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The United Nations World Water Assessment Programme

Scientific Paper

Climate Changes, Water Security and Possible Remedies for the Middle East

by Jon Martin Trondalen for UNESCO-PCCP

World Water Assessment Programme

The United Nations World Water Development Report 3
Water in a Changing World

Coordinated by the World Water Assessment Programme, the *United Nations World Water Development Report 3: Water in a Changing World* is a joint effort of the 26 United Nations agencies and entities that make up UN-Water, working in partnership with governments, international organizations, non-governmental organizations and other stakeholders.

The United Nations' flagship report on water, the WWDR offers a comprehensive review of the state of the world's freshwater resources and provides decision-makers with the tools to implement sustainable use of our water. The WWDR3 represents a mechanism for monitoring changes in the resource and its management and tracking progress towards achieving international development targets. Published every three years since 2003, it offers best practices as well as in-depth theoretical analyses to help stimulate ideas and actions for better stewardship in the water sector.

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Climate Changes, Water Security and Possible Remedies for the Middle East

Jon Martin Trondalen

From Potential Conflict to Co-operation Potential (UNESCO PCCP)

Executive summary

The public notion of the relationship between conflict and water resources change and degradation is gaining momentum. Statements in the aftermath of 2007 Nobel Peace Laureates, the Intergovernmental Panel on Climate Change (IPCC) and President Al Gore, are ample illustration of public concern as well as of the desire to develop national and international remedies.

In the past, there seems to have been a common wisdom that environmental and water resources changes take place over such a long time span that they are more or less irrelevant in relation to the immediate need for water and conflict-management interventions in the so-called water hot-spots. However, recent studies[1] as well as phenomena in the physical environment are beginning to call into question such a notion: Are we in fact witnessing climatic and subsequent environmental changes with such a magnitude that they may impact the stability and management of coastal areas and of vital national and international resources such as water and productive land?[2]

The scope of the IPCC process is global, and is divided into several regional studies that develop climatic circulation models and scenarios. It does not, however, link such estimations to the political, economic and social stability of such regions.

This report looks more closely at the Middle East and explores the relationship between climate change and water vulnerability – it also indicates some remedies in certain selected cases. The scope of the work rests on five questions:

1. According to authoritative scientific knowledge, what and where are the most likely climatic and water resources changes to take place in the Middle East?

1 From such authoritative sources as the IPCC: www.ipcc.ch

2 As well as potential evolution of new diseases.

2. What are the likely impacts on water vulnerability, stability, and water security in the Middle East?
3. Where are the risks of immediate and serious water vulnerability,[3] at the national and international levels, caused by such environmental changes?
4. What are the national and international water security challenges brought about by climate change?
5. Are there any remedial actions that could be taken to cope with water vulnerability and security?

Some experts argue that the implications for national and international water vulnerability and security in the Middle East could be severe. The fragile water resources situation makes the whole region extremely sensitive to changes in rainfall or the availability of water in terms of quantity and quality. In addition, it may happen that the flow of a number of major rivers will become increasingly variable – rivers such as the Blue Nile, the White Nile[4], the Euphrates, the Tigris (Turkey, Syria and Iraq), the Jordan, and the Yarmuk River in Southern Lebanon – affecting the recharging of aquifers such as those in Gaza and on the West Bank.[5]

Possible environmental implications, such as a rise in sea levels, would have immediate and devastating impacts on the coastal areas, especially in Gaza and Shat-al-Arab (Iraq, Iran, and Kuwait). Migration and changes in rainfall-dependant production systems should also be taken into account.

3 Vulnerability implications mean, in this context, the extent to which water resources and the environmental effects of climatic changes would impact economic and social development and political stability.

4 If the Nile River basin is to be included, it has to be expanded, due to the complexity of the eastern African environment and the fact that there are nine riparians.

5 Involving Turkey, Syria, Iraq, Iran, Jordan, Lebanon, Israel, and the West Bank and Gaza.

Acknowledgements

A report like this, which requires different skills and areas of expertise, would not have been possible without the input and contributions of others.

I am greatly indebted to Dr Yigal Salingar, who has been in charge of developing a synopsis of current climate-change research programmes in the Middle East as well as running a simulation model of different climate-change scenarios on Lake Tiberias basin. Many thanks also to Professor Pinhas Alpert's research group of climatologists, who reviewed the set synopsis.

My thanks too to the Director of UNESCO's Water Science Division and Secretary of the International Hydrological Program, András Szöllösi-Nagy; the co-ordinator of UNESCO PCCP (From Potential Conflict to Co-operation Potential), Léna Salamé, and not least, to Marwa Daoudy, editor of the side-publications to the *United Nations World Water Development Report 3*, for their constructive input and fruitful co-operation. I am also very grateful to Adrienne Cullen for her meticulous and painstaking language-editing as well as to Samantha Wauchope for her coordination.

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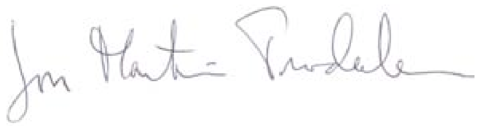
Finally, many thanks to Compass Foundation's research associate, Tone Aasberg, for providing the initial research overview for several of the topics covered.

Geneva, November 4th, 2008



Introduction

On the United Nations News Centre website on March 4th, 2008, the following message drew world-wide attention:

UN warns of climate change effects on water shortages

> The UN Food and Agricultural Organization has warned in a new report that climate change is likely to reduce agricultural output and make water shortages in the Middle East worse, threatening the poor of the region. The report warns of an increased risk of conflict over scarce resources, and predicts that an extra 155–600 million people could experience additional water stress if temperatures increase by a few degrees.
>
> www.un.org/News

The spatial impacts of climate change on the stability of social, economic and hydrological regimes and systems are indeed uncertain – but potentially devastating (see Mintzer, 1992 and Romm, 2007). A recent study by *SIDA* and International Alert (Smith and Vivekananda, 2008), describes conflicts and instability risks especially related to political turmoil, economic weakness, food insecurity, and large-scale migration: 46 countries – home to 2.7 billion people – are at high risk of conflict. Furthermore, another group of 56 countries (with 1.2 billion people) have governments that face great difficulties in taking the strain of climate change on top of their already current challenges.

In most of the countries in the Middle East, population, growth and land management may be far more significant and critical than climate change. Therefore, the impact of climate change on water security should be seen in a broader water development and conflict context.

As there is broad international consensus that there will be climate change and that risk and uncertainty are increasing, no one really knows the magnitude and significance of the consequences in terms of how they will affect instability and conflict. In any case, nations and the international community have to manage changed water-resource conditions that in some instances may fuel old water-related conflicts or even yield new ones, but could also – and probably in limited cases – contribute to stabilisation and the prevention of such disputes (Klare, 2002).

Relationships between potential and current water vulnerability, instability and climate changes

Ongoing intranational as well as international disputes and tension over water scarcity, water pollution, and water allocation may be escalated and fuelled by climate change (Soffer, 2000; Trondalen, 2008). Some of the relevant consequences of climate change that may foster water-related or induced conflicts could be summarised as follows: sudden 'hydrological shocks' as well as slow onset changes can increase the risk of conflict in unstable states and regions because the governments lack the capacity to respond, adapt, and recover. Recent research has shown that conflicts and instability in populated areas could be linked to key-sectors in water quantity (i.e., the extension of drinking water and its continuity) and quality (i.e., the extension of waste-water collection and treatment); urban hydrological problems (such as storm water); the impact of large cities on their water environment; the financing of investment issues; tariff setting; cost recovery, and the degree of freedom left to urban dwellers *vis-à-vis* the services provided (see UNESCO IHP, 2006).

There is a high probability that some hydrological systems would also be affected through increased runoff and early spring peak discharge in many glacier- and snow-fed basins. There would also be effects on thermal structure and water quality with the warming of rivers and lakes (IPPC, Dec. 2007 and Romm, 2007). Earlier snow-melting in the springtime might have enormous consequences for downstream countries – countries such as India, Bangladesh, Azerbaijan and Iraq.

Local, national and international water agreements that have already been agreed might have to be reopened and renegotiated. Such situations could trigger new tension, instability and even conflicts as climate change puts additional social and economic stress, especially in developing countries.

There are reasons to argue that the following geographical areas are likely to be the first to be at risk of instability and conflict:

Conflict prone areas: The Middle East, the Caucasus, Central Asia, and certain parts of central and eastern Africa.

Emerging conflict/instability areas: western and southern Africa, South East Asia, and South America.

As risks, uncertainties and vulnerability to changes of national and international water resources are increasing (as anticipated in the climate-change scenarios), the demand for national governments to develop adaptive policies and strategies becomes insistent. Countries would, under any circumstances, have to prevent and resolve local, regional, and international vulnerability and disputes related to the proper use, control, access and allocation of water resources (see, for example, Bruns and Meinzen-Dick, 2000).

Some concepts

— *Aquifer* is used to refer to various kinds of groundwater basin.

— *Basin* is used synonymously with *watershed*, *catchment*, or *watercourse*.

— *Conflict Management* comprises prevention, avoidance, settlement, and resolution

— *International water resources/watercourses* is preferred to *shared international water resources*

— *Return-flow* means the drainage water from irrigated land that could go to surface water and groundwater (compared to *run-off*, which is natural drainage)

— *Rule Curve* is a function that defines the use of water – either for power production or for irrigation.

— *Sustainable governance* means, in this context, sustainable solutions for the management of international watercourses

— *Virtual or invisible water* refers to the water that's used to grow or produce a particular product. In water-scarce countries, it is often preferred to conserve the precious national supply by importing crops and goods that require a lot of water to produce.

— *A river system* comprises both the main course and all the tributaries that feed into it. The area that the river system drains is known as its catchment or watercourse.

— *A water management regime* means a water arrangement that specifies the use of water flow according to certain timescales and specifications of water-quality standards

— Lake Tiberias in the upper Jordan River basin has many other names – including the 'Sea of Galilee' (a Biblical expression) and 'Lake Kinneret'.

— *Auditing*: a systematic, independent and documented process for obtaining evidence and evaluating it against agreed, pre-set criteria.

— *Monitoring*: The systematic surveillance and measurement of defined parameters.

— Some names are spelled in different ways such as the Hasbani, Hasbanye or Hasbanya (a tributary of the River Jordan, called the Snir in Israel). As far as possible, the most common names in English usage are applied.

— The contemporary name for the geographic area of the West Bank is used instead of the Jewish terms, Judea and Samaria, which include a larger area

— Various *water monitoring* and *verification systems* are proposed, and the following concepts are used:

— Verification: Confirmation, by examination and the provision of objective evidence, that results have been achieved or that specific requirements have been fulfilled (or the status of requirements)

— CIF: the newly established World Bank led Climate Investment Fund.

Dispute is used synonymously with Conflict

JR: the Jordan River

LTB: Lake Tiberias basin

MENA countries: the region known as Middle East and North Africa.

UJRB: the upper Jordan River basin

(Source: derived from Trondalen, 2008)

Climate change will have different impacts in different regions, and traditional patterns of conflict will – with high probability – change in certain areas. In some cases, nations might achieve successful co-operation due to less water stress – but in many already politically charged areas, the disputes are likely to increase in intensity and complexity – in a different form than in the past – and would require new and rapid adaptive conflict-management strategies.

Climate changes could potentially significantly affect current water vulnerability and security situations in the management of national and international waters in areas that are already conflict prone – such as the Middle East and Central Asia.[6]

Instead of discussing the 'linkages' in more academic terms, likely 'linkage-situations' from the Middle East are elaborated – with a concretisation of some of the climate-change estimates and likely implications on the water resources situation in one of the sensitive areas, the upper Jordan River basin (sections 1 and 2).

The Euphrates and Tigris rivers are also looked at because of their strategic, political, economic, energy, and agricultural significance for Turkey, Syria, and Iraq.

The following sections elaborate ways for these countries to adapt to changes and outline how the international community can assist them towards that end.

1. Current research on climate change and the water situation in the Middle East

1.1 A synopsis of current research on climate change and the water situation in the Middle East

Climate is usually described in terms of mean temperature, variability of temperature, precipitation, and wind over a period of time. Climatic factors, principally temperature and precipitation, are the major controls on the broad-scale distribution of biomes (Matthews et al., 2003).

There are many predicted and observed changes attributed to global warming and climate change. Some of the changes are increased temperature, altered patterns of precipitation, sea-level rise and a diminishing ice and snow cover (Matthews et al., 2003). A change in temperature and rainfall modifies the distribution of vegetation and wetlands, and vegetation in semi-arid areas is strongly sensitive to climate-induced variability (Zaitchik et al., 2007). Rising sea levels induce changes in coastal ecosystems by saltwater intrusion and possibly by increased erosion. Changes in nutrient availability and ocean currents may alter marine ecosystems.

When ice and snow cover diminish, it results in reduced freshwater storage and supply. This supply is especially important in regions where water availability is already limited. It is predicted that the greatest effects of global warming (climate change) will occur in high latitudes (Matthews et al., 2003).

The Intergovernmental Panel on Climate Changes (IPCC) is one of the most renowned publishers of internationally acclaimed research on global climate change. Its recent *Technical Paper on Climate Change and Water* (IPCC Working Group II, 2008)[7] outlines some general statements that are relevant for the Middle East region – such as:

- By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics. Many semi-arid and arid areas (for example, the Mediterranean basin, western USA, southern Africa and north-eastern Brazil) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change (high confidence). (Section 2.36)
- Changes in river flows, as well as lake and wetland levels, due to climate change depend primarily on changes in the volume and timing of precipitation and, crucially, on whether precipitation falls as snow or rain. Changes in evaporation also affect river flows. Flows in high-latitude rivers increase, while those from major rivers in the Middle East, Europe and Central America tend to decrease. (Section 3.2.3)
- In areas where rainfall and runoff are very low (for example, desert areas), small changes in runoff can lead to large percentage changes. In some regions, the sign of projected changes in runoff differs from recently observed trends (Section 2.1.6).
- In some areas with projected increases in runoff, different seasonal effects are expected, such as increased wet-season runoff and decreased dry-season runoff. (Section 3.4.1)

Finally, it voices some reservations in interpreting the large-scale predictions:

> … note the large areas where the direction of change is uncertain. This global map of annual runoff illustrates large-scale changes and is not intended to be interpreted at small temporal (for example, seasonal) and spatial scales (Section 2.3.5).

