Hydrologic simulations of global warming impact using dynamically downscaled data: case study of the Seyhan river basin in Turkey

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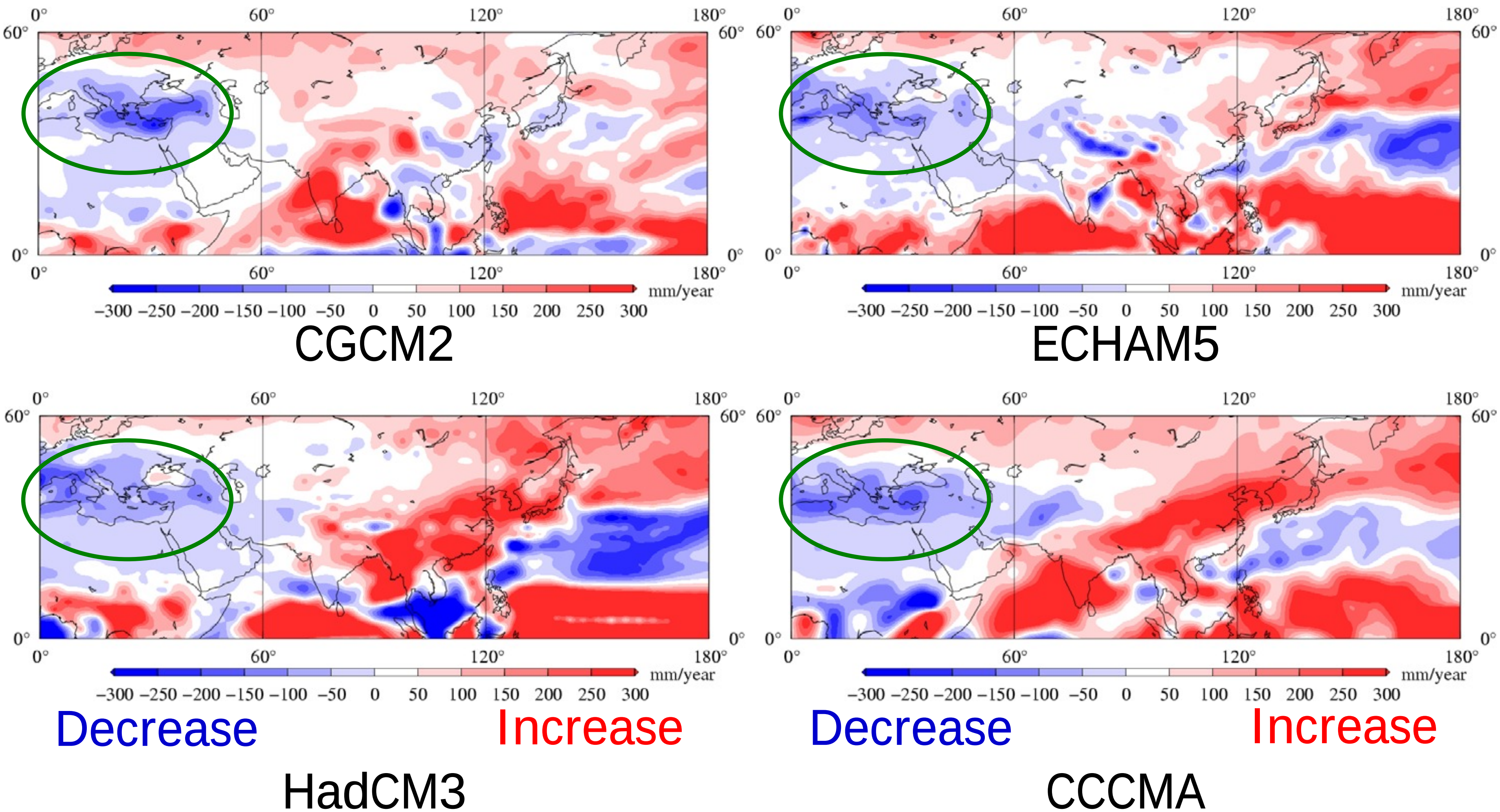
Background: Mekong region - Turkey

- Japan International Research Center for Agricultural Sciences (JIRCAS)
  - Intensification of water use and diversification of farm operations through farmer participatory approach in rainfed agriculture of Indochina (Rainfed agriculture project)

- Research Institute for Humanity and Nature (RIHN)
  - Impact of climate changes on agricultural production system in arid areas （ICCAP）
  - Project leader: Prof. Tsugihiro WATANABE
  - The study region is Mediterranean region, Turkey
  - Seyhan River basin (21,700 km2)
  - Research period: 2002 April - 2007 March

