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# Climate Adaptation Strategies and Projections on Water Discharge in the Euphrates-Tigris River Basin

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**Abstract** The main aim of this thesis is to analyse the climate adaptation strategies regarding water resources in the regional context of the three major riparians of the Euphrates and Tigris rivers: Turkey, Syria and Iraq. The objectives are: to base the analysis on the criteria benefit, consequences and limits to the social as well as the technical factors affecting the water availability and to use WW-HYPE, which is a HBV based model, to support literature on climate projections in the area. Water discharge projections reveal that the peak in flow rate will change, in the years 2041-2070 in relation to reference values from 1971-2000, with on an average (of three locations in the basin) -18 % for a RCP4.5 emission scenario. The projected water discharge decrease is larger in the north of the basin which is also the location of the rivers headwaters in Turkey. The downstream riparians are less affected by the natural water discharge change, but will suffer the effects of being in a disadvantaged position downstream. Syria is the country of the three with the highest amount of water discharge per capita. The adaptations measures evaluated are virtual water, desalination, re-use of wastewater, improvements on infrastructure and irrigation, water pricing and implementation of a trilateral treaty. This thesis highlights the importance of diversification of measures and the involvement of communities for acceptance of policy. There is a need for supply-side measures as well as conservation techniques. Although collaboration over borders would be preferable in the basin, a possibility to implement a trilateral treaty is not expected in the near future.

**Preface** This thesis has been written at the Division of Water Resources at the Faculty of Engineering at Lund University by Marika Mourujärvi. Supervisor was Professor Ronny Berndtsson and Examiner was Assistant Professor Hossein Hashemi. The work has benefited from input from peers and professors at Lund University.

# Contents

# 1 Background

Climate change is believed to be one of the major future issues of the Middle East and in most areas a decrease in precipitation is projected, especially in the summer season. [1] The Tigris and Euphrates rivers are very important sources of water for the countries in the area surrounding the rivers. Turkey is the upstream country in the river system and Syria and Iraq are two other major recipients. All three countries are categorized as being under "High baseline water stress" by World Resources Initiative. [2] If adaptation strategies to the future climate changes, are not implemented the consequences could be disastrous. [3] Therefore it is valuable to compare possible strategies of climate adaptation in the area. To do this, it first is necessary to study climate change in the area and water issues related to climate change. To achieve a better understanding of how the water resources changes in the basin as a result of climate change, projections on temperature, precipitation and water discharge can be performed. This thesis aim to achieve this, with a main focus on water discharge.

Since a decrease in precipitation will likely result in water scarcity the major impacts of scarcity are important to investigate, including for example climate, the population's water needs, rates of consumption, reliability of water quality and flow in various locations, growth patterns of population, demography, distribution of water resources, technical capacities, policies in place regarding rates of distribution and consumption of water, efficiency, embedded losses in the system and waste. [4] All these factors together exceeds the scope of this thesis, which will include part of these important areas of study. A focus will lie in the natural water resources available, the equitable distribution of them, losses in the system and water related transboundary issues in this regional context.

Under Güney Doğu Anadolu Projesi or the Southeastern Anatolia Project (GAP), Turkey has envisioned to build 22 dams, 19 hydroelectric plants and make extensive irrigation plans for the Euphrates and Tigris river system with ambition for constructions to be completed by 2023. It is one of the largest internal development projects in the world. The project affects riparian states downstream the dam constructions, primarily Syria and Iraq, which suffers significant water quality and quantity loss. [4] A regional context will be applied to the analysis as the basin has a history of water tension which will affect the water resources in the three countries as the Euphrates and Tigris River Basin is a transboundary river system.

## 1.1 Aim and Objectives

The main aim of this thesis is to analyse the climate adaptation strategies regarding water resources in the regional context of the three major riparians of the Euphrates and Tigris rivers: Turkey, Syria and Iraq. The objectives are: to base the analysis on the criteria: benefit, consequences and limits to the social as well as the technical factors affecting the water availability and to use projections created on data from WW-HYPE, which is a HBV based model, created by SMHI to support literature concerning the climate changes in the area.

## 1.2 Structure of Thesis

The thesis consists of this brief background, which includes aims and objectives of the thesis, information on geography and population relevant for the study area and background theory of radiative forcing and the role of dams in the Euphrates and Tigris river basin.

This section is followed by literature study, projections and analysis on the climate situation in the basin as well as water issues related to climate change. The following section consists of literature study on the transboundary issues in the basin, which is included to give enough background knowledge needed to perform analysis on strategies available in this regional context.

Climate adaptation strategies are evaluated and discussed regarding benefits, consequences and limits, in the regional context of the Euphrates and Tigris river basin. Finally the thesis is concluded. In the appendix a list of figures and a list of tables is provided as well as coordinates of the locations in which projections were made, See Appendix 10.1 and 10.2.

## 1.3 Geography and Hydrology

The Euphrates and Tigris rivers rise in eastern Turkey and two thirds of their courses pass the highlands of eastern Anatolia and valleys of Syria and Iraq before entering Mesopotamia. Mesopotamia is the area between the two rivers in the Euphrates-Tigris Basin (ETB from here on). [5]

The Euphrates river enters Iraq at Al Qaim and merges with the Tigris river near Qurna. Shatt-al-Arab is the name of the joined Euphrates and Tigris rivers which empties in the Persian gulf. [6] Within Iraq the two rivers are also connected through several canals. The transboundary basin has an area of 879 790 km2 in total. [5] See Figure 1.

Turkey, Iraq and the Syrian Arab Republic are riparians of both rivers. Saudi Arabia and Jordan are riparians of the Euphrates river and the Islamic Republic of Iran is a riparian of Tigris river. [5] Saudi Arabia is part of the drainage basin but does not have contribution or borders with the Euphrates. The Euphrates is the longest river in western Asia, stretching almost 3000 km. The Tigris river is the second-largest river in western Asia. [6]

Snowmelt from the Taurus Mountains, the Armenian highlands and Zagros Mountains are an important source of water in the ETB. [7] Located in the uplands of north and eastern Turkey, Iraq and Iran snow precipitation from mountains feed the rivers. This gives rise to the hydrological regime which is characterised by irregular, between seasons as well as years, flow with flooding during snowmelt in the spring. [6]

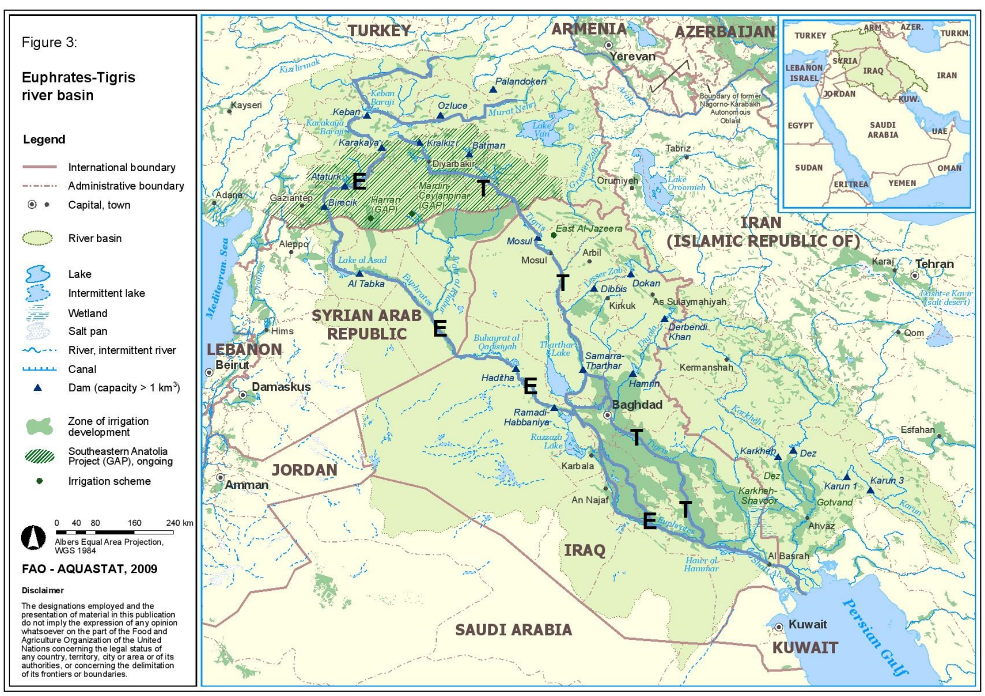


Figure 1: Euphrates and Tigris river area map with Euphrates (E) and Tigris (T) rivers marked out as a blue line. [5]

## 1.4 Radiative Forcing

Radiative forcing (from here on, RF) represents change in energy fluxes for drivers of climate change, where a positive RF leads to surface warming and negative RF leads to surface cooling. [8]

The Intergovernmental Panel on Climate Change, IPCC, for its Fifth Assessment Report has had scientists set up four scenarios denoted Representative Concentration Pathways, RCPs. These are connected to their approximate total RF in year 2100 relative to 1750. The RCPs are: 2.6 $W/m^2$ for RCP2.6, 4.5 $W/m^2$ for RCP4.5, 6.0 $W/m^2$ for RCP6.0 and 8.5 $W/m^2$ for RCP8.5. [8] See table 1 for the expected global surface warming of each RCP.

RCP2.6 is considered a very low forcing level, RCP4.5 and RCP6.0 are stabilization scenarios and RCP8.5 is considered a very high emission scenario. For RCP2.6 RF peaks and declines, for RCP4.5 it stabilizes by 2100 and for RCP6.0 and RCP8.5 RF does not peak by 2100. [8]

The Paris negotiations succeeded mobilising policy makers, civil society and businesses setting the target of staying below 2°C, but achieving this is a major challenge as the world is on course for 3°C. [9] While mitigation is important, adaptation simultaneously needs to be implemented.

Table 1: Global surface temperature change by the end of the 21st century, relative to the average from year 1850-1900. [8]

| Warming (°C) | Likeliness to exceed certain temperature | RCP | Confidence |
|---|---|---|---|
| 1.5 | Likely | 4.5, 6.0 and 8.5 | High |
| 2.0 | Unlikely | 2.6 | Medium |
| 2.0 | More likely than not | 4.5 | High |
| 2.0 | Likely | 6.0 and 8.5 | High |
| 4.0 | Unlikely | 2.6, 4.5 and 6.0 | High |
| 4.0 | About as likely as not | 8.5 | Medium |

## 1.5 Population

The population forecast provided by the Worldometer, using data from United Nations, shows an expected increase in population in Turkey, Iraq as well as Syria. See Table 2. Turkey, Iraq and Syria have populations of approximately 84.4 million, 40.2 million and 17.5 million in 2020, respectively. [10] With a population increase demand on water increases due to domestic use of water as well as water for production of food and electricity.