Concrete interpretations of these statements in terms of water resources in the Middle East – at least at the country level – are hard to make, except that there is high probability that some changes will take place. Others will go further and state that: 'With the

6 The notion of international water resources should be applied rather than transboundary waters, as the latter is more vague and limited in scope.

7 www.ipcc-wg2.org

Middle East being the world's most water-stressed region, climate change – which is projected to cause sea-level rise, more extreme weather events such as droughts and floods, and less precipitation – will contribute to even greater water stress in the region' (Freimuth et al., 2007)

Although there seems to be international consensus that if climate change takes place as these and other authors predict, a further question is to go beyond the report of IPCC's Working Group II and assess available regional research on regional climate change.

The following analysis of current research in the Middle East is based on published material. Although there are also a number of prominent unpublished national studies in the Middle East, most of them are not made available publicly, as some states consider this to be sensitive national information.[8]

The Compass Foundation has therefore commissioned a group of scientists[9] from the Middle East to assess existing and current internationally recognized research and to answer the following question:

> **According to authoritative scientific knowledge what are the most likely climatic and water resources changes to take place in the Middle East and were will they occur?**

Their findings are as follow:

Climatological aspects

A climate-change workshop for the Middle East brought together scientists and data for the region to produce the first area-wide analysis of climate extremes for the region Zhang et al. (2005) and to report trends in extreme precipitation and temperature indices. The trends were examined for the period 1950–2003 at 52 stations covering 15 countries, including Armenia, Azerbaijan, Bahrain, Cyprus, Georgia, Iran, Iraq, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, and Turkey:

- Results indicate that there have been statistically significant, spatially coherent trends in temperature indices that are related to temperature increases in the region.
- Significant, increasing trends have been found in the annual maximum of daily maximum and minimum temperatures, the annual minimum of daily maximum and minimum temperatures, the number of summer nights, and the number of days where daily temperature has exceeded its 90th percentile.
- Significant negative trends have been found in the number of days when daily temperature is below the 10th percentile of its average temperature range.
- Trends in precipitation indices, including the number of days with precipitation, average precipitation intensity, and maximum daily precipitation events, were weak in general and did not show spatial coherence.

Hansen et al. (2005) used a global climate model to compare the effectiveness of many climate forcing agents in producing climate change:

- Increasing greenhouse gases in their model caused increasing rainfall in the Intertropical Convergence Zone, the eastern United States, and East Asia, while intensifying dry conditions in the subtropics including the south-west United States, the Mediterranean region, the Middle East, and an expanding Sahel.

Shindell (2007) investigated the potential for sudden climate change during the current century. This investigation takes into account evidence from the Earth's history, from climate models and from our understanding of the physical processes governing climate shifts:

- Sudden alterations to climate forcing and ocean circulation seemed to be improbable, with sudden changes instead most likely to arise from climate feedbacks.
- More probable sudden changes are large increases in the frequency of summer heat waves and changes resulting from feedbacks involving hydrology, such as ice sheet decay.
- Reductions in subtropical precipitation are likely to be the most severe hydrologic effects this century, with rapid changes due to the feedbacks of large-scale circulation patterns.
- Water stress may become particularly acute in the south-west of the United States, Mexico, the Mediterranean and the Middle East, where rainfall decreases of 25% (regionally) and up to 40% (locally) were projected.

Alpert et al (2002) investigated the paradoxical increase of Mediterranean extreme daily rainfall despite decreases in total values:

- They showed that the torrential rainfall in Italy exceeding 128 mm/d has increased percentage-wise by a factor of four during the period 1951 t01995 with strong peaks in El-Nino years.
- In Spain, extreme categories at both tails of the distribution (light: 0–4 mm/d and heavy/torrential: 64 mm/d and up), increased significantly.
- No significant trends were found in Israel and Cyprus.

8 See for example the following information from AUB, Beirut: www.aub.edu.lb/~webifi/

9 Under the leadership of Dr. Yigal Salingar.

- The consequent redistribution of daily rainfall categories – torrential/heavy against the moderate/light intensities – is of utmost interest, particularly in the semi-arid, sub-tropical regions in relation to water management, soil erosion and flash-flood impacts.

Morin et al. (2007) analyzed extreme flood-causing rainstorms over Israel:

- Extreme rain intensities with recurrence intervals of more than 100 years were found for rains of durations of one hour and more, as well as for daily rain depth values.
- Specific peak discharges were as high as 10–30 $m^3/s/km^2$ for catchments of 1–10 km^2 – values larger than any recorded floods in similar climatic regions in Israel.

Alpert et al. (2004) carried out a classification of daily synoptic systems by analysing climate data over the eastern Mediterranean for the period 1948–2000:

- By analysis of trends in the annual frequencies of the synoptic systems, they show that the frequencies of the mostly dry Red Sea trough systems have nearly doubled since the 1960s, from 50 to about 100 days per year.
- This explains a dominant decreasing trend of rainfall in most of the eastern Mediterranean, along with a rainfall increase in the southern part of the eastern Mediterranean region, where the Red Sea trough is deep enough to bring tropical moisture over this area.
- The increasing tendency towards heavier daily rainfall, in spite of the general decrease in total rainfall, may be explained by the increase in the active and stormy types of Red Sea trough situation.
- The annual frequency of the Cyprus lows was noticed to drop slightly between 1983 and 1998 to 26, compared with about 30 during the period 1967 to 1982. The high positive correlation between the recent increase in the North Atlantic oscillation index and the pressure over most of the eastern Mediterranean countries is linked to these tendencies in the synoptic systems.

Krichak and Alpert (2005) analysed decadal trends between 1950 and 2000 in the east-Atlantic-west-Russia pattern, as well as Mediterranean precipitation:

- Their findings provide an explanation of the observed precipitation decline over the eastern Mediterranean region during the last decades of the past century, in terms of the positive trend of the east Atlantic – west Russia pattern; atmospheric flow transports the air masses from the Atlantic to the eastern Mediterranean, or advection of the air masses from central Europe to the eastern Mediterranean.

Alpert et al. (2008) analyzed the results of regional climate modelling of the Eastern Mediterranean region:

- It was found that the average temperature over the Mediterranean area has increased by 1.5–4 °C in the last 100 years.
- Temperatures in 2071–2100 are predicted to increase by about 4–6 °C over northern Israel in comparison with the control period of 1961–1990.
- Precipitation over most of the Mediterranean shows a dominant negative trend in the last 50 years.
- A large negative trend in one scenario (A2) is found over northern Israel, while another scenario (B2) shows no significant trend.
- There is a tendency toward extreme events. It was found that the extreme precipitation over northern Israel shows significant increasing trends for the A2 and B2 scenarios with respect to the present climate.
- Also, the standard deviation of the average annual precipitation is higher in the A2 and B2 scenarios, showing a trend towards drier as well as wetter years in the future.

Zangvil et al. (2003) investigated connections between the eastern Mediterranean seasonal mean sea height (500 hPa) and sea-level pressure patterns, and the recently observed changes in winter rainfall distribution over Israel:

- They constructed a conceptual model of the mechanism responsible for the relative increases in seasonal (winter) rainfall over the southern part of the country and the decrease over the north.
- The researchers demonstrated that the direct atmospheric agent responsible for this change in the spatial rainfall distribution is an increased frequency of occurrence of 500 hPa troughs oriented from north-east to south-west, accompanied by prominent positive sea-level pressure anomalies centred over Turkey.
- Their analysis further shows that these atmospheric systems are consistent with the persistence of a positive phase of the North Atlantic Oscillation and with the latest IPCC predictions of precipitation patterns over the eastern Mediterranean basin.

Ziv et al. (2005) points out that:

- There are indications of an aggravation of summer heat conditions over the Mediterranean basin.
- Summer temperature variations over the Mediterranean basin were studied through the 850 hPa level for the months of June to August during the period 1948–2003.

- The most prominent feature found is warming, which is greater than the global average, over the majority of the study region, with maximum warming over Sicily.
- At the same time, cooling was noted over Algeria and the Balkans.
- Their analyses also implied that heat waves lead general long-term trends, and suggested that the Mediterranean basin manifests an increase in the greenhouse effect in the summer season.

Bar-Matthews et al. (2003) investigated sea–land oxygen isotopic relationships from *planktonic foraminifera* and *speleothems* in the eastern Mediterranean region. The oxygen and carbon-stable isotope compositions of cave *speleothems* provide a powerful method for understanding continental climate change:

- These records for the last 7,000 years show a trend toward increasing aridity, which concurs with similar climatic and archaeological data from northern Africa and the Middle East.
- The detailed lake-level history of the closed Lake Lisan (paleo-Dead Sea) in the Middle East has been reconstructed from shoreline indications and high-resolution U-Th and C-14 chronologies, thus providing data on the response of the lake's catchment area to climate changes during the corresponding period.

a decreasing trend in rainfall in most of the eastern Mediterranean and increased rainfall over the southern part of the East Mediterranean

Bartov et al. (2003) present a correlation between the newly developed Lake Lisan level curve for the past 55,000 years and the North Atlantic Heinrich events:

- The correlation indicates a closely connected climate response between these North Atlantic events and hydrologic conditions that prevailed in the eastern Mediterranean.
- Their findings show that, although the generally cooler conditions that prevailed during the last glaciation favoured high levels in the lake, catastrophic events in the North Atlantic, which are associated with maximum cooling, have been responsible for droughts in the eastern Mediterranean.

Bartov et al. inferred that cold-water input to the Mediterranean, originating in the collapse of the North Atlantic Deep Water circulation, caused a reduction of evaporation and less precipitation in the eastern Mediterranean.

Using the C-13/C-12 and O-18/O-16 ratios of stem cellulose of *Tamarix jordanis* (a tree common in *wadis* in arid regions) and relative humidity data, Lipp et al. (1996) showed that, since the Roman period, relative humidity at the ancient fortress of Masada has decreased by about 17%, while the delta (18)O value of local groundwater has remained similar to present-day values:

- This suggests that changing atmospheric circulation has played a role in climate change in the Middle East over the past two millennia.

Weiß et al. (2007) examined the change in current 100-year hydrological drought frequencies in the Mediterranean in comparison to the 2070s, as simulated by the global model, WaterGAP. The analysis considers socio-economic and climate changes as indicated by the IPCC scenarios A2 and B2 and the global general circulation model ECHAM4:

- Under these conditions, today's 100-year drought is estimated to occur 10 times more frequently in the future over a large part of the northern Mediterranean, while in north Africa, today's 100-year drought will occur less frequently.
- Water abstractions are shown to play a minor role in comparison to the impact of climate change, but can intensify the situation.

The synopsis outlines a set of possible and probable changes that would – if they do take place – have serious impacts on the water resources situation in the Middle East, especially the international surface and sub-surface basins.

Therefore, and in order to improve the quality assurance of the synopsis, Professor Pinhas Alpert's research group conducted the following assessment of these findings.[10]

1.2 A brief assessment of the findings of the synopsis of research on climate change in the Middle East

Professor Pinhas Alpert's research group conducted the following assessment of the findings outlined above:

Climate change has impacts on many levels

On the synoptic level, it has been found that the mostly dry Red Sea trough systems have nearly doubled since the 1960s, from 50 to 100 days in a year. The east Atlantic-west Russia pattern also shows a positive trend, as well as the occurrence of 500 hPa troughs. These all explain the dominant decreasing trend in rainfall in most of the eastern Mediterranean, and increased rainfall over the southern part of the east Mediterranean. The Lake-level history of Lake Lisan (Paleo-Dead Sea) also shows a climate connection between North Atlantic events and the hydrologic conditions that have prevailed in the eastern Mediterranean over the past 7,000 years.

10 Professor Pinhas Alpert is a leading international expert in climate change in the Middle East, with a research group at Tel Aviv University, Geophysics and Planetary Science

Temperature trends for the region show a significant increase in maximum and minimum daily temperatures. The average temperature over the Mediterranean area has increased by 1.54 °C in the last 100 years, and temperatures in the years 2071–2100 are predicted to increase by 4 °C to 6 °C over northern Israel.

There are indications of an aggravation in summer heat conditions over the Mediterranean basin, with an increase in heat waves, which heads the general long-term trend. Models predict annual mean increases of up to 4.5 °C; with some variations – for example, increases of only 1.5 °C are predicted in the coastal areas of the eastern Mediterranean.

Precipitation above most of the Mediterranean shows a dominant negative trend in the last 50 years. In Israel, precipitation shows no trend.

Extreme precipitation shows significant increasing trends. In southern Europe (Italy and Spain) torrential rainfall increased by up to a factor of four during the period 1951 to 1995.

There are indications that extreme flood-causing rainstorms have also increased in Israel.

There is a trend toward both drier as well as wetter years in the future, accompanied by generally increasing aridity, as shown by cave speleothems records for the last 7,000 years and the relative humidity of Masada, which has decreased by about 17% since Roman times.

It seems obvious that climate change in one way or another will take place, with significant impact on the water resources situation. To go one step further in assessing a few scenarios, the next section points to possible water resources changes in the region, and specifically in the upper Jordan River basin.

trends show a significant increase in maximum and minimum daily temperatures

2. Climate changes and possible water resources related implications in the Middle East

The previous section aimed to establish the factual basis of climate-change scenarios. This section builds on these findings and examines further possible water-related impacts of these climatic trends.

It begins with an assessment of recent research on the water resources implications of climate change, both environmental and socioeconomic. Because of the availability of accurate data and because of the international significance of the area, the upper Jordan River basin is then examined in detail. Some scenarios for the Euphrates and Tigris rivers are then outlined briefly, and a number of water security issues are discussed.

