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POTENTIAL IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES AND ADAPTATION MEASURES IN THE ESCWA REGION

Summary

Despite the fact that the ESCWA region was historically the lowest contributor to global warming, scientific projections indicate with a high degree of confidence that climate change will disproportionately affect it. As at 2004, the total share of the ESCWA region was limited to 3-4 per cent of global emissions. Water in the ESCWA region is central to both climate change and human development and most of the impacts of climate change will hit the region through its scarce water resources.

Of the many social, economic and environmental impacts and vulnerabilities to climate change, the projected impacts of climate change on the qualitative and quantitative status of water resources in the ESCWA member countries are critical for people's lives and the economy in the region. Impacts of climate change on water resources might affect a wide range of socio-economic and environmental sectors including agriculture, health, public safety, biodiversity, desalination industry, tourism, hydropower production and river navigation.

In view of the challenges ahead, ESCWA prepared a paper to review the potential impacts of climate change on the water resources sector in the ESCWA region; identify feasible adaptation measures and approach to improve resilience of the ESCWA member countries to cope with and minimize the negative implications of climate change on the water sector; and finally identify the main climate change challenges to face managers of water resources in the region.

Furthermore, the paper proposes a vision for adaptation of the water sector to climate change in the ESCWA region. It highlights the importance of preparing a vulnerability assessment prior to the development of any climate change adaptation strategy for the region. Moreover, it stresses the need to mainstream adaptation of water sectors to climate change into Integrated Water Resource Management (IWRM) plans in order to more effectively respond to climate change impacts. The paper concludes with a set of expected challenges that water managers might face when responding to climate change threats to the water sector.

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I. INTRODUCTION

1. The latest Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007a) projected that global average temperatures in 2100 will be 1.8-4.0 °C higher than the 1980-2000 average. Sea levels are projected to rise 0.18-0.59 metres (m) by 2100. Rahmstrof et al. (2007) and Hansen (2005) indicated in a more recent estimate that the projected future sea level rise from business-as-usual emissions will range from 0.5 to 1.4 m in this century. More frequent and intense extreme weather events (including drought and flooding) are also expected.

2. Despite the fact that the ESCWA region was historically the lowest contributor to global warming, scientific projections indicate with a high degree of confidence that climate change will disproportionately affect it. As at 2004, the total share of the ESCWA region was limited to 3-4 per cent of global emissions. Water in the ESCWA region is central to both climate change and human development and most of the impacts of climate change will hit the region through its scarce water resources.

3. Of the many social, economic and environmental impacts and vulnerabilities to climate change, the projected impacts of climate change on the qualitative and quantitative status of water resources in the ESCWA member countries are critical for people's lives and the economy in the region. Impacts of climate change on water resources might affect a wide range of socio-economic and environmental sectors including agriculture, health, public safety (hurricane Gono in Oman), biodiversity, desalination industry, tourism, hydropower production and river navigation (case of Egypt).

4. The main consequences of climate change related to water resources in the ESCWA region can, conceptually, be attributed to increases in temperature, lower soil humidity, higher evaporation-transpiration, shifts in precipitation patterns in terms of temporal and geographic distribution, extreme annual and seasonal variability, down-pouring and flash flooding, frequent droughts and desertification, less snow cover at high altitudes (mountain terrains in Lebanon, Syrian Arab Republic and to a much smaller extent in Iraq), and the possible damaging impact of future sea level rises on the near-shore fresh groundwater resources. Furthermore, climate change is expected to negatively impair water quality (pollution of surface water and seawater intrusion to groundwater aquifers). The expected changes will undoubtedly have impacts on all the socio-economic and environmental goods and services that depend on these variables either directly or indirectly. The consequences are far-reaching in the ESCWA region and are likely to be felt the hardest by the most vulnerable groups such as women, the elderly, children, the poor and disadvantaged.

5. In general, the impacts of climate change on the water sector will undermine national development plans, affect human security and livelihoods and act as a push factor for massive population movements and migration (environmental refugees). The situation can be further complicated by the heavy reliance of the region on international fresh water resources from upstream countries. Water scarcity can trigger international conflicts and disputes among countries sharing water resources at interregional and intraregional levels.