Table 2: Population by country and expected mean yearly growth during 2020-2050. [10]

| Country | Population (million) | Mean expected yearly growth 2020-2050 |
|---|---|---|
| Turkey | 84.4 | 0.61 % |
| Syria | 17.5 | 1.78 % |
| Iraq | 40.2 | 1.99 % |

## 1.6 The Role of Dams

Because of the nature of the ETB, characterized by floods and droughts, governments of the countries in the area have since the 1950's built dams to secure a water supply for irrigation and energy production. The dams further functions as a mechanism to control floods. [11]

There are however risks of constructing dams. The natural flow is disrupted around the dam where the ecosystem in the area is adapted to the irregularity of the flow. Intentionally decreasing the flow can cause sediment build-up which leads to reduced water depth which smothers habitats and decreases the size of the river making it incapable of containing water amounts in wet years when the flow is increased. Severe social consequences are also a significant impact of dams. Vast areas including towns and arable lands are flooded, forcing resettlement and depriving people of their livelihoods. In large reservoirs such as dams the risk of waterborne diseases increase as well, according to Bremer. [11] Increasing the surface area which is the case when constructing dams, naturally increases the evaporation losses.

With massive issues related to dam developments, which have taken place to a very large extent, comes issues in transboundary relations but on the other also now benefits in form of secured water resources in dry seasons. This is why dam development projects and transboundary issues will be relevant for this thesis.

# 2 Methodology

This thesis consists of three parts: Literature study and projections using WW-HYPE on water discharge in the ETB to evaluate the climate change the area is facing, literature study on the dam developments and transboundary water issues in the region to apply a regional perspective and finally evaluation of climate adaptation strategies concerning the water resources in the region.

## 2.1 WW-HYPE by SMHI

WW-HYPE is a HBV-based model computed for the entire planet earth. The prefix "WW" stand for World Wide and "HYPE" is short for "HYdrological Predictions for the Environment". The "HBV" acronym stands for "Hydrologiska Byrån Vattenbalansavdelningen" and is the name of the department at the Swedish Institute for Meteorology and Hydrology, SMHI, where the model was developed in the 1970s. [12]

The model is used in this thesis to gain knowledge on how the climate is predicted to change and affect the water discharge. The data used concerns seasonal temperature, seasonal precipitation and water discharge and is collected from WW-HYPE at specific coordinates. Three coordinates are chosen, located in the three riparian countries of the Euphrates and Tigris rivers, Turkey, Syria and Iraq. See Table in Appendix 10.2 3 for exact coordinates of locations. These coordinates where chosen in the middle-to-the-end of the basin in each territory attempting to have the data show as fair of a picture as possible, of the water discharge in each. Water discharge has also been investigated on the borders between the countries. The climate data will be relevant for the analysis on the water resources available showing the difference in water discharge in the north, middle and south of the basin and how the countries positions might affect them.

The investigated RCPs are one stabilisation emission scenario RCP4.5 and one very high emission scenario RCP8.5, to show two different possible future climate scenarios with different outcomes. See table 1. The RCP4.5 is a scenario that might lead to an increased global temperature of 2 degrees Celsius. The RCP8.5 is a scenario that could result in a global average temperature rise of 4 degrees Celsius, which is very severe.

## 2.2 Criteria for Analysis

To make an analysis on adaptation strategies the criteria for analysis need to be chosen. As the basin is subject to major change due to climate change, a natural resource perspective is needed and the technical capacity is of interest. Because of the tension between the countries a regional perspective is important to take into account in the analysis. The criteria the thesis will aim to assess is: benefit, negative consequences and limits to the technical capacity of the measure and the social applicability factor.

# 3 Climate Situation

An arid to semi-arid steppe or desert climate is prominent in the area. It provides wet winters and dry summers in southeastern Turkey as well as in the north of Syria and Iraq. A large part of the precipitation falls as snow in the mountainous head water areas which melts in the spring causing rise of the rivers, increased by a seasonal rainfall maximum between the months of March and May. Average annual precipitation in the area is approximately 335 mm, it does however vary along the basin area [5]. In the Mesopotamian Plain the annual rainfall is often below 200 mm, and approaches 1 045 mm in other places in the basin. [5] The Anatolian and Zagros highlands are places where the annual precipitation exceeds 1000 mm. [6]

The annual average temperature is 18 °C over the entire basin but it varies from average temperatures in the summer of 37 °C in the hottest places to average winter temperatures of -11 °C in the coldest places in the basin. [5]

## 3.1 Climate Classification

Climate classification is an additional method this thesis uses to illustrate the climate situation in the area, which provides more information on the type of climate in terms of for example aridity and humidity, that is present in the area and how different areas of the basin are characterised.

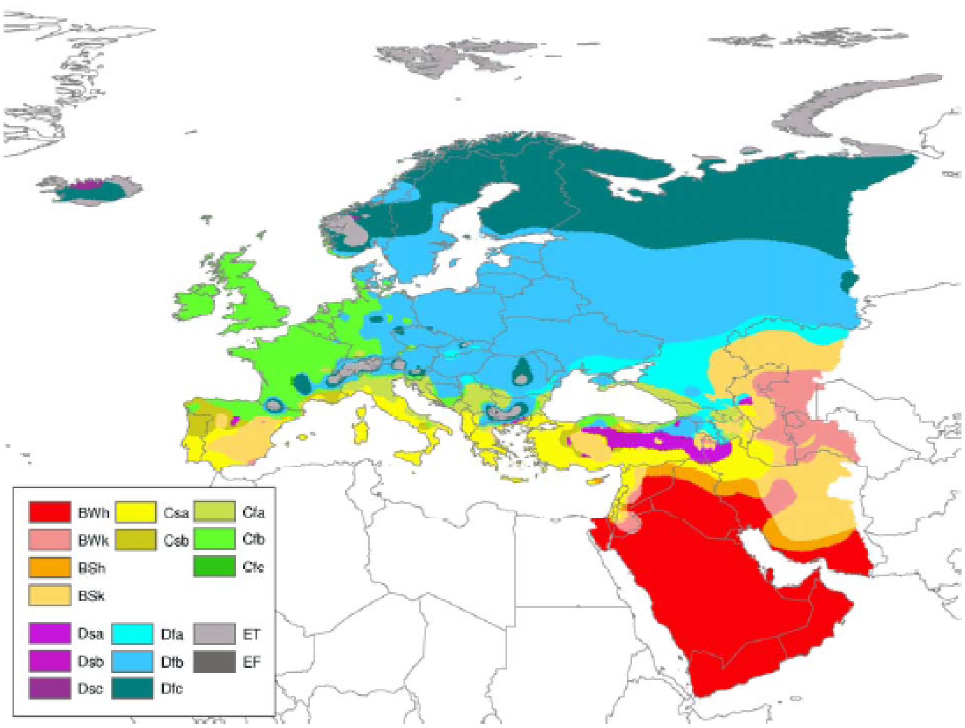


Figure 2: Classification by Köppen-Greiger Classicifation System

The letters are classifications that distinguishes if the climate is cold, hot, arid, semi-arid etc. This thesis will only explain the meaning of the classifications that are relevant for the ETB: BSh, BWh, BWk, Dsa and Csa. See figure 2. BSh stands for "Arid, Steppe, Hot", BWh stand for "Arid, Desert, Hot", BWk stand for "Arid, Desert, Cold", Dsa stand for "Cold, Dry Summer, Hot summer" and Csa stand for "Temperate, Dry Summer, Hot summer", which is the classifications of the climate zones present in the ETB. [13]

Figure 2 shows that in the north of the ETB there is colder areas, with hot and dry summers, in the north-to-middle of the basin there is a temperate climate with dry and hot summers, there is some areas with cold arid desert climate and the larger southern part of the basin has a hot arid desert climate.

## 3.2 Temperature and Precipitation Historic Data from WW-HYPE

To complement the literature temperature and precipitation data has been plotted together, in the three locations chosen to study in the basin. Note that these vary a lot over the basin and have here only been plotted for specific locations.

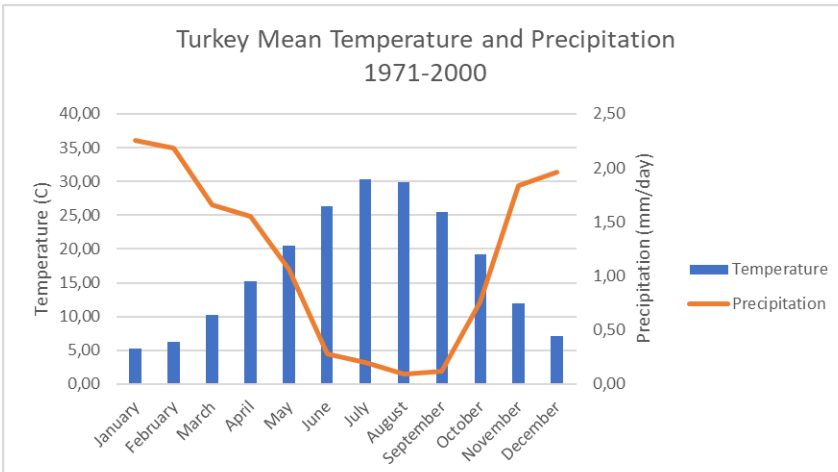


Figure 3: Mean temperature and precipitation reference values in Turkey during 1971-2000.

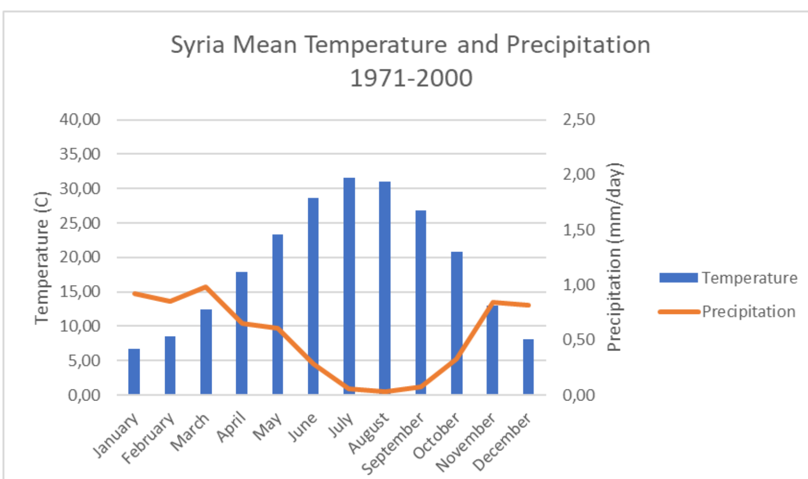


Figure 4: Mean temperature and precipitation reference values in Syria during 1971-2000.

