CLIMATE CHANGE AND WATER RESOURCES MANAGEMENT IN THE SOUTHERN MEDITERRANEAN AND MIDDLE EAST COUNTRIES

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Abstract

Water has always been the central concern to life in the southern Mediterranean and Middle East (SMED & ME) countries. The overgrowing population and the recent droughts are exerting a lot of pressure on the water resources and calling for new approaches for water planning and management if the rainfall will continue to decrease and the temperature will continue to rise. At present, the water exploitation index estimated as percentage of renewable annual water resources is already high. For example it is 83% for Tunisia, 92% for Egypt, 140% for Israel, 169% for Gaza and 644% for Libya.

The climate of the Mediterranean region is characterised by hot dry summer and mild wet winter. The region suffers frequently from years of low rainfall and most of the region was hit by severe drought and some have seen poor rainfall. The UK Hadlley Centre's global climate model has been run on monthly basis for the SMED & ME countries to predict the percent change in Rainfall with respect to mean monthly values. The results show that for the dry season (April to September), by the year 2050 North Africa and some parts of Egypt, Saudi Arabia, Iran, Syria,

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Jordan, Israel, are expected to have a reduced rainfall amounts to 20 to 25% less than the present mean values. This decrease in rainfall is accompanied by temperature rise in those areas between 2°C and 2.75°C. For the same period, the temperature in the coastal areas of the SMED & ME countries will rise by about 1.5°C. In winter time, the rainfall will decrease by about 10% to 15%. In the wintertime, the temperature in the coastal areas will also increase but by only 1.5°C on average while inside the region it will increase by 1.75 to 2.5°C.

Given the above mentioned facts, in order to meet the water demands in the next century, some dams and water infrastructure will have to be built in some SMED & ME countries and a new paradigm by rethinking the water use with the aim of increasing the productive use of water will have to be adopted. Two approaches are needed: increasing efficiency with which current needs are met and increasing the efficiency with which water is allocated among different uses. In addition, non-conventional sources of water supply such as reclaimed; recycled water and desalinated brackish water or seawater is expected to play an important role.

KEY WORDS: **CLIMATE CHANGE, WATER RESOURCES MANAGEMENT, MEDITERRANEAN, MIDDLE EAST**

1. INTRODUCTION

Over the past century, population growth, industrial development and expansion of irrigated agriculture have increased dramatically. World population has grown from 1,600 million in 1900 to 6,000 million in 1995 while land under irrigation increased from around 50 million hectares to over 250 million hectares for the same period. In addition to other factors these have led to a nearly seven fold increase in fresh water withdrawals. The latter have increased from 580 $km^3\ yr^{-1}$ in 1900 to 3,580 $km^3\ yr^{-1}$ in 1990 and are estimated to be 3,940 for year 2000. At present, 54% of accessible runoff on earth is in use and it is expected that future population growth could make use of 70% of the accessible runoff by the year 2025 (GLEICK, 1998, SHIKLOMANOV, 1997). Because of the expected increase in population, agricultural production and per-capita water demand, planners and policy makers have expected a rise in water demand. It is expected to exceed the actual water supplies and it will be a water management problem as to how to bridge the gap. Water has always been the central concern to life in the SMED & ME countries. Early civilisations emerged along the Nile, Tigris and Euphrates and the struggle for water shaped the life of desert communities. The overgrowing population and the recent droughts in this part of the world are putting a lot of pressure on the water resources. Subsequently, new approaches for water planning and management are needed if escalating conflicts are to be avoided and environmental degradation is to be halted and reversed.

According to the WORLD BANK (1993), the minimum water required to sustain human life is about 25 $l\ day^{-1}$ (10 $m^3\ yr^{-1}$) A reasonable supply to maintain health may be 100-200 $l\ day^{-1}$ per capita (40-80 $m^3\ yr^{-1}$) though in developed countries domestic use can exceed 300-400 $l\ day^{-1}$ per capita (up to 150 m^3 yr^{-1}or more). By year 2025 renewable water resources in four SMED & ME countries will barley cover the basic human needs in Jordan, Libya, Saudi Arabia, and Yemen.

At present, the water exploitation index taken as percentage of renewable annual water resources for Tunisia is 83%, Egypt is 92%, Israel is 140%, Gaza is 169%, Libya is 644% (because 84% come from non-renewable fossil water from beneath the Sahara), Syria is nearly 50%, Lebanon is about 25%, Algeria is 20%, and Morocco is nearly 40% (PEARCE, 1996).

The world's leading scientists consider that we are now on the verge of changing our climate due to human activities that causes the greenhouse effect. The latter has great impact on water resources. According to the IPCC (1996), the global average temperature in the year 2100 is likely to be 2°C warmer than at present. This increase might not look significant to someone but a difference of only 1°C in average global temperature is all that separates today’s climate from that of the Little Ice Age in the period from the fourteenth to the seventeenth century. An increase of 2°C would bring the average global temperature beyond anything experienced in the past 10,000 years (GLEICK, 1998). Therefore, Water managers, policymakers and public must think about long-term water planning and management.

There have already been some significant changes in the Earth’s climate. Since the late 19th century, the global mean surface temperature has increased by 0.3°C to 0.6°C and that was enough to make the past decade to be the warmest decade in the period of instrumental record. Precipitation has increased in the high latitudes of the Northern Hemisphere, particularly during winter. Global sea level has risen by 10 cm to 25 cm over the past 100 years.

The Mediterranean region suffers frequently from years of low rainfall. Most of the region was hit by severe drought in 1989-1990 and some have seen poor rainfall. Tunisia suffered severe drought from 1987-1989, while Morocco has suffered continually since 1990. Because countries are using their water resources with growing intensity, poor rainfall increasingly leads to national water crises as water tables fall and reservoirs, wetlands and rivers run dry.