6. Climate change scenarios for the water sector in the ESCWA member countries cannot be discussed in isolation from fast population growth, industrial development, urbanization and the need for irrigation water to feed a growing population.

7. The socio-economic costs and possible benefits of climate change to the water sector in the ESCWA region are very difficult to determine. Costs would include the costs of damages (displacement due to extreme events, deterioration in water quality, soil erosion, loss of biodiversity, etc.) and the costs of adaptation to reduce or avoid damage (construction of dikes, new dams and reservoirs, desalination plants, water treatment plants, pumping stations, etc.). With respect to water supplies and sanitation, it is projected that the costs will be significantly higher to accommodate for higher variability in water quality and to retrofit the water and wastewater treatment infrastructures to cater for different water characteristics.

8. The main objectives of this paper are to review the potential impacts of climate change on the water resources sector in the ESCWA region; identify feasible adaptation measures and approach to improve resilience of the ESCWA member countries to cope with and minimize the negative implications of climate change on the water sector; and finally identify the main climate change challenges to face managers of water resources in the region.

II. REVIEW OF THE POTENTIAL IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES IN THE ESCWA REGION

9. Using global climate models to compare the effectiveness of various climate-forcing agents, including Green House Gases (GHGs), Hansen et al. (2005) projected intensifying dry conditions in the Mediterranean region and the Middle East. During his investigation for potential sudden climate change, Shindell (2007) noticed that water stress might become more acute in the Mediterranean and the Middle East. He estimated the rainfall to decrease by 25 per cent at a regional level and by up to 40 per cent in some specific localities.

10. Alpert et al (2004) attributed higher frequency of dry Red Sea trough systems to the dominant decreasing trend of rainfall in the Eastern Mediterranean. In a different study, Alpert et al. (2008) found that average temperature in the Mediterranean region increased by 1.5 to 4 C^{o} and predicted an increase of 4 to 6 C^{o} in the years 2071-2100. They also projected a tendency towards extreme events and revealed that precipitation in most of the Mediterranean was dominated by a negative trend during the last 50 years.

11. In a projection of rainfall and stream-flow in the "Fertile Crescent" using a high resolution global climate model (20 Km), Kitoh et al. (2008) indicated that by the end of the 21st century, the Fertile Crescent will lose its current shape and might disappear altogether. The alarming study projected that the discharge of the Euphrates River will decrease by 29 to 73 per cent as will the stream-flow of the Jordan River.

12. Ragab and Prudhomme (2000) indicated that by the year 2050 the dry period extending from April to September will experience a reduction of 20 to 25 per cent in the present values of rainfall. Meanwhile, during the wet seasons, the rainfall will decrease by 10 to 15 per cent in North Africa, some parts of Egypt, Syrian Arab Republic, Jordan, Palestine and Saudi Arabia.

13. By using different general circulation models (GCMs), Bou-Zeid and El-Fadel (2002) projected that by the year 2020, Lebanon will witness a 15 per cent decrease in availability of water resources and a 6 per cent increase in water demand for agriculture.

14. In their investigation on the impact of climate change on water availability in the Middle East and the Upper Jordan catchment, Kunstmann et al. (2007) projected a 25 per cent decrease in the mean annual precipitation in the Upper Jordan catchment, a decrease of 23 per cent in total runoff at the outlet, coupled with a significant decrease in groundwater recharge.

15. The overall picture that emerges from the limited literature on the region and from IPCC (2007a) projections indicates that water availability will be highly sensitive to climate change. Climate change will have significant impacts on freshwater; affecting both availability of freshwater and frequency of floods and droughts in the ESCWA member countries. Climate change might undermine national development plans, affect human security and livelihoods, significantly impact agriculture, tourism and industry and act as a push factor in population movements and migration.

16. Table 1 compiles the potential impacts of climate change on vulnerable sectors in each ESCWA member country as stated in published literature, IPCC (2007c) report and national communications to the United Nations Framework Convention on Climate Change (UNFCCC).