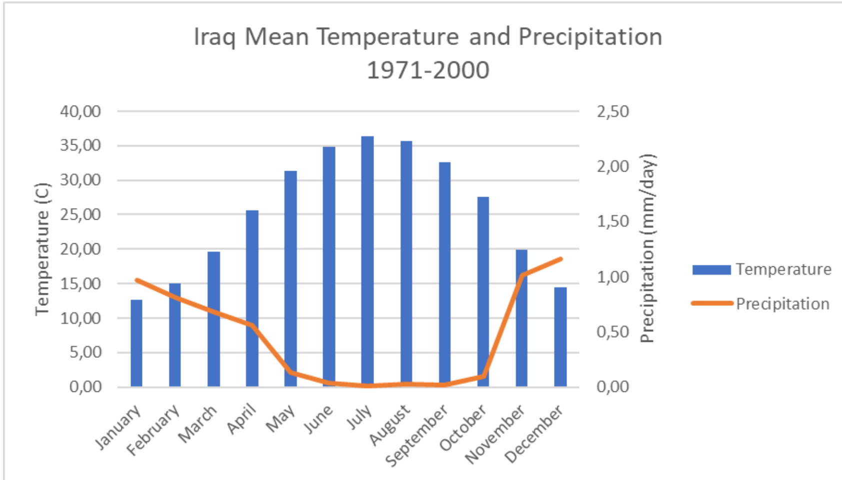


Figure 5: Mean temperature and precipitation reference values in Iraq during 1971-2000.

Looking at the figures 3, 4 and 5 it is easy to see that the seasonal variation is large. Dry and hot summers and mild and wet winters is the majority of the areas characterizing weather. As climate change increases temperatures all over the basin and decreases precipitation in the most part, the climate is likely to become more arid and hot which will have a significant negative affect on the water available in the ETB. We see that the peak of temperature occurs in July in all three locations which is around the same time as the precipitation is at low point. Only looking at the precipitation doesn't give the full picture of the water available as the availability depends on the characteristics of the catchment, such as topography and types of soil. Therefore the following sections includes water discharge data and projections.

## 3.3 Mean Water Discharge Historic Data from WW-HYPE

To asses the amount of water flowing between the countries the water discharge has been investigated at the place where the rivers cross the borders. The water discharge is the volume of water flowing in a river, through a cross-section in a unit in time. [14] In this case the unit is $m^3/s$.

The Euphrates flows into Syria from Turkey and later into Iraq from Syria. The Tigris river flows from Turkey into Iraq, touching the Syrian border on the way, See figure 6. In figure 7 and 8 we see the water discharge flowing in the Euphrates river on the borders between Turkey and Syria and Syria and Iraq respectively. In figure 9 we can observe the water discharge at the border to Iraq after passing Syria. A list of the exact coordinates of data used can be found in appendix, See Appendix 10.2 Table 3.

The data used for all climate projections in this thesis are provided by WW-HYPE, and they are mean values from an ensemble of forecasts. Ensemble forecasting is the method of using several forecasts, as a dynamical approach to quantifying forecast uncertainties, which are large due to the difficulty in predicting behavior of the atmosphere. [15]


Figure 6: Map of Tigris crossing the border from Turkey and Syria into Iraq [16]

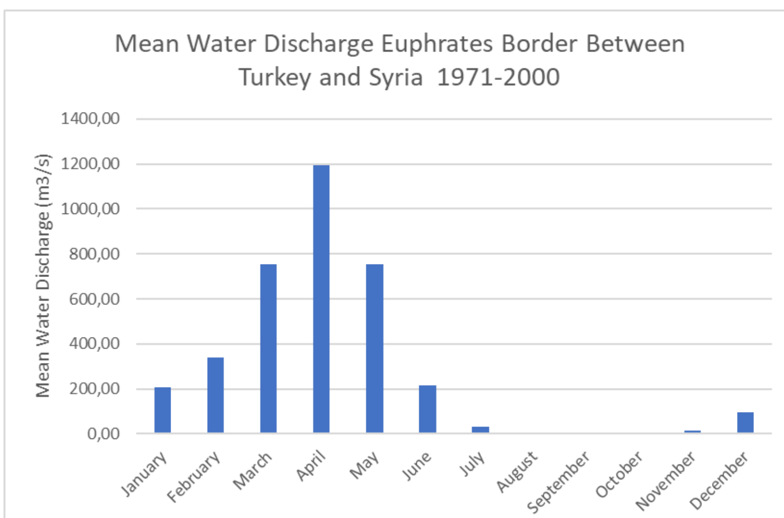


Figure 7: Mean Water Discharge in the Euphrates on the border between Turkey and Syria

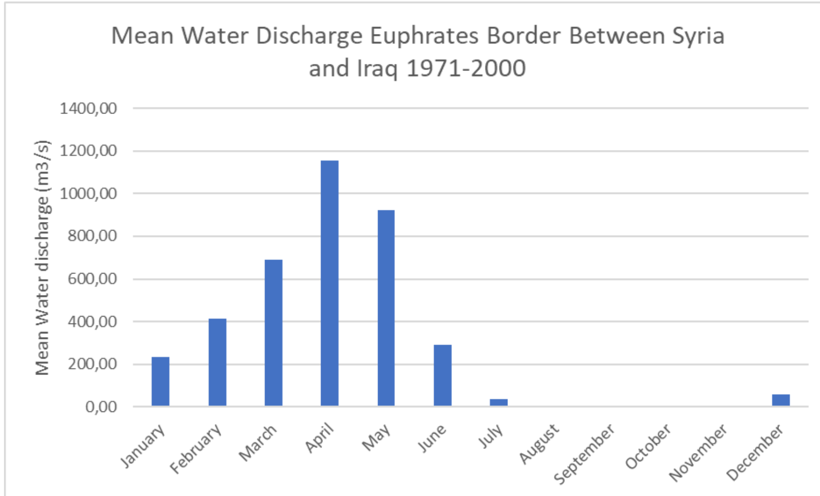


Figure 8: Mean Water Discharge in the Euphrates on the border between Syria and Iraq

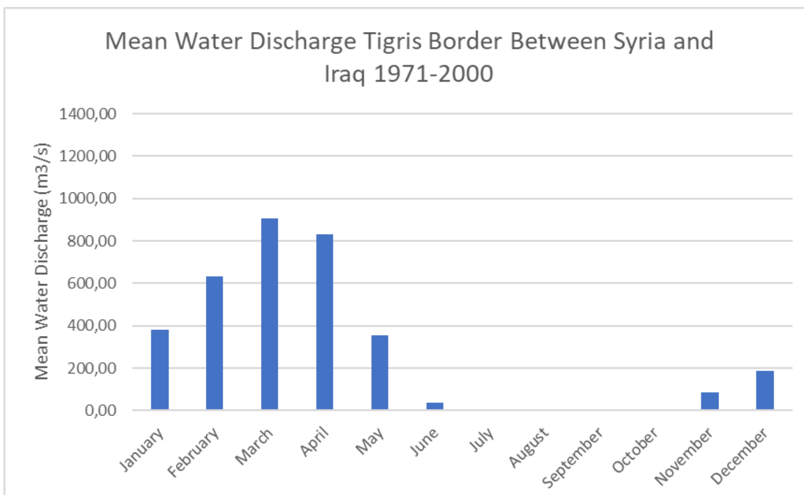


Figure 9: Mean Water Discharge in the Tigris on the border between Syria and Iraq

There is a large natural variation in the water discharge due to the hydrologic scheme of the area. [6] We can see this is the case for all three locations investigated. See figure 7, 8 and 9. Comparing these figures with the temperature and precipitation data it is clear that the peak flow doesn't occur simultaneously as the peak precipitation. This can be explained by the precipitation falling as snow and that the snow melt in the spring feeds the basin and causes a peak water discharge later on.

We can see that the water discharges differ for the rivers. The Euphrates has a water discharge of 1200 $m^3/s$ at peak flow at the border between Turkey and Syria and slightly less on the border between Syria and Iraq. The Tigris river has a water discharge of 900 $m^3/s$ on the border to Iraq. These are values from a model that takes precipitation, topography and other characteristics of the catchment into account, that naturally affect the water discharge. The developments, such as dams, in the area are altering the flow and even out the minimum and maximum flow rates, so this gives an idea of the "natural" behavior of the rivers, but not the actual flow.

### 3.4 Climate projections

The Middle East and North Africa region is one of the emerging hot spots for drought, extreme heat and aridity worsening. In this region a warming of 0.2 degrees per decade has been observed between the years 1961-1990 and now the warming is happening at an even higher rate, according to IPCC. [8]

The precipitation is predicted to decrease in the ETB. After 2021, observations project decrease at around 12 %, a percentage that increases to 26 % after 2030. Projections on runoff indicate a decrease of about 30 % after 2040, according to Şen. [17]

A feature that highly affects the ETB is the melt of snow in the mountains. The precipitation will decrease as mentioned, but the precipitation will also change to rain precipitation, rather than snow causing little snow cover in the late 21st century in the headwaters of the rivers, according to Kibaroğlu. [18]

The flow rates of Tigris and Euphrates rivers are expected to decrease. In Turkish territory the flow in the Euphrates river will reduce by 23.5% and the Tigris river flow is expected to drop by 28.5 %, by the end of the twenty-first century. The reason is lower precipitation and higher temperatures causing higher evapotranspiration, according to Kibaroğlu.[18]

To support above mentioned literature this thesis includes data on water discharge for the three different countries, including two scenarios of emissions for the period 2041-2070 computed by the WW-HYPE model by SMHI. [12] Make note that there are not values provided for the locations in Turkey and Syria during the months of September and October.

