Policy Brief

May 2019

Hydrology and Climate Change

Image of Karacaöen Reservoir. Duesentrieb 17 November 2006. CC BY-SA 3.0. Wikimedia Commons

Key Findings

The Hydrology and Climate Change Taskforce (TF-HCC) with occupied with modelling the hydrology in the Euphrates and Tigris rivers (Euphrates-Tigris) and understanding how various climate change scenarios would affect the availability of water in the basin. Understanding the impacts of climate change on hydrology will help policymakers and legislators plan for the potential changes and maintain the food, water, and economic security of the populations that are reliant on the resources in the riparian areas.

Modelling results (using the HYPE model) show that climate change will significantly reduce available water resources in the Euphrates-Tigris basin in the future, especially towards the end of the current century. The basin will face reductions in snow accumulation and coverage in the upstream regions, worsening water scarcity, increased frequency and intensity of floods and droughts, and damage to water quality and ecosystems. These impacts on water resources will have cascading effects on human health, economy and society across the basin. These results emphasize an urgent need for continued and enhanced collaboration between the countries sharing and managing the water resources in the region.

Key Messages

The HYPE hydrological modelling of the three sub-basins in the Euphrates and Tigris basin forecasts significant reductions in river flow. The net change in annual river flow for the Karasu river (North) for the period 2071 to 2100 varies between +2% to -5% flow. For Lesser Zab (Northeast) the change in river flow was estimated to range between -9 to -27%, while the Karkheh's (East) flow can be expected to change by -10 to -19%. While this analysis is only an estimate of expected changes across the basin it provides direction for both immediate and long-term planning. These results align with observations that the changing climate will more severely impact the eastern part of the Euphrates and Tigris basin.

The HYPE model calibration results for 2081-2100 show that under the milder climate change scenario (RCP4.5) the Euphrates at the border between Turkey and Syria will experience a reduction in peak flow in June from approximately 1,240 m^3/s to 1,190 m^3/s. Under the RCP8.5 scenario however, peak flows decline to 770 m^3/s, a reduction of -38%.

Evapotranspiration increases at higher ambient temperatures; higher evaporation rates from upstream areas will adversely impact downstream water availability.

The rainfall pattern towards the end of the 21st century is expected to shift eastwards in the direction of the Zagros mountains and northwards to Northeast Turkey and Armenia, with reduced rainfall in the Euphrates and Tigris basin. The Tigris basin seems to be more vulnerable from this process than the Euphrates. Rivers like the Lesser Zab are projected to flow 9 to 27% less, depending on the emission scenario (RCP4.5 or RCP8.5).

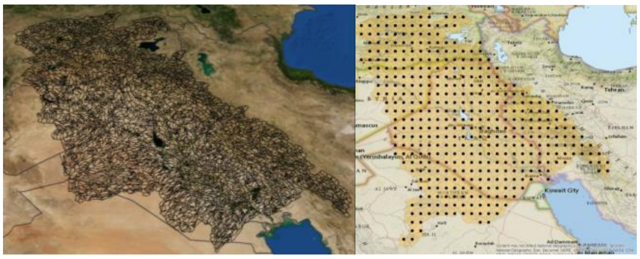
ANALYSIS OF HYDROLOGY AND CLIMATE CHANGE

INTRODUCTION

The Euphrates-Tigris basin is one of the most vulnerable regions to the potential ravages of climate change. The region is already experiencing rising temperatures, leading to hotter summers and more frequent heat waves. The reduced rainfall predicted for the future will further exacerbate regional water shortages. Weather patterns are becoming more unpredictable, and the region is subject to growing extremes in terms of unusual meteorological events, droughts and floods, and shifts in seasons. There is increasing variability in river flows and recharge to groundwater aquifers.

TF-HCC provided an assessment of meteorological, hydrological, and climatic conditions of the basin. The Swedish Meteorological and Hydrological Institute (SMHI) led the efforts under this taskforce, supported by the taskforce members of the project Country Partners. The taskforce evaluated the overall water balance for the Euphrates-Tigris basin for past and present climate conditions, and for future climate scenarios - and developed appropriate tools and models to do this. Initially, it was planned to configure and calibrate the most suitable hydrological model as correctly as possible for the entire basin. However, because of the limited access to data from the nationally monitored observation stations, it was agreed to set up the model for selected representative sub-basins only. This taskforce also focused on delivering training in hydrological modelling to the Country Partners.

