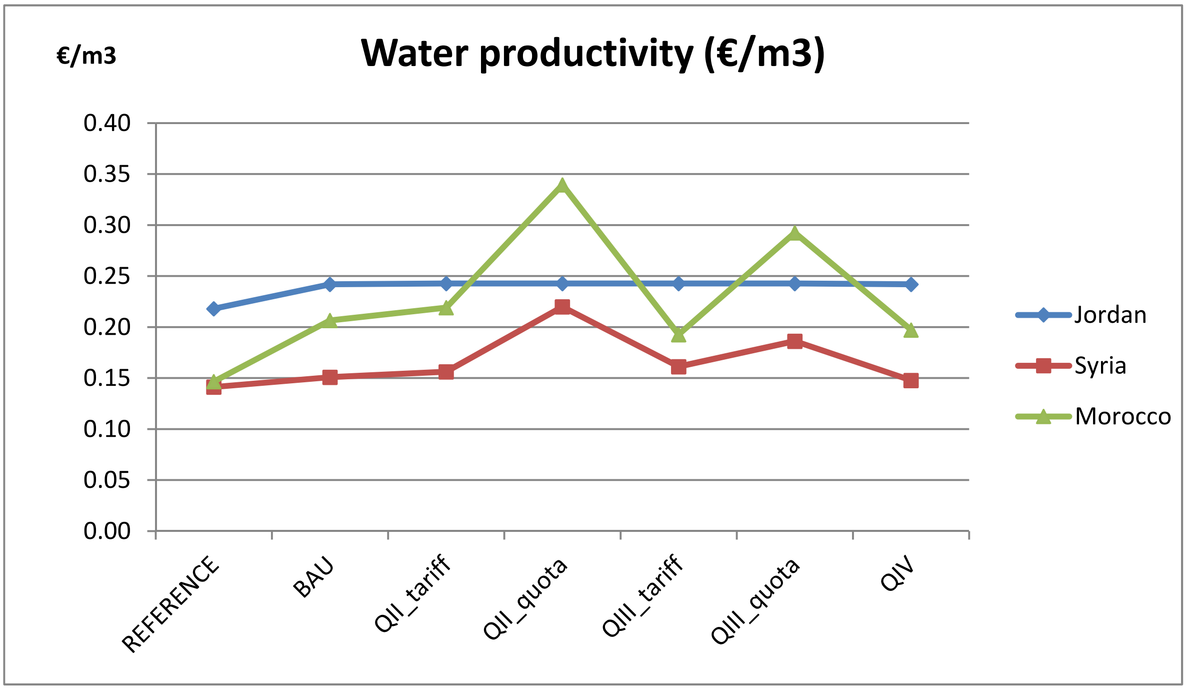
	Jordan	Syria	Morocco
QI	- Income increases by 11% - Labour decreases by 6.8% - No structural change - Water demand increases by 46% $\begin{cases} wheat: 4.5\%\ pressurized \\ potato: 16.5\%\ pressurized \\ tomato: 13\%\ furrow, 14.5\%\ pressurized \\ olive: 5\%\ rainfed, 46.5\%\ pressurized \end{cases}$	- Income increases by 9% - Labour increases by 9.9% - Water consumption increases by 2.1% - Water demand increases by 37% $\begin{cases} wheat: 62\%\ furrow \\ cotton: 14\%\ furrow, 10\%\ pressurized \\ tomato: 6\%\ furrow, 8\%\ pressurized \end{cases}$	- Income increases by 44% - Labour increases by 86% - Water consumption increases by 2% - Water demand increases by 30% $\begin{cases} wheat: 4.5\%\ rainfed, 47.5\%\ furrow \\ tomato: 16\%\ furrow, 23\%\ pressurized \\ citrus: 9\%\ pressurized \end{cases}$
QII – Tariff	- Income increases by 11.4% - Labour decreases by 14.6% - No structural change - Water demand increases by 63% $\begin{cases} wheat: 10\%\ pressurized \\ potato: 15.5\%\ pressurized \\ tomato: 10\%\ furrow, 13\%\ pressurized \\ olive: 0.5\%\ rainfed, 51\%\ pressurized \end{cases}$	- Income decreases by 22.7% - Labour decreases by 55.9% - Water consumption decreases by 30.1% - Water demand decreases by 2% $\begin{cases} wheat: 7.9\%\ furrow, 21.4\%\ pressurized \\ cotton: 0.1\%\ pressurized \\ tomato: 0.1\%\ furrow, 7.5\%\ pressurized \end{cases}$	- Income increases by 28% - Labour increases by 136% - Water consumption decreases by 14% - Water demand increases by 11% $\begin{cases} wheat: 30.5\%\ rainfed \\ tomato: 27.5\%\ furrow, 33\%\ pressurized \\ citrus: 9\%\ pressurized \end{cases}$
QII – Quota	- Income increases by 11.4% - Labour decreases by 14.6% - No structural change - Water demand increases by 63% $\begin{cases} wheat: 10\%\ pressurized \\ potato: 15.5\%\ pressurized \\ tomato: 10\%\ furrow, 13\%\ pressurized \\ olive: 0.5\%\ rainfed, 51\%\ pressurized \end{cases}$	- Income increases by 9.7% - Labour decreases by 54.1% - Water consumption decreases by 29.6% - Water demand decreases by 2% $\begin{cases} wheat: 70.5\%\ furrow, 21\%\ pressurized \\ cotton: 0.5\%\ pressurized \\ tomato: 0.5\%\ furrow, 7.5\%\ pressurized \end{cases}$	- Income increases by 98% - Labour increases by 136% - Water consumption decreases by 14% - Water demand increases by 11% $\begin{cases} wheat: 40\%\ rainfed \\ tomato: 18\%\ furrow, 33\%\ pressurized \\ citrus: 9\%\ pressurized \end{cases}$

