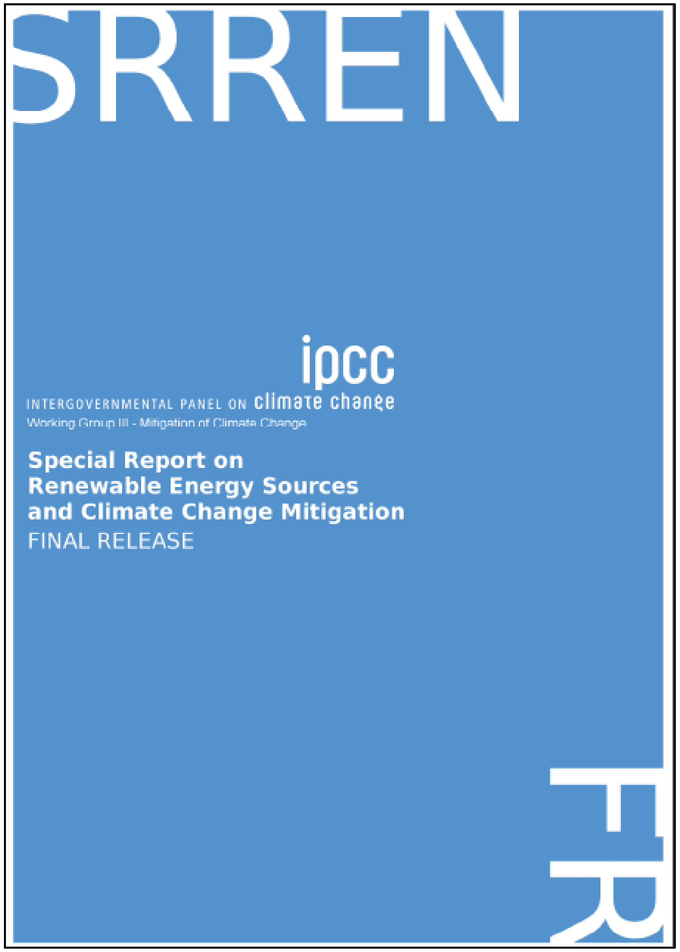
Reservoirs – water consumers or collectors?

&

The effects of change in climate and irrigation practice on the hydropower resources in Kizilirmak River Basin, Turkey

Tor Haakon Bakken, NTNU

Water consumption - what raised the attention?

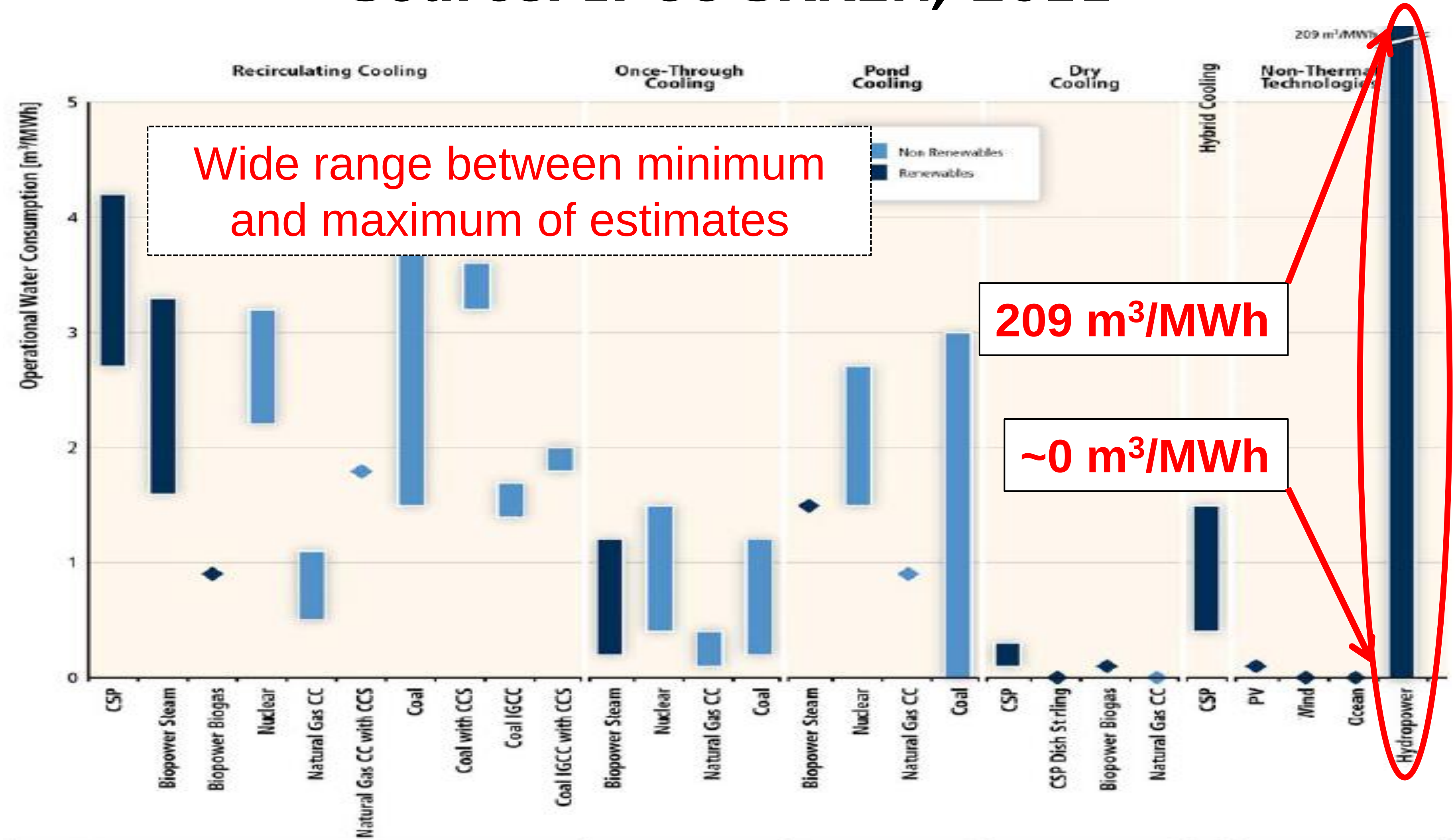


IPCC Special Report on Renewable Energy (2011):

- What is the potential for renewable sources to replace fossil-based fuels?