Generally, the climate of the Mediterranean is characterised by hot dry summer and mild wet winter. The coasts of Algeria and Libya normally have seven dry months, receive only around 200 mm of rain in an average year and have typical July temperature of 30°C. When rain does fall, it tends to arrive as heavy storms, falls of over 125 mm in a day, often with thunder, are not uncommon and records for individual sites include more severe storms such as Tripoli (130 mm) and Haifa (183 mm) (ACREMAN, 2000). Thus, some areas receive their total annual rainfall in a few days.

There is a growing debate about whether these droughts are simply another manifestation of the notorious variability of Mediterranean rainfall or a sign of a long term shift in rainfall patterns perhaps linked to global warming. There has been a decrease in rainfall throughout the region over the past century. In summer, rainfall is now 20% less than at the end of the 19th century. In Tangiers, rainfall has dropped by 100 mm in 40 years and at Ifrane, in the Moyen-Atlas Mountain in Morocco, Such changes create uncertainty. Are long term average of rainfall or river flow any longer valid as a basis for planning water resources use? The Greek hydrologists were forced to reconsider their estimates of average flows in the 220 km River Acheloos, the country's longest river and scheduled for a major diversion project to irrigate fields (PEARCE, 1996).

Global warming could unleash further changes, further variability and further uncertainty on the region. Several computer models of climate change suggest that the region will continue to become drier and hotter, with reduced rainfall and increased rates of evaporation. Some models suggest more than 5% decrease in rainfall by mid-21st century if the world warms by 2°C.

The objective of this work is to highlight the issue of the increasing demand on the limited water resources in the southern Mediterranean and Middle East countries, to predict the possible future climate change up to the year 2050 and to suggest possible means to manage this limited water resources under the possible impact of climate change on water resources.

2. WATER RESOURCES IN SMED & ME COUNTRIES: AN OVERVIEW

The total annual renewable water resources in SMED & ME countries average about 350 Billion m^3 (1,436 m^3 per head), of which some 120 billion m^3 is accounted for by river flows from outside the region. In 1990, of 18 countries only seven had per capita availability of more than 1000 m^3 per year. Between 1960 and 2025, per capita renewable supplies is expected to fall from 3,430 m^3 to 667 m^3 and in several countries of the regions renewable fresh water resources will barely cover basic human needs into the next century (WORLD BANK, 1993, FAO, 1997). Irrigation accounts for about 80% of withdrawals. However the demand is expanding very rapidly in urban areas. Withdrawals in Libya, Saudi Arabia, the Gulf States and Yemen are already exceeding the renewable supplies while Egypt, Israel and Jordan are essentially at the limit. In addition, Algeria, Iran, Morocco and Tunisia face sever regional deficits even if in total they are in surplus. Water transfers are sometimes feasible but can be very expensive and sometimes impractical. Only Iraq and Lebanon appear to have renewable supplies adequate to their relatively small population.

2.1 Surface water resources

Major water resources in SMED & ME are shared between countries. Nile, Jordan and Euphrates and Tigris river basins are shared (GISCHLER, 1979). Large aquifers underline North Africa and Arabian Peninsula, could be shared by several countries but agreement on abstractions does not exist. Table 1 gives some information on the renewable water resources, Annual river flows, and renewable water resources per capita in the SMED & ME countries while Table 2 shows the distribution of the water resources between the different sectors.

Deteriorating water quality is an increasingly serious issue in SMED & ME. This is due to combination of low river flows, inadequate treatment, agricultural runoffs and uncontrolled effluent from industry. The decline in water quality affects directly the utility of the water resources and increases the treatment costs. Seawater intrusion into coastal aquifers is a critical issue in these regions. Water quantity and quality are inseparable since there is a certain water quality level associated with each water use. Water management and planning must therefore deal appropriately with both aspects in an integrated approach.

Table 1 Water availability SMED & ME countries (WORLD BANK, 1993).

Country	Total annual	Annual River flows		Net annual renewable	Renewable Resources per capita		
	Renewable water resources	From other countries	To other countries	Resources	1960	1990	2025
	B m^3	B m^3	B m^3	B m^3	m^3 yr^{-1}		
Algeria	18.90	0.20	0.70	18.40	1,704	737	354
Bahrain	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Egypt	1.8	56.50	n.s.	58.30	2,251	1,112	645
Iran	117.5	n.s.	n.s.	117.50	5,788	2,152	1,032
Iraq	34.00	66.00	n.a.	100.00	14,706	5,285	2,000
Israel	1.70	0.45	n.a.	2.15	1,024	467	311
Jordan	0.70	0.40	n.s.	0.90	529	224	91
Lebanon	4.80	n.a	0.86	3.80	2,000	1,407	809
Libya	0.70	n.a.	n.a.	0.70	538	154	55
Morocco	30.00	n.a.	0.30	29.70	2,560	1,185	651
Oman	2.00	n.a.	n.s.	2.00	4,000	1,333	421
Qatar	n.a.	n.a.	n.s.	0.00	n.a.	n.a.	n.a.
S. Arabia	2.20	n.a.	n.s.	2.20	537	156	49
Syria	7.60	27.90	30.00	5.50	1,196	439	161
Tunisia	3.75	0.60	n.a.	4.35	1,036	532	319
U.A.E.	0.30	n.a.	n.a.	0.30	3,000	189	113
Yemen	2.50	n.a.	n.s.	2.50	481	214	72
MENA	228.45	152.05	31.86	348.30	3,430	1,436	667
Africa	4,184	n.a.	n.a.	4,184	14,884	6,516	2,620
Asia	10,485.00	n.s.	n.s.	10,485.00	6,290	3,368	2,134
World	40,673.00	n.a.	n.a.	40,673.00	13,471	7,685	4,783
Cyprus	0.9					1213(1995)	

According to SHAHIN (1996) the Average flow in (10^6 m^3 yr^{-1}) of the Nile is 85.5, Tigris is 48.7 and Euphrates is 29.0. There is a River Nile water agreement signed in 1959 between Egypt and Sudan (GISHLER, 1979) stipulating that Sudan's share is 18.5 billion m^3 and Egypt's share is 55.5 billion m^3 (It is worth to note here that Evaporation losses from Lake Nasser is 10 billion m^3 per year).