TABLE 1. VULNERABLE SECTORS AND POSSIBLE IMPACTS OF CLIMATE CHANGE IN THE ESCWA MEMBER COUNTRIES
(Modified from Food and Agriculture Organization of the United Nations 2008 report)

Country	Vulnerable sectors and possible impacts of climate change	Reference
Bahrain	Low-lying areas of the country's islands vulnerable to sea level rise.	Bahrain's initial communication to UNFCCC secretariat.
Egypt	Reduced productivity of crops and increased water requirements. Heavily populated Nile Delta vulnerable to sea level rise.	IPCC (2007b).
Iraq	Possible impacts on Tigris-Euphrates stream flow and increasing irrigation demand.	IPCC special report on the regional impacts of climate change: an assessment of vulnerability, Middle East and Arid Asia 1997.
Jordan	Increasing irrigation demand with possible rainfall decrease adds stress to already scarce water resources.	IPCC special report on the regional impacts of climate change: an assessment of vulnerability, Middle East and Arid Asia 1997.
Kuwait	Low coastal areas vulnerable to sea level rise. Storm surges affect coastal oil production.	IPCC special report on the regional impacts of climate change: an assessment of vulnerability, Middle East and Arid Asia 1997.
Lebanon	Increased stresses in water resources. Shift of arable area to more arid climate zone. Negative impacts on citrus, olive, apple and sugar beet production.	Lebanon first national communication to UNFCCC secretariat.
Oman	Seawater intrusion into freshwater aquifers. Storm surges affect coastal oil production. Decreasing groundwater level.	IPCC special report on the regional impacts of climate change: an assessment of vulnerability, Middle East and Arid Asia 1997.
Qatar	Increasing water stress. Storm surges affect coastal oil production.	IPCC special report on the regional impacts of climate change: an assessment of vulnerability, Middle East and Arid Asia 1997.
Saudi Arabia	Water stress will increase due to warmer temperature.	First national communication of Saudi Arabia to UNFCCC secretariat.
The Sudan	Decreased precipitation and increased temperature and evaporation will lead to reduced groundwater recharge. Water stress will increase. Dependence on water originating outside border. Projected decrease of millet and sorghum.	Sudan's National Adaptation Program of Action 2007.
Syrian Arab Republic	Possible impacts on Tigris-Euphrates stream flow. Increasing irrigation demand.	IPCC special report on the regional impacts of climate change: an assessment of vulnerability, Middle East and Arid Asia 1997.
United Arab Emirates	Seawater intrusion into freshwater aquifers. Storm surges affect coastal oil production.	IPCC special report on the regional impacts of climate change: an assessment of vulnerability, Middle East and Arid Asia 1997.
Yemen	Risk of desertification. Increasing irrigation demand.	IPCC special report on the regional impacts of climate change: an assessment of vulnerability, Middle East and Arid Asia 1997.

III. POTENTIAL IMPACTS OF CLIMATE CHANGE ON SPECIFIC WATER SUBSECTORS IN THE ESCWA REGION

A. IMPACTS OF CLIMATE CHANGE ON GROUNDWATER RESOURCES

17 Groundwater supplies will be at great risk from rising sea levels in the ESCWA member countries. Higher sea level would cause seawater intrusion leading to salinization of ESCWA groundwater aquifers close to coastlines. Excessive withdrawal from aquifers will magnify the problem. Furthermore, many GCMs suggest greater precipitation variability and those downpours will become more intense. This would increase runoff and flash floods while reducing the ability of water to infiltrate the soil to recharge the aquifers (Case of hurricane Gono in Oman). Conceptually, seawater intrusion to coastal groundwater resources might pose a threat to Egypt, Lebanon, Syrian Arab Republic and Gulf States.