- The different technologies benchmarked with respect to various criteria, including ‘water needed to produced 1 MWh electricity (*water consumption*)’

Water consumption from energy generation: *Source: IPCC SRREN, 2011*



N:	18	4	1	5	4	1	16	2	7	3	1	3	3	9	1	1	1	7	11	2	1	2	4	2	2	1	4
Sources:	11	3	1	5	4	1	8	1	2	1	1	3	3	4	1	1	1	2	4	2	1	2	2	2	2	1	2

IPCC SRREN (2011) states

- *Upper values for hydropower result from few studies measuring gross evaporation values, and may not be representative.*

- *Research may be needed to determine the net effect of reservoir construction on the evaporation in the specific watershed.*

- *Allocation schemes for determining water consumption from various reservoir uses in the case of multipurpose reservoirs can significantly influence reported water consumption values.*

ISO 14046 Water Footprint

DRAFT INTERNATIONAL STANDARD ISO/DIS 14046

ISO/TC 207/SC 5 — Secretariat: AFNOR

Voting begins on 2013-03-18 — Voting terminates on 2013-06-18

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Environmental management — Water footprint — Principles, requirements and guidelines

Management environnemental — Empreinte eau — Principes, exigences et lignes directrices

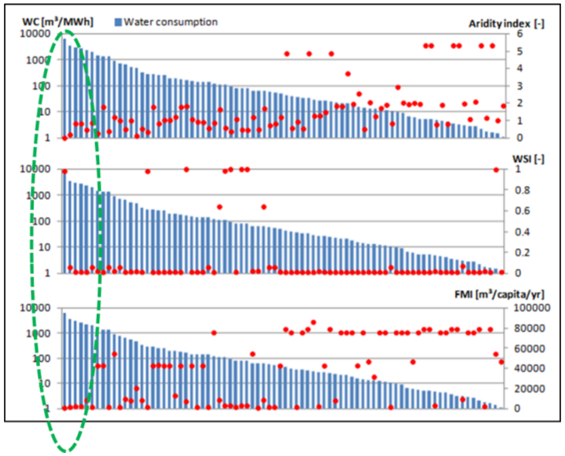
Might affect the energy sector in a similar way as carbon footprint assessments

On-going scientific debate

- Bakken et al. (2013) claims the methodological framework is immature and presents a biased picture. Has received support from e.g. Demeke et al. (2013), Chenoweth et al. (2014).

- 'LCA-based scientific communities' claim hydropower production is globally a large water consumer, e.g. Gerbens-Lenes (2009), Mekonnen and Hoekstra (2012).

- High water consumption values can be observed in water-stressed regions, but this is also where the reservoirs are most needed (Weichert, 2013).



- Reservoirs are needed to mitigate the effects of climate change on the water resources (e.g. IPCC, 2008)

ICOLD-database

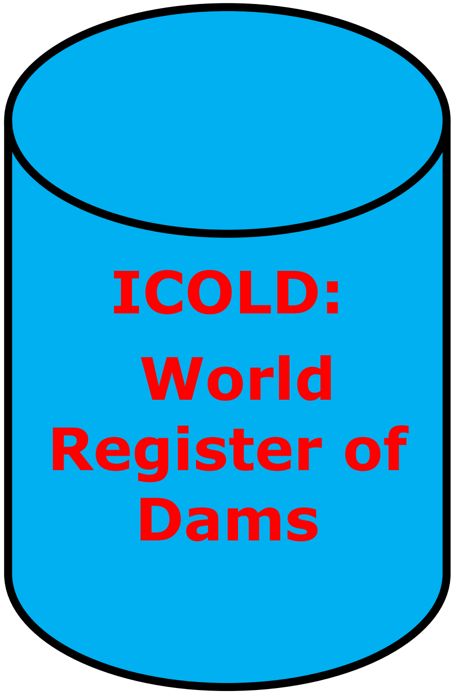
Contains information on a large number of dams > 15 meters

Holds information such as installed capacity, energy production, dam characteristics, country of location and purpose

- single versus multi
- main purpose
- secondary purpose

Non-complete in terms of properties

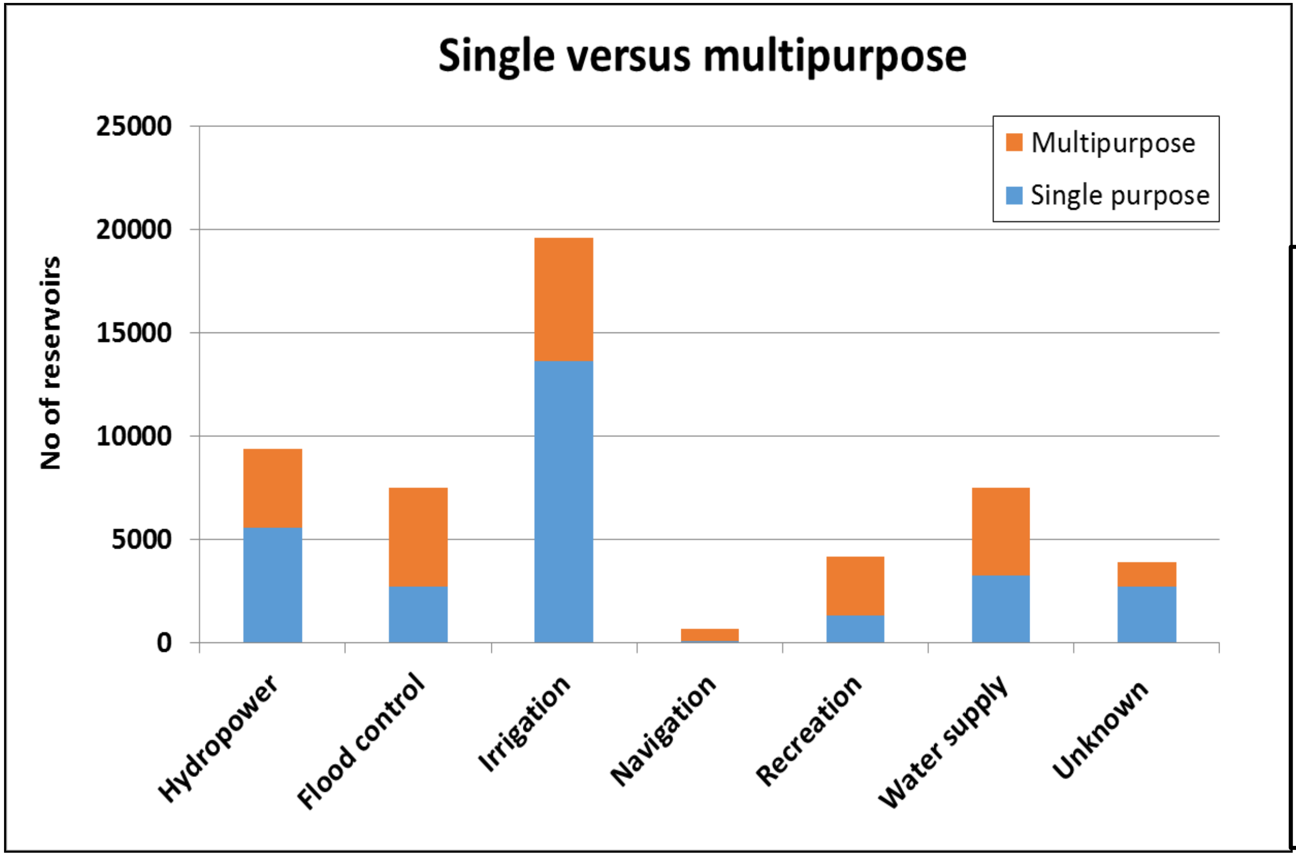
Other sources estimate the total number of dams > 15 meters to be around 45 000 world-wide (ICOLD-web: ~ 50 000)