Table 2 Water resources availability and uses in SMED & ME countries (GLEICK, 1998)

Country	Annual renewable water Resources	Total fresh Water withdrawal	Domestic use	Industrial use	Agricultural use	Irrigated area
	$km^3\ yr^{-1}$	$km^3\ yr^{-1}$	%	%	%	10^3 ha
Algeria	14.3	4.5	25	15	60	555
Cyprus	0.9	0.21	24	2	74	40
Egypt	86.8	55.1	6	8	86	3,265
Libya	0.6	4.6	11	2	87	470
Morocco	30.0	11.04	5	3	92	1,258
Sudan	154.0	17.8	4	1	94	1,946
Tunisia	4.1	3.08	9	3	89	352
Bahrain	0.1	0.24	39	4	56	3
Gaza St.	0.06	0.12	40		60	12
Iran	137.5	70.03	6	2	92	7,264
Iraq	96.4	42.8	3	5	92	3,525
Israel	2.1	1.9	16	5	79	193
Jordan	0.9	0.98	22	3	75	73
Kuwait	0.0	0.54	37	2	60	5
Lebanon	4.8	1.29	28	4	68	88
Oman	1.0	1.22	5	2	94	62
Qatar	0.1	0.28	23	3	74	13
Saudi A.	2.4	17.02	9	1	90	1,473
Syria	46.1	14.41	4	2	94	1,082
Turkey	200.7	31.6	16	11	72	4,186
U.A.E	0.1	2.11	24	9	67	67
W. Bank	0.4	0.10	6.5		93.5	10.4
Yemen	4.1	2.93	7	1	92	481

The Euphrates originates in Turkey where it receives 94% of the flow, 4% is added in Syria with no significant amount added in Iraq. The Tigris receives 40% of its flow from Turkey, 50% from Iraq and 10% from Iran (WORLD BANK, 1993). The two rivers join together to form Shatt Al-Arab waterway before entering the Persian Gulf. 80% of the withdrawal is for irrigation.

The Jordan River flow at its entry to lake Tiberias is 580 million m^3 reduced to 60 million m^3 at its entry at Dead Sea. Yarmuk River is the major tributary starts in Syria and forms the present boundary between Syria and Jordan for 40 km before it becomes the border between Jordan and Israel for 12 km. The Yarmuk discharge is about 450-475 million m^3 (KLIOT, 1994).

2.2 Groundwater Resources

Many countries in the regions mine groundwater. This is a non-renewable resource and cannot continue indefinitely. Several very large aquifers underlie SMED & ME countries. Examples are, the Eastern Erg, the Nubian and the Saq/Disi aquifers (KLIOT, 1994). The Eastern Erg is located south of Atlas Mountains in Algeria and extends into Tunisia. It covers an area of 400,000 $km^{2,}$ largely artesian, only 0.4% of its volume is recharged annually and its volume is about four times the average annual renewable supply of SMED & ME countries. The Nubian sandstone aquifer runs under Egypt, Libya and Sudan extending over an area of 1.8 million km^2 of which 150,000 km^2 are under artesian conditions. The Nubian aquifer is estimated to contain 6000 billion m3, which is twenty times the average annual renewable supply of the whole region. The renewable rate is ~2.5% of its volume. There is a massive exploitation in southeastern Libya and the water is transferred to Libyan coastal regions via “man-made river” project. There is a fear that this may reduce the groundwater reserves in neighbouring countries quite substantially. The Saq formation

(Disi aquifer in Jordan) covers an area of 106,000 km^2 and extends from Jordan to the east and south to Saudi Arabia. There is a concern that the low-return wheat cultivation in Saudi Arabia will reduce availability for higher priority uses in Jordan and Saudi Arabia. These aquifers are often at great depth and pumping costs rises as the water tables decline.

In Gaza strip, The irrigated area is about 20,000 ha; the Rainfall ranges from 200-mm to 300 mm in the north and 300 mm to 400 mm in the south. Natural replenishment of the aquifer is 60 million m^3 where the demand is 100 million m^3 leaving a deficit of 40 million m^3. The gap between the demand and supply is met by over abstraction. Future deficit will have to be met by importing water from outside the region and by desalination.

In West Bank, the cultivated area is 200,000 ha. Rainfall ranges between 500 and 800 mm in the mountain and 200 mm in the semi-arid southern part. The usable (naturally replenished) have been estimated at 400 million m^3 of water. The Palestinian quota of 130 million m^3 represents 20% of the rechargeable groundwater reserves. Irrigated land is 10,400 ha from 50,000 irrigable land. The total demand is 300 million m^3 to irrigate the 50,000 ha.

2.3 Non – Conventional water resources

Non conventional sources will become increasingly important. The region already accounts for more than 60% of the total world desalination capacity (SHAHIN, 1996). Given its cost (~2$ per m^3) it is only for domestic use and partly for industrial use in the Oil rich countries. Two thirds of the world desalination plants exist in the SMED & ME countries (Table 3). Within the region, wastewater (Table 4) will play an increasing role.