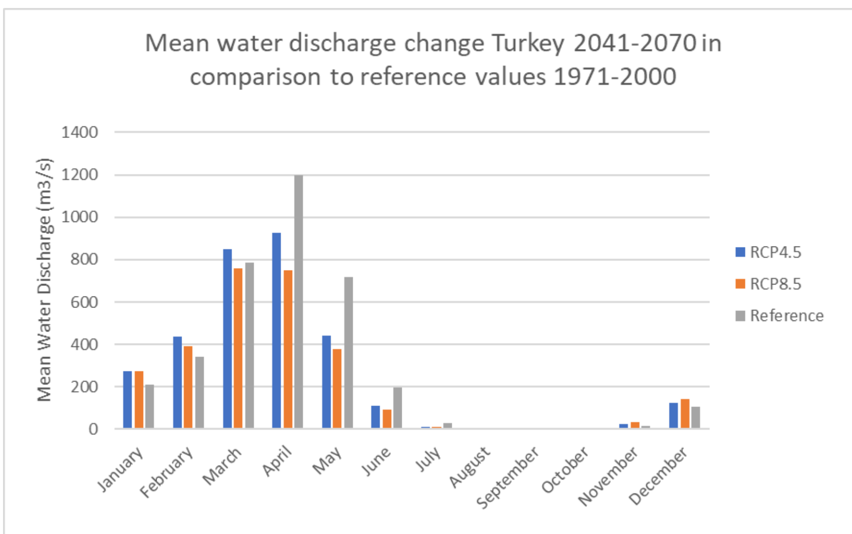


Figure 10: Mean water discharge change Turkey during 2041-2070 in comparison to reference values 1971-2000.

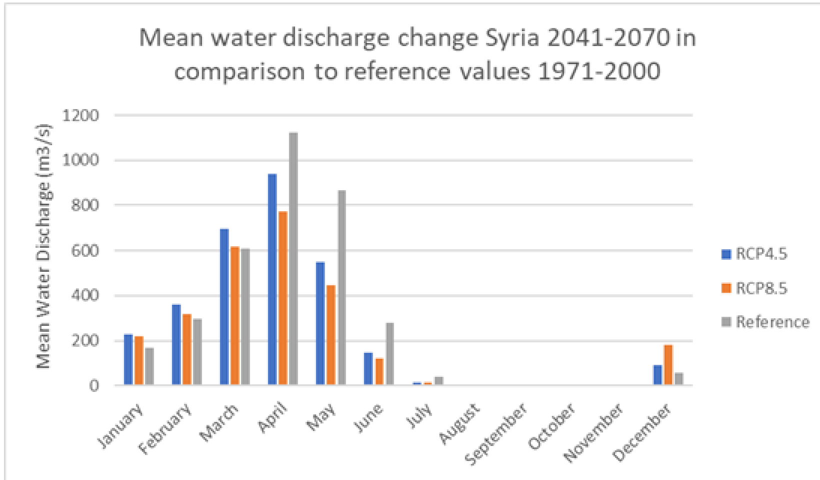


Figure 11: Mean water discharge change Syria during 2041-2070 in comparison to reference values 1971-2000.

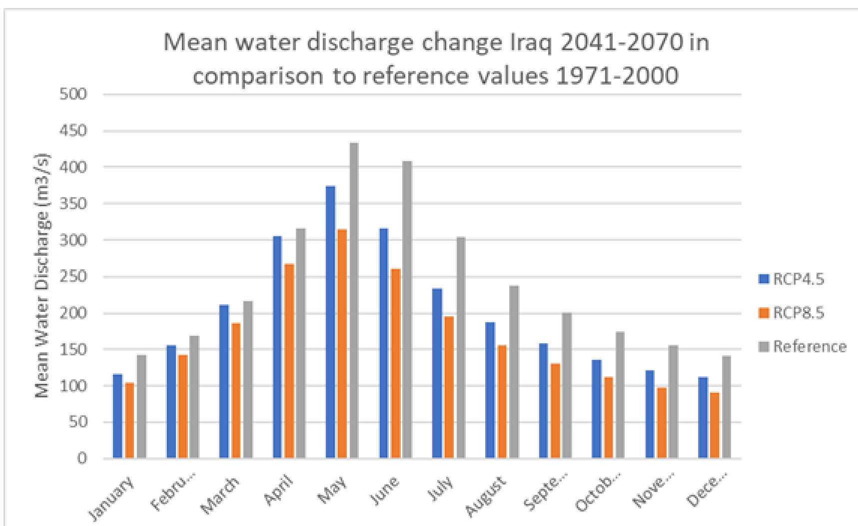


Figure 12: Mean water discharge change Iraq during 2041-2070 in comparison to reference values 1971-2000.

In all three locations the peak is projected to occur earlier in the future which supports the literature. See figure 10, 11 and 12.

In the location where water discharge was investigated in Turkey the peak in April, with a flow of 1200 $m^3$ in the reference data, seems to reduce by approximately 440 $m^3$ in the very high emission scenario (RCP8.5) and 270 $m^3$ in the lower emission scenario (RCP4.5). This corresponds to a decrease of peak flow of 27 % and 37% respectively.

In the location chosen in Syria the average water discharge reduces by approximately 350 $m^3$ in the very high emission scenario (RCP8.5) and 185 $m^3$ in the lower emission scenario (RCP4.5), comparing to the highest peak of 1100 $m^3$. This corresponds to a decrease of peak flow of 17 % and 31% respectively.

In the location chosen in Iraq a more steady decrease prevails, and lower amounts of water discharge are involved. The peak is reached in May and shows a decrease of approximately 120 $m^3$ at a very high emission scenario (RCP8.5) and 60 $m^3$ at the lower emission scenario (RCP4.5) which is a lot, comparing to the highest flow of only 430 $m^3$ in this location. This corresponds to a decrease of peak flow of 14 % and 28% respectively.

## 3.5 Water Discharge in Relation to Population Growth

Because climate change couples with population growth, increasing the water stress by simultaneously reducing the availability and increasing the water need, it is interesting to illustrate the relation between these effects which is done in this section. See figure 13, 14 and 15.

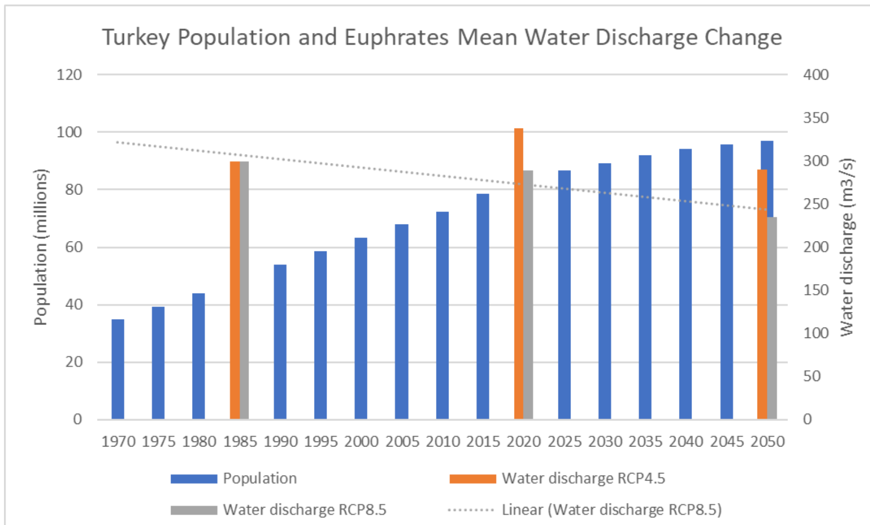


Figure 13: Population growth in relation to mean water discharge Turkey.

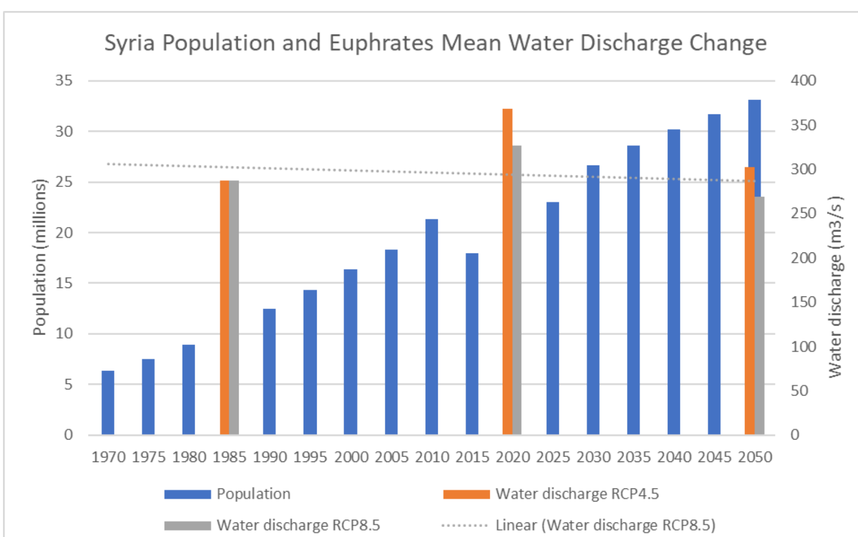


Figure 14: Population growth in relation to mean water discharge Syria.

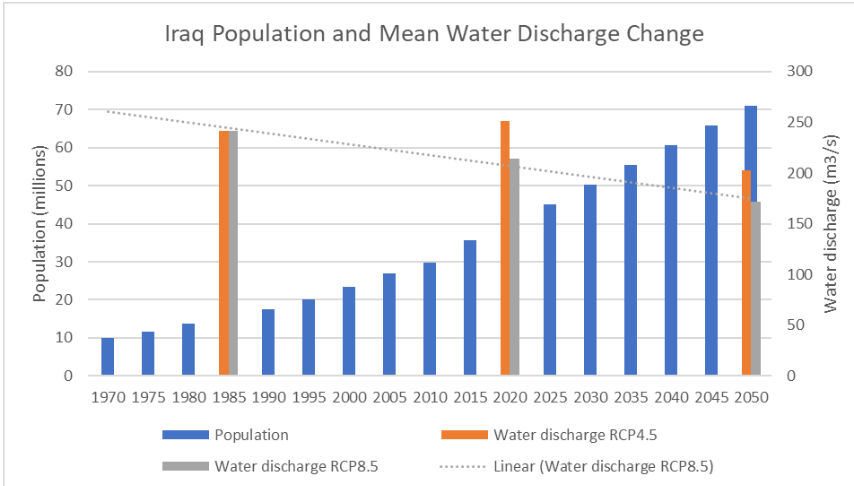


Figure 15: Population growth in relation to mean water discharge Iraq.

Population has been plotted over five year intervals from 1970 to 2050. The numbers on population before 2025 are historic values and from 2025 on, the values are projections, provided by Worldometer which uses information from United Nations. [10] On a secondary axis a mean water discharge has been plotted for the reference period 1971-2000 and for the time periods 2011-2040 and 2041-2070 using climate projections for RCP4.5 and RCP8.5 scenarios. The exact coordinates for the three locations can be found in Appendix, and are the same as used for projections in figure 10, 11 and 12, See Appendix 10.2 Table 3.