2.1 Water resources related implications[11]

Recent research on the water resource implications of climate change has been conducted by several scholars, some of which will be outlined in the following

Kitoh et al. (2008) present the first full projections of rainfall and stream-flow in the 'Fertile Crescent' of the Middle East. Until the time this research was carried out (early 2008), such projections had not been possible, due to a lack of observed data and atmospheric models of sufficient resolution. Kitoh et al. employed an innovative super-high-resolution (20-km) global climate model, which accurately reproduces the precipitation and the stream-flow of the present-day Fertile Crescent:

- It was projected that, by the end of this century, the Fertile Crescent would lose its current shape and could disappear altogether.
- The annual discharge of the Euphrates River will decrease significantly (29%–73%), as will the stream-flow in the Jordan River. Thus countermeasures for water shortages will become much more difficult.

Another research group, Jorgensen and al-Tikiriti (2003), established aridity (desertification) trends for archaeological sites in the United Arab Emirates, for the past 4,500 years, and correlated them with the trends of increased well depths and declining groundwater levels. Trends of declining groundwater levels were related to trends of increasing aridity (climate change). The increasing aridity had a pronounced effect on development in the research area. For example, non-irrigation farming could not be successfully sustained at the end of the Bronze Age. This thwarted economic development until a water conveyance structure was introduced in the Iron Age:

- The aridity trends in the research area correspond to contemporaneous aridity trends noted in Mesopotamia and the Dead Sea area, as well as in the Middle East, the Mediterranean and northern Africa, in general.
- Other global climatic changes that are contemporaneous with climate change in the research area have been noted. The increased aridity trends in the research area are contemporaneous with reported increased atmospheric CO_2 trends.

Ragab and Prudhomme (2000) calculated a high water exploitation index, estimated as a percentage of renewable annual water resources. For example, this was 83% for Tunisia, 92% for Egypt, 140% for Israel, 169% for Gaza and 644% for Libya. The authors ran the UK Hadley Centre's Global Climate Model on a monthly basis for the southern

11 The overview in this section was prepared by Dr. Yigal Salingar.

Mediterranean and Middle East countries to predict the percent change in rainfall with respect to mean monthly values:

- The results show that in the dry season (April to September), by the year 2050, northern Africa and some parts of Egypt, Saudi Arabia, Iran, Syria, Jordan and Israel are expected to have reduced rainfall amounts of up to 20% to 25% less than the present mean values.[12]
- This decrease in rainfall is accompanied by temperature rises in those areas of between 2 °C and 2.75 °C.
- For the same period, the temperature in the coastal areas of the southern Mediterranean and Middle East countries will rise by about 1.5 °C. In winter, rainfall will decrease by about 10%–15%. Winter temperatures 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 °C.

Ragab and Prudhomme (2000) claim that, given the above-mentioned predictions, in order to meet the water demands in the next century, more dams and water infrastructure will have to be built in southern Mediterranean and Middle East countries and, by rethinking water use with the aim of making it more productive, a new paradigm will have to be adopted. They argue that two approaches will be needed:

- Increasing the 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 or recycled water and desalinated brackish water or seawater, are expected to play an important role.

Bou-Zeid and El-Fadel (2002) characterize water resources in several Middle Eastern countries and evaluate regional climate predictions for various scenarios using general circulation models. Lebanon is selected as a case study for an in-depth investigation, with potential impacts on the water budget and soil moisture as indicators:

- Climate change is expected to further exacerbate existing water shortages in the country.
- Although precipitation was not predicted to decrease, temperature increases of 0.6 °C to 2.1 °C would have an impact on the water balance and reduce available resources.
- A maximums 15% decrease in available water and 6% increase in agricultural demand were projected by the year 2020.
- Adaptation measures were assessed, with a focus on no-regret actions in the context of local socio-economic and environmental frameworks.
- Most adaptation measures attempt to develop non-conventional sources of water that can be exploited in the future, including the use of surplus winter runoff, wastewater reclamation, seawater and brackish water desalination, rainfall enhancement by seeding clouds with silver iodide crystals, and the exploitation of submarine springs.
- In addition, the authors claim that conservation measures, as well as institutional reforms and capacity building, are also needed. The indirect impact of climate change on hydraulic structures may affect potential increases in precipitation intensities and modifications in river flow patterns.
- Similar hydrologic impacts might have different socioeconomic consequences depending on region-specific characteristics. In the context of the Middle East, different configurations of water resources systems might affect the magnitude of potential adverse effects, such as a reduction in gross domestic product, future population redistribution, workforce shifts to alternative economic sectors, and so forth.

Alcamo and Henrichs (2002) present a top-down approach for identifying regions whose water resources have higher sensitivity to global change than in other regions. The aim of this approach is to provide an overview of regions that may justify special attention from the research and development assistance community under particular global change scenarios. Under the scenario showing the largest increase in water stresses, the estimated area of critical regions in 2032 ranges from 7.4% to 13.0% of the total land area, depending on the criteria for identifying critical regions:

- Some regions always appear as critical regions regardless of the scenario. These include parts of central Mexico, the Middle East, large parts of the Indian sub-continent, and stretches of the north African coast.

Alcamo et al. (2005) estimated that the global demand for ecosystem services will substantially increase up to 2050:

- Cereal consumption will increase by a factor of 1.5–1.7; fish consumption (up to the 2020s) by a factor of 1.3–1.4; water withdrawals by a factor of 1.3–2.0, and biofuel production by a factor of 5.1–11.3.
- They point out that the risk of lower water availability, especially in the Middle East, could slow down an increase in food production.
- Their scenarios also show that certain hot-spot regions may experience especially rapid changes in ecosystem services: these include the central part of Africa, southern Asia, and the Middle East.

An assessment of the relative effect of climate change and population growth on future global

12 Note that in the dry period (April to September) it is almost totally dry in Jordan, with only a few mm of precipitation. This is also true in Saudi Arabia, southern Syria and many parts of Israel.

and regional water resources stresses, using socio-economic scenarios and climate projections, was performed by Arnell (2004). The research estimates:

- Water resources stresses in some parts of the world where runoff decreases, including around the Mediterranean.

Kunstmann et al. (2007) investigated the impact of climate change on water availability in the Middle East and the upper Jordan catchment by dynamic downscaling of ECHAM4 time slices and subsequent hydrological modelling. Two time slices (1961–1990 and 2070–2099) of the global climate scenario B2 of ECHAM4 were dynamically downscaled with the meteorological model MM5 in two nesting steps of 54 km and 18 km resolution. The results of the joint regional climate-hydrology simulations indicate:

- Mean annual temperature increases of up to 4.5 °C, and 25% decreases in mean annual precipitation in the mountainous part of the upper Jordan catchment.
- Total runoff at the outlet of the catchment is predicted to decrease by 23%, and is accompanied by a significant decrease of groundwater recharge.

Shadeed et al. (2007) analysed rainfall-runoff process in semi-arid sub-catchments of the lower Jordan catchments. Their results generally support the above-mentioned projections.

Environmental aspects

Developing sustainable land use practices under climate change requires a detailed knowledge of the system dynamics. This applies particularly for the management of domestic livestock in semi-arid and arid grazing systems, where the risk of degradation is high and likely climate change may have a strong impact. A suitable way to assess potential future trends of these complex systems is through the application of simulation models.

Tietjen and Jeltsch (2007) reviewed 41 models published between 1995 and 2005 simulating semi-arid and arid livestock grazing systems. The models were categorized according to the model aim and type, their temporal and spatial scale, and several indicators of model complexity. Additionally, the authors developed a list of model requirements for adequately simulating the effects of climate change. Based on these requirements, they evaluated the potential of current models to simulate the impacts of climate change and determine important shortcomings. Their analysis of current models shows that few existing models are able to assess the impacts of the predicted climate change. Therefore, they call for the development of new dynamic grazing models that provide land managers with the necessary tools to face the threat of future climate changes.

In Mediterranean semi-arid and arid regions, geomorphic processes are controlled by the characteristics of rainstorms and dry spells (Aviad et al., 2004). The beginning, end and length of the rainy season were analysed based on rainfall data for 30 years, presented for daily rainfall and for accumulated rainfall within a rain spell, and associated with different geomorphic processes.

Climate variability affects wave-heights in the Mediterranean. A study by Lionello and Sanna (2005) examined the variability of the monthly average significant wave height field in the Mediterranean Sea in the period 1958–2001, and linked it with North Atlantic oscillation and the Indian monsoons. The inter-annual variability of the mean significant wave height is associated with sea level pressure patterns, which present their most intense features above or close to the Mediterranean region, where they are most effective for wave generation.

Spatial pattern formation of shrub populations may be affected by climate change in the Middle East. Malkinson and Jeltsch (2007) concluded that as stress conditions (droughts) increase, the importance of intraspecific neighbourhood interactions decrease, whereas the importance of environmental factors in dictating intraspecific spatial pattern formation increases. Consequently, in mesic environments, intraspecific competition among adult shrubs determines the emerging patterns, while intraspecific facilitation is a negligible process.

Tielbörger and Valleriani (2005) investigated the germination strategies of density-regulated desert annuals, and found that seeds produced in a copious year had lower germination rates than seeds produced in drought years. Their findings are suggestive of an intriguingly simple and effective mechanism that may allow annual plants to partly predict their future success. Change in rainfall amounts has an impact on the selective forces of annual plants in the Middle East.

Petrů et al. (2006) studied phenotypic variation in a winter annual crucifer, *Biscutella didyma,* persisting along a steep gradient of increasing rainfall in Israel. Their overall findings indicate two strongly opposing selective forces at the two extremes of the aridity gradient, which result in contrasting strategies within the studied annual plant species. In another study, Petrů and Tielbörger (2008) separated local and regional environmental effects on the germination strategies of annual plants under changing climatic conditions and found that local environmental conditions may override the effects of climate, and so should be carefully addressed in future studies testing for the potential of species to adapt or plastically respond to climate change.

Though not yet studied in depth in the Middle East, soil respiration is affected by water availability, temperature and site properties – for example, site productivity as reflected by leaf area index (Reichstein et al., 2003). Furthermore, the effect of precipitation on soil respiration stretches beyond its direct effect via soil moisture. Jones et al. (2005) reported enhanced release of CO_2 to the atmosphere from soil organic carbon as a result of increased temperatures.

Steinitz et al. (2007) studied the effect of projected climate change on the mammals of Israel at both the species and assemblage level. They asessed two potential future scenarios: 'business-usual' and 'global adherence to Kyoto protocol', and concluded that the implementation of a greenhouse gasses policy will reduce the effect on mammals at the assembly level. Shtirberg et al. (2007) found significant differences in the biodiversity of several taxonomic groups along a climatic gradient in Israel.

a trend towards drier as well as wetter years in the future

A brief assessment of the findings of water resource and environmental implications[13]

Today's 100-year drought is forecast to occur 10 times more frequently in the future over a large part of the northern Mediterranean, while in north Africa, today's 100-year drought will occur less frequently.

All models show intensifying dry conditions, with rainfall decreases of up to 25% (regionally) and 40% (locally), and projected increases in the frequency of summer heat waves.

One study predicted that at the end of this century, the Fertile Crescent may disappear altogether. The annual discharge of the Euphrates River will decrease by 29%–73% as will the stream-flow in the Jordan River. By the year 2050 north Africa and some parts of Egypt, Saudi Arabia, Iran, Syria, Jordan and Israel, are expected to have reduced rainfall amounts of up to 20%–25% less than the present mean values.

The GLOWA project predicts 25% decreases in mean annual precipitation in the mountainous part of the upper Jordan catchment. It also predicts a total runoff decrease of 23% at the outlet of the catchment, accompanied by a significant decrease of groundwater recharge.

In the United Arab Emirates, trends of declining groundwater levels were related to trends of increasing aridity.

Across the region, even if precipitation does not decrease, temperature increases of 0.6 °C to 2.1 °C would have an impact on the water balance and would reduce available resources.

Estimates of the decrease in available water range up to 15%, whereas the increase in agricultural demand for water by the year 2020 is estimated at 6%.

13 Professor Pinhas Alpert's research group conducted the following assessment of the findings outlined above.

Models all show intensifying dry conditions, with rainfall decreases of up to 25% (regionally) and 40% (locally), and projected increases in the frequency of summer heat waves.

Global demand for ecosystem services is projected to substantially increase by 2050, with water withdrawals increasing by a factor of 1.3 to 2.0.

Modest climate changes, as anticipated till 2020, are beneficial to agriculture (such as early season supply to markets), while drastic climate change in the long run, as anticipated till 2100, will be detrimental. A reduction of about 20% in state-wide annual agricultural net-revenues by 2100 is projected in comparison with 2002.

The effect on natural ecosystems is very hard to quantify. Studies show that local environmental conditions may override the effects of climate changes.

There are, however, significant differences in the biodiversity of several taxonomic groups along a climatic gradient in Israel – which might translate into biodiversity changes as climatic conditions change. Species that cannot move with the changing climate, for example, northward to lower temperatures, may become extinct.

2.2 Some excerpts from current research on the socioeconomic aspects of climate change in the Middle East

The interrelationships between climate change on the one hand and water resources; environmental impacts, agricultural production; food security, and other related socioeconomic issues on the other hand are complex and will not be dealt with in depth here. Several publications have substantially dealt with theses issues – such as two recent World Bank publications (World Bank, 2007 and Shetty, 2006). These both highlight the fact that agriculture and the rural economy are important elements in the Middle East region, and also point out that the relative contribution of agriculture to overall GDP in most MENA countries is low and has been declining. They further acknowledge that water, not land, is now the limiting factor for improving agricultural production in the region – an issue that will be exacerbated by the predicted trends of climate change.

The World Bank (Shetty, 2006) takes a broader development standpoint, and notes that agriculture claims the largest share of the workforce in the region, with a high proportion of the poor depending on the sector for their livelihoods. Region-wide, 88% of the economically active population works in agriculture. However, in some countries – such as Syria – the economically active population engaged in agriculture has fallen from 31.6% in 1970 to 19.6% in 2006 (Syrian Central Bureau of Statistics, 2007). Thus, despite its small contribution to GDP, agriculture is still important to development in Syria and in the region.