Table 3 Total Plants capacity in some SMED & ME countries (SHAHIN, 1996).

Country	Capacity	Percentage of total
	$m^3 d^{-1}$	%
Algeria	204,312	1.841
Bahrain	315,197	2.841
Egypt	87,044	0.785
Iraq	333,093	3.002
Jordan	8,445	0.076
Kuwait	1,523,210	13.731
Libya	677,750	6.110
Morocco	15,325	0.138
Oman	162,096	1.461
Qatar	582,074	5.247
S. Arabia	5,020,324	45.257
Sudan	1,776	0.016
Syria	7,703	0.069
Tunisia	50,914	0.459
U.A.E.	2,081,091	18.760
Yemen	37,188	0.335
Total	11,093,008	100
Cyprus	6,275	

TABLE 4									
Use of non-conventional sources of water in selected countries (FAO, 2000)									
	Total water		Desalinated		Reused treated		Use of desalinated water	
COUNTRY	withdrawal		water		wastewater		and treated wastewater	
		million m^3		million m^3		million m^3	million m^3	as % of total
	Year	per year	Year	per year	Year	per year	per year	withdrawal
		(1)		*(2)*		*(3)*	*(4)=(2)+(3)*	*100*(4)/(1)*
ALGERIA	1990	4 500,0	1990	64,00		-	64,00	1,422
BAHRAIN	1991	239,2	1991	44,10	1991	8,03	52,13	21,793
CYPRUS *	1993	211,0		-	1995	11,00	11,00	5,213
EGYPT	1993	55 100,0	1990	25,00	1993	200,00	225,00	0,408
IRAN	1993	70 034,0	1991	2,90		-	2,90	0,004
IRAQ	1990	42 800,0		-		-	-	-
JORDAN	1993	984,0	1993	2,00	1991	50,30	52,30	5,315
KUWAIT	1994	538,0	1993	231,00	1994	52,00	283,00	52,602
LEBANON	1994	1 293,0		-	1991	2,00	2,00	0,155
LIBYA	1994	4 600,0	1994	70,00	1990	100,00	170,00	3,696
MALTA	1995	55,7	1995	31,40	1993	1,56	32,96	59,174
MOROCCO	1991	11 045,0	1992	3,40		-	3,40	0,031
OMAN	1991	1 223,0	1995	34,00	1991	26,00	60,00	4,906
QATAR	1994	284,9	1995	98,60	1994	25,20	123,80	43,454
SAUDI ARABIA	1992	17 018,0	1995	714,00	1992	217,00	931,00	5,471
SYRIA	1993	14 410,0		-	1993	370,00	370,00	2,568
TUNISIA	1990	3 075,0	1990	8,30	1993	20,00	28,30	0,920
TURKEY	1992	31 600,0	1990	0,50		-	0,50	0,002
UNITED ARAB EM.	1995	2 108,0	1995	385,00	1995	108,00	493,00	23,387

* ***Cyprus*****: The figure for total water withdrawal refers to the government controlled area; other figures refer to the whole island.**

3 THE CLIMATE OF SMED & ME COUNTRIES

3.1 The variability in temperature, rainfall and potential evapotranspiration

The SMED & ME countries enjoy large variations in its climatic conditions. These variations could be significant within a single country. Countries like Algeria, Libya, Egypt and Tunisia exhibit large variation between their north Mediterranean regions and their deserts in the south. There is a large difference also between the Gulf and the Mediterranean countries in terms of rainfall, temperature and evapotranspiration, ET_p as shown in Table 5. The ET_p values vary from 100 mm per year along the Mediterranean coast of northwest Africa to more than 2200-mm y^{-1} in the desert between Libya, Egypt and Sudan. The Gulf States and Egypt seem to have the lowest rainfall.

Table 5 Mean values of temperature, rainfall and potential evapotranspiration for some countries in SMED & ME countries (SHAHIN, 1996).

Country	Mean Temperature in January °C		Mean Temperature in July °C		Mean annual rainfall	Mean annual Pot. Evapo-transpiration
	Max	Min	Max	Min		
Algeria	16-20.2	5-9	28-40.5	21-25.1	23 - 818	1000 - 2450
Bahrain	20	13.9	37.2	29.4	74	1900
Cyprus		9	35 (Aug.)		503	
Egypt	17.7-22.2	6.2-9.8	28.7-40.6	20.6-25.8	25 - 190	1580 - 2300
Iraq	12.8-15.6	1.1-3.9	38.3-43.3	21.1-24.3	107 - 717	1600 - 2000
Jordan	12.2-13.4	3.8-3.9	31.5-32.2	18-19	100 - 625	1640 - 1960
Kuwait	16.1	9.4	39.4	30	100 - 141	2000
Lebanon	16.5	10.5	30.5	23	559 - 765	1250 - 1400
Libya	16-20.5	6-8.5	29.5-43	21-24	1 - 577	1350 - 2450
Morocco	9-17	-5-9	26-31	12-19	103 - 654	1000 - 1700
Oman	25-27.2	17.8-18.9	27.8-36.1	23.9-30.6	54 - 99	1700 - 3000
Qatar	20.5-21.5	10.5-10.8	38.7-42.4	26.3-27	60 - 100	1850
Saudi. A.	21.1-28.9	7.8-18.9	37.2-41.7	25.6-26.1	37 - 193	1700 - 2300
Sudan	24-32	7.8-19.9	38.5-41.2	24.9-28.1	64 - 777	2020 - 2450
Syria	11.7-12.9	1.3-2.2	35.5-38.7	18-23.7	100 - 1147	1425 - 1650
Tunisia	14-16	4-6	32-37	21-22	96 - 864	1200 - 1650
U.A.E	23.3	12.2	37.8	27.8	n.a.	2400
Yemen	24.1-29	0.5-22	31.5-37.2	14.1-28	117 - 864	2050 - 2200