Table 19. cont'd

	Jordan	Syria	Morocco
QI	- Income increases by 11% - Labour decreases by 6.8% - No structural change - Water demand increases by 46% $\begin{cases} wheat: 4.5\%\ pressurized \\ potato: 16.5\%\ pressurized \\ tomato: 13\%\ furrow, 14.5\%\ pressurized \\ olive: 5\%\ rainfed, 46.5\%\ pressurized \end{cases}$	- Income increases by 9% - Labour increases by 9.9% - Water consumption increases by 2.1% - Water demand increases by 37% $\begin{cases} wheat: 62\%\ furrow \\ cotton: 14\%\ furrow, 10\%\ pressurized \\ tomato: 6\%\ furrow, 8\%\ pressurized \end{cases}$	- Income increases by 44% - Labour increases by 86% - Water consumption increases by 2% - Water demand increases by 30% $\begin{cases} wheat: 4.5\%\ rainfed, 47.5\%\ furrow \\ tomato: 16\%\ furrow, 23\%\ pressurized \\ citrus: 9\%\ pressurized \end{cases}$
QII – Tariff	- Income increases by 11.4% - Labour decreases by 14.6% - No structural change - Water demand increases by 63% $\begin{cases} wheat: 10\%\ pressurized \\ potato: 15.5\%\ pressurized \\ tomato: 10\%\ furrow, 13\%\ pressurized \\ olive: 0.5\%\ rainfed, 51\%\ pressurized \end{cases}$	- Income decreases by 22.7% - Labour decreases by 55.9% - Water consumption decreases by 30.1% - Water demand decreases by 2% $\begin{cases} wheat: 7.9\%\ furrow, 21.4\%\ pressurized \\ cotton: 0.1\%\ pressurized \\ tomato: 0.1\%\ furrow, 7.5\%\ pressurized \end{cases}$	- Income increases by 28% - Labour increases by 136% - Water consumption decreases by 14% - Water demand increases by 11% $\begin{cases} wheat: 30.5\%\ rainfed \\ tomato: 27.5\%\ furrow, 33\%\ pressurized \\ citrus: 9\%\ pressurized \end{cases}$
QII – Quota	- Income increases by 11.4% - Labour decreases by 14.6% - No structural change - Water demand increases by 63% $\begin{cases} wheat: 10\%\ pressurized \\ potato: 15.5\%\ pressurized \\ tomato: 10\%\ furrow, 13\%\ pressurized \\ olive: 0.5\%\ rainfed, 51\%\ pressurized \end{cases}$	- Income increases by 9.7% - Labour decreases by 54.1% - Water consumption decreases by 29.6% - Water demand decreases by 2% $\begin{cases} wheat: 70.5\%\ furrow, 21\%\ pressurized \\ cotton: 0.5\%\ pressurized \\ tomato: 0.5\%\ furrow, 7.5\%\ pressurized \end{cases}$	- Income increases by 98% - Labour increases by 136% - Water consumption decreases by 14% - Water demand increases by 11% $\begin{cases} wheat: 40\%\ rainfed \\ tomato: 18\%\ furrow, 33\%\ pressurized \\ citrus: 9\%\ pressurized \end{cases}$

Finally, Figure 132 shows how water productivity changes across the scenarios for each country. Water productivity, in terms of €/m^3, increases for Syria and Morocco under the two sustainability scenarios QII and QIII. There are several reasons for this result, the main one being that an improvement in irrigation technology together with a decrease in water availability produces a shift towards more efficient crop production. In addition, the impact of climate change, considering the effects of increased CO_2 concentrations against a background of no limitations on per-hectare water allocation to crops, produces higher yields, which in turn lead to increased production per cubic metre of water. The case of Jordan differs from Syria and Morocco, however. Jordan is the most water-scarce country considered in this study, and water-use efficiency is already rather high. Therefore, there is little room for improvement in water technology, and water productivity remains constant across the scenarios.

Figure 132. Water productivity in the four scenarios for the three countries studied



7. Conclusions

This analysis of the agricultural sector and water withdrawal for MEDPRO WP4a has sought to assess the effects of different social, economic and climate scenarios on the economy and on the availability of water resources in the 11 SEMCs. To address this complex interaction, the analysis has developed a modelling-based methodology that allows a comparative analysis across the 11 SEMCs as well as a more detailed analysis of the water and socio-economic systems in selected case-study countries in the region. An initial econometric model captures a temporal representation along a 25-year horizon and a spatial representation across the individual countries. It is used to define the main drivers that determine water use in the region and its future projections on a long-term horizon to 2030 (to 2040 in the case of climate change scenarios), where climate change and socio-economic scenarios are included. Following this regional and country-level analysis, for selected countries (Spain, Syria, Jordan and Morocco) the methodology integrates three models into a common platform for further country-level, aggregate evaluation: an economic optimisation model, a hydrology model (Water Evaluator and Planning system, WEAP) and a crop-based agronomic model (AquaCrop). This integrated modelling has proven to be a robust tool to analyse the short and long-term spatial and temporal effects of the MEDPRO scenarios, including climate change as well as demographic, economic and social projections.

The socio-economic analysis enables forecasts to be made of how the current configuration of the countries' agricultural sectors might be altered under different water-stress conditions, in response to climate and socio-economic shocks. The hydrologic analysis facilitates a spatial representation of the countries' water systems, water supply and demand across all sectors of the economy. It allows an assessment to be made of the short- and long-term responses across the entire hydrologic system to climate as well as socio-economic developments. The agronomic model provides for an evaluation of the effects at crop level of IPCC climate change scenarios, including CO_2 emissions as well as changes in precipitation and temperature.