The greatest consumer of water, by far, in the Middle East is irrigation/agriculture. The World Bank highlights that the issue is not just the absolute use but the *relative* use of water. As water will continue to be the main input in agriculture, it is more important (and realistic) to focus on how technology and research may be able to help improve efficiencies and reduce overall usage. While agriculture and the rural economy are important elements in the MENA countries, the relative contribution of agriculture to overall GDP in most countries is low and has been declining. Recent research shows that agriculture, even in Syria, which has the highest share of contribution to GDP in the region, contributes only 24 %, whereas agriculture in Jordan contributes only 2 % of GDP.

As MENA countries experience the effects of climate change and increased water scarcity, there is increasing pressure to allocate water away from agricultural to industrial and municipal uses, as well as to increase water efficiency within the agricultural sector (Shetty, 2006). Some countries, such as Israel, Tunisia, Morocco and Jordan, have begun addressing the issue of water reallocation whereas others, notably the Gulf countries, have not (Adams et al., 1999).

the socio-economic implications of climate change for some of the countries in the region could be severe

From a macro-economic perspective, one could argue, based on the information from the World Bank, that the effects of climate change may not have direct and severe economic consequences (because agricultural production's relative contribution to GDP is low). However, the socioeconomic implications could be severe – as in the case of Syria, where about 20% of all active workers are employed in the agricultural sector.

More recently, some other studies have looked at the potential economic impact of climate change:

Fleischer and Sternberg (2006) analysed the economic impact of global climate change on Mediterranean rangeland ecosystems. They looked specifically at Israel (because of the relative good quality of data), and show that the urban population in Israel values the green landscape of the rangelands in the mesic Mediterranean climate region and is willing to pay to preserve it in light of the expected increasing aridity conditions in this region. The value people put on the landscape is higher than the value they put on the grazing services these rangelands provide for livestock growers. The researchers implemented a Time-for-Space approach with which they were able to measure changes in biomass production and rainfall at four experimental sites along an aridity gradient.

Fleischer et al. (2007) tested the relationship between annual net revenues and climate across Israeli farms. Their model predicts that only modest climate changes, as anticipated till 2020, are beneficial, while drastic climate change, as anticipated till 2100, will be harmful. Although Israel has a relatively warm climate, a slight increase in temperature is beneficial because it enables producers to supply international markets with Public Disclosure Authorized farm products early in the season. Their findings lead to the conclusion that securing water rights and international trade agreements for the farmers can be important policy measures that help farmers adapt to climate change.

Kan et al. (2007) developed a regional scale economic model for analysing climate-change impacts on agriculture. The model was applied to the case of Israel and the results indicate a reduction of about 20% in state-wide annual agricultural net-revenues by the year 2100 in comparison with 2002. Land allocated to field crops is increased at the expense of forages and vegetables. The shares of field crops and forages in the agricultural irrigation-water allotment are increased, while those of vegetables declines.

In the following discussion, two disconnected hydrological basins are outlined as possible implications of climate change. These have primarily been selected because of the availability of data, as well as for their strategic significance to the countries involved. They are the upper Jordan River basin and the Euphrates and Tigris rivers.

2.3 Possible water resources implications of climate change in the upper Jordan River basin

Climate change in the Middle East, together with upper Jordan River basin vulnerability, makes this area a highly relevant and illustrative case study for the potential impact of climate change on water resources. Certain factors, including a rise in temperatures, a decrease in rainfall, population growth and general increased consumption, are expected to decrease water availability in the sensitive upper Jordan River basin, and more specifically in the Lake Tiberias basin.

Precipitation and snow cover: Mount Hermon and the Golan Heights

Lake Tiberias (Sea of Galilee/ Lake Kinneret) is located in northern Israel. The lake is an important freshwater resource, supplying more than 30% of Israel's total water and 50% of its drinking water. (Avissar and Pan, 2000). The Jordan River is the main tributary to Lake Tiberias and rainfall, along with the snowmelt from Mt. Hermon, recharge the main tributaries of the upper basin of the Jordan River. Knowledge of the geo-hydrology of the Mt. Hermon area is limited. Only a few hydrological quantitative studies have been conducted, and estimations of snow and rainfall on Mt. Hermon have previously been based on stations located at lower elevations (Rimmer and Salingar, 2006).

Rainfall in the area is generally restricted to the wet season, from October to April. The four heaviest rainfall months are from November to February. The Hermon high regions (over 1,000 m above sea level) has over 1,300 mm of rainfall per year (Simpson and Carmi, 1983; Rimmer and Salingar, 2006). Snow usually falls and accumulates on the highlands from December to March and may persist at elevations of 1,400 to 1,900 m until early summer (Simpson and Carmi, 1983; Rimmer and Salingar, 2006).

> **this report presents the results of the modelling of possible scenarios of climate change for the upper Jordan**

In the Golan Heights, annual precipitation varies from more than 1,200 mm in the northeast to less than 500 mm in the south. Recharge is estimated in different studies to vary from between 10% and 30% of the total precipitation in different parts of the Golan Heights (Dafny et. al, 2006).

The vulnerability of water resources in the Jordan River basin caused by global climate change is addressed by an interdisciplinary project 'GLOWA Jordan River' (www.glowa.org). An integrated approach provides scientific support for sustainable and co-operative management practices. The project addresses conventional as well as non-conventional methods of water management and their ecological and socioeconomic implications. Research institutions from Israel, the Palestinian Authority, Jordan, and Germany have contributed scientific knowledge from a range of sources and a modelling framework has been developed to integrate data and methods from various disciplines.

In the Middle East, water crises have impacts far beyond food and water shortages.

Climate change scenarios

As outlined above, climate change is likely to influence both water availability and water consumption:

- Data show that in the Middle East, the average temperature rose by 1.5 °C to 4 °C during the course of the twentieth century (Alpert et al., 2008) and that there was an aggravation in summer heat levels (Ziv et al., 2005).
- Future climate predictions in the Middle East for the next 100 years foresee droughts that are 10 times more frequent (Weib et al., 2007). Temperatures will rise by 4 °C to 6 °C (Alpert et al., 2008), rainfall will decrease by up to 15 % (Ragab and Prudhomme, 2000), and the Jordan River flow predictions show a decrease of between 23% and 73% (Kitoh, 2008).
- Bou-Zeid and El-Fadel (2002) predict a 15% decrease in available water, and a 6% increase in agricultural water demand.

Although only a few examples of climate-change predictions are given here, as stated earlier, there is a general consensus that water scarcity is expected to increase in the Middle East.

Water crisis frequencies in Lebanon, Syria, Jordan, Israel and areas under the Palestinian Authority (PA) have increased in the last two decades. In the summer of 2008, Jordan, Israel and the Palestinian Authority confronted their third water crisis since 1990.

For Israel (which is where the data in this simulation are derived from[14]), the country's three main water resources: the mountain aquifer on the West Bank, the coastal aquifer and Lake Tiberias, are approaching their 'red lines'.

The geopolitical sensitivity of the Lake Tiberias basin (Map 1) is well known (see Daoudy, 2004 and 2008; and Trondalen, 2008) and is interconnected with water quantity and quality issues, as the area's economy depends on agriculture and tourism. More importantly, however, the basin is the only remaining example in the region of a large, freshwater ecosystem. The lake supplies about 30% of Israel's total water consumption and almost 50% of its drinking water. The basin's total area is 2,713 km^2, of which 676 km^2 are in Lebanon. In the northeast, Mt. Hermon is the major water resource of the Jordan River's three main tributaries. Only 7% of its area is in Israel. The Hasbani basin is mostly in Lebanon, as are the two other major tributaries, the Dan and the Baniyas. The east part of the Lake Tiberias River basin is on the Golan Heights, but some of the basalt aquifer recharge area is in Syria (Dafny et al., 2003).

The rest of the Lake Tiberias sub-basins, west of the lake, are in Israel. Their contribution to the replenishment of the lake is the least important.

The fact that the upper Jordan River basin covers three countries gives rise to geo-political complications (for more information on hydro-political issues, see Trondalen, 2008). The question of water resources is already a major issue in the relationship between the three countries.

14 The geographical selection of the simulation was solely on the basis of access to reliable data.

The lower Jordan River, which involves Jordan, Israel and the Palestinian Authority is beyond the scope of this simulation.

Lake Tiberias Water Balance

The Lake Tiberias annual operational volume is about 680 Mm^3 – between the upper (-208.80 m) and the lower (-213 m) 'Red Lines'. The Jordan River's average annual flow into Lake Tiberias is 410 Mm^3. The east and west direct watersheds contribute about 90 Mm^3, and the rest is mainly winter rain (66 Mm^3) and runoff (83 Mm^3). The Dan River is the upper Jordan River's biggest water contributor, with an average annual flow of approximately 245 Mm^3. The Baniyas and Hasbani rivers contribute 125 Mm^3 and 115 Mm^3 annually.

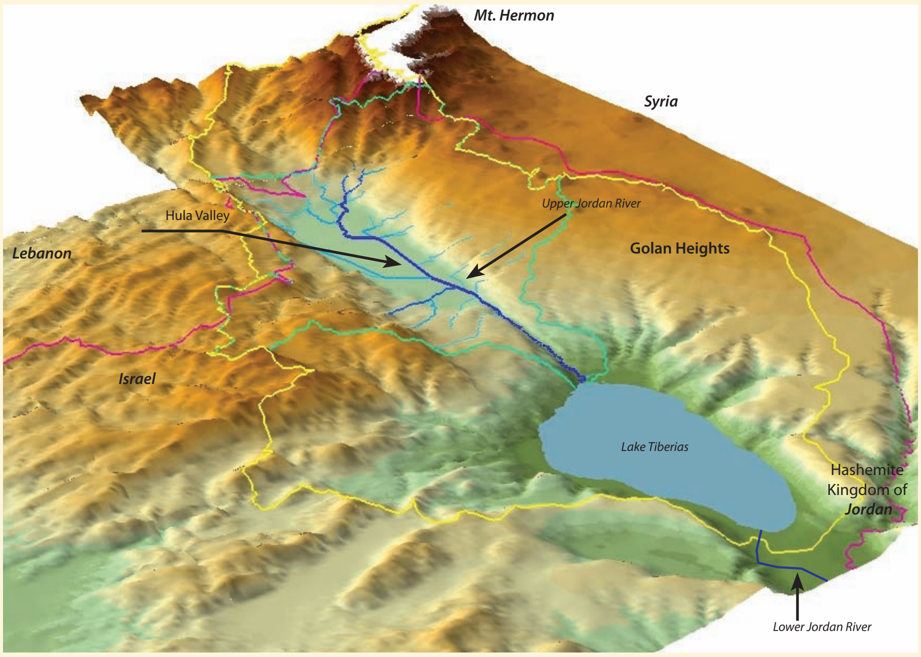
are agriculture in the Hula Valley (90 Mm^3/year) and the Golan Heights, and urban consumption in Eastern Galilee.

Water Management

The Lake Tiberias basin and the lake itself yield about 750 Mm^3 of water annually, of which 400 Mm^3 is transferred by the NWC southwards to the populous centres, and some to areas under the Palestinian Authority.

Water resources include, beside the lake and streams, reservoirs, springs, groundwater and effluent. Most of the natural water resources in the basin are exploited. To maintain water quality and a sustainable ecosystem, there is a great need for accurate monitoring of water use (for agriculture, domestic use, or industry).

Map 1 **Lake Tiberias basin (Yellow line) upper Jordan River basin (Green line) and the ceasefire lines between Lebanon and Israel (Magenta line)**



Source: Trondalen, 2008.
Note: at present, the pre-1976 line along the JR and the LB has not been shown due to technical challenges.

Many streams flow into the upper Jordan River, providing 70 Mm^3 annually in addition to the water resources on the Golan Heights and about 100 active springs.

The biggest consumer in the basin is the Israeli National Water Carrier (NWC) which pumps 400 Mm^3 per year from the lake. Evaporation loss of the lake is 250 Mm^3 and the rest of the water is stored in the lake or flows downstream to the Dead Sea, when the upper 'Red Line' reaches -208.8 m.[15] The other main consumption uses in the basin

The water balance in the lake is systematically monitored, and the pumping restrictions do not permit water withdrawal when the lake level drops below the lower red line (-213 m); in fact, the current operational lower red line is -215m. The 'upper red line' is set at -208.80m, to prevent coastal flooding, with the regulation line at Dgania Dam in the south-western part of the lake.

In other parts of the basin, data are collected on stream-flow, spring discharges and consumption (Ingerman and Zonenstein, 1994; Minitzker, 1993; Tahal 1993, 1994 and 1997). Recently, a calibration scheme that includes all water-balance components

15 Please, note that 50 Mm^3 is pumped to Jordan annually from the Lake Tiberias basin – and that amount is included in the balance as part of the storage: Cf. Annex IV of the Jordanian-Israeli Peace Agreement of 1994.

for the basin was published (Sivan et al., 2007). This scheme will assist in planning water allocation in the event of future climate change, and could assist in the basin's water management under different scenarios of economic development, land-use changes and potential geo-political developments.

A WEAP Model of the Tiberias Basin

A Water Evaluation and Planning Tool (WEAP) operates on the basic principal of water balance (Yates et al., 2005). Closing a water balance on a monthly and yearly basis is essential to understanding the water system in the basin. The WEAP is an integrative tool designed to show an overall picture of a water system both in its current state and in predicted future scenarios. The main goal of a WEAP model is to serve as a decision-support tool.

An elaborated database that includes all water resources, consumptions, hydrology and physical data of the basin is crucial for an accurate water-balance simulation.

Please note: The data are of very high reliability and are derived from open sources made available by Israeli official institutions – the Hydrological Yearbook of Israel, annual reports of the Hydrological Service, the Mekorot Water Company's periodicals on Lake Kinneret Watershed Basin and the Upper Jordan Catchment, and the Kinneret Drainage Authority's annual reports.

Simulations and Scenarios

WEAP simulations are used to evaluate water allocation in the Lake Tiberias basin according to different scenarios.

According to the background given above, it is assumed that a decrease in total available water in the basin is due to causes such as climate change.[16] Even though forecasts are uncertain, a 20% decrease in the flow of the Jordan River is a conservative estimate (Kitoh, 2008). In the following simulations, the monthly flow of the Jordan tributaries (Dan, Hasbani, and Baniyas) was reduced by 20 percent, in comparison with a Reference Scenario, which is the actual water balance through the 15 years 1989–2003.