Why in Turkey?
future (2070-2099) - present (1961-1990), A2

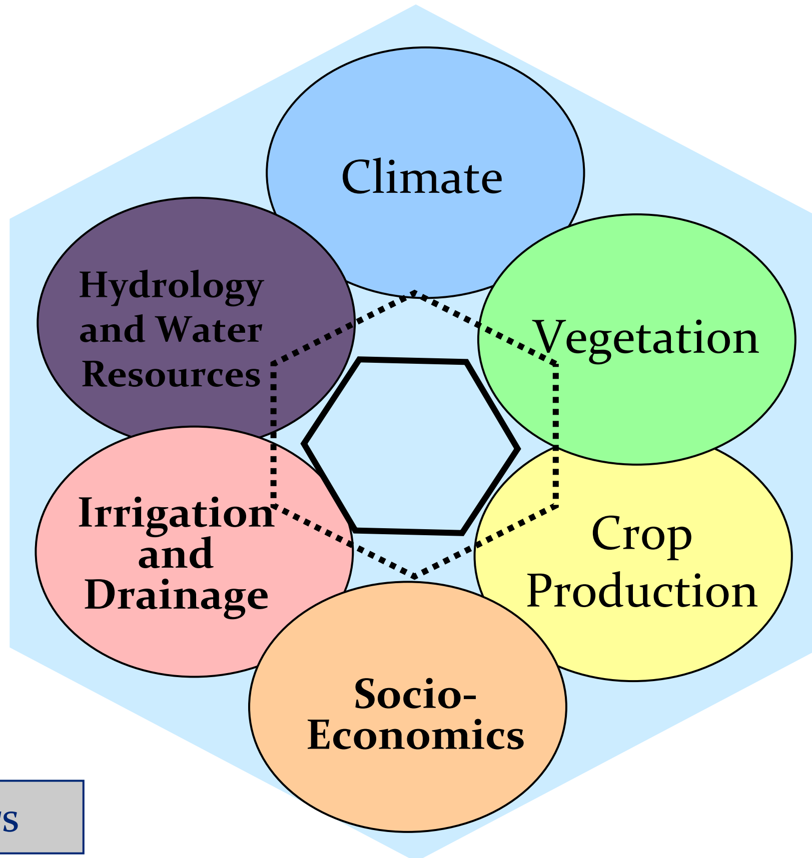


Research organization

Japan

RIHN

43 collaborators



Turkey

TÜBITAK

Scientific and Technical Research Council of Turkey

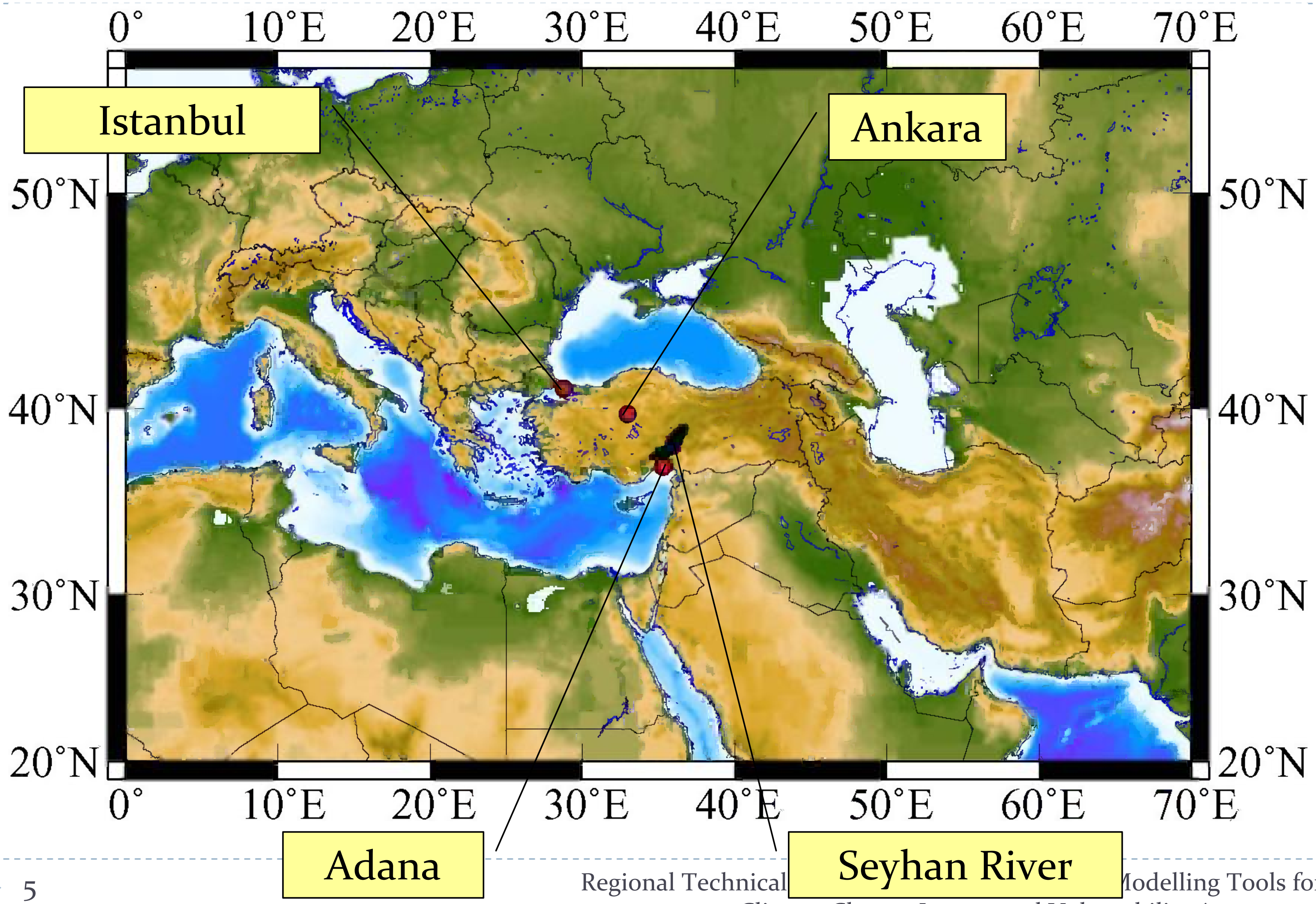
54 collaborators

Advisers

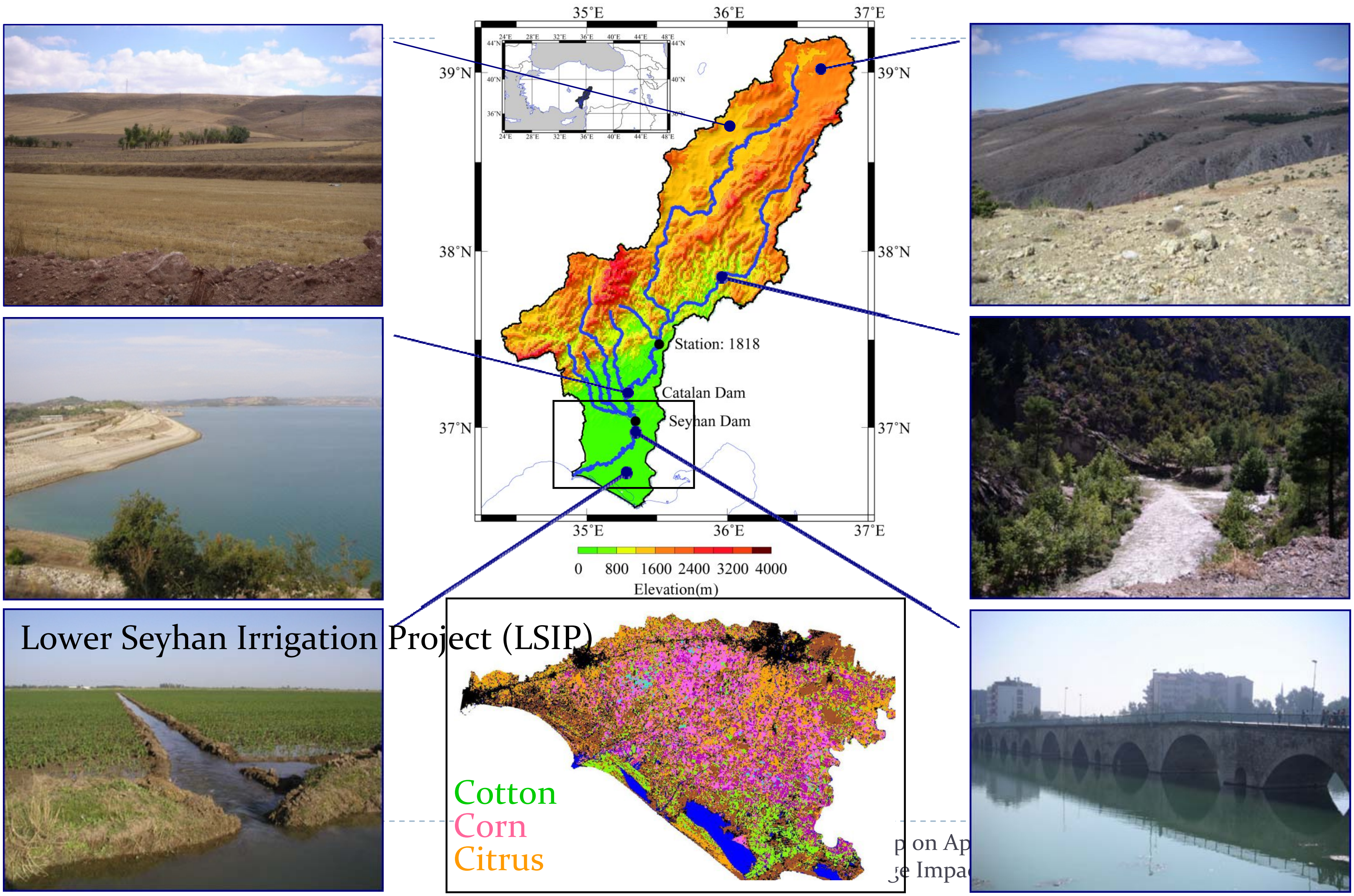
Coordinators