The comparative analysis across the 11 SEMCs indicates that measurement of water use, especially in agriculture, is very challenging. Sometimes it is just not possible and other times it requires specific technologies and precise monitoring systems. There are difficulties associated with gathering sufficient time series and relating water consumption to other variables. For some countries, data availability is so limited that the analysis is not meaningful. That is the case for the Palestinian territories and Libya. Although in general terms it is argued that the main drivers of water withdrawal are population growth, tourism and the expansion of irrigation, there are also other factors, such as the geographical location of the country, the overall level of socio-economic development and the structure of economic sectors. In some countries, like Spain or Israel, water consumption does not depend so much on demographic trends as in the case of other countries on the southern rim of the Mediterranean (e.g. Algeria, Egypt and Morocco).

The econometric analysis shows that location is a key element for determining water use trends. Clear differences appear across the two main areas of the Mediterranean region, the northern Mediterranean countries and the southern and eastern Mediterranean countries. Economic growth is a critical explanatory variable for water use in the region but demographics seem to be a more determinant factor for the SEMCs than for their northern counterparts. Water scarcity is another important element explaining water demand trends. In water-scarce countries (such as Egypt, Jordan, Libya, Syria, Jordan and the Palestinian territories), water use trends are largely affected by agricultural-based indicators, such as the irrigated area and irrigation technology. Conversely, in water-abundant countries (such as Lebanon or Turkey) water use is more dependent on cropping choices and non-agricultural activity (such as tourism).

To respond to the MEDPRO objective of social and environmental foresight for the Mediterranean region, the future trends in water consumption towards 2030 have been analysed for the four MEDPRO scenarios, using as main drivers the projections of population, GDP and trade along with irrigated area, technology and governance-related structural factors. Despite the inherent limitations of the lack of reliable data in some countries, the econometric analysis reveals that in most countries, water consumption tends to increase substantially in the first years, to continue thereafter at a slower pace and to stabilise around 2015 (Algeria, Syria, Turkey and Libya). For some countries, irrigation expansion proves to be a limiting factor to the increase of water consumption in future years, with the agricultural sector being the largest water consumer in the Mediterranean region. Indeed, some countries could reach their national potential for irrigated area in the coming years and therefore water consumption patterns will be rather stable by the end of 2030 (Syria, Algeria and even Turkey). Very water-scarce countries, such as Jordan and Israel (and even Libya), reveal a stable and decreasing trend of water consumption towards 2030, evidencing the substantial development of water-saving technologies (mainly in Israel), which are already in place in most of the irrigated areas.

From a general perspective, water withdrawals in 2030 in the reference scenario would still be below the total, natural, renewable water resources in most of the countries analysed. Yet in irrigation-dependent agricultural economies, such as Egypt, current water withdrawals are reaching the nation's total available amount of renewable water resources. Consequently, economic development and social stability would require more sustainable economic activities, less water-consuming and more technically-efficient irrigated agriculture, and in turn the implementation of water-saving policies. Tunisia, as well as Morocco, from the perspective of a continuation of trends, may face a similar situation of increased water scarcity by the end of the period analysed. In sum, the projections for water consumption towards 2030 in the reference scenario show that mounting water withdrawals over

a long-term horizon could increase water scarcity in the 11 SEMCs analysed. Increased water scarcity could hinder more balanced and sustainable socio-economic development if other technical, institutional and policy measures are not actively implemented.

In the Sustainable Euro-Mediterranean Development and Enhanced Cooperation (QII) scenario and the Fragmented Cooperation (QIII) scenario, water withdrawals are largely mitigated up to the 2030 horizon. Although in principle water consumption could be high because of greater socio-economic development, GDP growth and trade, in all 11 SEMCs structural changes and active policies geared towards protecting water resources, improved water-use efficiency and better governance could counterbalance this trend, reduce water use and conserve water resources. The last scenario, which represents the fracture of EU relations with the 11 SEMCs and non-cooperation, proves to have detrimental effects on water consumption. In spite of less economic growth and active trade, the absence of modern water-saving technologies and adequate policies to limit water demand results in large volumes of water being consumed. Closing the gap between the scarce water supply and the mounting water demand in all countries in the region will require a combination of technical and management measures. In the scenarios of Euro-Mediterranean integration (QII) and fragmented collaboration (QIII), which include sustainable water practices, less costly government measures affecting the demand side (water tariffs or good management) will offset the more costly and harder supply-side measures (dams and reservoirs). Therefore, increasing the efficiency of water use (through both technical advances and management) will be less expensive in these scenarios.

The analysis of selected case studies (Syria, Jordan and Morocco) reveals that the integration of economic, hydrologic and agronomic models enables a more focused and detailed study of the long-term evolution of the water and socio-economic systems. The results show that climate and socio-economic projections may have clear differential impacts on these countries. These differences reflect the distinct social, economic and environmental characteristics of the case-study countries in relation to water resources and agriculture. For the reference scenario with climate change, water consumption will increase at a much higher rate in Syria, Jordan and Morocco (relative to Spain, used as the comparative baseline) due to estimates of population growth. Although irrigation continues to be the heavy water consumer in all countries in 2030, water use by the industrial sector increases more than is proportional in Syria and in Jordan, owing to projections of industrialisation. In Jordan, one of the most water-scarce countries in the world, the expansion of irrigation will be constrained by structural limitations in water availability unless new water infrastructures and non-conventional water sources (e.g. reclaimed water and desalinated seawater) are developed. The economic model shows that in Syria, Jordan and Morocco (and also in Spain), farm income may increase as a result of the positive effects of climate change on yields (as a response to increased CO_2 concentration). Future water restrictions will have a negative impact on farm income, but in Syria technological change will compensate for these projected losses. In Morocco, an ample cropping potential could help farmers to adapt their strategies to less water being available and prevent a decline in farm income. Meanwhile, Jordan will experience less technological change as modern pressurised systems are already installed across a large share of the irrigated area.

In general the study reveals that integrated modelling is able to capture many of the multi-faceted features of the agricultural and water systems in the area, for both current and future developments. Nevertheless, the MEDPRO project has complemented the analysis with more qualitative issues, such as governance structures, policy developments, institutional capacity and social acceptance, which has undoubtedly enriched the overall analysis.