n=39188 by June, 2014

n=39064 for our study

Overview of purposes

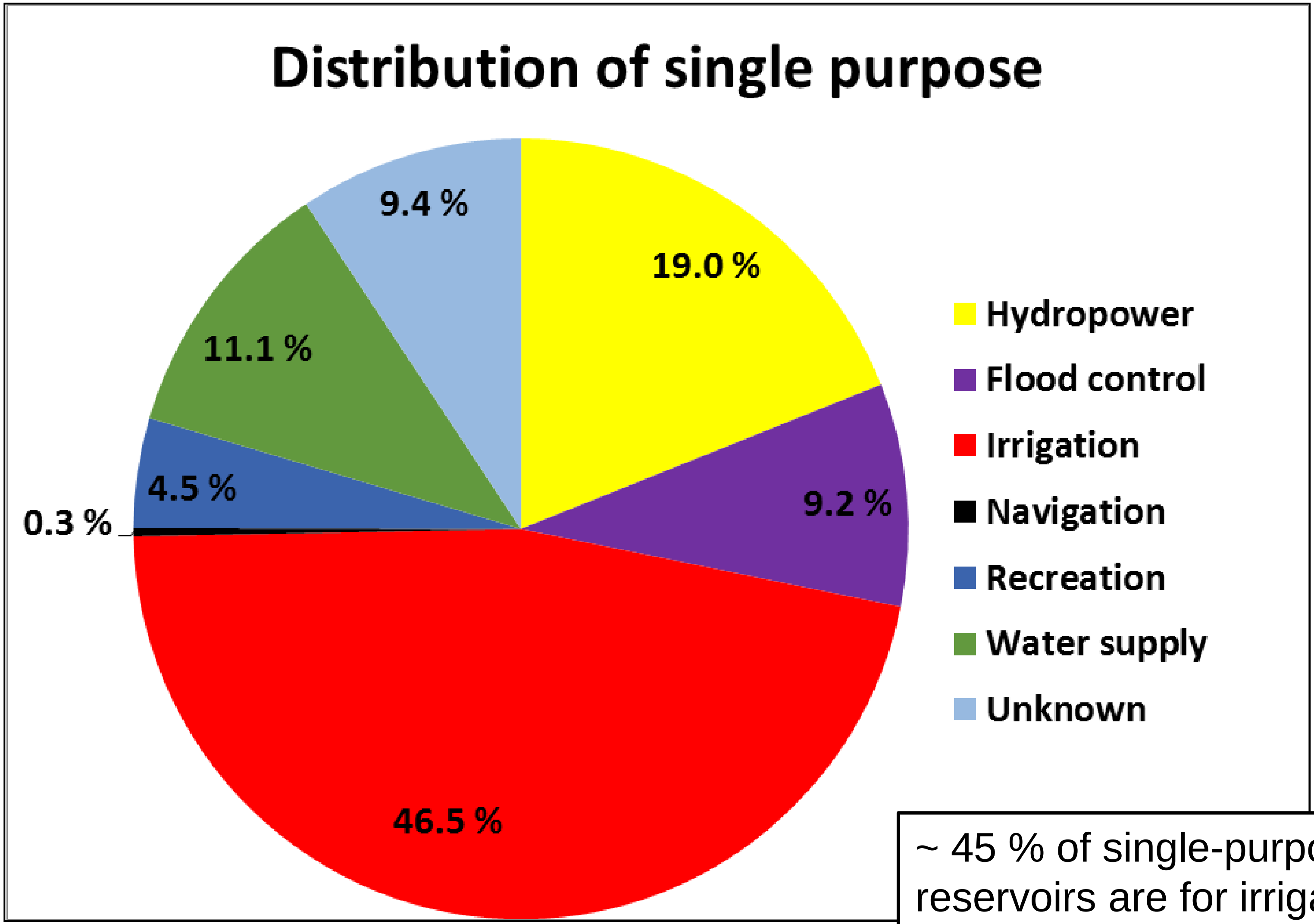


Approx. 75 % of the reservoirs are single purpose

The most frequent purpose: Irrigation

The second most frequent purpose: Hydropower

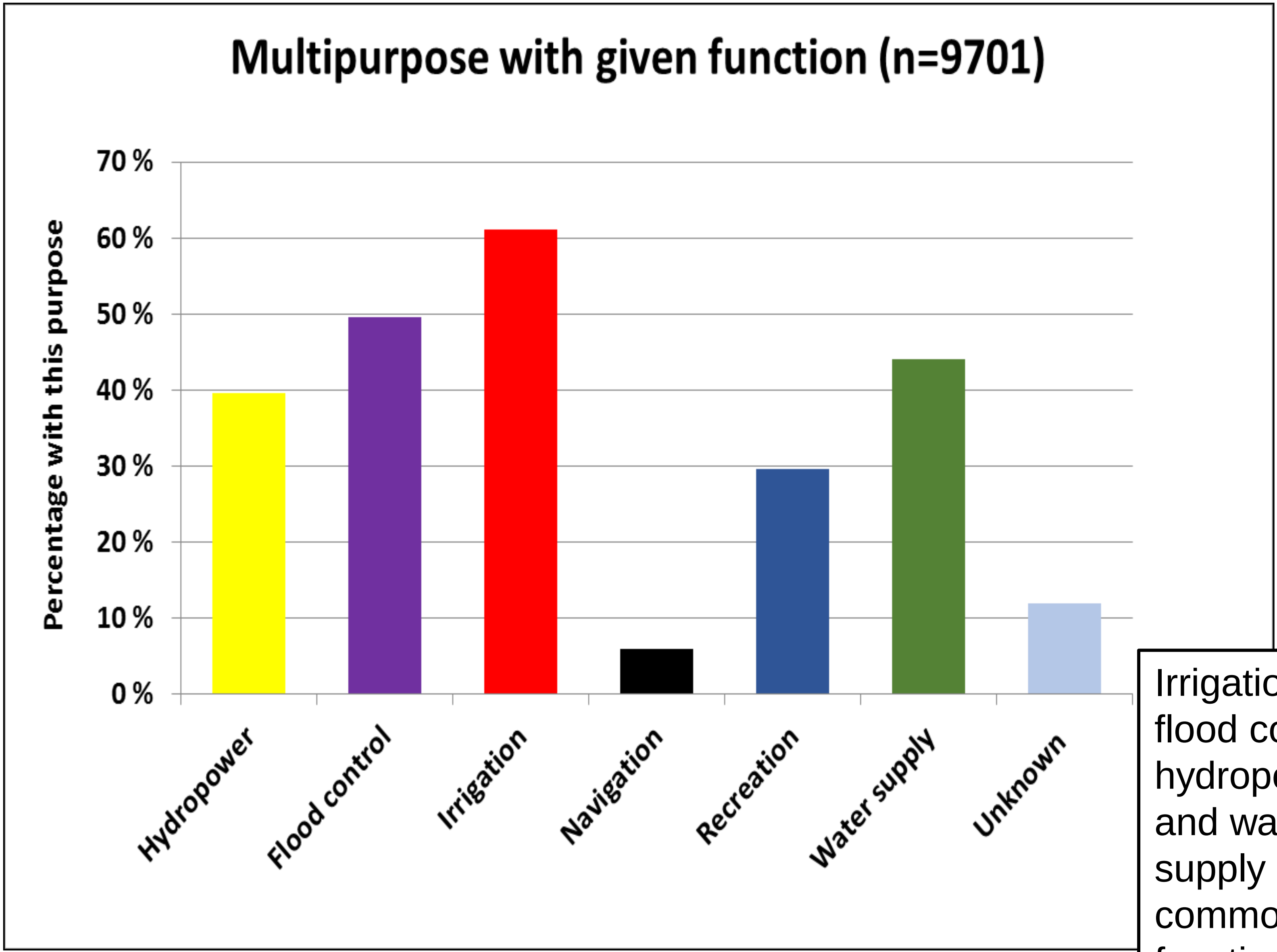
Source: ICOLD database



~ 45 % of single-purpose reservoirs are for irrigation

~ 20 % of single-purpose reservoirs are for hydropower

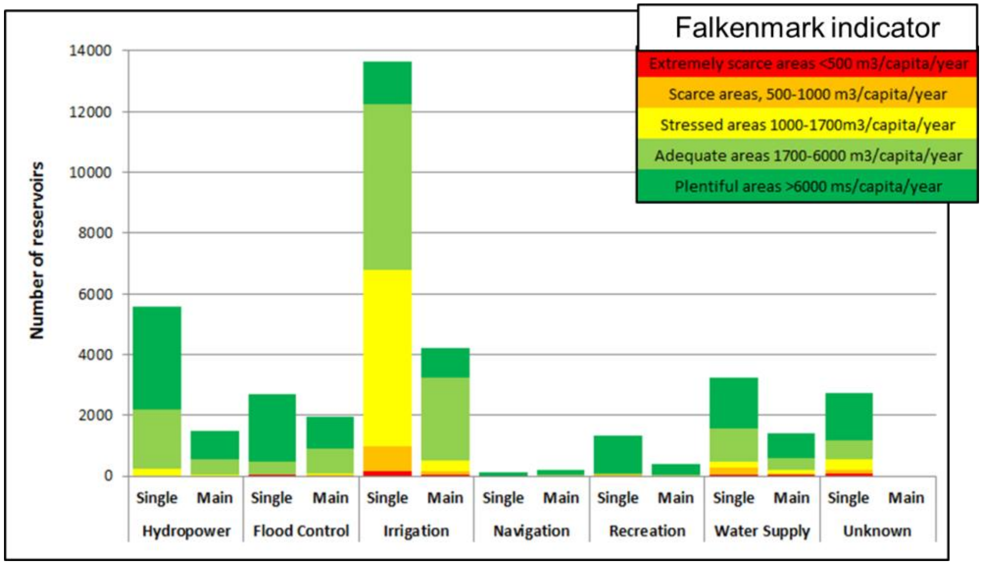