Some assumptions in the simulation:

First Priority to NWC for water allocation means that water is first given to the NWC, and only after that is water allocated to the upper Jordan River basin.

Second Priority to NWC for water allocation means that water is first allocated to the upper Jordan River basin and then to the NWC.

Simulation number 1 (Scenario 1) represents a 20% decrease in the Jordan's monthly inflow. Simulation number 2 (Scenario 2) represents the Jordan's inflow as in the first scenario, but with the NWC allocated second priority. The results are viewed by examining the unmet water demand in the upper Jordan River basin and in the NWC, as they are the major consumers in the Lake Tiberias basin. The results are also examined by fluctuations in the water-level of the lake under the different scenarios.

Two Scenarios were performed:

	Scenario*	
	(1) NWC 1st priority and Upper Jordan River basin 2nd priority	(2) Upper Jordan River basin 1st priority and NWC 2nd priority
Decrease in the Jordan River monthly inflow	-20%	-20%

* The reference scenario is the actual water balance through the 15 year period, 1989–2003

Results and Discussion

Unmet demand for water supply in the upper Jordan River basin is presented in Figure 1. In the reference scenario, water shortage was seen only in the summer of 2001, after four consecutive dry years.

NWC gets first priority, Scenario 1:

- A reduction of 20% in the Jordan River flow causes water shortage in dry summers.
- Those shortages are emphasized in summer simulations of the years 1998, 2000, and 2001.
- In those years, the shortages are about one-third of average consumption.
- The recurrence of such large shortages three times in four years makes the managements of such crises harder.

UJRB gets first priority, Scenario 2:

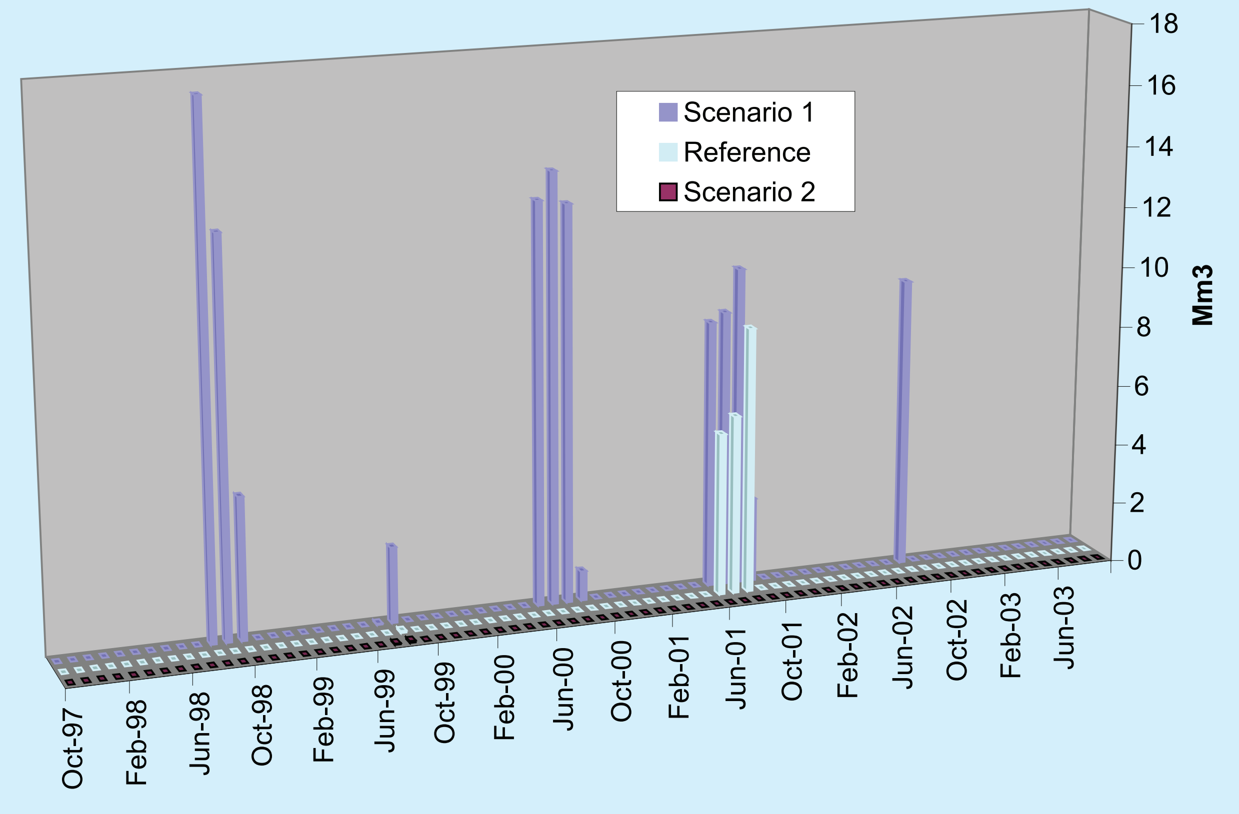
- No unmet water demands will be experienced in the upper Jordan River basin, even during consecutive dry years.

In Figure 2, the unmet water demand of the NWC under both simulations is almost a mirror image of the upper Jordan River basin unmet water demand (Figure 1).

No unmet water demand was calculated in the reference scenario.

16 A reduction of such a magnitude could also be caused by other factors – such as hydro-political ones.

Figure 1 **Unmet water demand in the upper Jordan River basin under reduction of 20% in the Jordan River flow (Scenario 1 with 1st priority to NWC–and with 2nd priority to the NWC in Scenario 2)**



Note: all the scenarios are with respect to the water balance in the 'reference years' of 1989–2003.

When the NWC is set to first priority and the river flow is reduced by 20% (Scenario 1), there are only a few months in the summers of 1998, 2000 and 2001 where not all water demands in the upper Jordan River basin were supplied – and the unsupplied volume was smaller than 5 Mm^3 /month.

On the other hand, if the NWC is in second priority (Scenario 2), there is unmet water demand through all the dry years. The shortage reaches a maximum of almost 140 Mm^3 in the simulation of summer 2000, when all the summer months are summed up.

Of course, the impact on the water supply to the NWC would be significant.

The unmet water demand scenarios clearly show that securing the future water supply in the upper Jordan River basin can only be done if it is given higher priority than the NWC.

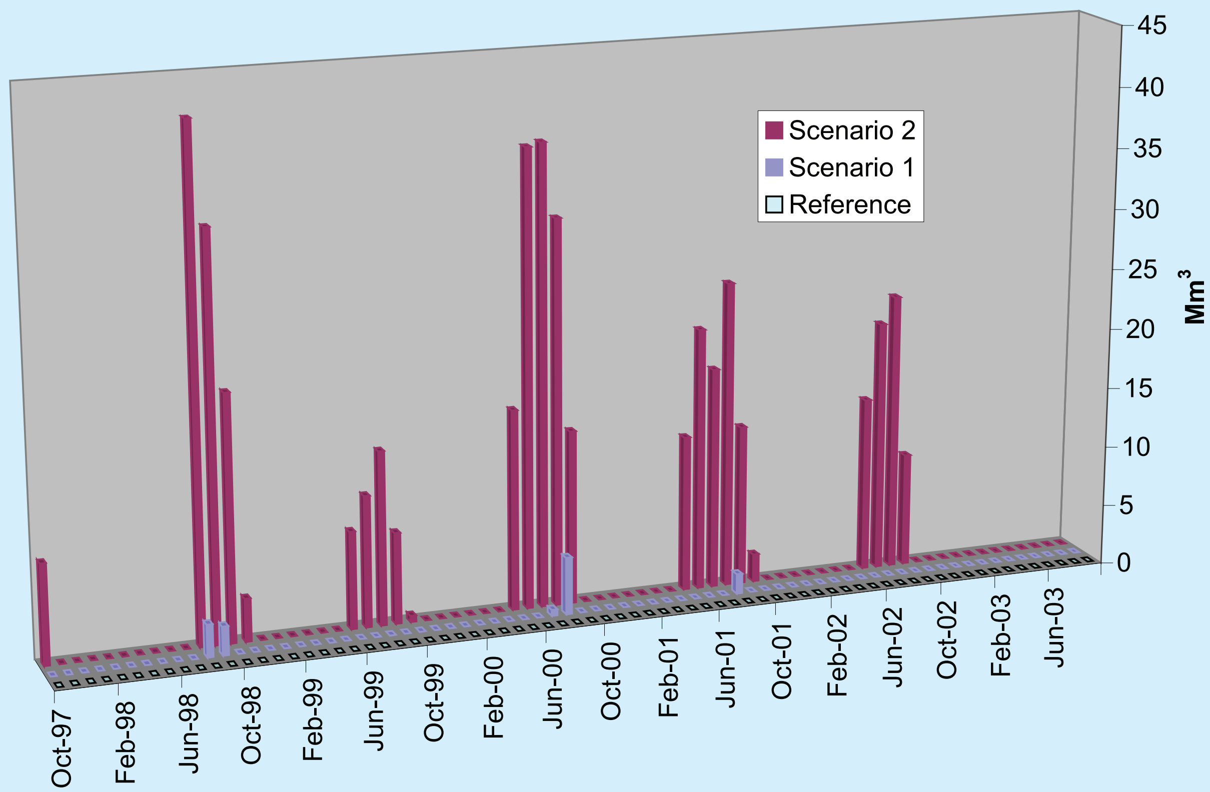
Evaluation of the influence of a 20% reduction in the river flow on Lake Tiberias's water level fluctuation (Figure 3) suggests that the priority setting has no influence. Closer examination reveals that 20% reduction scenarios lower the water level below the red line through 66 months; this is in comparison with the reference scenario, where the Tiberias water level crossed the red line in only 16 months.

Water level influences the lake's water quality and ecosystem stability (Zohari, 2004), as well as tourist and recreation activities.

Another possible implication is related to the restoration of the lower Jordan River, from the lake southwards to the Dead Sea. This river section receives 20 Mm^3 of low-quality water, which is only 3% of the historical flow. As the NWC is by far the biggest consumer in the Lake Tiberias basin, in the long run it is the only water consumer that holds significant amounts of water that could be allocated for the lower Jordan River restoration.

Guaranteeing the economy of the current Lake Tiberias region, together with its water ecosystem, and endeavouring to allocate water to the lower Jordan River for restoration purposes would apparently be feasible only if the NWC priority were to be changed. However, any realistic option may be through additional and alternative water-supply sources, such as desalination and water transportation.

Figure 2 **Unmet water demand of the NWC under reduction of 20% in the Jordan River flow (Scenario 1) and reduction of 20% in Jordan River flow together with changed priority in the NWC (Scenario 2)**



Note: all the scenarios are with respect to the water balance in the 'reference years' of 1989–2003.

In addition, and of course necessary for all countries in the region, are improved water-demand management and water efficiency.

Summary

The Lake Tiberias basin's vulnerability and geo-political significance make it a relevant case for studying the potential impacts of climate change on water resources.

Rising temperatures, decreasing rainfall and increased demand for water as the economy and population grow – as well as possible geo-political changes – would decrease the water availability in the basin.

Maintaining current basin economy and sustainable lake management, together with the future restoration of the lower Jordan River, may be achieved by re-allocating water at the expense of the NWC. This would imply a setting of alternative water priorities and further development of new and additional water sources.

2.4 Possible scenarios for the Euphrates and Tigris river basins

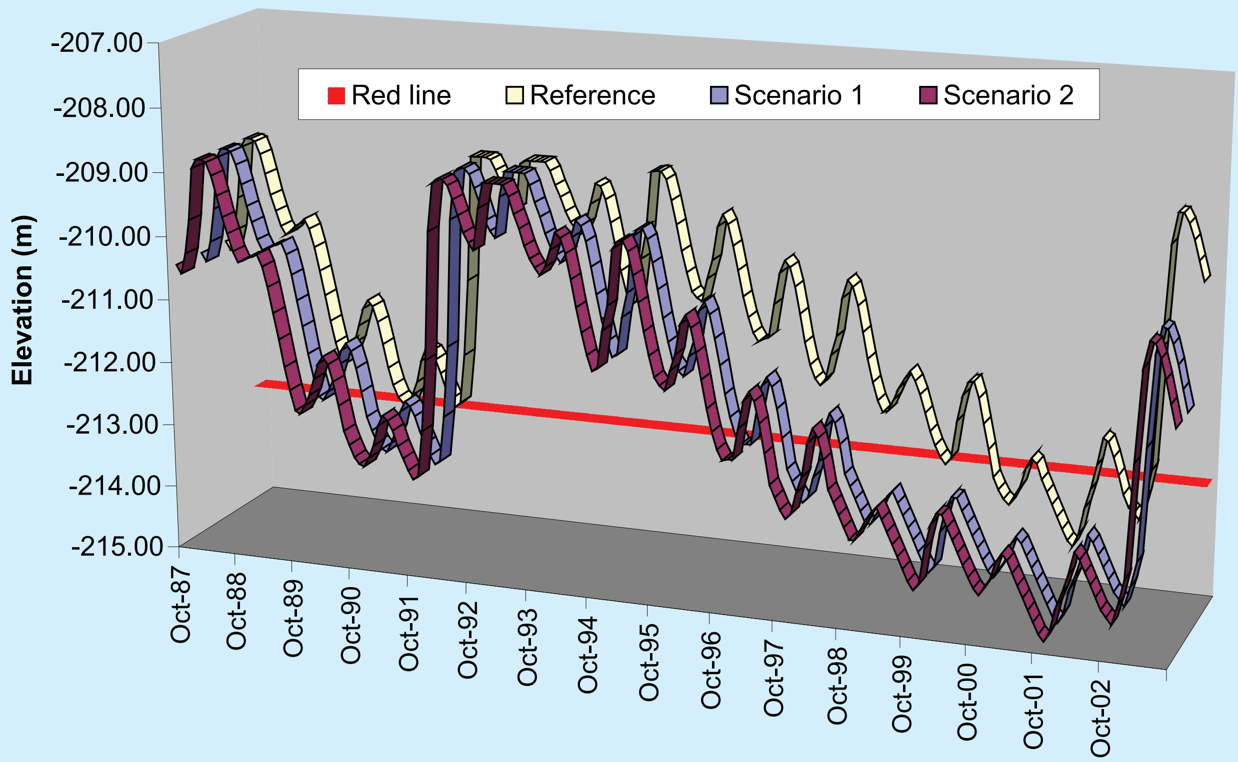
The influences of climate change on the Euphrates and Tigris river basins are currently under investigation by the countries concerned. There is very little, if any, reliable research publicly available, and this section is to a large degree based on two sets of information: first, the limited, although reported, research findings, and second, Trondalen's (2008) book *Water and Peace for the People*, which is based on 40 years of base-line data and modelling[17], and on possible implications for future water management.