With respect to policy implications, the study gives rise to the following insights:

Deriving policy considerations for water withdrawal and the agricultural sector in the 11 SEMCs will require an integrated vision. Technical and agronomic drivers alone will not be sufficient, and economic, social and institutional factors must also be taken into account for implementing sound and efficient policies.

For all the countries, the scenarios of Euro-Mediterranean integration (QII) and fragmented collaboration (QIII) mitigate the trends of substantial water consumption of the past. As agriculture is

the largest water consumer, agricultural policies that support irrigated crop production will have to consider that irrigation expansion may reach its limits in some countries (Syria, Algeria and even Turkey). Thus, improving water management efficiency will be necessary.

In a future involving Euro-Mediterranean integration and fragmented collaboration (QII and QIII), substantial GDP growth, population expansion and trade development could result in greater demand. Hence, policies that support structural change, technological improvement and better governance will counterbalance this trend, reduce overall water consumption and conserve renewable water resources.

Water scarcity in the SEMCs requires investment in water technologies to close the gap between water supply and demand. In the scenarios of Euro-Mediterranean integration and fragmented collaboration (QII and QIII), these investments will be less costly. They will rely largely on demand-side measures (such as better management and efficient water pricing) and will offset the harder and more costly supply-side measures (such as the construction of dams).

Water-demand policies in the 11 SEMCs are site-specific and need to be applied discretely across countries and areas. Differences in the future scenarios are more acute in water-scarce countries (Jordan, Israel and the Palestinian territories), where a scenario of decline and conflicts (QIV) could considerably increase the costs of water. Thus policies will need to conserve water resources and encourage socio-economic sustainability.

At the country level (Syria, Morocco and Jordan), the application of water-demand policies (tariffs and quotas) are effective for reducing water consumption under Euro-Mediterranean integration. Still, water tariffs need to be applied carefully, as in some areas they could have a negative effect on farm income. This effect could be prevented by inducing cropping changes to adjust to reduced water availability and technological improvements.

In the irrigated agricultural sector, Euro-Mediterranean integration (and to a lesser extent fragmented collaboration) will be successful in securing agricultural production, farm income and the conservation of water resources, provided it is accompanied by effective water management, governance and structural changes.

Finally, from a general perspective, it can be concluded that in scenarios involving Euro-Mediterranean integration and even fragmented collaboration, the SEMCs could benefit from agricultural and water policies that are developed and applied with an integrated vision, thereby avoiding conflicting objectives and fostering synergies and cooperation.

References

Ayadi, R. and C. Sessa (2011), *What scenarios for the Euro-Mediterranean in 2030 in the wake of the post-Arab spring*, MEDPRO Policy Paper No, 2, CEPS, Brussels, October.

Belghazi, S. (2012), *Scenarios for the agricultural sector in South and East Mediterranean countries by 2030*, CASE Network Report No. 109, CASE, Warsaw.

Benoit, G. and A. Comeau (eds) (2005), *A Sustainable Future for the Mediterranean: The Blue Plan's Environment and Development Outlook*, London: Earthscan.

Bruinsma, J. (2009), *The resource outlook to 2050: By how much do land, water and crop yields need to increase by 2050?*, Paper presented at the FAO Expert Meeting "How to Feed the World in 2050", Rome, 24-26 June.

Carmona, G. (2011), "Development of a participatory DSS for the impact assessment of future scenarios and water management options: Application to the Guadiana basin in Spain", PhD Thesis, Universidad Politécnica de Madrid (Spain) (unpublished).

Coutinho, L. (2011), "Long-term growth projections for the MED-region", Draft, WP5, MEDPRO project, March.

Doorenbos, J. and A.H. Kassam (1979), *Yield response to water*, FAO Irrigation and Drainage Paper No. 33, FAO, Rome.

Droogers, P. and C. Perry (2008), *Scenario-based Water Resources Model to Support Policy-Making*, FutureWater Report No. 79, FutureWater, Wageningen.

European Environment Agency (EEA) (2004), *Impact of climate change*, EEA Report No. 2/2004, Luxembourg: Office for Official Publications of the European Communities (http://reports.eea.eu.int/climate_report_2_2004/en).

Evans, J. (2008), Evans plot of the change in precipitation by amount (hue) and significance (sat) (http://web.maths.unsw.edu.au/~jasone/eplots/pics/evans_4_1_lg.png).

Garrote, L., F. Martín-Carrasco and I. Rodríguez (2004), "An analysis of sensitivity of regulated basins to climate change", Paper presented at the International Conference on Hydrology, "Sciences & Practice for the 21st century", British Hydrological Society, London, July.

Giannakopoulos, C., P. Le Sager, M. Bindi, M. Moriondo, E. Kostopoulou and C.M. Goodess (2009), "Climatic changes and associated impacts in the Mediterranean resulting from a 2ºC global warming", *Global and Planetary Change*, Vol. 68, No. 3, pp. 209-224.

Groenewold, G., J. De Beer and C. Huisman (2012), *Population Scenarios for South Mediterranean Countries 2010–2050*, MEDPRO Report No. 2, CEPS, Brussels.

Groves, D.G., D. Yates and C. Tebaldi (2008), "Developing and applying uncertain global climate change projections for regional water management planning", *Water Resources Research*, Vol. 44, No. 12.

Immerzeel, W., P. Droogers, W. Terink, J. Hoogeveen, P. Hellegers and M. Bierkens (2011), *Middle-East and Northern Africa Water Outlook*, FutureWater Report No. 98, FutureWater, Wageningen, January.

Intergovernmental Panel on Climate Change (IPCC) (2000), "Summary for Policymakers", in N. Nakicenovic and S. Swart (eds), *IPCC Special Report on Emissions Scenarios A Special Report of IPCC Working Group III*, Geneva.