Source: ICOLD database



Irrigation, flood control, hydropower and water supply are all common functions

Source: ICOLD database

Reservoirs summed up



The majority of reservoirs are single (75%) and irrigation is the dominating purpose

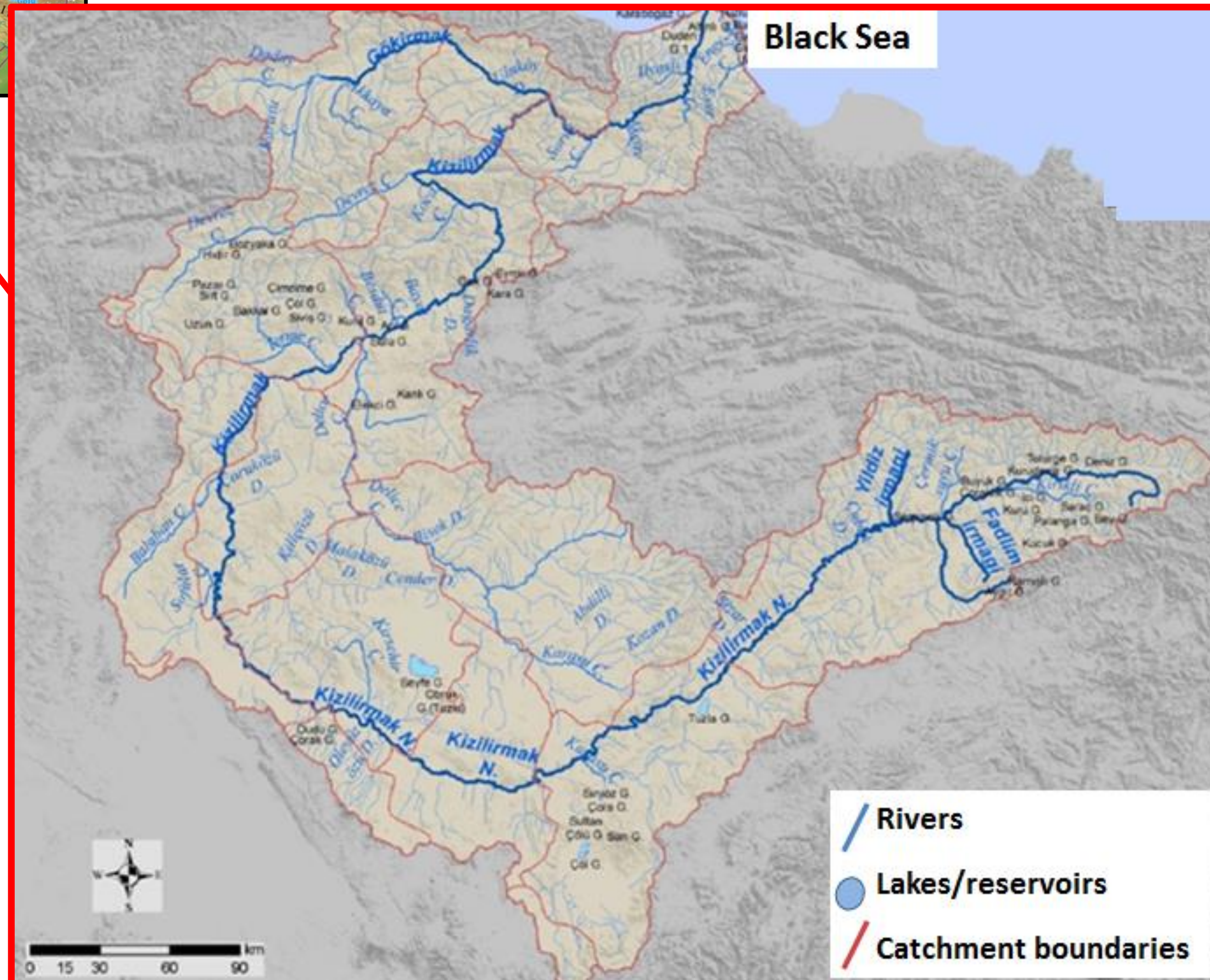
Irrigation, flood control, hydropower and water supply are all common functions of multipurpose reservoirs

Very few reservoirs with single or main purpose hydropower are located in water-scarce regions