First, just a brief description of the area and then an overview of some selected publications that highlight the significance of climate changes on the two basins:

The Shatt al-Arab River has its headwater in Turkey, Syria, and Iraq and is formed by the Euphrates River, the Tigris River and the Karun River. According to Cullen and deMenocal (2000), a conservative estimate states that 88% of the water in the Euphrates River is derived from precipitation falling in Turkey, thus, making it highly sensitive to Turkish precipitation, while the Tigris receives almost 60% of its water below Baghdad, making it less sensitive but still linked to variations in Turkish precipitation.

17 Based on authorised data provided by the three countries – cf. Trondalen, 2008.

Figure 3 **Lake Tiberias' water level fluctuation under a reduction of 20% in the Jordan River flow (Scenario 1) and under a reduction of 20% in Jordan River flow together with changed**



Note: all the scenarios are with respect to the water balance in the 'reference years' of 1989–2003.

The Euphrates River basin has a north-to-south precipitation gradient with humid highlands in the north and the arid plain of Mesopotamia in the south. In the highlands, precipitation is over 1,200 mm/year and in the south the annual average rainfall is about 100mm (Zaitchik et. al, 2005). In portions of the Euphrates basin that are marginal for dryland production, the difference of one or two rain events can mean the difference between crop success and crop failure (Zaitchik et. al, 20054, Zaitchik et. al, 2007).

The Euphrates and Tigris have two primary flooding periods. The first, from November to March, is mostly due to rainfall. The second, occurring during April and May, results form snowmelt and generates 50% of the annual runoff (Cullen and deMenocal, 2000). According to Aqrawi (2001), the highest river discharge is restricted to the spring season, particularly April. Many parts of the lacustrine-marsh regions in the Euphrates have been subjected to drainage modifications during the 1970s and 1980s (Aqrawi, 2001). Discharges reaching southern Mesopotamia are often contaminated with high concentrations of salt-ions, reflecting the return-flow from intensive irrigational systems and natural river-bed leakages on the Tigris River and especially on the Euphrates River (Trondalen, 2008 and Aqrawi, 2001).

The Shatt al-Arab River is the main source of fresh-water into the Arabian Gulf. Variability in salinity is determined by the return-flow from irrigations, as well as rainfall and snowmelt upstream, and is probably the dominating component in the region's production of economically important shrimp and finfish fisheries (Al-Yamani et al., 2007).

As outlined in Section 1, the climate-change scenarios are not yet clear, but they are potentially staggering for the basins – such as: 'The severity and magnitude of water resource stress in Turkey is most likely to be exacerbated by the continuance of the present unsustainable trends of environmental degradation and global climate change whose greatest adverse impact on water resources is expected in the countries located around the Mediterranean and the Middle East' (Odemis and Evrendilek, 2007).

Furthermore; 'There are considerable uncertainties as to the impacts of global climate change on changes in the demand and supply of water and water quality. Possible reductions in run-off may be attributed to increased evapotranspiration, decreased precipitation, or a combination of both, which will be influenced by global climate change. The sensitivity of river discharge to climate change is of significance to the Middle East region.'

Map 2 **Image of the Euphrates and Tigris rivers**

Source: Trondalen, 2008

Al-Yamani et al (2007) notes that: 'Unfortunately, discharge records for the Shatt Al-Arab River have not been made available for the scientific community for the past three decades.'

Taking into account these statements, there are reasons to argue that several renowned scientists highlight the susceptibility of the two rivers to climate change. A brief summary of some of the scientific bases of possible trends (cf. Section 1) are outlined in the following:

- A decreasing trend in rainfall in most of the Eastern Mediterranean and increased rainfall over the southern part of the eastern Mediterranean.
- Trends show a significant increase in maximum and minimum daily temperatures.
- A trend toward drier as well as wetter years in the future.
- One study predicts that at the end of this century, the Fertile Crescent may disappear altogether.
- The annual discharge of the Euphrates River will decrease by between 29% and 73%.
- By 2050, there is an expectation that rainfall amounts will be reduced by up to 20–25% below present mean values.
- All models show intensifying dry conditions, with rainfall decreases of up to 25% (regionally) and 40% (locally), and projected increases in the frequency of summer heat waves.

If even the conservative estimates are taken, it will have a profound impact on the water resources for the two largest basins in the Middle East.

Based on years of leading studies and modelling of the two rivers and co-operation with the three countries, Trondalen (2008) outlines a set of conclusions and recommendations for the nations and the international community to adopt (see section 6).

Water security, possible co-operation, and climate change

Traditionally, water and security have been treated as separate entities; when they were combined it was often as 'water security' such as in relation to safely procedures or security concerns for water infrastructures and transportation. Security studies have a long tradition of interpretation in military, strategic, and political contexts, while water has been regarded from a geo-science perspective or strictly as a water management issue.

In the late-eighties however, the epistemic community began to analyse the nexus in a broader sense, and scholars like Westing (1986) stated that comprehensive security has two intertwined components: *political security,* with its military, economic and humanitarian subcomponents, and *environmental security,* including the protection and use of resources and the environment. Much of the research on environment and security was in fact more about strategic resources like water and security aspects than about environmental issues in a broad sense (see also Trondalen 1993 and 1997).

It is worth noting that the acceptance of the link between security and water is not universal. One of the difficulties in assessing the nexus is due to the ambiguity surrounding the term 'security'. Researchers working in the area of water and security come from a variety of backgrounds and disciplines, and each interprets the term 'security' in a different way, ranging from a strict definition of safety from armed conflict to a more general interpretation of 'human security', or 'human livelihood security', which includes social, cultural, economic, environmental, and other broader aspects (Lonergan and Brooks, 1994).

The notion of water security in this context is linked to different actors' need to attain control and access to water resources in order to secure their vital interest on various scales and geographical levels, seen from a strategic, political, economical, cultural, environmental and social perspective. The fact that different actors have incompatible, competing, or conflicting strategic interests often create conflicts with varying intensity (Trondalen, 2008). As conflicts escalate, stakeholders will be exposed to conflict vulnerability, which in turn could be a threat to security or simply creating a sense of insecurity.[18]

As national security has often been understood in terms of assuring strategic interest (and even risking the lives of citizens to attain security concerns), it is increasingly recognized that communities also often view access and control of basic goods and services such as food and water as fulfilment of their need for security.

In light of the sensitive water resources in the Middle East, the following broad categories related to water and security have been developed:[19]

- **Water resources as strategic[20] goals** — Obviously, in areas such as the Middle East, access and control of precious water resources is vital from a security and strategic perspective.
- **Water resources as strategic targets** — Modification of water resources for military purposes is a long-standing issue (such as in about 2400 BC, when the Sumerians dug a canal to divert water from the Tigris to the Euphrates to gain independence from Umma – cf. Roots, 1992).
- **Water resources as strategic tools** — Water resources are, under certain conditions, powerful strategic tools – an example is an upstreamer's ability to restrict the flow of a vital river in order to fulfil other vital interests.
- **Water resource inequities as the roots of conflict and insecurity** – Growing disparities between water-resources-rich and water-resources-poor communities and countries, in terms of access and control of the resources, has created a constant tension in some areas and open rebellion in others, especially in areas that are heavily dependant on either rainfall or irrigation for their food security.
- **Water resources changes as the roots of vulnerability to conflict** – As water resources are altered either through human intervention or simply due to natural variations, and not least in relation to possible climate changes, scarcity in terms of quality and quantity are aggravating conflict vulnerabilities. Communities and states could then be exposed to a perceived risk to their security, which in some instances has severe implications.

Under each category, water, security and various sectors including energy, agricultural production/'food-security,' and social and economic factors as well as political ones are intertwined. An alternative way of crafting out water security categories would be to investigate such sectoral causalities. However, to raise the awareness and significance of the water security nexus in the Middle East, this report will just highlight some of the water security concerns (before turning to a discussion of remedies in the next section).

The Centre for Strategic and International Studies and the Centre for a New American Security recently published a comprehensive report that aims to shed light on climate change, security and, among other issues, water: *The Age of Consequence: The Foreign Policy and National Security Implications of Global Climate Change* (CSIS and CNAS, 2007). Although their study took a United States perspective, its findings are quite relevant internationally – and staggering. Such an approach could well be carried out for the Middle East, and probably, most of the countries have unilaterally done that (but not made their findings publicly available).

Another and complementary perspective is a report published by Friends of the Earth and EcoPeace.[21] 'Climate Change: A New Threat to Middle East Security' (Freimuth et al, 2007), outlines several water security concerns related to water and climate change. Some of their findings are (p. 4):

- Climate change is likely to act as a 'threat multiplier' – exacerbating water scarcity and tensions over water within and between nations linked by hydrological resources, geography, and shared political boundaries. Poor and vulnerable populations, which exist in significant numbers throughout the region, will likely face the greatest risk.

18 Stakeholders could range from parties that have stakes in the water in one way or another – such as an 'impoverished community' in a mega city, a 'farming community' in a predominately agriculturally based society, or even 'states'.

19 The text in the first four categories is derived from Lonergan and Brooks (1994)

20 A *strategic resource,* like water, is one that is indispensable for a society in the short term.

21 Two environmental NGOS represented in the Middle East.

- Water shortages and rising sea levels could lead to mass migration in the region. Scenarios conducted by the United Nations Environment Programme (UNEP) and other organizations indicate that a 50-centimetre (0.5 metre) rise in sea level, for example, could displace between 2–4 million Egyptians by 2050. The drinking water of 1.5 million Palestinians in Gaza would be further contaminated by rising sea levels leading to sea-water intrusion of their only freshwater source, the Coastal Aquifer.
- Economic unrest across the region, due to a decline in agricultural production from climate impacts on water resources, also could lead to greater political unrest, which could threaten current regimes, thereby affecting internal and cross-border relations. These factors place greater pressure on the entire region and on already-strained cross-border relations, and potentially foster more widespread heightened tensions or conflicts.

The report goes on to outline some of the factors that would determine the likelihood of conflict or co-operation in the region as climate impacts become more significant (Freimuth et al, 2007, p. 4):

- The existence of water agreements, and their degree of sustainability, including the ability of parties to deal with extreme circumstances, such as longer periods of drought.
- The influence of destabilizing economic and political factors – for example, unemployment and mass migration due to agricultural decline and the large-scale flooding of agricultural areas.
- The extent of national economic and political development, including the degree to which local institutional structures and infrastructure exist.
- A given political entity's ability to mitigate or adapt to climate change.

There are other reports that use a different methodological approach, such as the application of security impact assessments (SIA) for analysing the redistribution of actual and perceived security as a result of water development interventions and projects among the key stakeholder groups (Warner and Meissner, 2008)[22].

The outcome of such a SIA for the Middle East would probably have given other findings. However, most of the available literature seems to support the following conclusions:

- The scale of the potential consequences of climate change in the Middle East makes it difficult to determine the extent and magnitude of the possible water security challenges.
- The least resourceful countries seem to have limited ability to adapt to climate change – even the modest and early manifestations.
- Climate change effects will aggravate existing international crises and problems.
- Reliable and relevant data and modelling are needed to determine with any sense of certainty the direct impact of climate change.

Nevertheless, based on even these broad but potentially serious conclusions, the next section will explore ways of handling the potential impacts of climate change on the nexus of water security.

3. National water security challenges resulting from climate change

As water resources will be diminished in the Middle East as a result of population growth, land management and climate change, countries have of course to reduce their consumption and improve the efficiency of existing resources.

Structural changes such as the reduction of water for irrigation may be one option, but as these changes take place, national governments will face increased competition internally and internationally. In some instances instability, disputes and security threats may evolve.

These issues will be dealt with in the following. A critical question is whether current policies, institutional setups, and programmes are appropriate to handle increased risks and uncertainties. What has yet to be determined is how quickly, where, and with which magnitude and significance water resources systems are likely to change.

as climate changes evolve, national governments would have to operate under higher risks and uncertainties

As climate changes evolve, national governments would have to operate under higher risks and uncertainties, although, governments are always making decisions in an area of relative risk and uncertainty. Awareness and understanding of climate change on national and international water resources is increasing, but no one really knows the magnitude and significance of the risks and uncertainties, especially where regional and basin-wide changes are taking place (see, for example, WWF International, 2006).

Historically, risks and uncertainties related to natural resources may stimulate unilateralism and less co-operation (see, for example, Klare, 2002), while the current and future challenge is to counter that trend and craft out ways that stimulate co-operative actions (see, for example, Dinar et al.,

22 They employ SIA to examine water security trade-offs in the Okavango Basin, highlighting the positive role of information and knowledge exchange as a means for alleviating actual as well as perceived insecurity.

2007). Some countries that are exposed to high risks and uncertainties are required to take precautionary measures. However, what's still unclear is the degree of influence that climate change has on a country's *vulnerability* to water disputes and instability. Nevertheless, there are a set of national policy instruments that may prevent and resolve such disputes in a sustainable manner.