B. IMPACT OF CLIMATE CHANGE ON SURFACE WATER RESOURCES

18. Global GCMs predictions for the River Nile system range from an increase of 30 per cent to a decrease of 70 per cent in run-off (Ministry of Water Resources and Irrigation, Egypt, and Ministry of Foreign Affairs, the Netherlands (2001)). Climate change may also reduce Euphrates and Tigris flow by as much as 30-50 per cent (IPCC 2007a). As more winter precipitation falls as rain instead of snow in the Syrian Arab Republic, Lebanon and parts of Iraq, water managers will have to balance the need to fill reservoirs for water supply and the need to maintain reservoir space for winter flood control. Additional storage needs to be developed to equalize variability with high economic and environmental costs. Diminished snow-melt (Lebanon and Syrian Arab Republic) flowing through dams will decrease the potential for hydropower production. Climate change will also have serious implications for winter tourism in Lebanon due to declines in snow-pack leading to a much shorter ski season.

C. IMPACT OF CLIMATE CHANGE ON THE DESALINATION INDUSTRY

19. Desalination is projected to be one of the main future options to fill the gap between water supply and demand. However, climate change will affect the physical, biological and bio-geo-chemical characteristics of the water bodies surrounding the ESCWA region. In this connection, it is projected that climate change leading to a higher temperature of cooling water will reduce the efficiency of the power-desalination production operation. Also high salinity resulting from evaporation of feed water in semi-enclosed seawater intakes might affect production capacity of desalination plants.

20. Higher temperature of near-shore seawater will lead to an increase in the biological content and algae blooms forcing the use of higher doses of chlorine at intakes to control bio-fouling. In turn, higher chlorine doses would chemically react with natural organic precursors to form the carcinogenic brominated trihalomethanes (THMs). These brominated Volatile Liquid Hydrocarbons (VLHs) would appear in the produced drinking water by co-distillation.

D. IMPACTS OF CLIMATE CHANGE ON WATER QUALITY

21. Higher water temperature will affect the redox potential, dissolved oxygen, stratification, mixing rate, biological growth and self-purification with significant consequences for water quality higher temperature will also promote algal blooms and increase the bacterial and fungal content. With such a high biological content, chlorination of drinking water for disinfection purposes will lead to bad odour and taste and the formation of toxins. Furthermore, the extreme events of flood will also lead to the release of more nutrients, suspended solids, pathogens, pesticides, heavy metals and toxins washed into surface water bodies following intense raining. On the other hand, droughts will also lead to stagnation of surface water; eutrophication; accumulation of sediments, bio-accumulation and bio-magnification of pollutants.

22. Due to degradation in surface water quality, numerous diseases can be transmitted either by drinking or by consuming crops irrigated with water polluted through extreme events of rainfall or extended drought in the region.

E. Impacts of climate change on shared water resources

23. Impacts of climate change on internationally shared water resources in the ESCWA region would probably raise the issue of equity and increase the potential for political conflict. If climate change has its predicted impacts on reducing water resources in the region, interregional and intraregional conflicts could be sparked by competition over varying and declining water resources with up-stream countries. Furthermore, displacement and mass immigration by cross-border movements of environmental refugees might also lead to North-South political conflicts.

IV. A VISION FOR ADAPTATION OF THE WATER SECTOR TO CLIMATE CHANGE IN THE ESCWA REGION

24. Adaptation of the water sector to climate change can be defined as actions societies take in response to, or in anticipation of, projected or actual climate change, to reduce adverse impacts posed by climate change. Anticipatory adaptation takes place before impacts of climate change are observed such as construction of baffles to prevent seawater intrusion to groundwater erection of dams, relocation of communities, etc. On the other hand, reactive or planned adaptation is the result of a deliberate policy decision by water resources stakeholders, based on an awareness that conditions have changed or are about to change and that action is required to return to a desired state.

25. At present, ESCWA member countries opt for an ad-hoc approach known as spontaneous or autonomous adaptation, which does not constitute a conscious response to climatic stimuli, but it is rather triggered by changes in natural hydrological systems and by market changes in human systems. It is worth noting that due to the importance of the water sector, Governments should not leave adaptation to climate change entirely to social or market forces.