6 Researchers from the third countries and International organizations

Seyhan River basin in Turkey

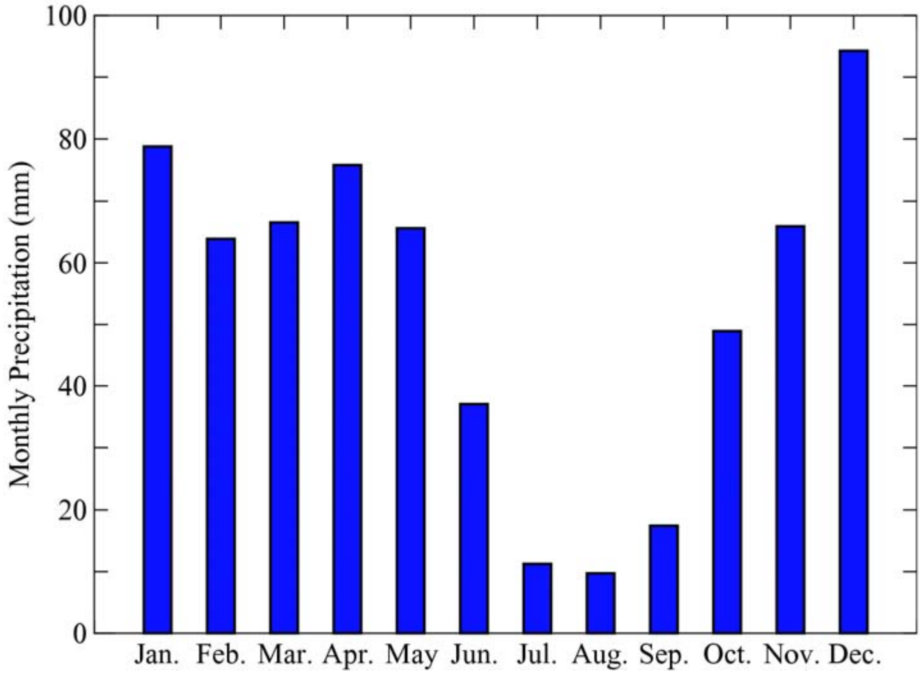


Outline of Seyhan River basin

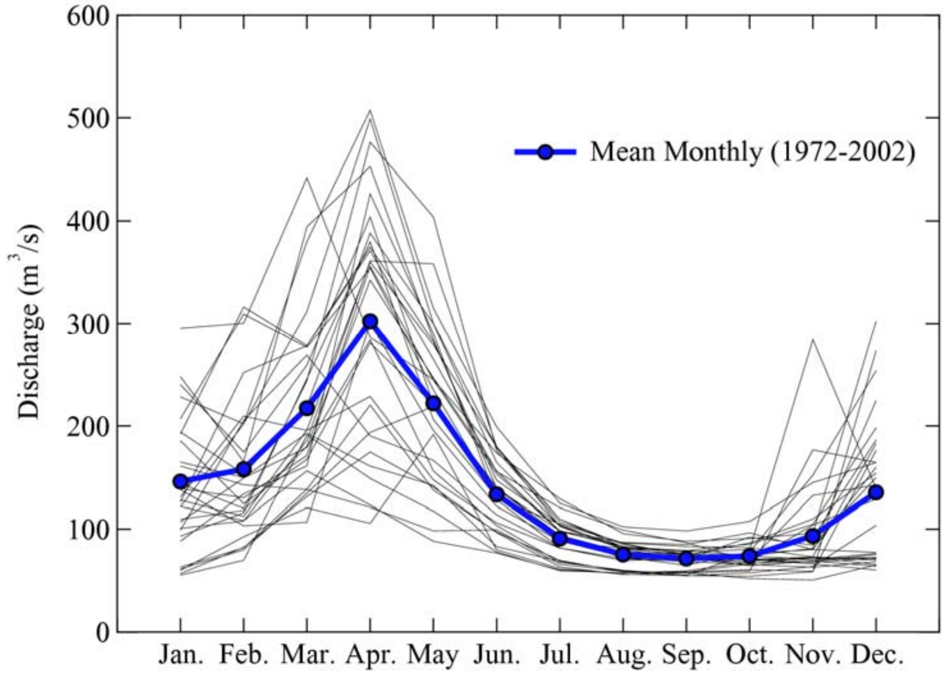


Hydrological characteristics

- Rainfall: lower 700mm/y, middle 1000mm/y, upper 400mm/y
- Runoff: 280mm/y （5.5 billion m3）