In all three locations, in Turkey, Syria and Iraq, we can see that populations increase and mean water discharge decreases in the basin, which is expected. Although it is a good illustration, it is also interesting to compare the water discharge per capita for the countries which is what is plotted in figure 16.

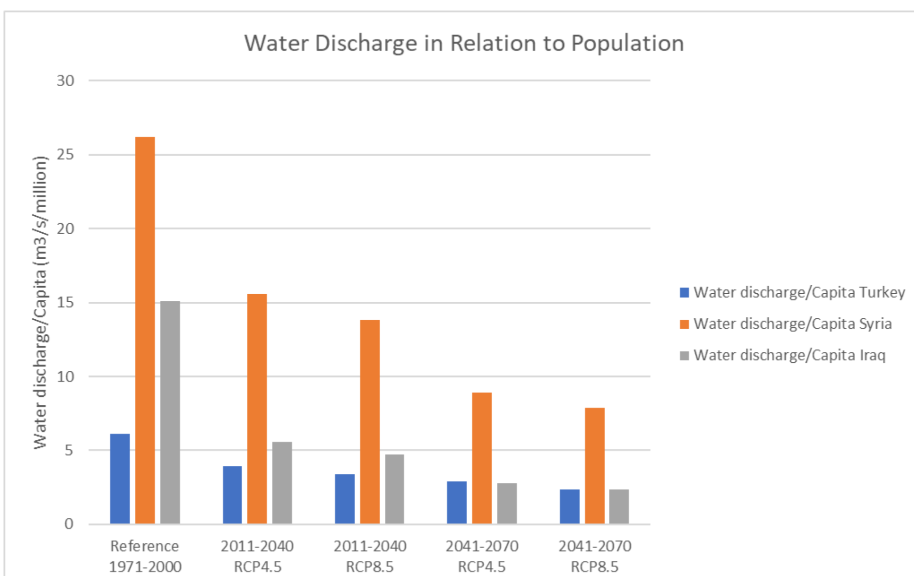


Figure 16: Mean water discharge per capita in Turkey, Syria and Iraq.

Turkey has a massive growing population and Syria and Iraq have a higher acceleration of growth. Syria is the country among the three that has the highest abundance in water per capita, and Turkey is the country with the lowest. Turkey and Syria however, have other resources of water such as other rivers and groundwater while Iraq is more dependent on the Euphrates and Tigris rivers. To make the graph in figure 16 values on population after 2050 are needed, and these values are not provided by Worldometer. An assumption is made that the growth rate during 2050-2070 for the countries is 0.373, 0.990 and 1.167 respectively, which is based on an average of the growth rate in the ten years prior (2040-2050).

### 3.6 Water Issues Related to Climate Change

There is going to be a large impact on the water sector due to climate change. Social and political vulnerabilities will be pressured as climate change interacts with social, economic and political factors. Climate change can be viewed as a "threat multiplier" for already vulnerable populations. [19]

Turkey, Syria and Iraq are all considered to be under high water stress as the ratio of total withdrawals to the total renewable water supply is in the category 40-80 % according to World Resources Initiative, making them countries under "High baseline water stress". [2]

Drought, like the one Syria and Iraq experienced in 2007-2010, could become two to three times more likely as climate change is happening. The three-year drought was the most devastating recorded. [20] Droughts are expected to be longer and rainfall events more variable and intense due to acceleration of the hydrological cycle. The probability of floods and desertification increases as well. [19] According to the World Bank, Syria could be facing desertification of 60 % of its land area as a result of rise in temperature, lack of rainfall and unpredicted weather. [21]

Since warming in snow-dominated areas will result in earlier peak flows, greater winter flows and summer flows this is likely the case in the ETB. It is also likely that there will be a greater climate variability and an increase in the risk of extreme hydrological events due to warmer temperatures. [3]

Much of the problems that come with climate change are already occurring in much of the MENA region. There is observation of deteriorating water quality, rising sea level, contamination and over-extraction of groundwater aquifers, salinization of agricultural areas and water shortage. [19]

Demographic growth is a factor that couples with climate change making all water issues more severe as a higher demand largely affects water availability and water quality in the MENA region. [19]

The water discharge of the ETB is predicted to decrease according to the projections made in this thesis. This is stated by Kibaroglu as well, that further points out that it will have a significant negative impact on water available for irrigation, energy production and industrial and domestic use. [18] The agricultural sectors in the countries in the ETB will be affected greatly, in Iraq for example, 85 % of its renewable freshwater resources are consumed by this sector. [22]

The losses are massive from the rivers and consist of natural and technical losses. Natural losses occur in form of evaporation from surfaces and river flow into desert depressions and distributaries. The depressions and distributaries can be man-made aswell. For example, the Euphrates forms a giant alluvial delta starting at Ramadi in Iraq and from that point on the river passes deserted regions of Iraq where there is large losses into several natural and man-made desert depressions and distributaries. [6] Leaky infrastructure is another contributor to water losses. In Syria the losses are 60 percent of its total water resources. [20]

The main issues this thesis will focus on is the shortage of water in the ETB and possible adaptation measures. The issues that this thesis highlights is leakage through infrastructure, overuse of water in agriculture, less water available in the rivers for drinking purposes, irrigation and energy production. Possible adaptation strategies will be discussed later on, and will include both supply-side measures and conservation techniques.

# 4 Transboundary Water Issues and GAP

It is appropriate to disclaim that this thesis cannot include all events that occurred in the region that all collectively affect the transboundary relations of these three water sharing countries. It will merely highlight the major events to give enough background to be able to analyse the adaptation strategies in this regional context.

## 4.1 Güneydoğu Anadolü Projesi (GAP)

As the three countries dam constructions are important, altering the flow of the rivers, it is important to talk about the Southeastern Anatolian project, known by its Turkish acronym, Güneydoğu Anadolü Projesi, hereafter GAP. It is one of the largest national development projects in the world. [4]

Turkey has a distinct geographical advantage as it lies in the headwaters of the Euphrates and Tigris rivers. [20] Prior to the developments in the 1960's, Turkey consumed 10 % on average of the two rivers, and this number is expected to become over 50 % after the completion of the project in 2023. [4] In 2016, Turkey reportedly used 41 per cent of the water resources within its territory, which shows that it already has increased its consumption largely. [20] The water withdrawal rate in Turkey is expected to increase under GAP, which intends to irrigate 1.6 million hectares of agricultural land, which together with the expected increase in temperature and changes in land-use due to climate change, will increase the water demand. [23]

According to a study on the Haditha reservoir in Iraq, droughts combined with water management affect the farthest downstream water bodies the most making the downstream riparians especially Iraq, vulnerable to developments upstream. [7]

GAP is mainly, but not only, a dam development project including 22 dams, 19 hydroelectric plants and large irrigation plans. It has grown to include sectors such as agriculture, industry, health care, education, urban and rural infrastructure and transportation [6]. In the late 1990s and 2000s Turkey had an interest in joining the European Union and during this time concerns about human rights were addressed increasingly.[4]

## 4.2 Hasankeyf

GAP seemingly has many areas of benefit for the state of Turkey, one of which is functioning as a domestic sociopolitical tool in the southeast to pacify the marginalized, largely Kurdish region. [4] Even with Turkey being a developed country that has an increased focus on industry and has been moving away from being an agricultural economy, the southeastern region lags largely behind other parts of the country, both in social and economic development.[4]

One major negative effect of GAP is the flooding of small towns where they are building dams. Hasankeyf is an example of a 12 000 year old Kurdish community on the Tigris river that is subject to flooding. According to the Turkish government 15 000 people will have to move from Hasankeyf which is a city with a rich history and is legendend to be the location of the Garden of Eden. Hasankeyf meets 9 out of 10 criteria to be a UNESCO world heritage site but has despite this never been acknowledged for this by the Turkish government, According to an article in Svenska Yle written by Lindholm. [24]

The Iraqi government have as have many others been protesting the construction of the Ilisu dam in Hasankeyf, in their case because of fear of water shortage in Iraq. Environmental activists have protested because of lost ecosystems due to the constructions. [24]

Environmental injustice has befallen on disadvantaged people as a result of GAP. According to a study by Ökten a big obstacle in the process of development brought by GAP among people who are associated with agriculture, is the unequal distribution of lands in the region. These structural characteristics of the region cause a socio-economic benefit for big landowners. A significant number of people have been affected by GAP as they have been displaced, not resettled properly and suffered loss of genuine public participation as they have not been properly involved in the decisions made. [25]

### 4.3 Transboundary Agreements and Events

In total Turkey's developments include 22 dams, Syria's developments comprises three large dams, Iraq's include 15 dams on the Euphrates and Tigris rivers and although Iran will not be included in the analysis on adaptation later on it is worth mentioning that Iran's developments on the tributaries of the Tigris comprises 14 dams. It was not until the first large dams were built in the ETB that any significant tensions between the countries involved, occurred. The first large dam constructed in the ETB was the Dukan Dam on the Tigris completed in 1959 on Iraqi territory. In 1966 constructions started of the Keban Dam on Euphrates in Turkey. Syria's first dam, the Tabqa Dam, on the Euphrates was finalized in 1973. [11]

Before the major dam constructions, the earliest agreement for the rivers were initiated in 1920 by French mandatory government of Syria and the British mandatory government of Iraq, with the goal to lay the foundation for future utilization. As early as 1946 another bilateral agreement between Turkey and Iraq was signed, namely the Treaty of Friendship and Good Neighborly Relations. The parties agreed in this treaty, to consult with one another over water usage and share related data as well as establish a committee to implement further agreements. [4]

In 1975 there was tension between Syria and Iraq due to filling of the Tabqa Dam which was resolved when they came to an informal agreement stating that Iraq would receive 60 per cent allowing Syria to utilize 40 per cent of the water from the Euphrates. [20]

In 1980 the Joint Technical Committee on Regional Waters was initiated by Turkey and Iraq, initially it was between these two countries but Syria joined in 1982. In 1987 a promise by Turkey was formalized, guaranteeing a flow of 500 $m^3/s$ across the border to Syria. This promise was unfortunately not always held up to on Turkeys behalf as it often without warning, altered the flow of the river, affecting the downstream riparians water supply. [20]

In the 1980s Turkey and Iraq despite this had a close relationship, being brought together by their shared interest in dealing with Kurdish separatists and guerrilla movements. Turkey was also important for Iraq as an outlet for oil whilst preoccupied with its war with Iran. The Gulf war did bring tension between the countries as well, as Turkey was part of the United States-led coalition against Iraq. During the coming years Iraq complained at many occasions that Turkey was violating the 1987 agreement by not letting enough water in the Euphrates river pass the border to Syria, which affects Iraq in turn. [4]