The adaptation of coherent national planning, programmes and interventions would prevent such disputes at a national level – and reduce the chances of spill-over effects internationally. In addition, policies related to water legislature revisions and national capacity building in conflict management should be given priority, especially in light of the following factors:

- Implications of climatic variability and climate change on flood control and on reductions of the quantities of surface water and groundwater.
- Adherence to co-operative arrangements and implications on water legislation and regulation.
- Consequences in relation to protection from pollution and deteriorating water quality.
- Allocation of water to consuming sectors such as agriculture – timing, spatial distribution and amount.
- Increased pollution from local and transboundary sources.
- Improving the analytical capacity of relevant water resources data as international co-operation on these issues increases.
- Fostering multiple stakeholders' dialogues. As water management often affects diverse stakeholders, involving them would increases legitimacy and the sustainability of decisions.

Some countries are already entrenched in conflicts. The current and the new conflict dimensions will create additional challenges.

Issues to be addressed by the various governments would include:

- Reformulations of hydro-political positions and interests.
- Changed conditions for the conflict in terms of intranational and international dimensions (foreign influence creates both constraints and opportunities).
- Ability to adopt international assistance (both technical assistance and so-called process tools [like negotiation assistance]).

4. Water security challenges for the international community resulting from climate change

The international community is faced with current and new challenges in assisting countries, or groups of countries, that are already entrenched in domestic or regional conflicts (either water-related or not).

International organizations have different roles in resolving water security issues as well as preventing and resolving water-related disputes – such as the United Nations, multilateral organizations, development banks and regional organizations. Since the nature of many of the causes behind instability, security challenges and disputes is the same, the key challenge is not necessarily to create new interventions and institutions, but rather to improve and target the instability/conflicts in a different way than in the past. Many attempts have been made to analyse how such improvements could be done, and there are unfortunately no quick-fix solutions (CESAR, 1999). Recent comprehensive studies of how, for example, a pivotal organization could improve its performance in preventing instability and disputes (see, for example, Mason et al., 2008), do not offer any substantial new insight into how multilateral institutions, such as the United Nations, can effectively act – except for already important and known measures such as:

- improve inter-agency co-ordination,
- enhance technical assistance to national governments to prevent and manage conflicts and post-conflict situations,
- develop financial arrangement that would create win-win situations and benefit sharing arrangements (as the World Bank has done in the Pakistani-Indian Indus basin or in the Nile River basin between Ethiopia and Egypt),
- provide capacity-building assistance in relevant sectors (such as water, agriculture, energy and health),
- assisting nations in setting up alternative dispute-resolution programs, especially at the community level
- develop independent assessments and descriptions of the water resources situation – such as water monitoring systems and institutional support – as a basis for national and international management,
- adjustm national *versus* international/regional water legislative frameworks,
- improve third-party assistance programmes – such as 'good offices' (involving both environmental and mediation expertise),
- strengthen international legislation – and, equally important, the enforcement of existing international legal frameworks (laws, conventions, protocols, and declarations).

In reality, most of the remedial actions have been taken as a joint effort between the national governments and the international community. The following section explores joint challenges and adaptive strategies.

5. Possible adaptation strategies for nations and the international community to jointly adopt

Over the years, instability and water vulnerability and security problems have occurred under different conditions, and some nations and international organizations have well-developed functional policies and programmes that can jointly be adopted (in contrast to the preceding sections that dealt with national and international measures separately).

Such situations are quite relevant in the Middle East where some countries need outside assistance in handling internal and international water-security problems and disputes. In such cases, a majority of them will probably not be able to sustain national water allocation or quality needs without external intervention, such as:

a national *acceptance* of the fact that hydrological changes are taking place is a necessity for action. A national *willingness* to address the matter through a capacity-building strategy must exist where awareness is the first step.

1. Generally, in large multi-country river/groundwater basins where management policies and actions have already been agreed on – and which have to be re-negotiated.
2. Where there is a demand for water management investment that goes beyond the capacity of the countries involved, or because 'third-party funds' would be more appropriate than neighbouring or bilateral funds.
3. In a politically grid-locked situation, either nationally or internationally.

One of the most important tasks that national governments and international organizations could jointly take on is to assess and develop water vulnerability/security/conflict-management strategies. With respect to possible climate changes, such strategies ought to be developed on the following basis.

The government must know the status and changes of the water resources. In this context, mapping and describing the changes of the water resources situation (such as rainfall pattern, resilience of hydrological systems, water availability, and sustainable yields) is critical. Although it's probably regarded as being obvious, a national acceptance of the fact that these changes are taking place is a necessity for action. A national willingness to address the matter through a capacity-building strategy must exist where awareness is the first step.

At present and quite often, such a basis is lacking, but some international organizations are assisting nations to deal with these facts (for example, the World Bank, UNDP, UNESCO, and ESWCA in the Middle East).

Several concrete and well proven joint measures could be taken by nations or groups of nations together with the international community (often by international organizations):

a. **Conflict resolution capacity** in most countries is weak, and sometimes almost non-existent. A common notion is that conflicts are handled *ad hoc,* and that senior officials or even political leaders are assigned the task of 'solving' or 'fixing' the problems when they occur. It is increasingly recognised that a national capacity to actively resolve or settle conflicts is something that must be given priority to in complex and inter-sectoral issues, like water disputes. Climate change accentuates this need. United Nations organizations (such as UNESCO's PCCP and UN ESCWA) and other organizations (such as COMPASS and the CESAR Foundation and CMG/Harvard University) offer such assistance.

b. **Specific financial and economic instruments** that are tailored to meet local, national and international needs. The popular notion of benefit-sharing has a high academic value, but is limited in real-life situations, in the sense that operationalization of the concept has been quite limited (Phillips et al, 2006 and Jägerskog and Lundquist, 2006). That does not exclude the fact that one of the very few ways for nations to prevent instability and water-related disputes is to develop solutions that take each nation's concerns into account. Financial and economic instruments and arrangements such as swap-mechanisms – like 'the up-streamer that gets water while the down-streamer gets energy or trading concessions' offers opportunities that might prove to be sustainable. Another advantage is that as climate change influences hydrological systems at a national or regional level, some of the disputes and tensions can be defused by swapping water resource costs and benefits in monetary terms – such as trading, energy, water or other tradable resources, infrastructure, and commodities. In mid-2008, the World Bank set up a Climate Investment Fund (CIF), which has pledged US$1.6 billion. The CIF is an important new source of interim funding, through which the Multilateral Development

Banks (MDBs) will provide additional grants and concessional financing to developing countries to allow them to address urgent climate-change challenges.[23] In addition, an Adaptive Fund is being established under the combined auspices of the World Bank and the Global Environmental Facility.

c. **The establishment of compensation mechanisms:** The recognition that countries involved in water disputes and climate-related conflicts have mutually incompatible goals has prompted the incipient design of compensation mechanisms – either in terms of monetary, energy, or even commodity compensation. Such mechanisms are quite complex, especially since they demand a long-term perspective, which is often in conflict with short-term political decisions. As climate change may force the reformulation of current water agreements, compensation mechanisms will probably be an instrument which has huge potential in such contexts, as well as in already grid-locked ones (see further reading in Trondalen, 2008).

d. **The development of mechanisms for leasing waters between nations** (as proposed in Trondalen, 2008, regarding the Wazzani water dispute between Lebanon and Israel). Such mechanisms require international assistance, especially in acting as an interlocutor in the monitoring of agreements.

e. **International assistance and investment in water infrastructure** is in many instances one of the few ways in which countries are able to cope with water disputes. The recent planned Egyptian and Ethiopian joint dam development on the Blue Nile is an example of how a preventive initiative is supported by the international community (with the assistance of, in this case, among others, the Nile Basin Initiative and the World Bank).

f. **Institutional and legal capacity building** would form the core of joint national and international efforts, and should include following aspects (see also Sherk, 2000 and Scholz and Stiftel, 2005):

   - Legal and institutional instruments and arrangements offered for consideration in relation to fulfilling the provisions of international agreements: As some nations strive to prevent instability and conflicts, agreements will be designed, but quite often, the hard part is to implement the agreement – Strengthening implementation through institutional capacity building is pivotal.
   - Outlining the specific roles, rights, obligations, and responsibilities of the countries in all aspects related to the management of water. Quite often, nations face major challenges in defining and carrying out such functions, and even more so when international agreements are developed. One point of departure is to specify the institutional functions and enhance countries' capacity to carry them out.
   - Outlining the basic elements in procedures and protocols (in relation to, for example, visits and the systematic exchange of information). In general, institutional and legal capacity building is broad in its scope, but in this context, it is recommended that countries tailor their work towards concrete actions aimed at implementing water agreements.

g. **Joint commission:** when countries decide to start co-operative management of international waters or to implement a negotiated agreement, a **joint commission** or group is usually established. Some countries have been reluctant to do this, while others can trace back a century-old structured and fruitful record of co-operation – for example, the 1909 International Joint Commission regarding the Great Lakes between Canada and the US (Grover and Khan, 2007) – which could serve as a model for others. Joint Commissions, or River Basin Organizations (RBOs) normally provide assistance to countries in achieving the aims and principles set out in a co-operative framework, especially on water policy issues.

- RBOs also provide assistance to riparian countries to develop legislative, regulatory instruments and other measures in order to implement the provisions of the framework agreement (such as identifying and facilitating the filling of gaps).
- When a riparian country cannot implement the provisions of the agreement or the RBO's decisions, certain policy advice and assistance from the RBO will be provided to the countries concerned.
- RBOs have also proven be have problem-solving capacity at different stages in international lack of co-operation (Tänzler et al, 2007):

h. **Streamlining and developing water policy in an international context**. In a national context, it is an obvious necessity to establish water policies on such critical issues as water rights and ownership, privatization, liabilities, pricing and tariffing, and pollution abatements. Any international water context is likely to make national water policies more complex, because such national policies are, by nature, crafted out on the basis of principles of national sovereignty. Therefore, national water policies are normally not adjusted to the fact that the water resource is shared with a neighbour. Nations adhering to

23 The CIF aims to enable a dynamic partnership between the MDBs and developing countries in order to undertake investments that achieve a country's development goals through a transition to a climate-resilient economy and a low carbon development path (see http://web.worldbank.org

international agreements very often have ambiguities and gaps in their national policy and legislation. Some international organizations, such as the International Network of Basin Organizations (www.inbo-news.org), share knowledge and provide technical assistance in such contexts. Since climate change is expected to alter national and international water systems, nations must expect new challenges that should be reflected in their legislation and policies. Countries that do not have the capacity to adapt and develop in this way will be even more exposed to instability and conflicts.

i. **Enhancing the mapping and analytical capacity of water resources**. Some countries have, even today, limited knowledge and understanding of existing water resources, especially in the areas of groundwater and water quality changes and trends. As climate changes alter the hydrological systems, countries with limited assessment capacities will potentially be exposed to 'sudden hydrological surprises' (such as acute water contamination of drinking water sources). Many international organizations, including UNESCO's International Hydrological Programme (IHP), have for years provided assistance to national governments. Contemporary technologies such as Geographical Information Systems (GIS) provide streamlined tools for governments to develop national overviews and analytical capacities that will enable them to systematically map and assess changes in their hydrological systems. UNEP has taken a lead in such initiatives (see text box below).

j. Establishment of water-resources early warning systems. As climate changes evolve, hydrological changes will happen – some will occur slowly, while others will take place quickly (such as the saturation of water quality attributes like odour), nations must develop an early warning capacity as well as developing water-quantity and water-quality monitoring systems (including the standardisation of parameters):

- International organizations and partnerships between government and the private sector will enable countries to establish national and international water-quantity and water-quality measuring programmes, especially as 'hydrological surprises' could be detected at an incipient stage.
- Establishment of an early warning system for water quality as well as for hazards such as floods and droughts. This is probably one of the most cost-effective preventive measures that can be taken to prevent sudden instability and disorder due to unexpected pollution or water unavailability.

In some cases, the international community is unwilling or unable to provide assistance in the circumstances mentioned above. Likewise, some countries may be either unwilling or unable to receive such assistance, but there would be at least some issues that most nations would consider to be 'acceptable' international assistance or intervention – see some examples in the following textbox:

Box 1

Examples of concrete assistance that international organizations might provide to countries that are exposed to problems related to water security and disputes:

- Water monitoring and mapping technology (such as Geographical information Systems):
- Development of institutional setup and systems to react to the (above-mentioned) results – such as technical assistance in water monitoring and assessment, institutional capacity building, and legislative reform programs
- Financial and economic packages (for example, relating to compensation) that would target 'given water situations' (such as the development of water allocation schemes between users and sectors and economic instruments) – cf. new instruments such as the CIF.
- Development of conflict-management capacities – such as enhancing the negotiation skills of national delegates; developing negotiation strategies; enhancing the capacity to draw upon available legal, technical, negotiation and economic expertise.

6. A particular focus on co-operation in the Euphrates and Tigris basins

It should be quite obvious – based on the available studies, uncertainties related to climate-change projects, and lack of understanding of water-related implications at river basin level – that one should be quite careful in prescribing remedies and ways out for countries affected by the anticipated changes to their climates.

The modelling of the upper Jordan River basin and its potential implications revealed quite severe impacts. Due to the political complexity and sensitivity of the area[24], this report will not, however, elaborate various ways of mitigating the effects (as expressed in the modelling), except for pointing to the more general measures as outlined in the preceding sections. More importantly, however, is the UNESCO publication, *Water and Peace for the People: Possible Solutions to Water Disputes in the Middle East* (Trondalen, 2008), which deals with these matters more extensively.

Nevertheless, even the most conservative estimates of climate change, such as those expressed in Sections 1 and 2, support the argument that countries have to plan and take measures to minimize the potential staggering effects on the water security situation. The situation may be described as follows:

24 This demands a more elaborate explanation and assessment than the format of this report permits.

- The scale of the potential consequences of climate change in the Middle East makes it difficult to determine the extent and magnitude of the possible water security challenges.
- The least resourceful countries seem to have limited capacity to adapt to climate change – even in modest and early manifestations.
- Climate change effects will aggravate existing international crises and problems.

Because there is a lack of reliable and relevant data and modelling to determine with certainty the direct impact of climate change, the data and information that follow is taken from one of the few international studies and models of the Euphrates and Tigris rivers that are publicly available: *Water and Peace for the People: Possible Solutions to Water Disputes in the Middle East* (Trondalen, 2008).