Study of water management and the role of reservoirs in Turkey

Case study Kizilirmak River Basin, Turkey

Kizilirmak River Basin

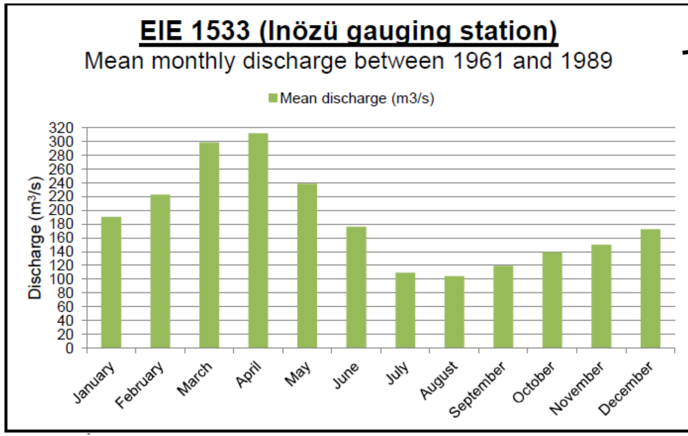


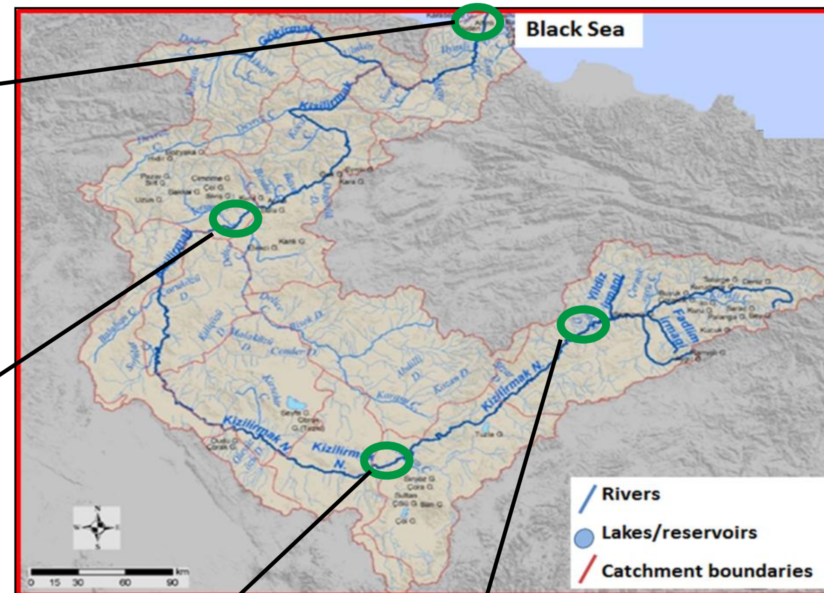
Concerns

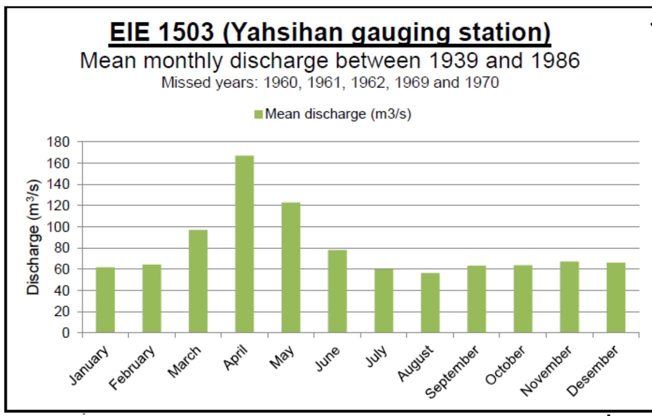
How much water will be available for power production in the near and long-term future?

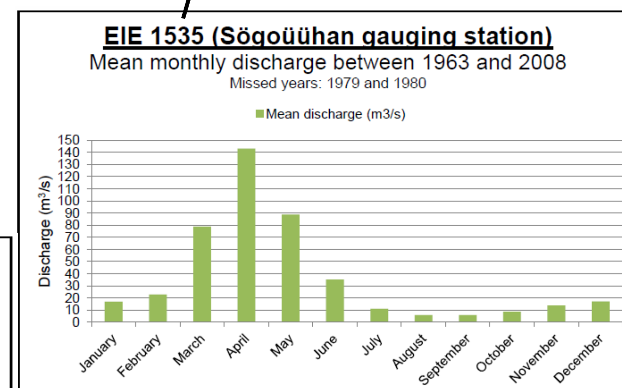
- Climate change and the effects on water
- Land use changes/irrigation practice