In 1984 Turkey proposed the "Three-stage Plan for Optimum, Equitable and Reasonable Utilization of Trans-Boundary Watercourses of the Euphrates-Tigris Basin". Syria and Iraq did however not agree and accused Turkey of attempting to claim the most part of the Euphrates waters. At this point they instead insisted that the two rivers shall be regarded as separate international rivers. [6]

The three involved parties have at least three different opinions on the rights to the water. According to Turkey, it alone has the right to determine how the resource is allocated since the majority of the region's water originates in Turkey. At least this has been argued in certain times in history. [20]. Iraq on the other hand has claimed sovereign and historic rights to the Tigris waters at occasions. Syria has at occasion offered a third perspective: "the Euphrates and Tigris rivers are 'international watercourses' which should be classified as 'shared resources' and must be divided among riparian states according to a quota, on the basis of their declared demands." [6] Iraq and Syria have on occasions agreed on the "international river" perspective and believe they have right to their fair share of the waters. On other occasions they have on contrast, claimed rights to Euphrates waters based on ”ancestral irrigation”. Three categories can be identified: upstream downstream riparian control, ancestral rights and finally equitable utilization. [4]

Intense tension further built in the Joint Technical committee on Regional Waters in 1989-1990 as Turkey filled the Ataturk Dam and reduced the flow from the Euphrates river to Syria and Iraq with only one months notice. Syria and Iraq protested claiming that Turkey had failed to give them reasonable notice to prepare for the reduced water flow causing water shortage downstream the construction. [20] Shrill protests from Iraq followed and even a threat from Iraq to bomb the dam. [4] Attempts have been made in the committee to come to agreement since then, but none have been successful. [20]

## 4.4 Events in Syria

In Syria the water resources are varied and include rivers, springs and groundwater potential, apart from the Euphrates river. Syria has constructed three large dams that are in operation: the Tabqa Dam, the Al-Baath Dam and the Tishrine Dam. Agriculture is the most important building block of Syria’s economy but because of rapid population growth it can not fulfill all of Syria’s needs. [6]

The Syrian government sponsored the expansion of farmland from 600 000 hectares to 1.2 million hectares, in the years between the mid-1980s and 2000. This put a massive strain on the ground water as the expansion largely was made possible by a doubling of the extraction wells for irrigation. Unfortunately many wells were overused to the extent that it between the years 1984 and 2010 caused a drop of the water table in some areas by more than 40 meters. [20]

When farmers found wells with unsuitable water or dried up ones in combination with reduced diesel subsidies many were faced with unmanageable strain on their operations and were forced into displacement. The drought had led to displacement of 1.5 million people in Syria in 2011. Cities during these times were largely affected by a massive urbanisation during a time already being overwhelmed by refugees from Palestine and Iraq. These hardships and poor management by the government contributed to early protests and discontent eventually leading to regional violence later on, and the country has been dealing with major crisis since then. [20]

## 4.5 Events in Iraq

After 1950 the start of dam and canal constructions were initiated in Iraq. Development continued and the most important took place in the years 1972-1990 when many new hydraulic structures were constructed. There has always been contradiction regarding the estimates of the irrigated area in Iraq but the total irrigable area is estimated to be around 4 million ha, a number that may have decreased to 2.78 million after the Iraq-Iran wars and the Gulf war.[6]

In Iraq 70-80 % of the water in the Tigris river is consumed by extensive irrigation and diversification canals before the river joins with the Euphrates.[20]

## 4.6 Iran’s Role in the ETB

Iran is considered a riparian state of the Tigris. The Euphrates river never enters Iran, on the Tigris river there are however important tributaries in Iran and Iranian developments, when regarding the utilization of the Tigris, are considered relevant. [11] The reason this thesis doesn’t include Iran in the analysis, although it has an affect on the water resources in the region, is mainly the magnitude of the topic and the focus on the thesis being the three major riparians and their transboundary relations.

The Karun river runs to the Shatt-al-Arab delta and therefore the developments on the river affect the ETB. Iran has constructed the Dez Dam which is its largest hydropower and irrigation development project, on a tributary to the Karun river and has further embarked on a multi-billion-dollar water management scheme on the river. On the river Karkheh Iran has inaugurated a large water reservoir with the purpose to supply the country with water for irrigation of 320 000 ha of land.[6]

### 4.7 Water Wars

Water is certainly a factor contributing to tension and conflict and there is an ongoing discussion on the possibility of "Water wars". In this region, with its current turmoil, both internal conflicts, the wide spread lack of central control and tensions surrounding Kurdistan Regional Government, it is not an impossible scenario that these countries would engage in war among each other, but the primary cause is not believed to be the water situation, according to Dohrmann. [4]

An interesting consequence of conflict that has been taken place is that in some occasions disruptions in agriculture can improve quality of water by reduced return flows from irrigation causing improved reservoir salinity. [7] There has on the other hand been effects on water infrastructure as a result of conflict, from other violent groups such as IS that have been using water infrastructure as a resource and a weapon. They have destroyed pipes, sanitation plants, bridges and cables and also flooded towns, polluted water bodies and put agriculture and economy at pause. These are also methods that have been used against IS which have affected surrounding population. In contrast to the negative affects on infrastructure from wars, some have argued that water management could possibly become a facilitator of cooperation and peace. [18]

## 5 Adaptation Strategies

In this chapter adaption strategies will be evaluated on the criteria: benefit, consequence and limits to the technical capacity and the social situation, in the regional context of the ETB.

In the process of climate adaptation water management should be high priority. Particularly the matters of irrigation and allocation of water among competing users. [26] Turkey, Syria and Iraq can be regarded competing users, which makes this the case in the ETB. Turkey does however have a clear advantage being located in the headwaters of the rivers.

In areas that are facing increasing water scarcity such as the ETB, is should be the main aim to reduce the water footprint by decreasing evaporation rates, harvesting rainwater and upgrading irrigation methods, according to Muratoglu. [27]

Desalination, interbasin water transfers, dam construction, tapping fossil groundwater aquifers, reusing treated wastewater and importing virtual water are measures that most governments in the Middle East already have implemented to combat water shortage. [3] These are all supply-side measures and will be looked into for our regional context in this chapter.

One key element of adaption is diversification of water management strategies. [19] This is an important argument for looking into many options and the possibility to implement or extend, the use of them, which this thesis aims to do.

Water experts in the region have advocated demand-side management that promotes conservation techniques and attempts to increase efficiency. [19] Conservation methods will be looked into as well.

A difficulty regarding the access to water is addressing the issue of equity. The resources are not distributed in a proper manner as users in cities and large agricultural users are privileged consuming more of the water resources available than vulnerable populations in certain regions and small scale farmers. [19]

It is increasingly important for leaders to engage societal actors in the adaptation process, by concerning the role of civil society. Regional networks are growing engaged in adaptation issues, raising awareness and participation with financial funding by international institutions. [19]

Political leaders are still unconvinced of the urgent need to prioritize the matter of climate adaptation, according to Sowers. [19]

## 5.1 Virtual Water

Food and water security are linked because of the very large volumes of water food production requires. Most of the world economies lack sufficient water resources to provide food security for their population, making them importers of virtual water. Virtual water can be measured in litres of water used in production and it can furthermore be defined as "the water required to produce the food, goods and services that we consume daily". [28] Three kinds of water use are regarded in the term virtual water: Green water, blue water and grey water. Green water is the rain water used to grow crops and the water lost in evapotranspiration, blue water is the water available to use for irrigation and grey water is waste water generated by different activities. [22] A product's virtual water content, will be measured in litres of water, but it will be important into what category the water falls and the origin of the water, when determining the "goodness" of the product in terms of virtual water. [28]

A limiting factor for using virtual water as a method to reduce water usage is the instability in the region contributing to a will to increase national food security. Countries such as Syria and Iraq, that have increasingly started to import more foods will likely go back to growing their own food as opportunity arises. [3] Syria nearly doubled their irrigated agricultural activity in the name of food security between the years 1985-2003. [19]

Turkey has a more balanced virtual water trade and imports as well as exports similar amounts of food products. [28] Syria and Iraq is "saving" more water by importing virtual water, Iraq even more than Syria while Turkey exports a lot of food products with a large water footprint. [27] Syria did attempt to scale back cultivation of cotton for export when faced with significantly low precipitation during the drought period around the years 2008-2009. Any more significant climate adaptation measures have not been implemented in Syria. [19]

Other countries depend on products, such as wheat, barley, cotton and rice, produced in the ETB. [27] The selection of crops produced is important as some need less water and some can be cultivated in rain-fed areas. [22] For example, lentil and wheat harvesting requires less water than pistachio and maize, which can be cultivated in some parts of the ETB. When trying to manage these food security issues it is important to look at both their virtual water content, but also their nutritional content and economical value. Evaluation of production methods is important as efficiency can vary greatly in major consumptive sectors. [27] In Turkey a part of the crops grown are grown on soil moisture that when the climate is not particularly arid, do not need irrigation, these are products such as melons and some types of tomatoes. Other important winter vegetables fed by winter rainfall are cabbage, cauliflower, garlic and onions. [28]

Authorities should encourage consumption of foods, goods and services with lower water footprints by for example raising awareness and labelling products in an informative matter, according to Muratoglu. [27]

## 5.2 Desalination

Desalination is a possible method of combating water shortage by treating salty or brackish water removing salts and other dissolved solids to be used for example for drinking purposes or irrigation. [29] It is a method that always should be evaluated as an alternative water resource option in coastal regions. [30]

There are thermal processes such as evaporation and crystallization, renewable processes such as solar and non-thermal processes such as using membrane technology, ion exchange or membrane distillation. [29] Reverse osmosis, (RO) goes under the category non-thermal and is a membrane technology process that removes ions, proteins and organic chemicals by purification through a semi-permeable membrane.

[31] RO is a process that especially in the case of desalination of brackish waters but also treatment of salty water, consumes less energy than other processes such as thermal. [29]

Some benefits that RO possesses is a possibility of automatic process control, a modular design making it suitable for different plant capacities and a small environmental footprint. It is also a relative low-cost process of water treatment. [31] For this thesis the most important benefit is that it is a process that gives opportunity for water scarce areas, like the ETB will be to a greater extent in the future, to increase its supply of clean water.