Intergovernmental Panel on Climate Change (IPCC) (2012), "Summary for Policymakers", in C.B. Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor and P.M. Midgley (eds), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, A Special Report of Working*

Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge (UK) and New York, NY: Cambridge University Press.

Kaisi, A., M. Yasser and Y. Mahrouseh (2005), "Irrigation system performance: Syrian country report", in N. Lamaddalena, F. Lebdi, M. Todorovic and C. Bogliotti (eds), *WASAMED Workshop: Irrigation systems performance, Options Méditerranéennes*, Série B, Etudes et Recherches, No. 52, CIHEAM-IAMB, Bari, pp. 187-201.

Katz, D. (2008), "Water, economic growth and conflict: Three studies", PhD Dissertation, University of Michigan.

Kok, K., and J. Alcamo (2007), *Report reviewing existing large-scale scenarios and reasons for selection of the set most relevant to European water issues for the fast-track process*, SCENES Deliverable 2.2, Wageningen University (http://www.environment.fi/syke/scenes).

Kok, K., M. van Vliet, I. Bärlund and J. Alcamo (2008), *First draft of pan-European storylines – Results from the first pan-European stakeholder workshop*, SCENES Deliverable 2,4, Wageningen University (http://www.environment.fi/syke/scenes).

Kouvaritakis, N., Z. Vrontisi and S. Tsani (2011), "Quantitative reference scenario for the MEDPRO project, MEDPRO project", Technical Report for WP8, ICCS/NTUA – E3MLab, September (unpublished).

Margat, J., and D. Vallée (2000), Mediterranean Vision on water, population and the environment for the 21st Century, Blue Plan 2000 (http://goo.gl/DMgZx)

Margat, J. (2004), *L'eau des Méditerranéens: situation et perspectives*, MAP Technical Report Series No. 158, UNEP/PAM, Athens (www.unepmap.gr).

Ministerio de Agricultura y del Medio Rural y Marino (MARM) [Spanish Ministry of the Environment and Rural and Marine Affairs] (2010), Precios percibidos, pagados y salarios agrarios, MARM, Madrid.

Melsmani, Y. (ed.) (2010), Initial National Communication of the Syrian Arab Republic, Submitted to the United Nations Framework Convention on Climate Change, MSEA/UNDP/GEF, Damascus.

OECD–FAO (2010), Agricultural Outlook 2010-2019 (online database), OECD and FAO, Paris and Rome (http://www.agri-outlook.org).

Paroussos, L., C. Fragiadakis, I. Charalambidis, S. Tsani and P. Capros (2012), "Quantitative macroeconomic scenarios for the MED-11 region using the GEM-E3 – MEDPRO general equilibrium model", MEDPRO Technical Report for WP8, ICCS/NTUA – E3MLab (unpublished).

Perman, R., and D.I. Stern (2003), "Evidence from panel unit root and cointegration tests that the environmental Kuznets curve does not exist", *Australian Journal of Agricultural and Resource Economics*, Vol. 47, No. 3, pp. 325-347.

Raskin, P., E. Hansen, Z. Zhu and D. Stavisky (1992), "Simulation of water supply and demand in the Aral Sea region", *Water International*, Vol. 17, No. 2, pp. 55-67.

Samuels, R., A. Rimmer, A. Hartmann, S. Krichak and P. Alpert (2010), "Climate Change Impacts on Jordan River Flow: Downscaling Application from a Regional Climate Model", *Journal of Hydrometeorology*, Vol. 11, No. 4, pp. 860-879.

Sandoval-Solis, S. and D. McKinney (2010), "Evaluation of Water Conservation Measures Implemented in the Rio Grande/Bravo Basin", in *Proceedings, World Environmental & Water Resources Congress 2010*, American Society of Civil Engineers, May.

Sessa, C. (2011), "Technical report on qualitative scenarios of cooperation and development in the Euro-Mediterranean Region", MEDPRO D9.1 (unpublished).

Steduto, P., T.C. Hsiao, D. Raes and E. Fereres (2009), "AquaCrop – The FAO Crop Model to Simulate Yield Response to Water: I, Concepts and Underlying Principles", *Agronomy Journal*, Vol. 101, No. 3, pp. 426-437.

Stern, D.I. (2003), *The Environmental Kuznets Curve*, International Society for Ecological Economics, Internet Encyclopaedia of Ecological Economics, Department of Economics, Rensselaer Polytechnic Institute, Troy, NY, June.

United Nations (UN) (2009), *World Population Prospects: The 2008 Revision*, Department of Economics and Social Affairs, Population Division, UN, New York.

United Nations Environment Programme (UNEP) (2007), *Global Environment Outlook 4, Environment for Development*, UNEP, Nairobi (http://www.unep.org/geo/geo4/).

Varela-Ortega, C. and J.A. Sagardoy (2001), *Final report on agriculture water use in Syria*, Project GCP/SYR/006/ITA, Assistance in Institutional Strengthening and Agricultural Policy, FAO-Government of Italy Cooperative Programme, Damascus.

Varela-Ortega, C., I. Blanco, C. Swartz and T.E. Downing (2011), "Balancing groundwater conservation and rural livelihoods under water and climate uncertainties: An integrated hydro-economic modeling framework", *Global Environmental Change*, Vol. 21, No. 2, pp. 604-619.

Venot, J.P., F. Molle and Y. Hassan (2007), *Irrigated agriculture, water pricing and water savings in the Lower Jordan River Basin (in Jordan)*, Comprehensive Assessment of Water Management in Agriculture Research Report No. 18, International Water Management Institute, Colombo.

Yates, D., D. Purkey, J. Sieber, A. Huber-Lee and H. Galbraith (2005), "WEAP21 – A demand-, priority- and preference-driven water planning model – Part 2: Aiding freshwater ecosystem service evaluation", *Water International*, Vol. 30, No. 4, pp. 501-512.

