

Impact of climate change on evaluation of future water demand in the Euphrates and Aleppo basin, Syria

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Abstract Syria is one of the Middle Eastern countries that suffer from scarcity in water resources availability, which affects the growth and development of economic activities. In this research, the Water Evaluation and Planning (WEAP) model is applied to evaluate future water demand in the Euphrates and Aleppo basin (EAB), Syria, by taking into account the climate change that may affect water demand in the domestic, industrial, and agricultural sectors until 2050. The climate change projections of temperature and precipitation were assessed using a new version of the MAGICC/SCENGEN tool with two greenhouse gas emissions scenarios (A2 and B2) of the Intergovernmental Panel on Climate Change (IPCC). Based on the results of IPCC (A2, B2) scenarios projections, the EAB basin is likely to face a decrease in precipitation amount by 21% according to A2 and by 12% according to B2, while temperature would increase by about 2.5°C according to A2 and by 2°C according to B2. Within the three scenarios adopted in this research: (1) available technology development; (2) increasing treated wastewater in agriculture and industry sectors; (3) and two combined scenarios, the results of the simulation demonstrated that the proposed scenarios are effective for reducing stressors on EAB's water resources, but are not sustainable to bridge the gap between demand-supply by the year 2050, which leads to the deterioration of the available water resources.

Key words MAGICC/SCENGEN tool; water resources management; water demand; climate change; WEAP; Euphrates and Aleppo basin

INTRODUCTION

Changes in temperature and precipitation patterns are likely to affect the hydrologic processes and water resources available for agriculture, population, mining, industry, aquatic life and hydropower. Climate changes will accelerate the global hydrologic cycle with an increase in the surface temperature, changes in precipitation patterns and evapotranspiration rates (Bates *et al.* 2008).

The phenomenon of climate change is considered today to be one of the most important discussed issues and contemporary challenges; it has aroused much debate and interest at both national and global levels. Syria cannot be separated from what is happening in the rest of the world. Despite the fact that Syria is not considered a prime contributor to the global emissions of gases (greenhouse), it may be affected by the possible consequences of world climate change (Meslmani 2010).

The 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007a) projects strong changes in climate across Syria. Temperatures are expected to increase, while at the same time substantial decreases in precipitation are projected. These elevated temperatures will result in higher evapotranspiration demands and this, in combination with decreases in precipitation, will severely stress the water resources in the region.

As a result of the above discussion, climate change would likely limit the water supply requirements on a relatively short term, which leads to an intensification of water deficits in various critical basins of Syria and reducing the contribution of dams to irrigation and the potential contribution of artificial lakes to drinking water and irrigation systems during dry seasons.

One of the most effective tools to project precipitation and temperature changes is the MAGICC/SCENGEN tool (Wigley 2008) which based on the climate change scenarios of the IPCC. It is used in many fields of study (Fordham *et al.* 2011, Roshan *et al.* 2012). The outputs from the projections of MAGICC/SCENGEN models were used in the Water Evaluation and Planning (WEAP) software, developed by the Stockholm Environment Institute's US Center (SEI, 2013) for analysis of the gap between demand and supply on water in the future.

Finally, the objective of this study is to assess water demand for the Euphrates and Aleppo basin (denoted by EAB) up to the year 2050, taking into account the effect of changes in climate mainly on water resources in this particular basin.

STUDY AREA AND DATA

Study area

The EAB basin is located in eastern Syria, bordering Turkey to the north; Tigris and Khabour basin to the east; Iraq to the south and both Orontes and al-Badieh basins to the west, as shown in Fig. 1. The basin is distributed among three cities: Aleppo, Al-Raqqa and Deirez-zor. The area of study basin covers about 51 238 km², which represents approximately 28% of the area of Syria, with a total estimated population of 5.9 million inhabitants.

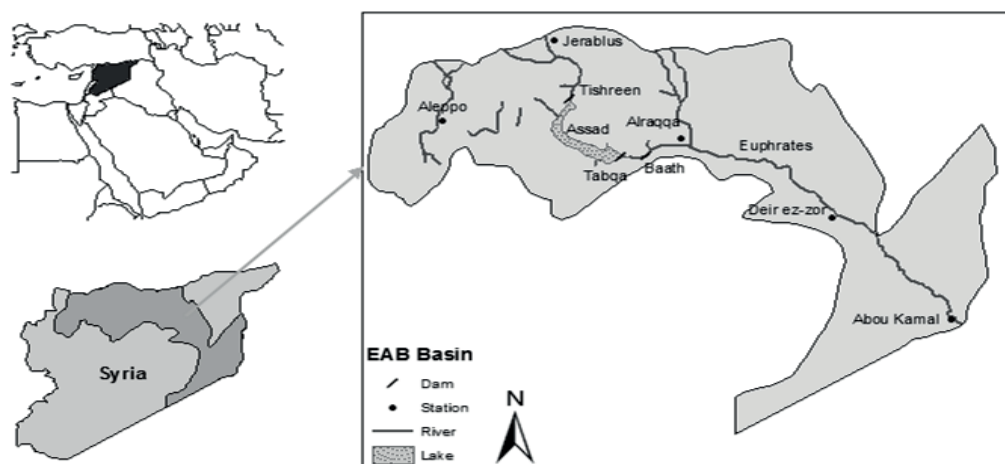


Fig. 1 Map of Syria with study area.