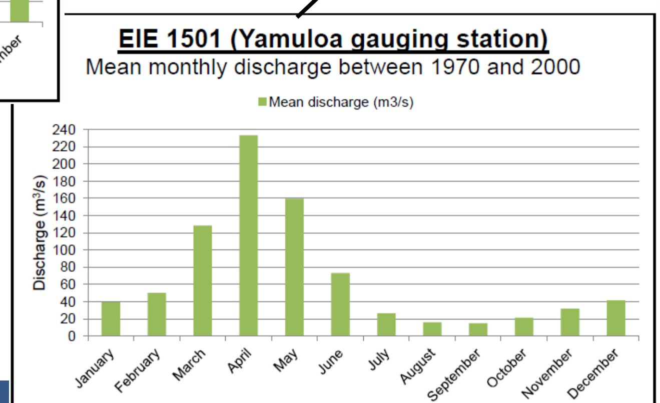
Monthly water flows



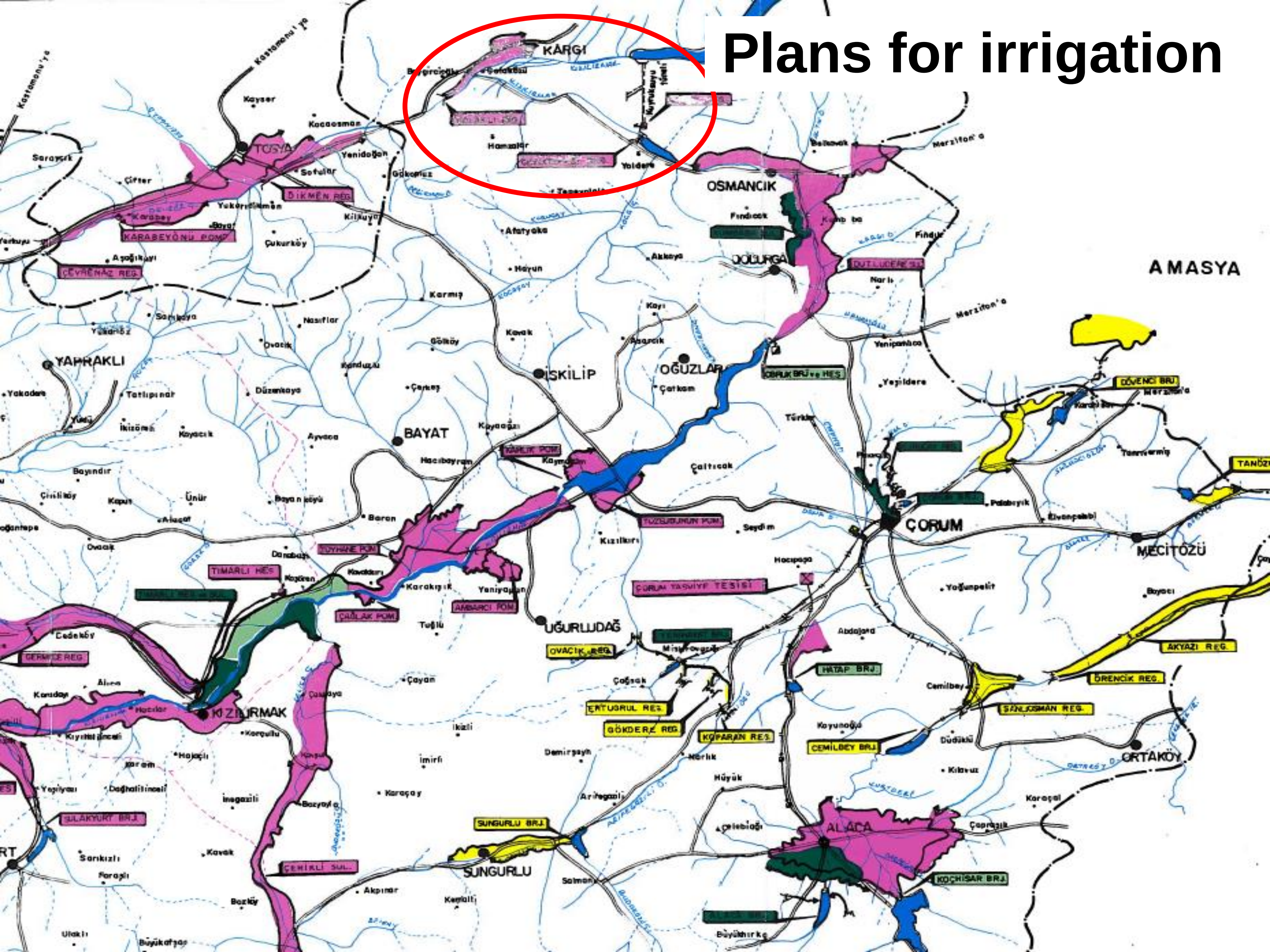




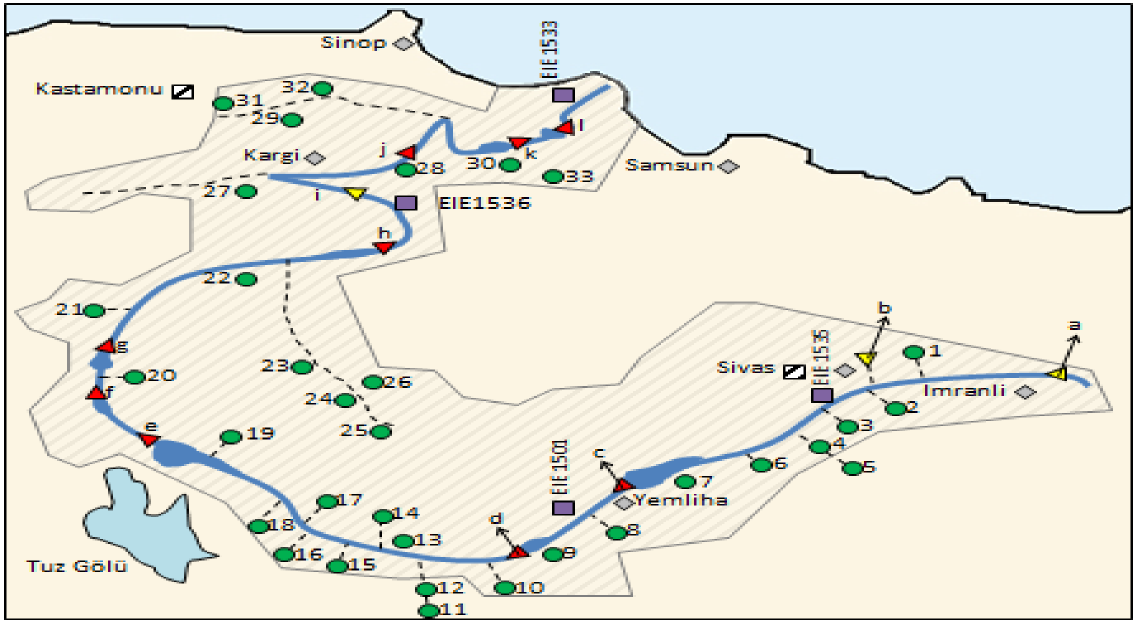




Plans for irrigation



Model setup (WEAP)



Irrigation			
1	Ozen-Pusat	18	Yalintas
2	Karacalar	19	Siddikli
3	Gazibey	20	Koprukoy
4	Maksutlu	21	Gokceoren
5	Yapialtin	22	Timarli
6	Sarioglan	23	Kuzayca
7	Yemliha	24	Karaova
8	Sarimsakli	25	Uzunlu
9	Bayramhacili	26	Yahyasaray
10	Damsa	27	Guldurcek
11	Kavali	28	Boyabat
12	Akkoy	29	Karacomak
13	Avanos-Ozkonak	30	Vezirkopru
14	Ayhanlar	31	Germectepe
15	Tatlarin	32	Karadere
16	Kultepe	33	Gumushacikoy
17	Cogun		

HP Dam	
a	Imranli
b	Cermikler
c	Yemliha
d	Bayramhacili
e	Hirfanli
f	Kesikkopru
g	Kapulukaya
h	Obruk
i	Kargi
j	Boyabat
k	Altinkaya
l	Derbent

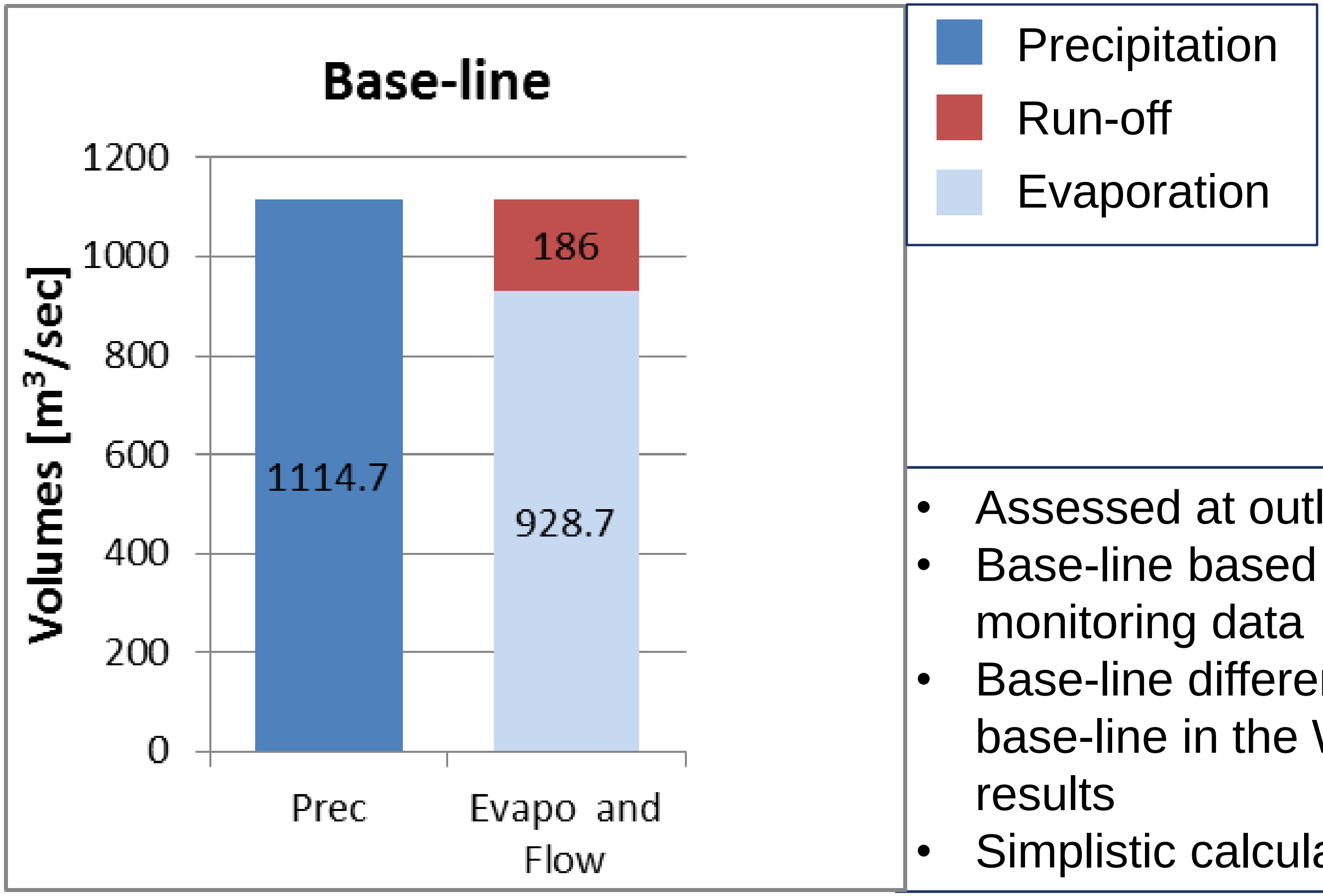
Legend
River basin
Kizilirmak
Tributary
City/town
Irrigation scheme
Hydropower (existing)
Hydropower (planned/under dev.)
Water flow station
Climate station