Yates, D., D. Purkey, J. Sieber, A. Huber-Lee, H. Galbraith, J. West, S. Herrod-Julius, C. Young, B. Joyce and M. Rayej (2009), "Climate Driven Water Resources Model of the Sacramento Basin, California", *ASCE Journal of Water Resources Planning and Management*, Vol. 135, No. 5, pp. 303-313.

Yates, D., J. Sieber, D. Purkey and A. Huber-Lee (2005), "WEAP21 – A demand-, priority- and preference-driven water planning model – Part 1: Model characteristics", *Water International*, Vol. 30, No. 4, pp. 487-500.

Appendix – General Database

World Bank data catalogue: World Development Indicators and Global Development Finance[9]

World Development Indicators – World Bank

World Development Indicators (WDI) are the primary World Bank set of development indicators, compiled from officially recognised international sources, for developing and high-income economies (includes 213 economies) from 1960 to 2009.

Global Development Finance – World Bank

The Global Development Finance (GDF) database focuses on financial flows, trends in external debt, and other major financial indicators for developing countries. It includes over 200 time series indicators at the national level from 1970 to 2008, for most reporting countries (including 128 economies).

Selected variables from the WDI and GDF:

Population

- Total population
- Rural population
- Population density (people per sq. km)

Agriculture

Land use

- Agricultural irrigated land (% of total agricultural land)
- Agricultural land (% of land area)

Production

- Agricultural machinery, tractors per 100 sq. km of arable land
- Agriculture value added per worker (constant 2000 US$)
- Land under cereal production (hectares)
- Fertilizer consumption (metric tonnes)
- Cereal yield (kg per hectare)

Environment

Freshwater

- Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal)
- Annual freshwater withdrawals, domestic (% of total freshwater withdrawal)
- Annual freshwater withdrawals, industry (% of total freshwater withdrawal)
- Annual freshwater withdrawals, total (billion cubic metres)

Energy production and emissions

- Electric power consumption (kWh)
- Electricity production from hydroelectric sources (kWh)
- CO_2 emissions (kg per 2000 US$ of GDP)

[9] The World Bank's DataBank website is at http://databank.worldbank.org/ddp/home.do?Step=2&id=4&DisplayAggregation=N&SdmxSupported=Y&CNO=2&SET_BRANDING=YES.

Economics

Economic activity

- GDP per capita (current US$)
- Economically active population in agriculture (number)
- Employment in agriculture (% of total employment)
- International tourism, number of arrivals

Development

- Improved water source (% of population with access)
- Population covered by mobile cellular network (%)
- Internet users
- Literacy rate, adult total (% of people ages 15 and above).

Millennium Development Goals

These are relevant indicators drawn from the World Development Indicators, reorganised according to the goals and targets of the Millennium Development Goals (MDGs). This database covers developing and high-income economies (213) from 1990 to 2009.

Selected variables:

- Annual freshwater withdrawals, total (% of internal resources)
- Improved sanitation facilities (% of population with access)
- Improved water source (% of population with access)
- Renewable internal freshwater resources per capita (cubic metres).

FAOSTAT

Selected variables:

- Gross production value (constant 1999–2001 million SLC)[10] (http://faostat.fao.org/site/613/default.aspx#ancor)
- Area harvested (ha) (http://faostat.fao.org/site/567/default.aspx#ancor)
- Yield (Hg/ha) (http://faostat.fao.org/site/567/default.aspx#ancor)
- Production (tonnes) (http://faostat.fao.org/site/567/default.aspx#ancor)

ResourceSTAT-Land (http://faostat.fao.org/site/377/default.aspx#ancor)

Variables:

Land use

- Country area (1000 ha)
- Land area (1000 ha)
- Agricultural area (1000 ha)
- Agricultural area organic, total (1000 ha)
- Agricultural area certified organic (1000 ha)
- Agricultural area in conversion to organic (1000 ha)
- Agricultural area irrigated (1000 ha)
- Arable land and permanent crops (1000 ha)

Arable land

- Arable land (1000 ha)
- Arable land organic, total (1000 ha)

[10] SLC refers to standard local currency.

- Arable land area certified organic (1000 ha)
- Arable land area in conversion to organic (1000 ha)
- Temporary crops (1000 ha)
- Temporary crops irrigated (1000 ha)
- Temporary crops non-irrigated (1000 ha)
- Temporary meadows and pastures (1000 ha)
- Temporary meadows and pastures irrigated (1000 ha)
- Temporary meadows and pastures non-irrigated (1000 ha)
- Fallow land (1000 ha)

Permanent crops

- Permanent crops (1000 ha)
- Permanent crops organic, total (1000 ha)
- Permanent crops area certified organic (1000 ha)
- Permanent crops area in conversion to organic (1000 ha)
- Permanent crops irrigated (1000 ha)
- Permanent crops non-irrigated (1000 ha)
- Permanent meadows and pastures (1000 ha)
- Permanent meadows and pastures organic, total (1000 ha)
- Permanent meadows and pastures area certified organic (1000 ha)
- Permanent meadows and pastures area in conversion to organic (1000 ha)
- Permanent meadows and pastures – Cultivated (1000 ha)
- Permanent meadows and pastures – Cultivated & irrigated (1000 ha)
- Permanent meadows and pastures – Naturally grown (1000 ha)
- Permanent meadows and pastures – Cultivated non-irrigated (1000 ha)

Other

- Forest area (1000 ha)
- Other land (1000 ha)
- Inland water (1000 ha)
- Total area equipped for irrigation (1000 ha)

AQUASTAT[11]

Variables:

Geography and population

Land use

- Total area (1000 ha)
- Arable land (1000 ha)
- Permanent crops (1000 ha)
- Cultivated area (1000 ha)
- Percentage of total country area cultivated (%)

Population

- Total population (1000 inhab.)
- Rural population (1000 inhab.)
- Urban population (1000 inhab.)