The largest consequence of RO is the high energy input demand. It also suffers from fouling of membranes and a low-quality result when comparing with thermal technologies. [31] Cost-benefit analyses performed show that a major cost is the energy cost, calculated to be 70 % of operating cost, which in turn in 50 % of total cost. The other 50 % is capital cost. [32] Since the cost of the water treatment is dependent on the energy cost it is sensitive to changes in energy prices and policy changes regarding greenhouse gas emissions. [31] To reduce the sensitivity of the policy change which also would benefit the environmental impact, it is in some areas possible to use renewable energy such as solar and wind power. In comparison, the cost changes from 1.8 $\$/m^3$ powering RO with diesel compared to 2.2 $\$/m^3$ for a RO unit powered by a combination of solar and wind power. [29] Joint academic programs and research projects can benefit the capacity building in desalination technology. [30] This might be difficult in a region with a long history of tension between them, but it also poses an opportunity for collaboration on a neutral ground, in the scientific community.

In Turkey there are many seas to chose from were they to implement desalination as an adaption method. Syria has a Mediterranean coastline and Iraq has brackish water in the Mesopotamian marshlands as well as the Persian Gulf in the south. But these countries, especially Syria and Iraq can not fully rely on private investors as the risk is large under the current political environment.

Since part of the energy production in the ETB requires water resources and the desalination process needs energy, there is an element of complexity. It is likely that the countries that have the possibility to resort to other alternative adaption methods will do so.

### 5.3 Re-use of Wastewater

Re-use of wastewater can be explained as the use of treated wastewater, which is a term for water of worsened quality due to human activity, to be used for purposes such as irrigation, groundwater recharge and domestic use. There are classifications into two categories: black water which is highly polluted water from for example toilets, and grey water which is less polluted water from for example sinks, showers and washing machines. [34]

There is great potential in re-use of wastewater. According to Maksimovic, a household could reach a level of water saving of 50 % by diverting grey water from sinks to be used when flushing toilets or irrigating a garden. The cost and energy required for the technology varies, more efficient technology being more expensive. In new buildings there is a higher chance such technology is worth installing as it is less expensive to incorporate into new constructions than to retrofit existing systems. [34] According to Agudelo-Vera et al this number however is closer to 30 %. [**?** ] Which still shows a large potential of water saving. In the ETB where water is scarce it can in many cases be worth implementing. It should however be implemented with caution and in combination with competence building in communities, as reusing contaminated water in many cases can pose sanitation risk.

There has been progress in the sewage treatment technology but despite this, reuse of wastewater is not always a possibility because the technical limitations of removing for example salts, boron and pharmaceuticals. Wastewater from domestic sources generally contain higher amounts of boron and salts than most fresh water aquifers. Sewage effluents are enriched in inorganic salts and this limits its application for salt-intolerant and sensitive crops. [19]

There is a link between desalination and re-use of wastewater. Since desalination processes have a limit when it comes to removal of boron, which leads to higher amounts of the substance in drinking water and in wastewater indirectly, it affects the agricultural sector. To be able to use wastewater effectively this limit needs to be taken into account, are there to be desalination plants constructed in areas where wastewater is recycled and used for agriculture. [19]

Re-use of wastewater for domestic purposes can fail partly because of a lack in public acceptance of policy, which could be influenced by better information to the community. There can also be an issue involved concerning administrative fragmentation, institutional conservatism, cost structures in place and a lack of involvement of people in planning stages. Sustainable water use through recycling can require improvements in coordination between governance policy and agencies and a greater engagement of the community. [35]

Urban grey water and water from irrigated fields can in cases of a topographic high point be reused by diversion to location at lower levels of an area. [36] This will be addressed further in the section on improvements on infrastructure, as water harvesting is evaluated.

## 5.4 Improvements on Infrastructure and Water Harvesting

Water infrastructure is needed for water supply, energy generation and flood control. [37] To reduce natural and technical losses improvements of water infrastructure is needed. Although infrastructure is only one of many sectors in which climate adaption measures can be implemented, it is a crucial one.

In cases where infrastructure is developed under responsive governance, nationally and at a trans-boundary level, the positive effects of it is greater. An important part of adaption is the boarder perspective of a whole basin rather than smaller areas such as cities. This perspective combined with strategies on management, finance, planning and governance and scientific advances can lead to more efficient and high quality management, planning, contributions and commitments from stakeholders. [37]

Reservoirs have become important offering benefits like water supplies, hydro power, flood control, drought mitigation, navigation, fish farming and recreation. [37] As mentioned many reservoirs have been constructed in the ETB, with both positive and negative effects. Although, the positive effects of them could have been greater and could have effected more people, had they been part of planning on a larger scale.

There has been a privatisation of the management services within the water and wastewater sector in Turkey with the aim to reduce the need for urban infrastructure investments. In municipalities that have populations of 10,000-50,000, there is commonly a 'water office' or directorate which is responsible for water supply matters. [38]

The privatisation has had mixed results due to disputes between decision makers and private operators. The reason is an unclear division of roles and responsibilities and differences in expectations among the parties involved. Another issue is that it has been difficult to reduce technical losses through leakage, because of inadequate maintenance investments. Another problem is related to privatisation concerning water tariffs on water usage which are in place to reduce water consumption, that when private participators are responsible the same service will encourage water usage since the company makes a profit from selling water for fixed fees. [38]

Rainwater harvesting (RWH) is the method of collecting and storing rainwater for later use, in a location where water is needed. The system is mainly consisting of the catchment area, storage tanks or cisterns, gutters and other transportation systems, a filtering system, a monitoring system and pumps or a gravity system. Saving water in this way provides many benefits but there are also some limits to the system such as availability of material, space and local expertise, cost of materials and labour, consideration of local traditions and climate and catchment conditions. [34]

In southern Syria rainwater is harvested through long channels capturing flood water from the banks of drainage basins leading water to reservoirs as well as diversion dams in rivers extracting water from sporadic rainfall events. Covered cisterns can sometimes be found on every house in some villages in this area, storing water harvested from the roof. There is a stable and durable local organization of water management in this region which is able to carry out maintenance such as rebuilding water intakes, repairing canals, dredging reservoirs etc. This technical and social competence is very important in these types of rural areas as the continued use of existing systems relies on it. [39]

In the ETB there are areas of ongoing armed conflict which has led to destruction of water infrastructure such as dams and aqueducts. These kind of infrastructural challenges are hard to predict and takes long time to recover from. There is likely going to be focus on rebuilding areas and a "putting-out-fires" mentality rather than a long term planning mindset which makes it harder to improve infrastructure as a measure to adapt to climate change.

## 5.5 Improvements on Irrigation

The existence of irrigation efforts can be dated back to 6000 BC in Mesopotamia and this has through history been important to the establishment of civilisations. [40] Today 70 % of water available is used by the agricultural sector globally. [41] In Iraq this number is larger, it amounts up to 80 %. [20] Irrigation is important in many ways as it improves income distribution in rural areas, creates employment, permits usage of fertilizers and allows more than one crop to be purchased from the unit area. [40]

To reduce natural and technical losses, improvements on irrigation techniques is important. Since it is the sector using the greatest amount of water by far, it is the most important to make improvements in. [3] Currently there are systematic inefficiencies such as low irrigation ratios, excessive water use and inequity in water distribution, according to studies on the irrigation associations in Turkey. [42]

In 2017, the irrigation distribution systems in Turkey consisted of 55.5% open canals, 22.5% canalette and 10 % pipes. By improving the water distribution systems and technology on management and farm levels the average irrigation ratio can be improved. It is vital to choose efficient methods and systems of irrigation and to provide training to increase skills of the labour force in the agricultural sector. [41]

It is useful to implement conserving techniques, such as drip irrigation. A limit to this implementation is that small scale farmers cannot afford it. States would have to invest significantly in agricultural infrastructure in these rural areas for this to be possible. [19] Drip irrigation is however when implemented, more economical. Other limits to drip irrigation is that it must work efficiently and be applied daily for it to sufficiently provide the roots of the plants with water and since it is applied through nozzles the water needs to be clear from weeds and seeds. If the nozzles are clogged the water can not reach each plant. [28]

Since 1950, there has been a global trend to transfer irrigation systems from governments to irrigation associations with the aim to protect facilities, fulfill maintenance needs and to achieve fair water distribution among others. This transfer has been successful in Turkey, as irrigation systems currently are run by The State Hydraulic Works (DSI). [41] It has dramatically empowered irrigators in the country and led to overcoming problems concerning irrigation fees. Unfortunately it has not improved irrigation efficiency, which was another goal of the transfer, which is still around 40 %. DSI have however been constructing pressurized piped irrigation systems, which gives opportunity to decrease energy-costs and increase water saving, were they to expand the systems onto larger areas. [42]

Allocating funds for maintenance and renewal is a challenge for both government and irrigation associations. There is support from policy on national level for prioritizing water, nutrition and food security as well as investment on infrastructure for irrigation. The difficulty however remains in the practical implementation through institutions for these improvements in equity and efficiency to be achieved. The situation in Turkey demonstrates a need for a broader consensus among farmers, government, the private sector, civil society and academia. [42]

## 5.6 Water Pricing

Water pricing is according to some, the most effective way to manage water demand. [30] Water pricing can improve the effectivity of water use and provide funds for distribution system improvements. A lack of water pricing can on the other hand encourage wasteful use of water resources. [6]

Within the agricultural sector, a water pricing for irrigation could be implemented. Irrigation associations in Turkey for example, collect fixed fees to cover irrigation costs for farmers as opposed to charging based on amount of water used. This fee is in many areas based on type of crops and the area of land irrigated by the farmer. [42]

For drinking water in Turkey, there is generally Increasing Block Tariffs (IBTs) with different blocks of amounts of water usage, with the aim to discourage excessive water usage. The block system is in place to ensure a minimum water volume availability at a low tariff. There has been critique to the system in relation to urbanisation in the country, after inadequate maintenance and lack of investments. [38]

The idea is that there is a water tariff that recovers the economical and environmental cost as it covers the cost of operation, maintenance and expansion of capacity. When water tariffs are implemented they are intended to optimize the water and power productions and it is important that policies relating these sectors are integrated for this goal to be achieved. [30]

Limits to the use of water pricing is the impractically that is linked to pricing agricultural water for small scale farmers both in political and economical perspectives. An indirect water price is already in place as there are diesel costs for pumping water for irrigation. [19] With canal systems, that are the main irrigation systems in place currently, it is impossible to measure the amount of water used on a farm level which limits the implementation of volumetric pricing. [42]

There is also the issue of private companies making profit on water fees, that are likely to encourage water use for this reason, as mentioned in section 5.4.

## 5.7 Trilateral Treaty

Climate adaptation could be optimised if a perspective of the entire ETB could be considered. If Turkey, Syria and Iraq could find common ground by technical collaboration and engage in equitable allocation of water resources, the outcome for the many people could be better. There is opportunity for collaboration by trading food, water and energy and collaborating on implementation of conservation methods. This is however a very optimistic view on the situation, as there is a long history of transboundary issues in the ETB.