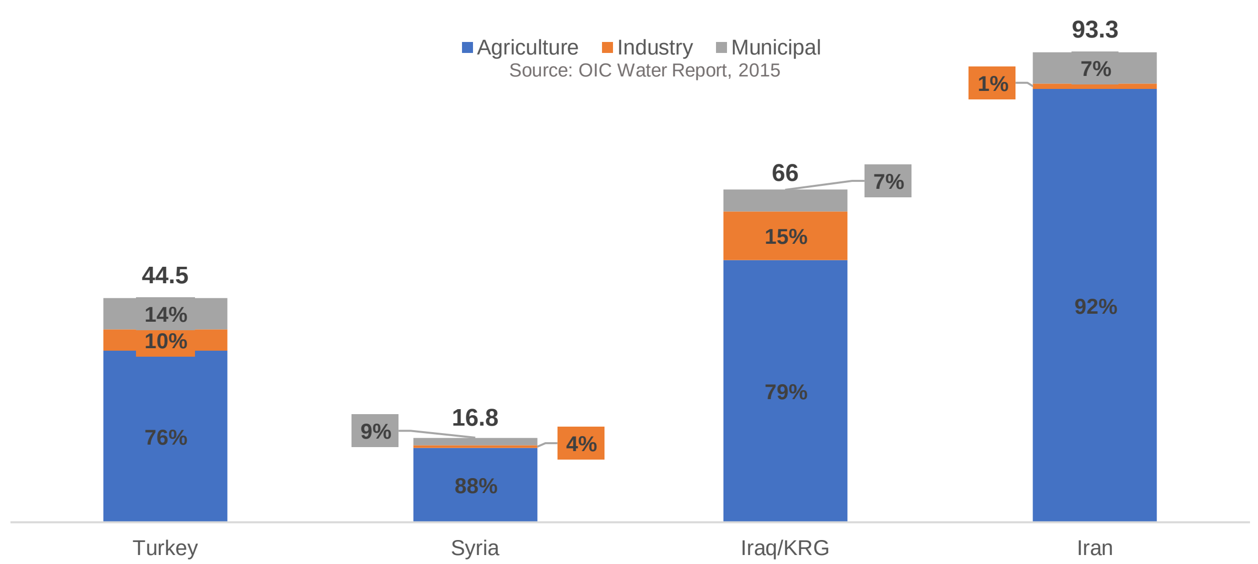
After evaluating various alternatives, the Taskforce decided to set up and use the HYPE model as the most logical option. The HYPE model had been previously used in the region under the UN-ESCWA RICCAR project, and the overall setup of the model at a coarser resolution was already completed. The model accommodates most of the selection criteria for hydrological modelling of the basin. Additionally, open source input data (precipitation and temperature) was available and pre-processed, and a structure including scripts to run and present the results from climate change simulations was in place at SMHI. The taskforce used gridded observed datasets that are publicly available for free of charge. These data have gone through quality control checks and further processing to improve their usability.