[11] The AQUASTAT website is at http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en.

- Population density (inhab./km2)
- Total economically active population (1000 inhab.)
- Total economically active population in agriculture (1000 inhab.)
- Male economically active population in agriculture (1000 inhab.)
- Female economically active population in agriculture (1000 inhab.)

Economy and development

- Human development index (HDI) (-)
- Agriculture, value added to GDP (%)

Water resources

Precipitation

- Average precipitation in depth (mm/yr)
- Average precipitation in volume (10^9m3/yr)

Internal renewable water resources

- Surface water: Produced internally (10^9m3/yr)
- Groundwater: Produced internally (10^9m3/yr)
- Overlap between surface water and groundwater (10^9m3/yr)
- Water resources: Total internal renewable (10^9m3/yr)
- Water resources: Total internal renewable per capita (m3/inhab./yr)

External renewable water resources

- Surface water: Entering the country (natural)(10^9m3/yr)
- Surface water: Inflow not submitted to treaties (actual)(10^9m3/yr)
- Surface water: Inflow submitted to treaties (actual)(10^9m3/yr)
- Surface water: Inflow secured through treaties (actual)(10^9m3/yr)
- Surface water: Accounted inflow (actual)(10^9m3/yr)
- Surface water: Total flow of border rivers (natural)(10^9m3/yr)
- Surface water: Total flow of border rivers (actual)(10^9m3/yr)
- Surface water: Accounted flow of border rivers (natural)(10^9m3/yr)
- Surface water: Accounted flow of border rivers (actual)(10^9m3/yr)
- Surface water: Accounted part of border lakes (natural)(10^9m3/yr)
- Surface water: Accounted part of border lakes (actual)(10^9m3/yr)
- Surface water: Total entering and bordering the country (natural)(10^9m3/yr)
- Surface water: Total entering and bordering the country (actual)(10^9m3/yr)
- Surface water: Leaving the country (natural)(10^9m3/yr)
- Surface water: Outflow not submitted to treaties (actual)(10^9m3/yr)
- Surface water: Outflow submitted to treaties (actual)(10^9m3/yr)
- Surface water: Outflow secured through treaties (actual)(10^9m3/yr)
- Surface water: Total external renewable (actual)(10^9m3/yr)
- Groundwater: Entering the country (natural)(10^9m3/yr)
- Groundwater: Entering the country (actual)(10^9m3/yr)
- Groundwater: Leaving the country (natural)(10^9m3/yr)
- Groundwater: Leaving the country (actual)(10^9m3/yr)
- Water resources: Total external renewable (natural)(10^9m3/yr)
- Water resources: Total external renewable (actual)(10^9m3/yr)

Total renewable water resources

- Surface water: Total renewable (natural)(10^9m3/yr)
- Surface water: Total renewable (actual)(10^9m3/yr)
- Groundwater: Total renewable (natural)(10^9m3/yr)
- Groundwater: Total renewable (actual)(10^9m3/yr)
- Water resources: Total renewable (natural)(10^9m3/yr)
- Water resources: Total renewable (actual)(10^9m3/yr)
- Water resources: Total renewable per capita (actual)(m3/inhab./yr)
- Dependency ratio (%)

Exploitable water resources and dam capacity

- Water resources: Total exploitable (10^9m3/yr)
- Total dam capacity (km3)

Water use

Water withdrawal by sector

- Agricultural water withdrawal (10^9m3/yr)
- Municipal water withdrawal (10^9m3/yr)
- Industrial water withdrawal (10^9m3/yr)
- Total water withdrawal (sum of sectors) (10^9m3/yr)
- Agricultural water withdrawal as a % of total water withdrawal (%)
- Municipal water withdrawal as a % of total withdrawal (%)
- Industrial water withdrawal as a % of total water withdrawal (%)
- Total water withdrawal per capita (m3/inhab./yr)
- Municipal water withdrawal per capita (total population) (m3/inhab./yr)

Water withdrawal by source

- Surface water withdrawal (10^9m3/yr)
- Groundwater withdrawal (10^9m3/yr)
- Total freshwater withdrawal (surface water + groundwater) (10^9m3/yr)
- Desalinated water produced (10^9m3/yr)
- Reused treated wastewater (10^9m3/yr)

Wastewater

- Wastewater: Produced volume (10^9m3/yr)
- Wastewater: Treated volume (10^9m3/yr)

Pressure on water resources

- Percentage of total, actual, renewable freshwater resources withdrawn (%)
- Percentage of total, actual, renewable water resources withdrawn by agriculture (%)

Irrigation and drainage development

Areas under agricultural water management

- Irrigation potential (1000 ha)
- Area equipped for full control irrigation: Surface irrigation (1000 ha)
- Area equipped for full control irrigation: Sprinkler irrigation (1000 ha)
- Area equipped for full control irrigation: Localised irrigation (1000 ha)
- Area equipped for full control irrigation: Total (1000 ha)
- Area equipped for full control irrigation: Actually irrigated (1000 ha)
- Percentage of area equipped for full control irrigation actually irrigated (%)
- Area equipped for irrigation: Equipped lowland areas (1000 ha)

- Area equipped for spate irrigation (1000 ha)
- Area equipped for irrigation: Total (1000 ha)
- Area equipped for irrigation: Actually irrigated (1000 ha)
- Percentage of the area equipped for irrigation actually irrigated (%)
- Percentage of the cultivated area equipped for irrigation (%)
- Percentage of irrigation potential equipped for irrigation (%)
- Flood recession cropping area non-equipped (1000 ha)
- Cultivated wetlands and inland valley bottoms non-equipped (1000 ha)
- Total agricultural water managed area (1000 ha)
- Percentage of agricultural water managed area equipped for irrigation (%)