Scenario definition

Scenario name	Temperature Summer/Winter	Precipitation Summer/Winter	Irrigation
Scenario 1A ('year 2050')	+2.5 / +1.5	-5% / -2.5%	No additional
Scenario 1B ('year 2050')	+2.5 / +1.5	-5% / -2.5%	Increased
Scenario 2A ('year 2090')	+3 / +2	-10% / -5%	No additional
Scenario 2B ('year 2090')	+3 / +2	-10% / -5%	Increased
Scenario 3 ('year 2090')	+3 / +2	-10% / -5%	Increased

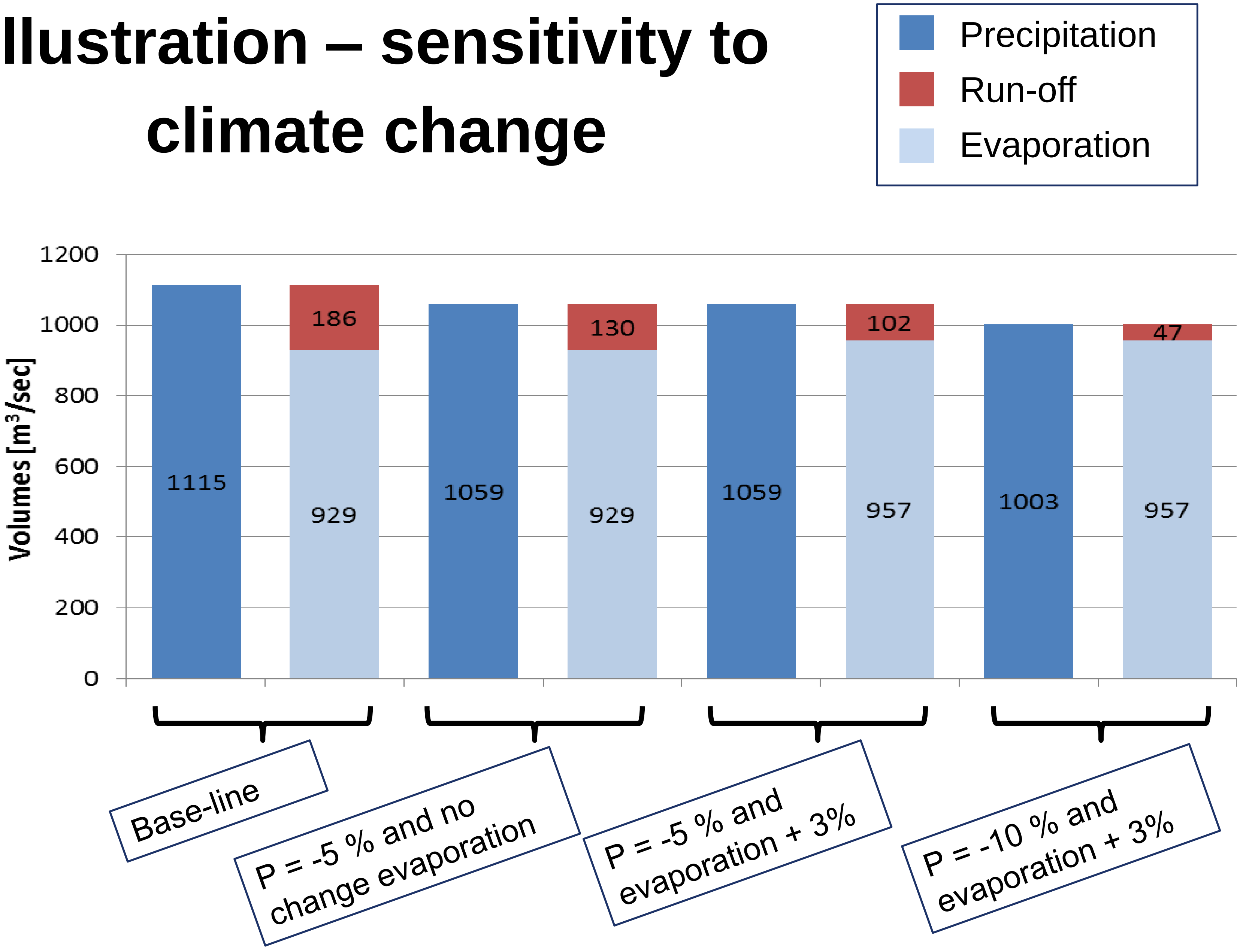
Source: IPCC, 2013: Annex I

Illustration – sensitivity to climate change



- Assessed at outlet of basin
- Base-line based on historical monitoring data
- Base-line different than base-line in the WEAP-results
- Simplistic calculation

Illustration – sensitivity to climate change



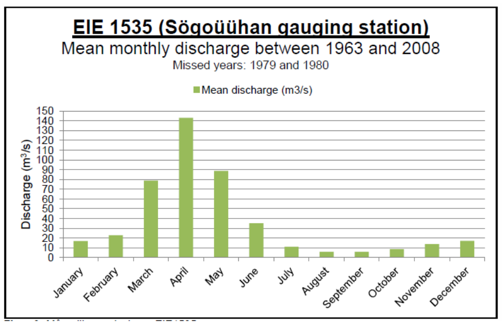
Conclusions

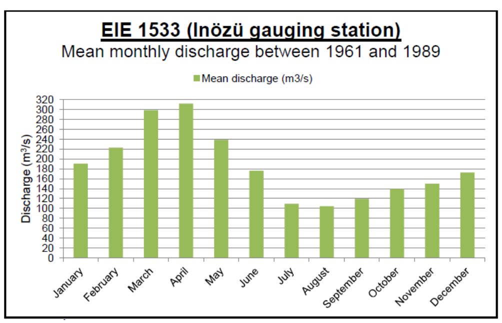
- There is clear competition over water between hydropower production and irrigation in Kizilirmak River Basin, Turkey
- The effect of climate change and irrigation will reduce the available water resources for hydropower production significantly. Similar trends found also by e.g. Milly et al. (2005), IPCC (2008), Maestre-Valero et al. (2013)
- The effect of climate change is stronger than the effect of continuous withdrawal/consumption in the agricultural sector in parts of the basin
- Small changes in climate will potentially make big changes in runoff when low runoff coefficients (low effective rainfall/high evaporation)
- Integrated assessment of the water resources needed in order to plan the mid- and long-term hydropower resources/production
- The risk profile of the investment portfolio is to a large extent affected by the location of the HP prospect compared to other water users

If hydropower is a water consumer or not?