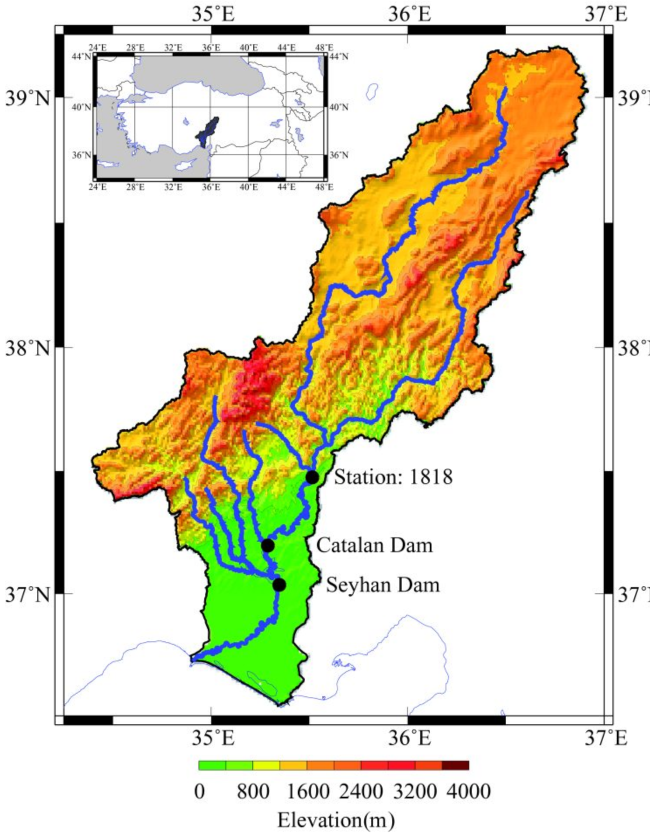


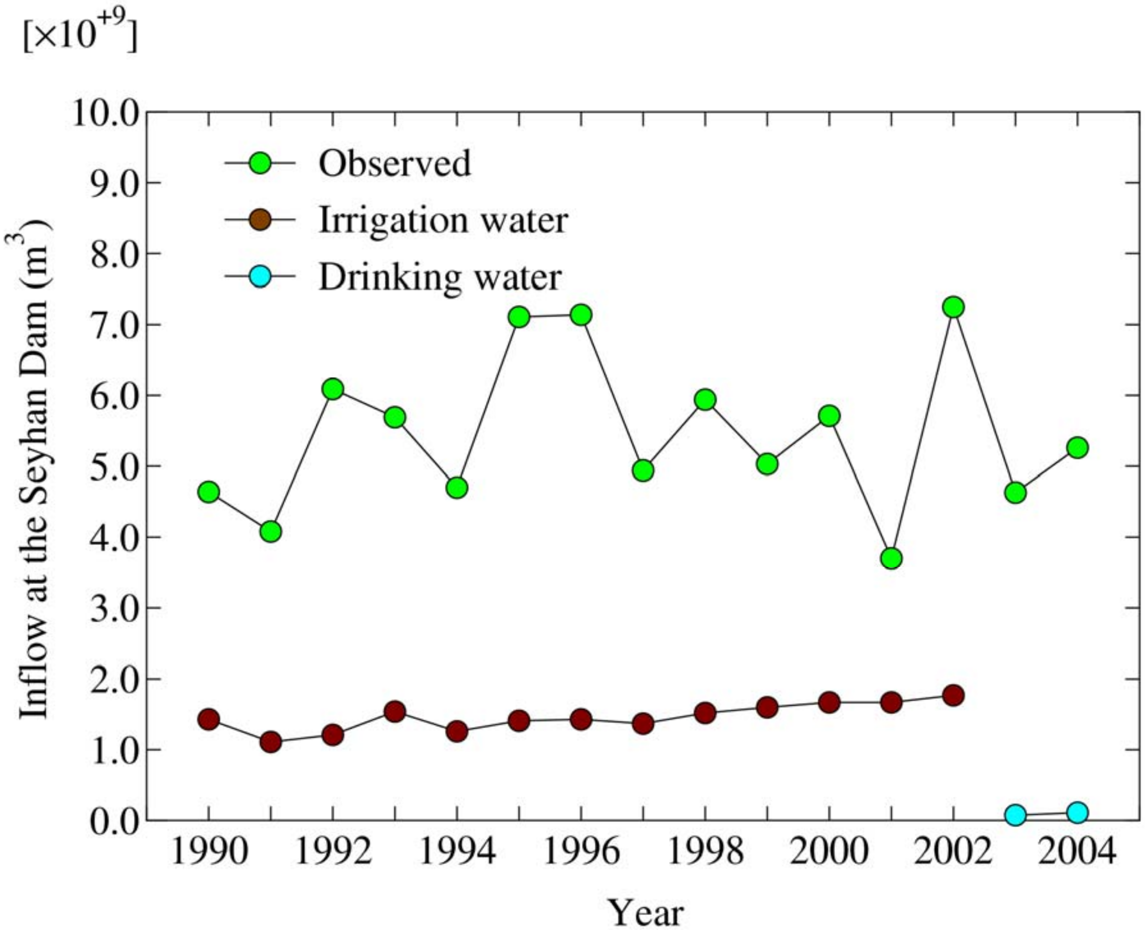
Rainfall



Runoff

Reservoir volumes and water use



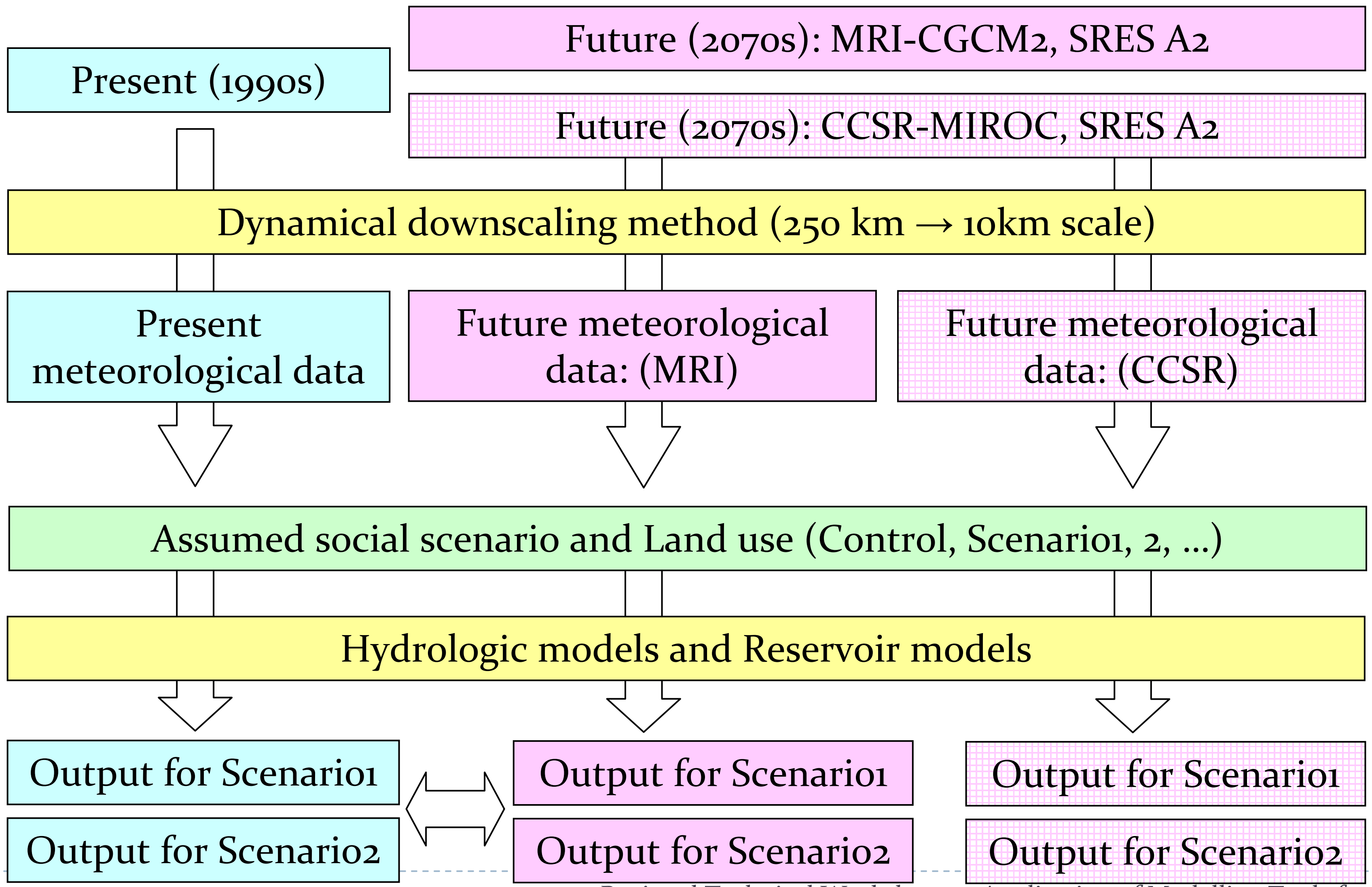


Reservoir volume

Seyhan: 0.88 billion m^3

Catalan: 1.6 billion m^3

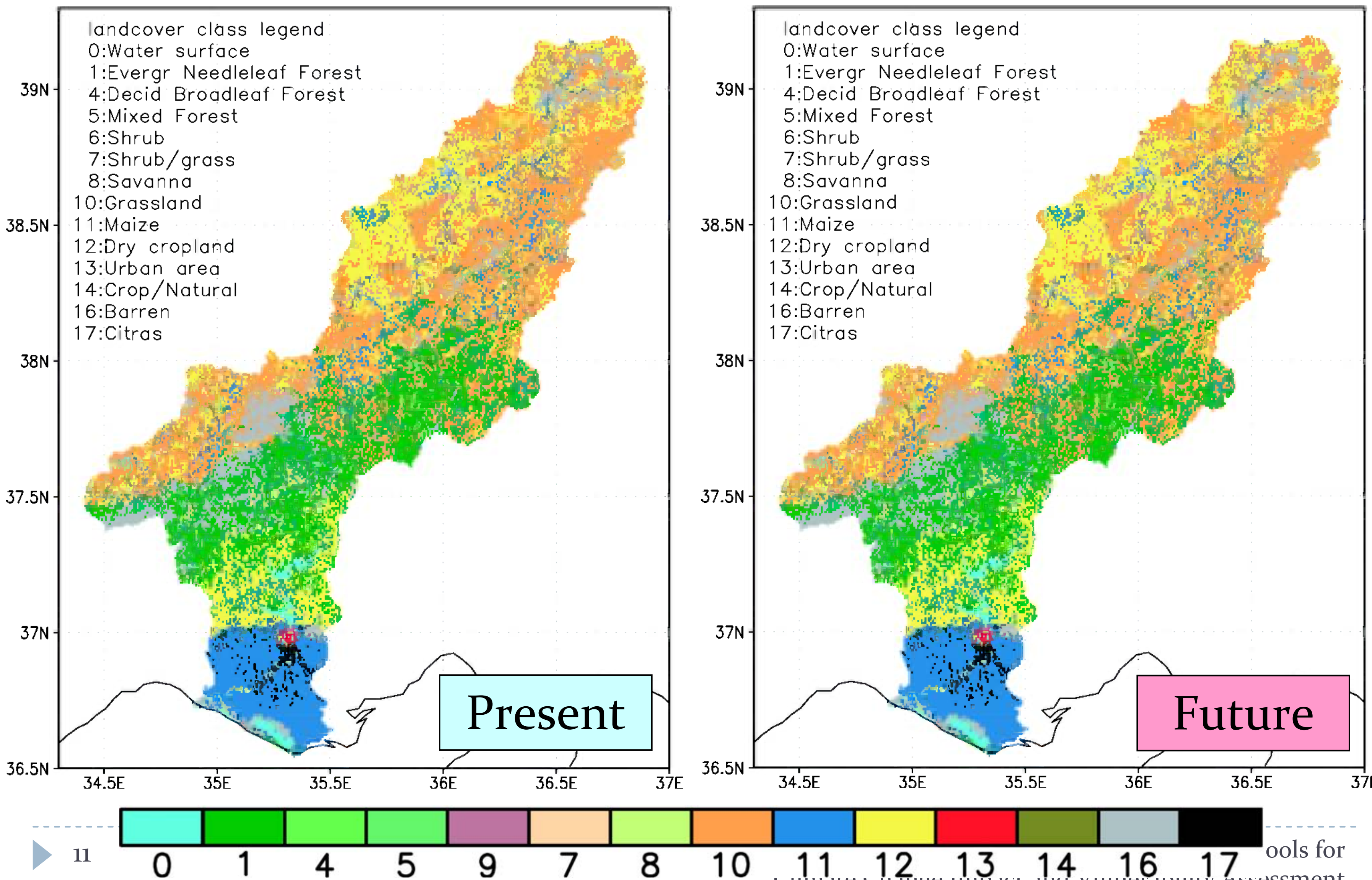
Approach used in this study