The set modelling and studies did not – at the time they were carried out – include data on climate change. Therefore, a conservative approach would be to use the recommendations for the absolute minimum measures that the three countries (Turkey, Syria and Iraq) should take. As climate change will aggravate the water situation, the argument is simply that the stated measures have to be taken earlier rather than later.

The recommendations could be grouped as follows: (1) what the three countries could do, and (2) what the international community could do to support them:

1) Recommendations for Turkey, Syria and Iraq:
It seems obvious that all three countries have to improve their water efficiency by using a combination of policy instruments, investment and institutional capacity building.

However, taking the sociocultural and political context into consideration, it is urgent that a trilateral water agreement is reached as soon as possible.

If no remedial actions are taken, irreversible damage, especially to the Euphrates watercourse in the lower part of Syria and in Iraq, may occur as irrigation volumes increase.

A conservative approach would therefore be to follow the recommendations for the three countries to take as an absolute minimum. As climate changes will aggravate the water situation, the argument is simply that the stated measures have to be taken earlier rather than later.

- To prevent the Euphrates River from being polluted – especially in dry periods – the application of rule-curves for extraction of water for irrigation is recommended. **Discharge values at the Turkish/Syrian and Syrian/Iraqi borders might therefore vary, and even more so in the case of increases in climatic change.**
- The consequences of doing nothing to address the above-mentioned points would cause severe humanitarian suffering.
- A *precautionary principle* should be applied to the planned irrigation schemes in the three watercourse countries in order to maintain sustainable development of the river basins.
- A water *quantity and quality monitoring programme* should be implemented at the borders and a set of limiting value-ranges for these parameters ought to be established.
- There should be an intensification of the application of sound environmental waste-water technology and joint research regarding the development of low-water-demand crops, as well as effective irrigation practices.
- From a sustainable water-management perspective, it is not necessarily important whether there are two associated agreements for the rivers or one unified one, as long as an agreement is reached on how to manage the rivers for the optimal benefit of all three countries. From a negotiation-process point of view, however, it seems conducive to develop one single agreement, or at least two linked river agreements.
- All three countries have, in principle, acknowledged their responsibility to protect and use the watercourses in an equitable and reasonable manner.
- All irrigation projects in the watercourses should be made subject to extensive Environmental Impact Assessment with respect to return flow, and the effects on soil and groundwater.

The above-mentioned conclusions and recommendations are considered to be an imperative. And of course, if climate change scenarios – even the conservative ones – were to be fully adopted, more far-reaching measures would have to be taken. Under any circumstances, co-operative frameworks between the three countries have to be in place sooner rather than later.

The 'zero-hypothesis' (where no sustainable agreements exist between them) will under any circumstances have severe consequences from a water resources and water security perspective.

A relevant question is to what extent it is realistic that the three countries take these steps alone – without any assistance from the international community. The fact that there have not been any serious trilateral discussions about these matters in 20 years illustrates the situation. The next section outlines ways in which the international community may assist the three countries.

2) Recommendation for the international community to support the three riparian states:
The three nations have of course the option of moving along the path of no substantive co-operation. Or they could open up for international support in their endeavours towards some sort of sustainable co-operative water management framework.

Based on Trondalen (2008), the international community could assist by establishing a new:

International Initiative for the Euphrates and Tigris river basins

Irrespective of the political changes and even climate-change scenarios, it seems obvious that a new, overarching international initiative must be taken:

- The Euphrates and Tigris Basins Initiative (ETI) could be a partnership initiated and led by the riparian states of the two rivers through a Council of Ministers with the full support of the international community through international organizations such as Arab development banks and institutions, together with for example, the World Bank (in association with GEF and the United Nations).
- Following the example of the Nile Basin Initiative (NBI), which encompasses nine riparian African states, an ETI could start with a participatory process of dialogue among the riparians that should result in agreement on a shared vision. For example, agreement could be reached on the principle of 'achieving sustainable socioeconomic development through the equitable utilisation of, and shared benefit from, the common water resources of the Euphrates and Tigris basins (cf. the similarity with the NBI). This vision could then be translated into a similar (to the NBI) Strategic Action Program with concrete activities and projects.

In light of these conclusions (which are based on estimates that did not include climate change), there will obviously be far-reaching implications for the water resources of the two rivers for all three countries – even if only the most conservative climate change forecasts come about.

One of the concrete proposals within an ETI is to mitigate cross-border pollution through the establishment of a 'Third-Party Compensation Mechanism' (Trondalen, 2008):

- The results of the modelling of the two rivers makes it quite clear that the water-quality aspects – especially for the Euphrates River today and in the near future – have to be given special attention in any basin-management strategy, particularly in terms of the impact of return-flow from irrigation.
- In order to avert the negative environmental (and subsequently, humanitarian) consequences of a situation that may be described as a crisis, there is a need for concerted measures to be taken to reduce the expected adverse impacts of intensified and expanded irrigation.
- In order to adequately address these impacts by maintaining a certain water-quality level according to agreed standards, a Third-Party Compensation Mechanism is proposed, at the first stage, i.e. at the border of Syria and Iraq. Later, similar plants would be located in the border areas of Turkey and Syria. Such a Compensation Mechanism demands funds that, realistically speaking, can only be raised by the international community.
- There are two reasons for this: 1) The amount of funds necessary to mitigate the pollution is so large that only a multi-donor effort can meet the financial requirements, and 2) stakeholders outside the region might consider this Compensation Mechanism to be effective in preventing unstable conditions that might stem from such a crisis.
- A Compensation Mechanism would aim to achieve internationally accepted water-quality standards and thereby minimize the negative effects of poor water quality on sustainable-development projects in the watercourse countries.
- First priority should be given to the Euphrates River. This would take into account and reconcile four key and potentially conflicting objectives:
    1. Turkey's planned agricultural use in the South Anatolia region (GAP).
    2. Syria's demand for expansion of irrigation.
    3. Iraq's long-term claim of access to usable water.
    4. Sustaining the ecological balance of the rivers.
- The most effective way of mitigating pollution of the Euphrates, and especially its salinity, is to propose that the Compensation Mechanism would compensate Syria for upstream measures to reduce the pollution of the water flowing into Iraq. In addition, and as a next step, the same mechanism could be put in place on the Turkish side at the Turkish/Syrian border in order to achieve acceptable water quality (especially along the drainage areas at the border zone).
- An implementation, monitoring and verification system should be an integral part of such a Compensation Mechanism – see more specifications in Trondalen (ibid).

Establishment of a Desalination Plant

Furthermore, Trondalen (2008) suggests that:

- *Economic compensation* could be used to reduce the negative downstream effects, which could – in the first instance – include a Desalination Plant at the Euphrates River on the Syrian side of the Syrian-Iraqi border.

- Economic compensation would also be given to Turkey in the GAP-region to undertake measures that aim to reduce the negative pollution effects downstream through the efficient application and transport of irrigation water, and the management of drainage water.
- Internationally, there are parallels to such a mechanism, such as the United States/Mexico agreement on the Colorado River, where a Desalination Plant is installed on the United States side that treats water in order to maintain agreed water-quality standards.

Trondalen also asks why the international community should fund such a Compensation Mechanism – and outlines a reply to the question:

- One may argue that national water usage for sustainable development should be governed through the respective countries' water-management legislation. In most cases, however, as in the Euphrates and Tigris basins, national legislations are currently not harmonized to each other, nor do they reflect international water-quality standards.
- It is well understood that unrestricted water use upstream would impose environmental, and thereby economic, burdens on downstream states. At present, improving downstream water quality and quantity to minimize adverse impacts will place additional costs on the upstream users.
- Over the past decade, this has been internationally recognized, as shown by the establishment of the joint World Bank/UNEP/UNDP Global Environmental Facility (GEF). One of its four prime objectives is to cover such additional costs related to international watercourses.
- Is seems obvious that the challenges to sound management of the two rivers falls within the mandate of GEF, which is a recognition of the responsibility of the international community in providing additional compensation to upstream countries that are adopting mitigation measures. Otherwise, the *overall cost* for the concerned national governments, as well as for the international community, is likely to be many times higher in terms of unintended humanitarian, economic, social and environmental consequences, as well as potential instability in the region.

Summing up

Even without climate change, there is a univocal conclusion from Trondalen (2008) that co-operative management of the Euphrates and the Tigris Rivers must be improved in the future. If not, these water resources will not only be insufficient for the countries to provide 'water for the people' (either in terms of quality or quantity), but, and equally importantly, the resources themselves may be irreversibly damaged.

However, reluctance on the part of the three countries and the international community to deal with these challenges will eventually create multiple problems, necessitating critical remedial actions – even before climate change starts to have an effect.

Without action, the problems will continue to grow, with tragic consequences for the people of these countries and possibly for others outside the three countries.

It is therefore the international community's obligation to urge Turkey, Syria and Iraq to take action now. In addition to 'sitting around the negotiation table', Turkey, Syria and Iraq should probably take two immediate concrete steps:

First, they should conduct a comprehensive exchange of information, and second, they should initiate a comprehensive twin-basin hydrological modeling of their region[25] in order to improve the factual basis for further actions.

if action is not taken, the problems will continue to grow with tragic consequences for the people of these countries and possibly for 'others' outside the three countries.

25 Such a comprehensive twin-basin modeling should be compared with the separate-basin model studied up to now (see Trondalen, 2008).

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World Water Assessment Programme side publications, March 2009

During the consultation process for the third edition of the World Water Development Report, a general consensus emerged as to the need to make the forthcoming report more concise, while highlighting major future challenges associated with water availability in terms of quantity and quality.

This series of side publications has been developed to ensure that all issues and debates that might not benefit from sufficient coverage within the report would find space for publication.

The 17 side publications released on the occasion of the World Water Forum in Istanbul in March, 2009, in conjunction with *World Water Development Report 3: Water in a Changing World*, represent the first of what will become an ongoing series of scientific papers, insight reports and dialogue papers that will continue to provide more in-depth or focused information on water–related topics and issues.

Insights

IWRM Implementation in Basins, Sub-Basins and Aquifers: State of the Art Review
by Keith Kennedy, Slobodan Simonovic, Alberto Tejada-Guibert, Miguel de França Doria and José Luis Martin for UNESCO-IHP

Institutional Capacity Development in Transboundary Water Management
by Ruth Vollmer, Reza Ardakanian, Matt Hare, Jan Leentvaar, Charlotte van der Schaaf and Lars Wirkus for UNW-DPC

Global Trends in Water-Related Disasters: An Insight for Policymakers
by Yoganath Adikari and Junichi Yoshitani at the Public Works Research Institute, Tsukuba, Japan, for the International Center for Water Hazard and Risk Management (ICHARM), under the auspices of UNESCO.

Inland Waterborne Transport: Connecting Countries
by Sobhanlal Bonnerjee, Anne Cann,Harald Koethe, David Lammie, Geerinck Lieven, Jasna Muskatirovic, Benjamin Ndala, Gernot Pauli and Ian White for PIANC/ICIWaRM

Building a 2nd Generation of New World Water Scenarios
by Joseph Alcamo and Gilberto Gallopin

Seeing Traditional Technologies in a New Light: Using Traditional Approaches for Water Management in Drylands
by Harriet Bigas, Zafar Adeel and Brigitte Schuster (eds), for the United Nations University International Network on Water, Environment and Health (UNU-INWEH)

Dialogue Series

Water Adaptation in National Adaptation Programmes for Action Freshwater in Climate Adaptation Planning and Climate Adaptation in Freshwater Planning
by Gunilla Björklund, Håkan Tropp, Joakim Harlin, Alastair Morrison and Andrew Hudson for UNDP

Integrated Water Resources Management in Action
by Jan Hassing, Niels Ipsen, Torkil-Jønch Clausen, Henrik Larsen and Palle Lindgaard-Jørgensen for DHI Water Policy and the UNEP-DHI Centre for Water and Environment

Confronting the Challenges of Climate Variability and Change through an Integrated Strategy for the Sustainable Management of the La Plata River Basin
by Enrique Bello, Jorge Rucks and Cletus Springer for the Department of Sustainable Development, Organization of American States

Water and Climate Change: Citizen Mobilization, a Source of Solutions
by Marie-Joëlle Fluet, International Secretariat for Water; Luc Vescovi, Ouranos, and Amadou Idrissa Bokoye, Environment Canada

Updating the International Water Events Database
by Lucia De Stefano, Lynette de Silva, Paris Edwards and Aaron T. Wolf, Program for Water Conflict Management and Transformation, Oregon State University, for UNESCO PCCP

Water Security and Ecosystems: The Critical Connection
by Thomas Chiramba and Tim Kasten for UNEP

Scientific Papers

Climate Changes, Water Security and Possible Remedies for the Middle East
by Jon Martin Trondalen for UNESCO PCCP

A Multi-Model Experiment to Assess and Cope with Climate Change Impacts on the Châteauguay Watershed in Southern Quebec
by Luc Vescovi, Ouranos; Ralf Ludwig, Department of Geography, University of Munich; Jean-François Cyr, Richard Turcotte and Louis-Guillaume Fortin, Centre d'Expertise Hydrique du Québec; Diane Chaumont, Ouranos; Marco Braun and Wolfram Mauser, Department of Geography, University of Munich

Water and Climate Change in Quebec
by Luc Vescovi, Ouranos; Pierre Baril, Ministry of Transport, Québec; Claude Desjarlais ; André Musy; and René Roy, Hydro-Québec. All authors are members of the Ouranos Consortium

Investing in Information, Knowledge and Monitoring
by Jim Winpenny for the WWAP Secretariat

Water Footprint Analysis (Hydrologic and Economic) of the Guadania River Basin
by Maite Martinez Aldaya, Twente Water Centre, University of Twente and Manuel Ramon Llamas, Department of Geodynamics, Complutense University of Madrid, Spain

From Potential Conflict to Cooperation Potential' (PCCP) facilitates multi-level and interdisciplinary dialogues in order to foster peace, co-operation and development related to the management of shared water resources.

Housed within IHP, and a contribution to WWAP, PCCP uses research and capacity building activities to bring players engaged in transboundary water management together and help them increase the opportunities for actual co-operation and development.

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