Turkey has a position of advantage in the basin, but also a wish to become independent on energy production and secure its food production for a growing population of more than 84 million people. Although the dam developments constructed under GAP has stabilised the flow of the rivers, providing benefits of stable flow and protection against floods for the entire basin, the downstream riparians have suffered at many occasions of decreased flow during filling of dams and droughts.

During the major drought in 2007-2009 Turkey managed much better than Syria and Iraq did, the drought period was only one year in Turkey. Vegetation data shows positive trends of productivity on the Turkish side of the border but a negative on the Syrian and Iraqi side. This shows that Turkey has more well-adapted management policies, and the infrastructure in place to effectively transport water to where it is needed. [43]

Turkey and Syria will, as they are located in the north of the basin, suffer a larger decrease of water discharge, but Iraq will be more impacted as the farther down riparian of the ETB. All countries are expecting higher temperatures, increasing populations and severe challenges due to climate change, which makes collaboration hard as all countries will try to secure as much water as possible for their territory and population.

If all parties can see advantage of cooperation there is still a chance of a trilateral treaty, although it is not likely to occur in the near future. Perhaps the region will stabilise further and dependence and trust between countries can build over a long period of time.

# 6 Discussion

It is clear that the water available in the future will be less in the ETB than it is today. With higher evaporation rates due to increased temperatures, less precipitation, especially in form of snow, less snow melt from the mountains, increasing population and higher probabilities of drought, the ETB is facing many challenges for the availability of water that need counter measures. The dam developments in the countries are providing an opportunity for a stabilised flow and protection against floods, which is a good start. There are however hegemonic issues related, as down stream riparians does not have mandate to control a decreased flow of water after developments.

The water discharge in the rivers in case of an emission scenario RCP4.5, which likely means an increase of 2 degrees Celcius, reduces by an average roughly 18 %. It is projected to decrease more in the north of the basin, but since the head waters lie in the north of the basin, the downstream riparians will be largely affected nevertheless. The downstream riparians, Syria and Iraq, have a clear disadvantage to Turkey. In the case of the very high emission scenario RCP8.5, which might lead to an increase of 4 degrees Celcius, the reduction of water discharge is on an average (of the three chosen locations) 32 %. Looking at the water discharge in the locations chosen it appears Syria is the country among the three has the highest amount of water per capita, and Turkey is the country with the lowest. Turkey and Syria however, have other resources of water such as other rivers and ground water while Iraq is more dependent on the Euphrates and Tigris rivers.

There is already water stress in the most part of the basin, which is mostly consisting of hot arid desert climate. Evaporation rates are very high and there are losses up to 70 % in parts of the area. Desertification will occur in large areas of the basin and cause problems for agriculture, which increases need for water for irrigation. Over-extraction of wells can deplete groundwater resources, as history tells, which causes displacement as farmers in many areas rely on groundwater for irrigation. Farmers that are dependent on surface water are also going to experience difficulties as it will decrease further.

There are several possible climate adaptation strategies in regard to water resources diminishing, all coming with benefits and consequences. There is also the issue of if they are socially and technically possible to implement.

Virtual water is certainly a possible measure for saving water by importing products and thereby putting less strain on the need for production. An overall perspective on the different products and their water footprint is helpful to achieve an efficient production fulfilling needs of nutrition for populations. Choosing to cultivate crops with low water foot print in relation to a high nutritional content is challenging but beneficial for improved food security with limited compromise on water saving. Trade among countries is a trust building mechanism that has upheld peace between countries in the past, and depending on each other has benefits in this way.

Desalination is a measure that is possible for countries with nearby sea water to utilise, if there is sufficient means of renewable energy production. The technology is available but the cost is only low if the energy cost is low in the circumstances, as the treatment of water by desalination is very dependent on energy cost. There are difficulties in finding sufficient funding for building treatment facilities. In unstable regions, investors are hesitant which sets a limit to the development of this measure. It can be implemented in the countries in the area, if the governance prioritises it. This prioritisation is not given, as it is an energy requiring treatment, but the MENA region is the region in the world with the most desalination plants, so it might be a possibility after other measures have failed to be enough to meet the increasing water supply needs.

Re-use of wastewater is a measure that comes with technical challenges of organic chemical removal. Re-use of wastewater can be viewed as controversial socially, as people can doubt the ”cleanness” of the water only based on ideas about where water should come from traditionally. To solve this problem information is only part of the solution, by increasing awareness of the technical capacity and control of the cleanness of the water some worries can be diminished. There is also benefit linked to the importance of involving communities in decision making and public debate, to the acceptance of policy.

Improvements on infrastructure is very important in the most part of the basin to reduce losses from leakage and evaporation which are very large. It is a promising area of water saving. In the aftermath of war there are many places that need investment for rebuilding infrastructure, water infrastructure included, as dams and water transportation systems have been destroyed. This recovery process will require investment in capital and time, and likely have setbacks as there is still armed conflict in many areas of the ETB.

Closed watersheds and pipe systems are preferred but costly in comparison to open channels and dikes. Strong local communities are present in some parts of the basin which increases the likelihood that infrastructures constructed or rebuilt will be utilized for a long time in the future, since knowledge and experience of maintenance is key to these structures' continuous functions and use. Maintenance is an important investment area, that needs regional and local governance and engagement and priority.

Water harvesting is a method on the supply side that largely benefits small communities and even singular households. It is a possibility for increasing water supply in the ETB by diverting excess water from areas with a topographical higher position to areas at a lower level where it is needed or installing for example cisterns that collect rainwater directly. It is a method that can have a relatively low cost, depending on what existing materials are available, but requires planning on implementation and maintenance and involvement of local communities. The ETB has many areas where it is a possible adaptation measure and should be implemented where the catchment characteristics allow it.

Irrigation is very important in the ETB as much of the economies are based on agriculture and there is not enough precipitation for growing crops, all year around. In some areas, at least in parts of the year, it is possible to grow crops without irrigation and only rely on soil moisture. Therefore an element of planning becomes important as the food production can be optimised by choosing crops that have high nutritional value and are used to produce the foods that the populations need the most, some of which might be possible to grow in periods of higher precipitation without irrigation. It is however going to be more difficult for farmers to rely on precipitation as climate change makes weather more unpredictable and increases the vulnerability in times of drought. More efficient irrigation systems, such as drip irrigation, therefore need to be installed as a way of conservation of water resources, but these are not often not affordable for small scale farmers. A need for investment in rural areas prevails.

Water pricing is a measure that can encourage sustainable water use but might not likely be implemented in cases where there is already a cost on fuel for pumping. It is a measure that is already implemented in part of the basin, on Turkish territory, but with privatisation occurring not stretched nationwide. Policy changes are needed for water pricing to be implemented consistently over the country. It is a measure that needs governance that prioritises water saving which is only the case for part of the basin.

There are many elements of injustice in the water sector. Small scale operators and rural communities are disadvantages to cities and major landowners. Turkey being the most upstream and also the more developed of the three countries has a clear advantage that was eminent in the way the country managed during the major drought period starting in 2007. Turkey has used water as a mechanism to pressure the southern countries and to pacify marginalised communities, which indicates that there is a risk that it will do it in the future. Therefore there is a large benefit in the implementation of a transboundary agreement where equitable use of the water is ensured. This is a very hard task for the involved parties, as the resources are scarce and there is little trust among them. It does not appear likely that there will be a trilateral treaty between Turkey, Syria and Iraq in the near future. There is some hope however that trade and collaboration on technical ground and within the scientific community, can improve the relations among the countries.

A diversification of climate adaptation measures in the water sector is important. Choosing to prioritise infrastructural developments and improved irrigation methods is a way to get closer to the goal but not all the way. There needs to be evaluation of new sources of water from for example desalination as well as a collective sustainable mindset promoting embracing conservation techniques. It is also important giving concrete gains to farmers implementing water saving techniques, such as subsidies or a water price.

A suggestion on further studies on the topic would be to make a thorough cost-benefit analysis that applies to the region as a whole, which could be important in the process of implementing a new treaty between the countries and planning actual implementation of adaptation strategies on a large scale.

The aim of this thesis was to analyse different climate adaptation strategies related to water resources in the ETB, which now is considered fulfilled. Work in climate adaptation is important as we are on course for a global warming of 3°C, and water resources is a field that needs much attention, furthermore the ETB is an important water basin in the Middle East, facing many challenges related to water scarcity which makes the topic of this thesis relevant.

# 7 Conclusions

In the ETB it is important to diversify the climate adaptation strategies regarding water resources and evaluate supply-side measures as well as conservation techniques. It will be difficult as much attention is diverted to more pressing issues such as conflict taking a focus from the matter of sustainable water use.

Making smart choices of allocation of resources is important. There can be increased efficiency of increasing food security by making choices based on consumption needs and nutritional value in relation to the water foot print of different crops. The water footprint can further be reduced by implementation of a water price on a larger scale than today, which can increase the motivation to implement conservation techniques.

The technology is available for improved irrigation methods, re-use of wastewater and construction of desalination plants but an allocation of priority and investment into rural areas is needed for a widespread effect of many of these measures. Investment into infrastructure is a focus many of these countries have, and it is important as they rebuild areas of ruined infrastructure that a sustainable and long term perspective is embraced. Water harvesting systems and re-use of grey water are examples of measures that can be implemented at lower cost when there already is part of structures needed in place.

Communities need to be involved in decision making processes, to build acceptance of policy and knowledge within on-site management of the systems. It is furthermore important to attempt planning with a basin wide perspective. Any treaties of such sort are not likely to be agreed upon in the near future, but it is a goal to keep in mind for the future as well as always striving for cooperation, justice and peace.

# 8 Conflict of Interest

The author of this thesis reports no conflict of interest.

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# 10 Appendix

## 10.1 List of Figures and Tables

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## 10.2 Coordinates for Data Collection in WW-HYPE

Table 3: Coordinates used to collect data from WW-HYPE, the country and the date of collected data.

| Country or Border | Coordinates | Figure | Date |
|---|---|---|---|
| Turkey | (37.34,38.15) | 3 and 10 | 2020-05-04 |
| Turkey/Syria | (36.82,38.02) | 7 | 2020-05-15 |
| Syria | (35.67,39.84) | 4 and 11 | 2020-04-30 |
| Turkey/Syria/Iraq | (37.05,42.36) | 9 | 2020-05-15 |
| Syria/Iraq | (34.42,40.99) | 8 | 2020-05-15 |
| Iraq | (31.10,46.76) | 5 and 12 | 2020-04-30 |