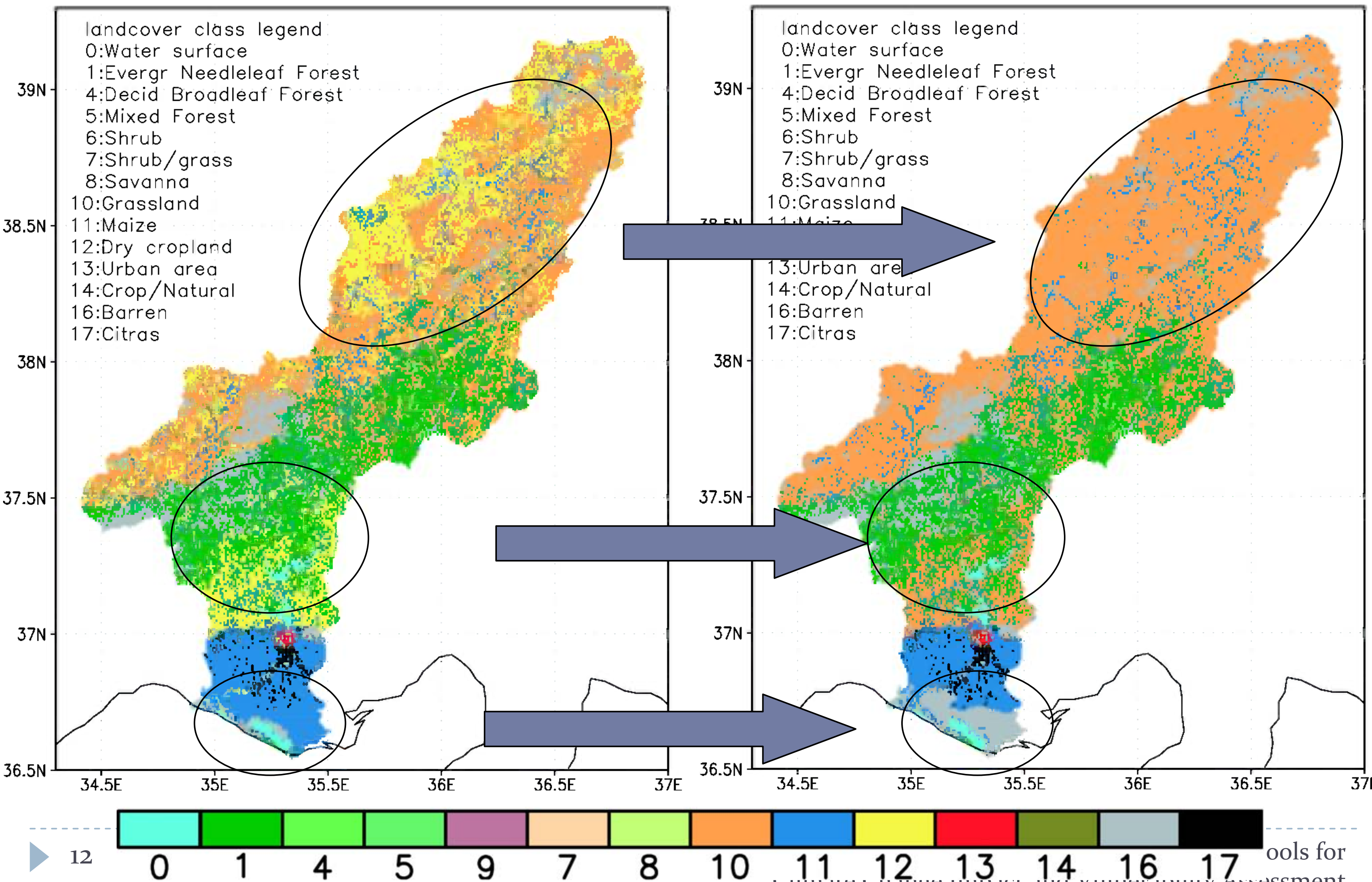
Assumed social scenario and land use

- Present
  - Actual conditions
  - Irrigation area is 133,000 ha
- Future
  - Basin conditions are the same as present
  - Control run
- Scenario 1
  - Winter rain-fed wheat is converted to pasture, due to little precipitation
  - Lower Seyhan Irrigation Project (LSIP) IV is completed. Irrigation area is 174,000 ha
- Scenario 2a-2e
  - Forest decreases, due to little precipitation
  - LSIP IV is completed, and irrigated farmlands are newly developed
  - Irrigation area is 174,000 ha + (2a) 20,000 ha, (2b) 40,000 ha, (2c) 60,000 ha, …