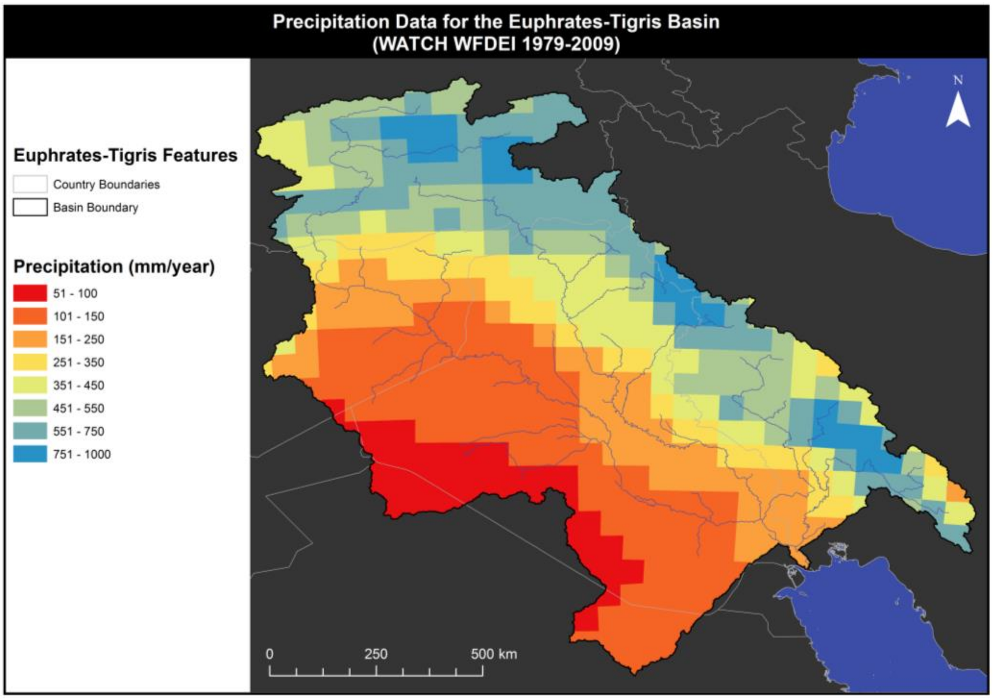


The HYPE Model sub-basin delineation used in the CPET project (left map) and the resolution for the input data from the WFDEI dataset with 50 km grid cells (right map).

The Euphrates-Tigris basin was divided into approximately 1,600 sub-basins with an average area of some 550 km^2. In the model, the individual sub-basins are linked together from the headwaters to form tributaries and finally the main river channels. The HYPE model can also be used to simulate river discharge at any sub-basin location between discharge monitoring stations. Results can, for example, be used for assessing potential hydropower production or irrigation water availability at various points of interest.

Syria, Iraq/KRG and Iran (in billion cubic metres (km^3) and percent (%) of national total).





Historical WATCH-WFDEI precipitation (1979-2009) data used by TF-HCC for the Euphrates-Tigris Basin.

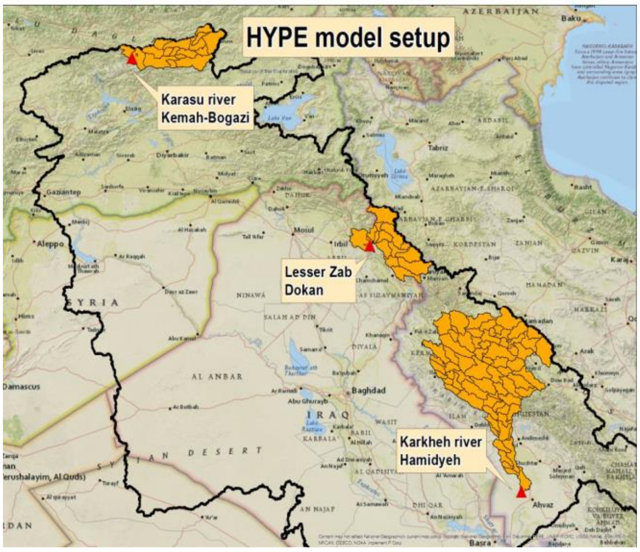
STUDY FINDINGS

Hydrological simulations with future climate

The impacts of future climate projections on flows were simulated using the HYPE model for the selected three study sub-basins: the Karasu River in the upper Euphrates basin in Turkey, the Lesser Zab River in the Tigris basin, Iraq (KRG), and the Karkheh River in the Tigris basin, Iran. Once calibrated using historical observations, climate change projections were introduced to assess how river flows in these sub-basins would respond to changing temperatures and precipitation. All three sub-basins showed decreasing river flows as a response to the changing climate, although with varying degrees of magnitude. The Karasu River exhibits the mildest response, while the Karkheh River shows a stronger response in the form of projected larger decreases in river discharge. For all three sub-basins the hydrological response to changing climate is less clear until about 2050, but a trend of decreasing river flows becomes more apparent thereafter. As could be expected decreasing flows are far more pronounced for the more severe emissions scenario (RCP8.5) than for lower emissions (RCP4.5). The most robust signal of decreasing flow is seen for the Karkheh River after mid-century under the RCP8.5 scenario.

Summary of large-scale hydrological impacts

Peak river discharge flows will be affected by a changing warmer climate in both the Euphrates and the Tigris basins. Snow accumulation and snowmelt would be the primary changing pattern in the basin with less snow and snowpack accumulation due to warmer temperatures. More precipitation will fall in the form of rain than snow, directly impacting on runoff. Under the milder climate change scenario, RCP4.5 (i.e., with global greenhouse gas (GHG) emissions peaking around year 2040 and then declining), more runoff will occur in the winter months as compared to the present climate. Under the scenario RCP8.5 (GHG emissions continue to rise throughout the 21st century), there is a diminishing of peak flows without much increase in winter flows.