3.2 Carbon Dioxide Emissions in SMED & ME countries

The Middle East may contribute a large fraction of the World's oil but through their own energy consumption produce only 6% of global CO_2 emissions (MARLAND *et al.*, 1994) from fossil fuels and cement. Due to the CO_2 emitted during the Kuwait oil field fires, exhibited a dramatic increase in CO_2 emission in 1991. The 1991 Kuwaiti oil field fires resulted in 130 million metric tons of carbon being emitted to the atmosphere, more than the total CO_2 emission of the 8th largest national emitter, Canada. The three major fuel consumers discharge 62% of the region's CO_2: Iran 60.7 million metric ton of carbon in 1991; Saudi Arabia, 58.7 million metric tons of carbon and Turkey 38.9 million metric tons of carbon. Gas flaring has been a major source of regional emission. Per capita emissions underwent rapid growth until 1973 but have changed little since then. Qatar has the highest national per capita CO_2 emission rate in the World, 12.2 metric tons of carbon per person. On Africa scale, south Africa contribute 41% of the continental total while another 40% come from Egypt, Nigeria, Algeria, and Libya combined. These are the only five countries with annual CO_2 emission in excess of 10 million metric tons of carbon. Libya has annual CO_2 emission of 2.5 million metric tons carbon. Iran total emission in 1991 reached 60.7 million metric tons of carbon. Crude oil and petroleum products account for the majority of emissions (65%). From a per capita standpoint, Iran is near global average at ~1 metric ton of carbon per person. Saudi Arabia is the world's twentieth largest CO_2 emitter in 1991, with nearly 59 million metric tons of carbon. Per capita emission is 3.81 metric tons of carbon per person well above the global average.

4 POSSIBLE FUTURE CLIMATE CHANGE IN SMED & ME COUNTRIES

As mentioned earlier, the expectations for SMED & ME countries are, the summer will be dryer and hotter. The UK Hadley Centre's global climate model is shown in figure 3. The model comprises several layers into the atmosphere and below soil surface and accounts for most of the essential/dominant hydrological processes. The model runs at spatial scale of $2.5° \times 3.75°$ grid squares for rainfall predictions and $0.5° \times 0.5°$ grid squares for temperature. Version two

(HadCM2) of this model accounts only for CO_2 impact (does not account for the aerosols impact). All the scenarios are for the time horizon 2050. They are expressed as percentage change (rainfall) or temperature change compared to the CRU climatology corresponding to the baseline period of 1961-1990 (New et al. 1999). The model has been run on monthly basis for the SMED & ME countries to predict the % change in Rainfall with respect to mean monthly values. The results are shown in figure 4 for the dray season (April to September) and for the wet season (October to March) up to the year 2050. Temperature changes in absolute °C are shown in figure 5 for the dry season and for the wet season. Figure 4 shows that by the year 2050 North Africa and some parts of Egypt, Saudi Arabia, Iran, Syria, Jordan, Israel, are expected to have a reduced rainfall amounts to 20 to 25% less than the present mean values. This decrease in rainfall is accompanied by temperature rise in those areas between 2°C and 2.75°C as shown in figure 5. For the same period, the temperature in the coastal areas of SMED & ME countries will rise by about 1.5°C. In wintertime, the rainfall will decrease by about 10% to 15%. In the winter time, the temperature in the coastal areas will also increase but by only 1.5°C on average while inside the region it will increase by 1.75°C to 2.5 as shown in figure 5.

4.1 Uncertainties in climate change predictions

The climate models used to generate estimates of future climate conditions are in need for refinement and improvement in many areas (GLEICK, 1998). Gaps in data and basic understanding of fundamental climatological processes slow any progress. Moreover, future unexpected large and rapid changes in climate as those of the past are very difficult to predict. These unpredictable events are attributed to the non-linear nature of the climate system

(GLEICK, 1998). According to JAGER and FERGUSON (1991) the uncertainties in climate predictions arise from our imperfect knowledge of:

1. Future rates of human-made emissions.
2. How these will change the atmospheric concentrations of greenhouse gases.
3. The responses of climate to these changed conditions.

There are many uncertainties associated with timing, direction and extent of these climatic changes as well as about their implications for societies. These uncertainties have great influence on the rational water-resources planning for the future. These uncertainties should not paralyse policy makers and water managers and stop them from rethink and re-evaluate current policies.