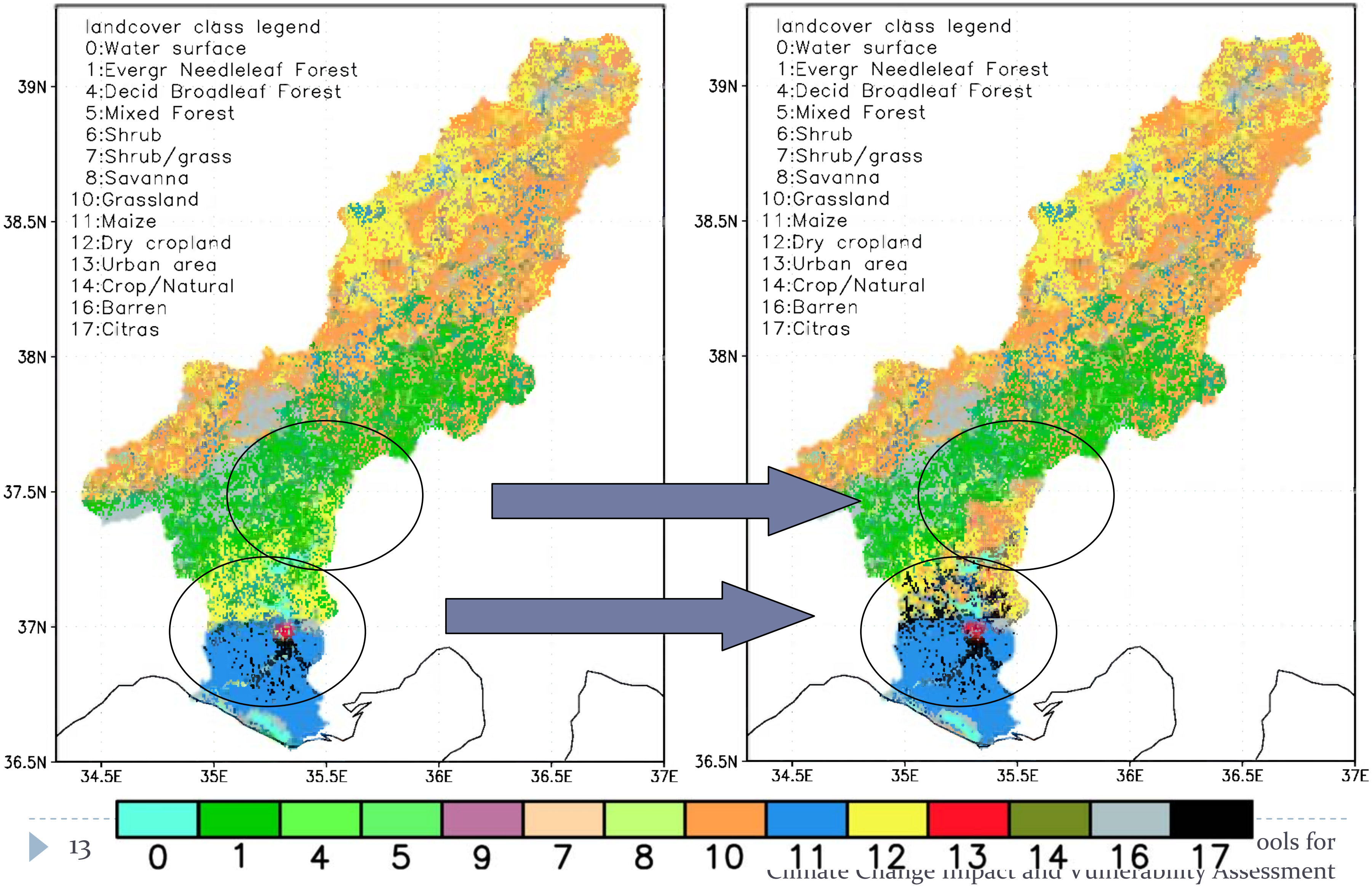
Present and future land use



Scenario 1


landcover class legend
0:Water surface
1:Evergr Needleleaf Forest
4:Decid Broadleaf Forest
5:Mixed Forest
6:Shrub
7:Shrub/grass
8:Savanna
10:Grassland
11:Maize
12:Dry cropland
13:Urban area
14:Crop/Natural
16:Barren
17:Citras
39N
38.5N
38N
37.5N
37N
36.5N
34.5E
35E
35.5E
36E
36.5E
37E
0 1 4 5 9 7 8 10 11 12 13 14 16 17

Scenario 2a-2e

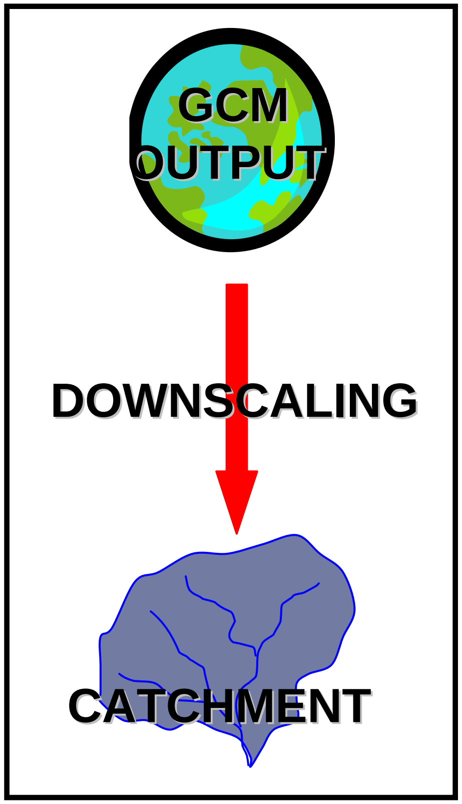


Water demand for each scenario

Scenario	Note	Irrigation area (ha)	Water demand (Gm3/y)
Present, Future	Present water use	133,000	1.60
Scenario 1	LSIP IV is completed	174,000	2.08
Scenarios 2a–2e	LSIP IV is completed, and irrigated farmlands are newly developed	(a) 174,000+20,000	2.32
		(b) 174,000+40,000	2.56
		(c) 174,000+60,000	2.80
		(d) 174,000+80,000	3.04

GCMs – River basins

- The GCMs outputs are inadequate to assess the impacts of climate change on river basins. The temporal and spatial resolutions of GCMs are too coarse compared with those of hydrologic models
- Pseudo global warming downscaling method has been recently developed



Dynamic downscaling method

- Present (1993 – 2004)

NCEP Re-Analysis data → RCM （Regional Climate Model）

Present meteorological data sets

- Future (2070s)