Selected study sub-basins for HYPE model simulations of water flow and future climate projections

For both the Euphrates and Tigris rivers, the RCP8.5 scenario has a far more severe impact than RCP4.5. This is particularly true for the Euphrates River. Under the RCP4.5 scenario, seasonal river flow regimes will change (as a result of more rainfall in winter months) but without much change in annual runoff. Under the RCP8.5 scenario, both seasonal river flows and annual runoff will change, which is a much more serious impact.

Any changes in river flow in the headwater regions will have an impact on reservoir efficiency and operations.

Seasonal flow changes could be partially compensated by modification of reservoir operating rules to match the changing patterns of inflow to the reservoirs and through outflow optimizations. Changes in annual volumes would present bigger challenges to existing reservoir storage, particularly if as severe as the decreasing inflows projected under the RCP8.5 scenario.

Management Scenarios

The taskforce members also held preliminary discussions to define ideas for management scenarios for adaptive water resources management in the Euphrates-Tigris basin. None of these suggested management scenarios has yet been simulated. The various options first need to be reviewed and vetted by relevant water resource representatives in the respective countries so that simulations are not unnecessarily undertaken on unacceptable suggestions. Development and simulation of the impacts and adaptive value of these management scenarios would be an important task for the new project of the CPET.

Data sharing within the CPET: The sharing of data within the CPET among the Country Partners is the first such sharing of data that is known to date. Although delayed and in some cases limited only to a few observation stations, this data sharing can therefore be considered as one of the important outcomes of the CPET, hopefully paving the way for a more open attitude in the future.

CONCLUDING REMARKS AND RECOMMENDATIONS

The analysis of TF-HCC modelled the hydrology and the possible changes to it under various climate change scenarios. Although future climate projections inherently include many uncertainties, the analysis shows that climate change will have an adverse effect on availability of water resources in the Euphrates-Tigris basin.

It is important to note that human interventions have a major impact on hydrological processes in the riparian areas, making accurate representation in models a difficult process. Nevertheless, modelling tools present an opportunity to assess current conditions in the basin and investigate the effects of changing conditions into the future.

As most of the renewable water resources originate in the mountainous headwater regions, warming temperatures are expected to impact snowfall and snow accumulation processes, and thus hydrological flows. As temperatures increase, runoff will decrease even if precipitation does not change. Even for milder temperature increases, river flows will change seasonally as less snow would be stored in the mountainous regions and thus less wintertime storage would be possible. However, the climate change signal is not uniform and climate change impacts will vary across different sub-regions of the basin. To successfully adapt to climate change, it is important that the basin countries continue to work together on hydrological modelling beyond this project.

Further Steps

Explore historic (20-30 year) time series of Precipitation (P), Normalized Difference Vegetation Index (NDVI), soil moisture, and surface temperature (Ts). Weather shifts and anomalies, trends in land degradation, and ongoing changes in land surface processes will all be better understood.
Update the water scarcity map for the period 2015-2025
Create accurate and high-resolution land cover and land use maps, including maps for specific crop types
Map net water withdrawals (P_{net} – ET_{act}) on a monthly basis using satellite data
Set up the HYPE model using maps of net withdrawals for estimating gross water withdrawals and mimic the reservoir operations related to these
Optimize reservoir operations with the primary use of water for agricultural purposes rather than energy generation
Introduce a basic system for water accounting
Report annual and monthly water balances for every country
Evaluate new open access databases for information on reservoir levels, lake sizes, cropping areas, surface temperatures, etc.
Triangulate observations, models and earth observations
Evaluate the performance of current irrigation systems (equity, flexibility, reliability, productivity)
Evaluate the performance of current drainage systems (leaching salt loads, control of waterlogging, changing groundwater tables, yield depression due to salinity)
In the next phase, the HYPE Model should be more finely calibrated for reservoir operations. It may be necessary to include water management, allocation and optimization models combined with HYPE to better simulate efficient use of water, especially for agriculture
Collectively simulate of the impacts and adaptive value of management scenarios proposed by the Country Partners.
Iran should be re-invited to participate.