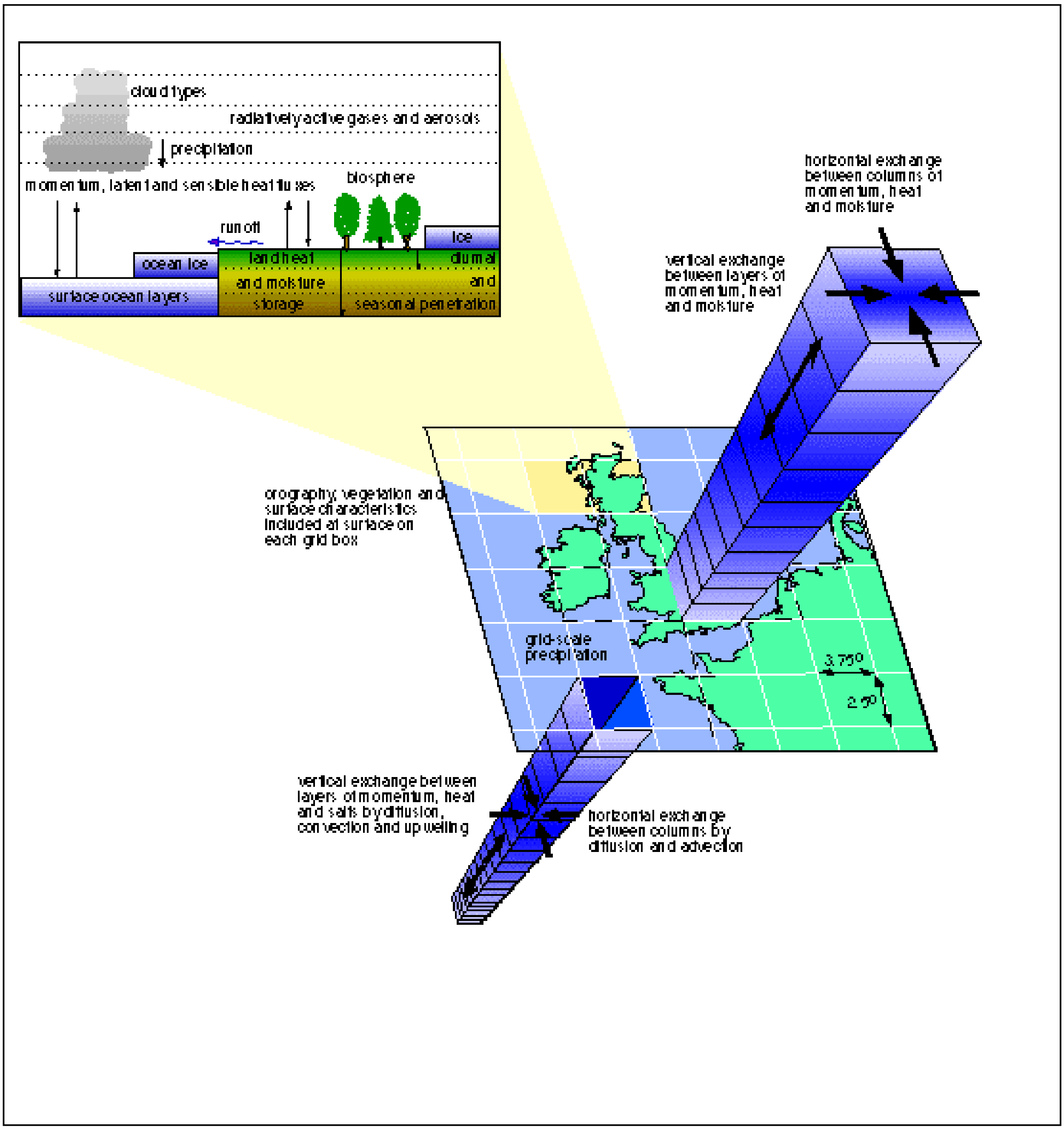

Figure 3 Conceptual Diagram of HadCM2

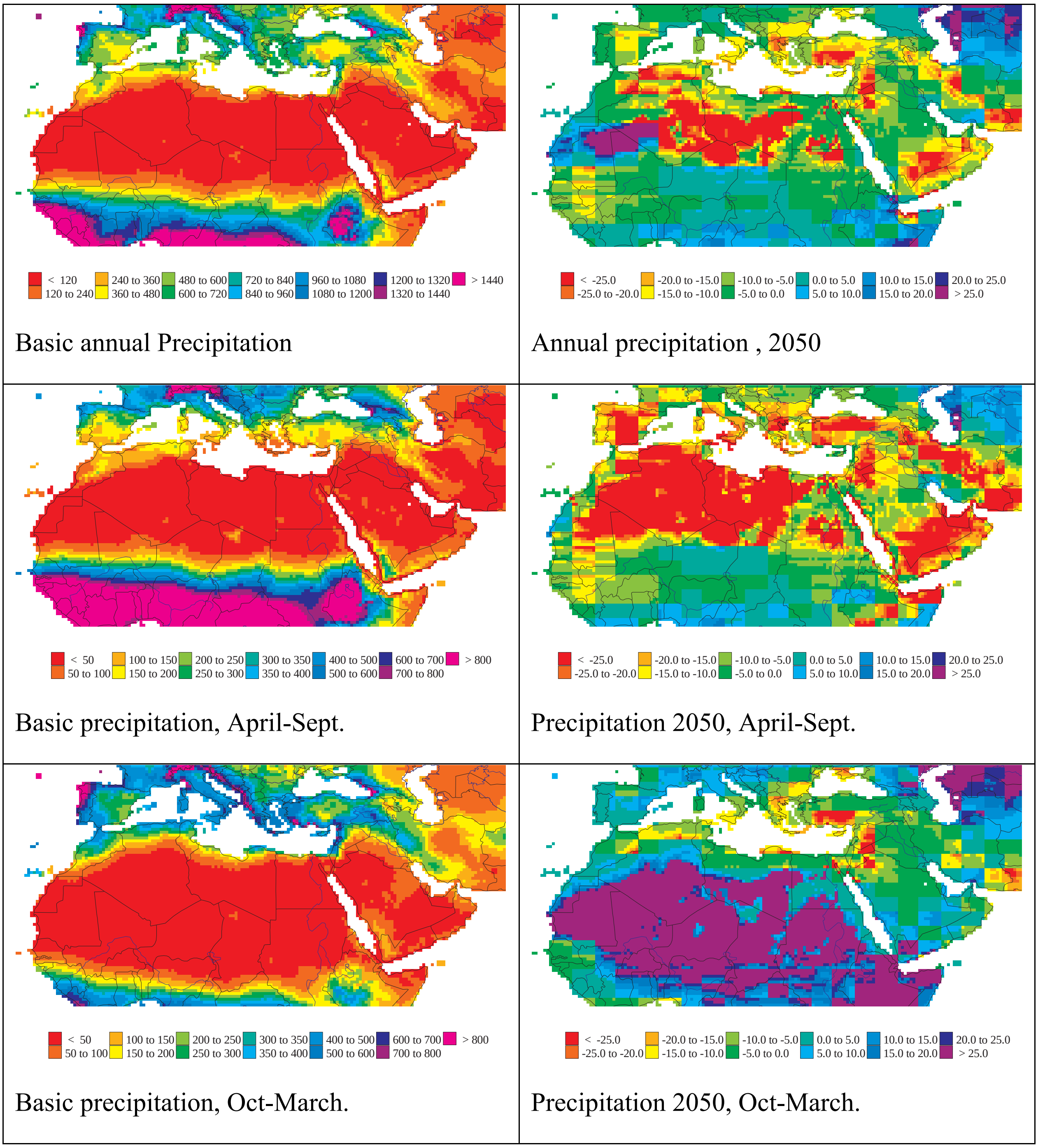

Figure 4. Basic Precipitation based on 1961-1990 data and Percent (%) Changes in precipitation for the dry season (April to September) and for the wet season (October to March) for the year 