26. In order to adapt the water sector to climate change, we first need to know precisely what component of the water sector will be affected by climate change and to what extent. Therefore, it is safe to assume that no adaptation can be envisioned without prior vulnerability assessment. Conceptually, the logic sequence for developing an adaptation strategy for the water sector in the ESCWA member countries would include:

A. Step 1: A vulnerability assessment

27. Vulnerability can be defined as the characteristics of a community in terms of their capacity to anticipate, cope with, resist and recover from the impact of climate change on the water sector. The vulnerability assessment provides a means of understanding how the impacts of climate change will be distributed, primarily to identify how vulnerability can be reduced.

28. Vulnerability assessment of the water sector will provide answers to two central questions: (a) how dangerous is climate change to the water sector in the ESCWA member countries? (b) how can the water sector adapt to climate change? The first question will be answered by scaling down GCMs by meteorologists leading the vulnerability assessment exercise. The second question can be answered by involving stakeholders and communities using a bottom-up approach.

29. Despite the fact that significance of climate change depends on the degree of change in the water sector and the characteristics of the society exposed to it, many ESCWA member countries appear to be far more vulnerable to climate change due to the following factors:

(a) Climate-induced changes in temperature and precipitation will occur unevenly, where ESCWA member countries on the Mediterranean will be suffering the most;

(b) The resources and wealth are distributed unevenly among communities in the ESCWA member countries;

(c) Non-oil exporting ESCWA member countries are more vulnerable to and have fewer adaptive capacities to climate change than developed nations around the world due to: (i) overpopulation (relative to current productivity, income and natural resources); (ii) debilitated ecological base (land degradation and fragmentation); and (iii) over-dependence on climate-sensitive sectors, mostly agriculture, grazing, eco-tourism, aquaculture, etc.;

(d) Technological skills and human resources are relatively limited;

(e) Poor pre-existing health conditions and services in some ESCWA member countries;

(f) Chronic political instability and military conflicts in occupied territories;

(g) Heavy reliance on international freshwater resources from upstream countries.

30. For vulnerable groups, adaptation strategies in the water sector are vital, as failure to adapt could lead to "significant deprivation, social disruption and population displacement, political instability and even morbidity and mortality". The problem lies in identifying those adaptations that respond to the needs of the most vulnerable groups in ESCWA member countries.

B. STEP 2: DEVELOPMENT OF A CLIMATE CHANGE ADAPTATION STRATEGY FOR THE WATER SECTOR IN THE ESCWA MEMBER COUNTRIES

31. As an outcome of the vulnerability assessment, managers of water resources in the region will be able to formulate an adaptation strategy for the water sector. In developing an adaptation strategy for water resources, managers of water resources need to distinguish between two types of adaptation, namely facilitation and implementation:

(a) *Facilitation* involves activities that enhance the adaptive capacity of the water sector namely, awareness generation, capacity-building, institutional and governance structure strengthening, etc.), thereby improving conditions for the implementation of adaptation measures;

(b) *Implementation* refers to activities that actually assist in alleviating and/or avoiding adverse impacts of climate change on the water sector.

32. Ragab and Prudhomme (2000) concluded that in light of the water shortage predictions in the Middle East region in this century, major water infrastructures need to be developed and innovative water resources management need to be adopted in order to increase water efficiency. They stressed the need to increase water productivity and accelerate the development of non-conventional water resources in the region. Furthermore, Bou-Zeid and El-Fadel (2002) came to the same conclusion with more emphasis on the development of non-conventional resources.

33. The development of an adaptation strategy can be illustrated by examples of adaptation of water management components to climate change as listed in table 2.

TABLE 2. EXAMPLES OF ADAPTATION OF WATER MANAGEMENT COMPONENTS TO CLIMATE CHANGE

Vulnerable water management components	Adaptation on the supply side	Adaptation on the demand side
Municipal water supplies	• Increase reservoir capacity • Desalinate • Inter-basin transfer • Rain harvest	• Use Grey water • Improve water use efficiency • Reduce leakages • Conserve • Use economic instruments • Enforce water legislations
Protection from pollution (Degradation of Water Quality)	• Enhance treatment works • Reuse and reclaim • Upgrade water protection	• Reduce effluent volume of waste • Promote alternatives to chemicals
Agriculture		
• Rain-fed	• Improve soil conservation • Supplement from other sources as needed • Develop bio-saline agriculture technology	• Use drought tolerant crops
• Irrigated	• Improve tilling practices • Harvest rainwater • Reuse adequately treated domestic wastewater	• Increase irrigation efficiency • Empower local water users associations • Activate economic instruments
Flood Management	• Build reservoirs and levees • Protect and restore wetlands	• Upgrade flood warnings • Reduce floodplain development