- The purpose of the reservoir must be investigated
- Allocation needed in case of multipurpose use
- NET effect important
- Investigate the tradeoff between the increased availability of the net loss of water due to evaporation

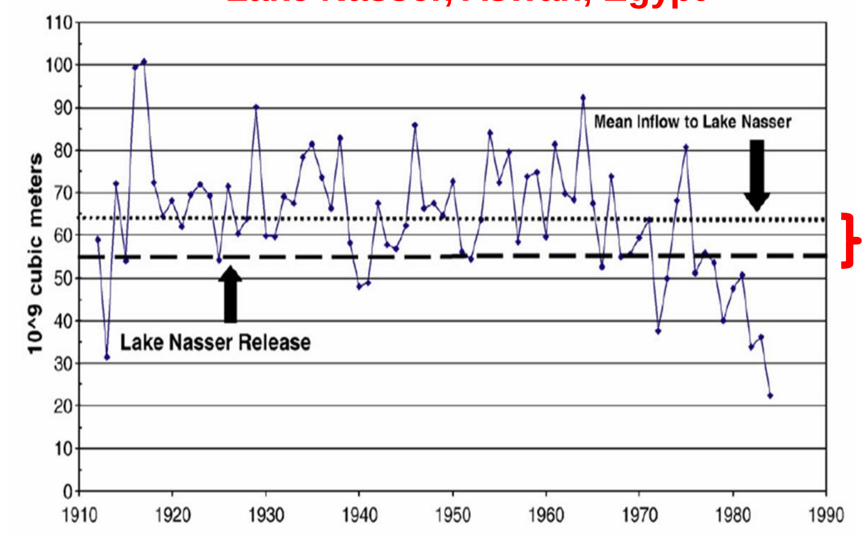
Kizilirmak River Basin, Turkey





Increased availability, but increased losses

Lake Nasser, Aswan, Egypt



Evaporative losses

Documentation

Submitted: J of Water Resources Management

Are reservoirs water consumers or water collectors?
Reflections on the water footprint concept applied on reservoirs

Authors: T.H. Bakken[1 & 2] (corresponding author), F. Kjosavik[1 & 2], Å. Killingtveit[1] & K. Alfredsen[1]

[1] Norwegian University of Science and Technology, Department of Hydraulic and Environmental Engineering, NO-7491 Trondheim, Norway. Corresponding author: tor.h.bakken@ntnu.no / Tel: +47 95156944

[2] SINTEF Energy Research, NO-7465 Trondheim, Norway

1 INTRODUCTION

IPCC (2011) presented an extensive review of the potential for renewable energy sources to replace fossil-based fuels and also benchmarked the different renewable technologies. One of the benchmark criteria were the water consumption of electricity production or the water footprint. IPCC (2011) revealed potentially very high water consumption rates from hydropower compared to the other renewables, up to a maximum of 209 m^3/MWh due to evaporative losses from the reservoir surfaces, but it was noted that only a very few studies were available and a number of methodological problems were identified. More recent publications (e.g. Mekonnen and Hoekstra 2012; Demeke et al. 2013; Bakken et al. 2013) present new estimates on water consumption from hydropower projects far beyond those earlier published by IPCC (2011), but do not provide a more consistent picture of the 'true water consumption of hydropower'. In the upper range, Mekonnen and Hoekstra (2012) find that the sum of evaporated water (water footprint) of a sample of 35 evaluated hydropower reservoirs is similar to 10% of the global blue water footprint from crop production and therefore argue that production of hydroelectricity is a large-scale water consumer. Similarly, Gerbens-Leenes et al. (2009) has calculated very high global values for water consumption from hydropower production. Studies within this field of science have, however, has also been criticized (e.g. Demeke et al. 2013; Chenoweth et al. 2014; Bakken et al. 2013) due to its weak methodological basis. Given the fact that there is a growing interest in assessing the water footprint of various products, with reference to for instance the on-going development an ISO Water Footprint standard (ISO 14046 2014), we find it reasonable to present our views on the relevance of assessing the water footprint of reservoirs with hydropower production. Before we continue the discussion we would recall the purpose of reservoirs that are to store water from the wet to the dry season[1] in order to supply water of sufficient quantities to those periods of the year where natural runoff cannot meet the society's need of water.

Submitted: ICOLD2015 conference

THE EFFECTS OF CHANGE IN CLIMATE AND IRRIGATION PRACTICE ON THE HYDROPOWER RESOURCES IN KIZILIRMAK RIVER BASIN, TURKEY

Tor Haakon BAKKEN
Research scientist & PhD-student water resources management
Norwegian University of Science and Technology (NTNU) & SINTEF Energy Research, NORWAY

Jørgen Melhuus RUGELBAK
MSc & Consultant hydrology
Norwegian University of Science and Technology (NTNU) & Rambøll, NORWAY

Marisa ESCOBAR
PhD & Senior Scientist water resources management
Stockholm Environment Institute, USA

Ali Ünal ŞORMAN
PhD & Professor emeritus hydraulic engineering
Middle East Technical University (METU), TURKEY & Near East University, Nicosia, Cyprus (Dean of faculty)

Knut ALFREDSEN & Ånund KILLINGTVEIT
PhDs & Professors hydrology
Norwegian University of Science and Technology (NTNU), NORWAY

1. INTRODUCTION

Turkey has vast hydropower resources calculated to 16 % of Europe's theoretical hydropower potential and 1% of the world total. Turkey's viable hydroelectric capacity potential is estimated at 35 GW and the installed capacity is by 2010 15.1 GW, of which 12.6 GW is reservoir hydro and 2.5 GW run of river hydro (ECON PÖYRY, 2010). Turkey has exploited close to 43% of its viable hydroelectric potential and the goal of the Turkish government is to utilize all technically and economically viable hydropower by 2023. There are currently (by year 2010) 444 hydropower projects with a capacity larger than 3 MW under development. The demand for electricity in Turkey has increased steadily by more than 8 % each year since 2000.

Thank you for listening!

Acknowledgment:

Jørgen Rugelbak, Fredrikke Kjosavik, Ånund Killingtveit & Knut Alfredsen
(Norwegian University of Science and Technology)

Rune Engesæter (NNCOLD, NVE)