2050 according to the HadCM2 Scenario-GHGX.

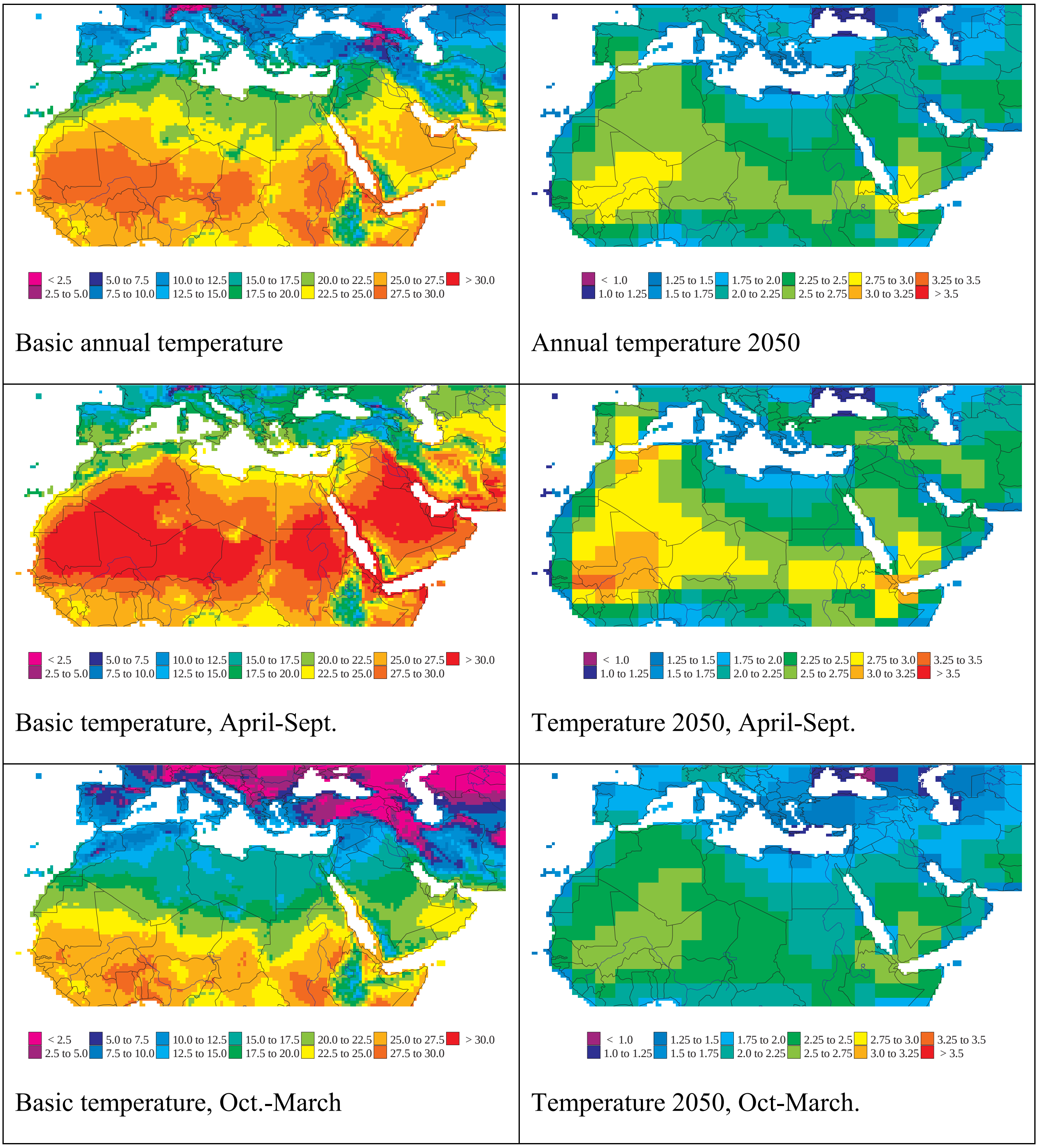

Figure 5. Basic Temperature based on 1961-1990 data and Changes in temperature °C for the dry season (April to September) and for the wet season (October to March) for the year 2050 according to the HadCM2 Scenario-GHGX.