Area equipped for irrigation by source of water

- Area equipped for full control irrigation by surface water (1000 ha)
- Area equipped for full control irrigation by groundwater (1000 ha)
- Area equipped for full control irrigation by mixed surface water and groundwater (1000 ha)
- Area equipped for full control irrigation by non-conventional sources of water (1000 ha)
- Percentage of area equipped for full control irrigation irrigated by surface water (%)
- Percentage of area equipped for full control irrigation irrigated by groundwater (%)
- Percentage of area equipped for full control irrigation irrigated by mixed water (sw and gw) (%)
- Percentage of area equipped for full control irrigation irrigated by non-conventional water (%)

Power irrigated area

- Area equipped for power irrigation (surface water or groundwater) (1000 ha)
- Percentage of area equipped for irrigation power irrigated (%)

Irrigated crop area and cropping intensity

- Total harvested irrigated crop area (full control irrigation) (1000 ha)
- Harvested irrigated crop area as a % of area equipped for full control irrigation (%)
- Harvested irrigated crop area as a % of full control irrigated area actually irrigated (%)
- Percentage of total grain production irrigated (%)

Drainage

- Area equipped for irrigation drained (1000 ha)
- Non-irrigated cultivated area drained (1000 ha)
- Total cultivated area drained (1000 ha)
- Percentage of area equipped for full control surface irrigation drained (%)
- Percentage of total cultivated area drained (%)

Conservation agriculture and water harvesting

Conservation agriculture

- Conservation agriculture area: >30% ground cover (1000 ha)
- Conservation agriculture area as a % of cultivated area (%)

Environment and health

Environment

- Area salinized by irrigation (1000 ha)
- Percentage of area equipped for full control irrigation salinized (%)
- Area waterlogged by irrigation (1000 ha)
- Area waterlogged not irrigated (1000 ha)

Health

- Population affected by water related disease (1000 inhab.)

Plan Bleu

SIMEDD (Mediterranean Information System on Environment and Sustainable Development). Data compiled by Jean Margat/Plan Bleu from various sources (http://www.planbleu.org/donnees/eau/simed/eau_simed_demandeUk.html)

Selected variable:

- Total water withdrawal – data for this variable come from different sources collected by Jean Margat for Plan Bleu. This is the most complete data series for water withdrawal available, although it is still very incomplete for some specific countries (such as Lebanon and Libya) and there are no data for Jordan or the Palestinian territories.

The world's water

Gleick, H.P., H. Cooley, M. Cohen, M. Morikawa, J. Morrison and M. Palaniappan (2009), *The World's Water 2008-2009: The biennial report on freshwater resources,* Washington D.C.: Island Press.

Selected variable:

- Total water withdrawal (value for the year 2000 or nearest years, depending on the country)

Gleick, H.P. (1999), *The World's Water 1998-1999: The Biennial Report on Freshwater Resources,* Washington D.C.: Island Press.

Selected variable:

- Total water withdrawal (value for the year 1999 or nearest years, depending on the country)

About MEDPRO

MEDPRO – Mediterranean Prospects – is a consortium of 17 highly reputed institutions from throughout the Mediterranean funded under the EU's 7th Framework Programme and coordinated by the Centre for European Policy Studies based in Brussels. At its core, MEDPRO explores the key challenges facing the countries in the Southern Mediterranean region in the coming decades. Towards this end, MEDPRO will undertake a prospective analysis, building on scenarios for regional integration and cooperation with the EU up to 2030 and on various impact assessments. A multi-disciplinary approach is taken to the research, which is organised into seven fields of study: geopolitics and governance; demography, health and ageing; management of environment and natural resources; energy and climate change mitigation; economic integration, trade, investment and sectoral analyses; financial services and capital markets; human capital, social protection, inequality and migration. By carrying out this work, MEDPRO aims to deliver a sound scientific underpinning for future policy decisions at both domestic and EU levels.

Title	MEDPRO – Prospective Analysis for the Mediterranean Region
Description	MEDPRO explores the challenges facing the countries in the South Mediterranean region in the coming decades. The project will undertake a comprehensive foresight analysis to provide a sound scientific underpinning for future policy decisions at both domestic and EU levels.
Mediterranean countries covered	Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia and Turkey
Coordinator	Dr. Rym Ayadi, Centre for European Policy Studies (CEPS), rym.ayadi@ceps.eu
Consortium	Centre for European Policy Studies, **CEPS**, Belgium; Center for Social and Economic Research, **CASE**, Poland; Cyprus Center for European and International Affairs, **CCEIA**, Cyprus; Fondazione Eni Enrico Mattei, **FEEM**, Italy; Forum Euro-Méditerranéen des Instituts de Sciences Economiques, **FEMISE**, France; Faculty of Economics and Political Sciences, **FEPS**, Egypt; Istituto Affari Internazionali, **IAI**, Italy; Institute of Communication and Computer Systems, **ICCS/NTUA**, Greece; Institut Europeu de la Mediterrania, **IEMed**, Spain; Institut Marocain des Relations Internationales, **IMRI**, Morocco; Istituto di Studi per l'Integrazione dei Sistemi, **ISIS**, Italy; Institut Tunisien de la Compétitivité et des Etudes Quantitatives, **ITCEQ**, Tunisia; Mediterranean Agronomic Institute of Bari, **MAIB**, Italy; Palestine Economic Policy Research Institute, **MAS**, Palestine; Netherlands Interdisciplinary Demographic Institute, **NIDI**, Netherlands; Universidad Politecnica de Madrid, **UPM**, Spain; Centre for European Economic Research, **ZEW**, Germany
Budget and Funding	Total budget: €3,088,573 EC-DG RESEARCH contribution: €2,647,330
Duration	1 April 2010 – 31March 2013 (36 months)
EC Scientific Officer	Dr. Domenico Rossetti Di Valdalbero, DG RESEARCH
Website	www.medpro-foresight.eu
Contact e-mail	medpro@ceps.eu