C. STEP 3: MAINSTREAMING ADAPTATION OF WATER SECTORS TO CLIMATE CHANGE INTO IWRM PLANS IN ESCWA MEMBER COUNTRIES

34. The primary objective for ESCWA member countries is to ensure that "adaptation of water sector to climate change" became part of programmes that further sustainable development planning. Embedding climate change adaptation into sector policies, programmes and projects, expands the range of opportunities for reducing vulnerability and also enables impacts to be addressed in a more streamlined and economically efficient manner. After the water sectors develop a strategy for adaptation to climate change and identify priority areas for enhancing adaptive capacity, more work will be needed to ensure that IWRM policies, programmes and projects incorporate these findings. Within a sustainability context, an adaptation strategy for the water sector in ESCWA region should have the following priorities:

First priority: To reduce the vulnerabilities of people and societies to shifts in hydro-meteorological trends, increased climate variability and extreme events.

Second priority: To protect and restore vital ecosystems that provide critical land and water resources and services.

Third priority: To close the gap between water supply and demand by enhancing actions aimed at reducing demand.

V. CLIMATE CHANGE CHALLENGES TO MANAGERS OF WATER RESOURCES IN THE ESCWA REGION

35. As a conclusion, all predictions indicate that climate change will reduce the overall amount of rain by 20 per cent and will increase variability making it much harder to manage. Even if emissions of GHGs were stabilized today, water availability and flooding problems will continue in the region for many decades to come. Coping with the most severe consequences of climate change in the region would require major changes in water management concepts, attitude and some times institutional and legislative infrastructure. The following are the main expected challenges to face water managers in light of climate change threats to the sector:

(a) *First challenge*: Most water resources managers in ESCWA member countries are influenced by a water resources management culture that is based on minimum variability. The introduction of uncertainty elements in water resources management in the region as a result of climate change represents an unprecedented challenge to water mangers;

(b) *Second challenge*: Managers of water resources will be compelled to address adaptation as an exclusive measure to reduce the impact of climate change on the water sector. Given the depth of today's water scarcity in the ESCWA region, better management of water resources would be imperative. Climate change is changing the rules of the game. Fortunately, creating new approaches is not the main concern: the main challenge in this connection is rather the incorporation of both anticipatory and reactive adaptation measures into sustainable development and IWRM policies which can work, as already known;

(c) *Third challenge*: Providing additional water supplies to meet increasing water demand and alleviate droughts can involve more investment in energy for desalination, pumping stations for inter-basin transfer and wastewater treatment for reuse. These measures often increase consumption of fossil fuel leading to higher GHGs emissions constraining national climate change mitigation measures. Water resources managers need to ensure that the adopted measures will not offset mitigation of GHGs emissions. The main challenge in this connection is to link adaptation to mitigation which currently operate separately at all governance levels in the region;

(d) *Fourth challenge*: The inadequacy (in some instances total absence) of research and information on vulnerability of societies and ecosystems to climate change in ESCWA member countries will hinder efforts to develop adaptation strategies for the water sector. The main challenge in this connection is to improve national capacities in the development of effective anticipatory and reactive adaptation strategies by conducting vulnerability assessments to climate change in the water sector and developing better databases on intensity, frequency and effects of extreme events, including responses to these events;

(e) *Fifth challenge*: Implementation of climate change adaptation strategies within national water resources strategic plans is multi-disciplinary in nature and will require interaction and horizontal coordination between multiple levels of Government institutions and the involvement of stakeholders, civil society, business sectors and the public. The challenge facing managers of water resources is to ensure such high level of coordination among concerned sectors and water stakeholders.

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