4.2 Climate change impact on the hydrological cycle

Climate change has always been associated with the increase in temperature through the use of "Global warming" or "Greenhouse effect". However some of the most sever impacts of climate change are likely to come not from the expected increase in temperature but from the changes in precipitation, evapotranspiration, runoff, and soil moisture which are crucial factors for water planning and management. The hydrologic system affects and is affected by the climatic condition. Changes in temperature affect evapotranspiration rates, cloud characteristics, soil moisture, storm intensity and snowfall and snowmelt regimes. Meanwhile, changes in precipitation affect the timing and magnitude of floods and droughts, shifts runoff regimes and alter groundwater recharge rates. Vegetation pattern and growth rates and the changes in soil moisture regime are also affected.

Some regions can expect an increase in the amount of precipitation, which will lead to changes in agriculture production and natural ecosystem (IPCC, 1988, 1990). In other areas soil moisture may diminish, especially where a moisture deficit in the soil is already experienced such as in Africa. A 1-2°C rise in air temperature accompanied by a 10% reduction in the amount of precipitation may cause a 40% to 70% drop in mean annual river runoff, which will substantially affect agriculture, water supplies and hydropower.

With respect to agriculture in the SMED and ME regions, the impact (JAGER and FERGUSON, 1991) could be as follows:

1. The growing season will increase, which might benefit the crop yield.
2. Increased CO_2 may also benefit crops.
3. Increase in disease and pest incidence could occur.

4. The demand for irrigation water will increase.

In terms of the hydrology cycle the impact could lead to:

- Changes in precipitation with significant variation and remarkable inter-annual variability.
- Change in evaporation and transpiration. With temperature rise, the available energy for evaporation and the atmospheric demand for water from land and water surfaces increase.
- Changes in soil moisture. Changes in climate in terms of precipitation patterns and evapotranspiration will directly affect soil moisture status, surface runoff and groundwater recharge.
- Changes in snowfall and snowmelt.
- Changes in storm frequency and intensity
- Changes in Runoff, flood and droughts

5 *WHAT ARE THE POSSIBLE SOLUTIONS AND CHOICES?*

5.1 The conventional solutions

It seems that the SMED & ME region is geared primarily to conventional solutions especially in North African countries (PEARCE, 1996). Algeria believes it will need another 5.5 km^3 of water a year by 2010, 50% for irrigation and 50% for domestic and industrial uses. It plans 50 more dams and 10 diversions canals and will tap non-renewable fossil water beneath the Sahara.

Tunisia is already using 90% of its surface water in the north and all of its groundwater. It will build new large dams and develop a network of pipes and canals to transfer water between river basins. It will have the capacity to transfer more than 50% of the water captured behind dams in the northern regions.

Morocco intends to double the proportion of its river flow that controlled by dams and extract more groundwater. It will build 60 large dams, sink boreholes with a total length of 100 km and build 280 km of water-transfer-structures.

All this will be very expensive for developing countries. Water infrastructure already accounts for more than 20% of public sector investment in Morocco and Tunisia and 12% in Algeria. Libya is planning to tap more under-groundwater and transporting it to the coastal aquifers such as Jefara, which have been destroyed by over-abstraction.

5.2 Innovative solutions!

New solutions to harvest rainwater. These could be based on old techniques used in the past especially in the deserts.

Desalination of seawater by reverse osmosis (is electricity consuming), evaporation using solar /wind energy (less expensive). The cost of desalination is three to five times the cost of tapping groundwater.

Brackish water could be desalinated but a cheaper is to develop salt tolerant crops that can be irrigated with this water either mixed with fresh (to dilute) or alone.

5.3 The alternative solutions

5.3.1 Reducing demand

Directing water policies toward cutting the demand using the advanced technology as a key factor. Present computer systems can monitor flows and pressure, can detect leaks and can prevent water wastage, whether in industrial or urban water-distribution networks. Market-oriented approach to water should be adopted using price incentive to encourage savings.

Leaks and evaporation should be reduced; these could amount to 60% in urban areas. It is 30% in Damascus, Malta 65% and Greece cities 45%. An evaporation rate in North Africa is 2 m per year and losses from surface waters and reservoirs can be great. For Example, evaporation losses from Lake Nasser are 14%.

5.3.2 Efficient irrigation systems

Surface irrigation is the common practice in the region. It represents more than 50%. Sensors linked to computer system can control flow of water in pipes and irrigation can be applied at night to reduce evaporation losses. The capital costs are high but the saving in water is substantial (between 30% to 50%). Drip irrigation is widely used in Israel, Jordan, and to a less extent in other countries.

5.3.3 Recycling

Treated wastewater of cities and farms can be recycled or reused for irrigation. This is already taking place in Morocco, Egypt, Libya, and Tunisia as well as in Israel.

6 CLOSING REMARKS: THE NEED FOR SUSTAINABLE VISION FOR FRESH WATER RESOURCES

As world population grows from the present six billion to seven, eight or nine billion, more water will be required to satisfy our basic needs. The climate change prediction for the Southern Mediterranean and Middle East regions indicated a drier and hotter climate is on the horizon. The present limited water resources will even get more and more limited. This very much-needed water in the future might come at a high financial and ecological price. Although, there is some uncertainty in predicting the future climate change, These regions are experiencing already a climate that is getting dryer and hotter year after year. This is very much in support of the climate change prediction for these regions. Based on the societies needs and choices, Policy makers can set goals for water use that is both sustainable and achievable. Policies with some positive vision and some thoughts about what truly sustainable water use means are very much needed.

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