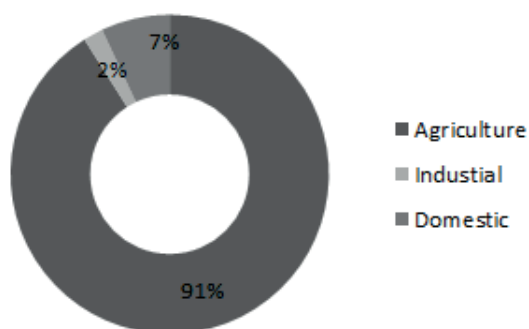


Fig. 2 The water demand requirements by sector for EAB basin (MoI 2012).

The Euphrates is the biggest river flowing in Syria, with a total length of 680 km. It originates in Turkey, flows through Syria, and joins the Tigris in Iraq to form the Shatt al Arab, which discharges into the Persian Gulf. Three dams have been constructed on the Euphrates in Syria (Tabqa, Baath and Tishreen). The mean annual rainfall decreases from 300 mm in the northern regions along the border, to 150 mm in the middle reach of Euphrates valley and 100 mm at Abu Kamal. Water use in the EAB Basin focuses on irrigation, hydropower, industry and drinking water supply.

The total water demand for agricultural, domestic and industrial needs were in 2008 about 7003, 526 and 153 MCM (millions m³) according to the Ministry of Housing and Construction (MoHC 2008) and the Ministry of Irrigation (MoI 2012). More than 90% of available resources are used for the irrigation, as seen in Fig. 2.

Data

The required database of this research were derived from various institutions, such as the MoHC, the MoI, in addition to the five hydrologic control stations (Jerablus, Aleppo, Deir ez-zor, Abu Kamal and AlRaqa) which are positioned in the main stream of the EAB basin. The two climate

change scenarios (A2 and B2) of the IPCC's fourth Special Report on Emission Scenarios (SRES) were used in this paper (IPCC 2007b). This study covers the period 1990–2010 for the base year (denoted by 2008s) and covers the two future periods: 2011–2030 and 2031–2049 for the future year (denoted by 2020s and 2040s, respectively).

MATERIAL AND METHODS

MAGICC/SCENGEN Tool

Many climate change tools have been developed and are currently in use across the world. However, there is no simple way for decision makers and planners to find out which climate compatible development tools are most appropriate to their work and local circumstances.

In this study, the Model for the Assessment of Greenhouse-Gas Induced Climate Change/Scenario Generator (MAGICC/SCENGEN) (Version 5.3) was used to obtain monthly projected changes in temperature and precipitation, based on climate change scenarios, for the EAB Basin. The reader can download the freely available software package from (<http://www.cgd.ucar.edu/cas/wigley/magicc/>). Further details of the software are provided in a companion Technical Manual (Wigley 2008).

The MAGICC/SCENGEN tool has been designed as an accessible piece of software that uses emissions scenarios for greenhouse gases, reactive gases, and sulphur dioxide in order to construct predictions of global mean temperature, sea level rise, and regional climate.

Hydrological model

The hydrologic model used in this study is the WEAP model, which was developed by the Stockholm Environment Institute (SEI). The water system in WEAP is represented in terms of supply sources which include: streamflow, groundwater and reservoir water, of water transfers which include: withdrawal and transmission, and of water demand which include: municipal and industrial demands, irrigation demands and hydropower energy demands (SEI 2013).

The model is semi-theoretical, continuous time, semi-distributed, and deterministic. As the model is semi-theoretical, it needs calibration and verification (Abrishamchi *et al.* 2007). The reader can find more details on this model elsewhere (<http://www.weap21.org/>).

Calibration and validation of WEAP model

In this study, the WEAP model was calibrated and validated to ensure the model discharge simulations fit the observations optimally. The streamflow data of years 1990–1998 and 2000–2010 were used for model calibration and validation, respectively, as shown in Fig. 3. The model was calibrated manually via trial and error method (Yates *et al.* 2005). The calibration parameters were spatially aggregated and modified. A description of these parameters is given in Table 1.

In addition, we adopted statistical characteristics as a criterion for assessing the performance of a model for the calibration and validation period as shown in Table 2.

Table 1 Calibration parameters of WEAP model.

Parameter	Initial value	Step
Effective precipitation	100%	±0.5%
Runoff/Infiltration ratio	50/50	±5/5

Table 2 The results of statistical analysis.

	Calibration period	Validation period
The Root Mean Square Error (RSME)	0.31	0.23
The Correlation Coefficient (R ²)	0.78	0.85