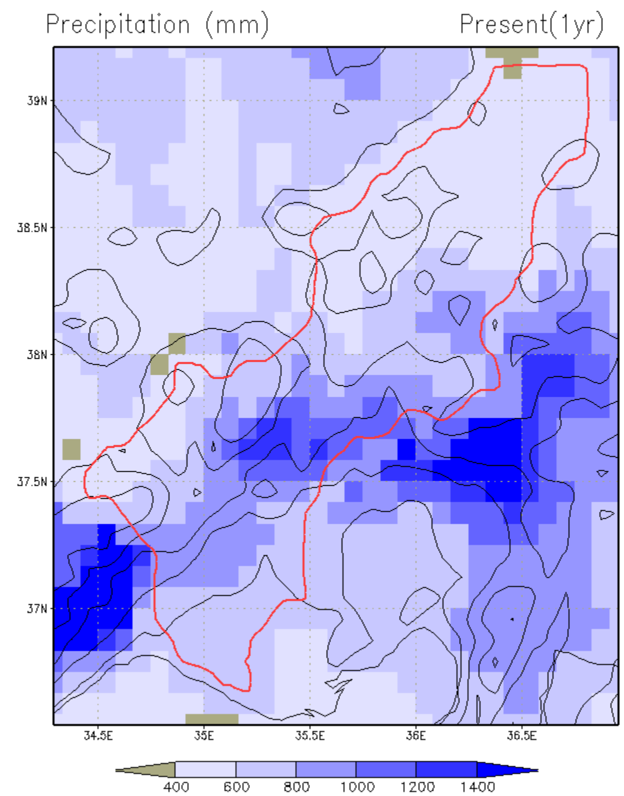
NCEP Re-Analysis data
+
ΔT, ΔP,…（2070's global warming） by GCM under A2

→ RCM

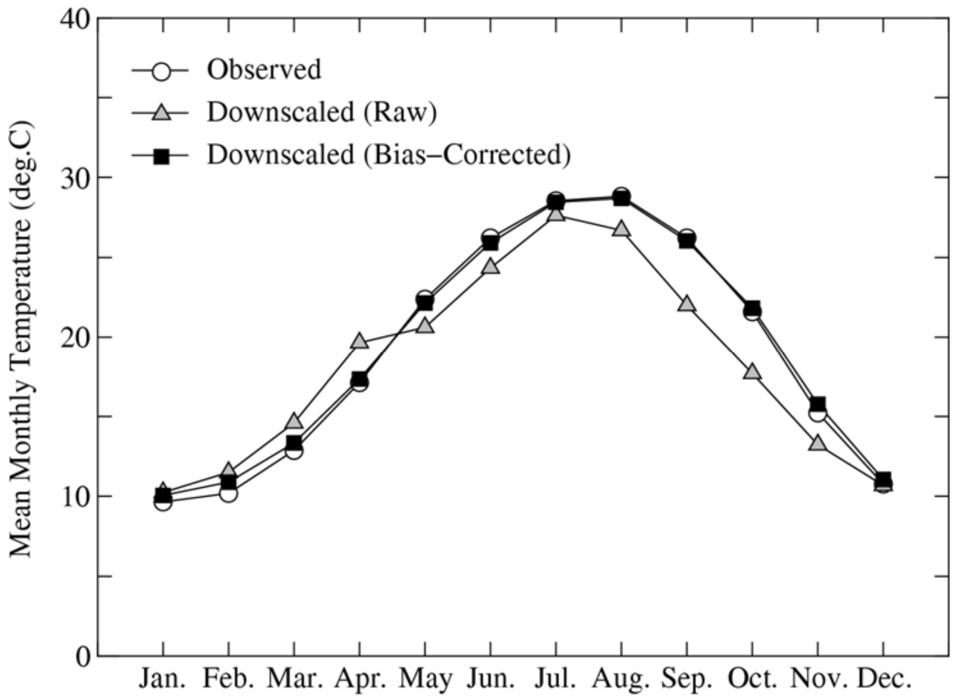
Future meteorological data sets

Application of downscaling method

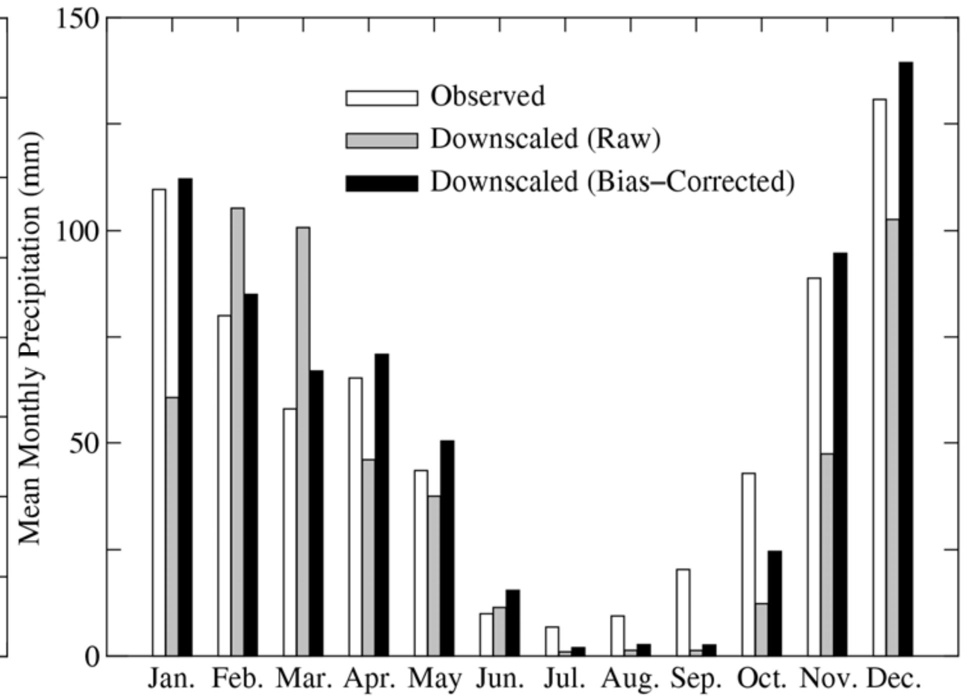
- Period
  - Present: 1990s (10-year), Future: 2070s (10-year)
- GCMs
  - MRI-CGCM2 (MRI)
  - CCSR/NIES/FRCGC-MIROC (CCSR)
  - SRES A2
- RCM
  - TERC-RAMS (Tsukuba Univ.)
- Outputs
  - Hourly, resolution: about 8.3km
  - Prec, downward shortwave / long wave radiation, wind, temp, pressure, specific humidity
- Bias correction
  - (1) DS by RCM, (2) use, (3) characteristics of bias, (4) turning of RCM
  - Repeat this procedure (1) –(4) many times
  - Finally, statistical bias correction was done



Temperature and Precipitation (present)



Temperature

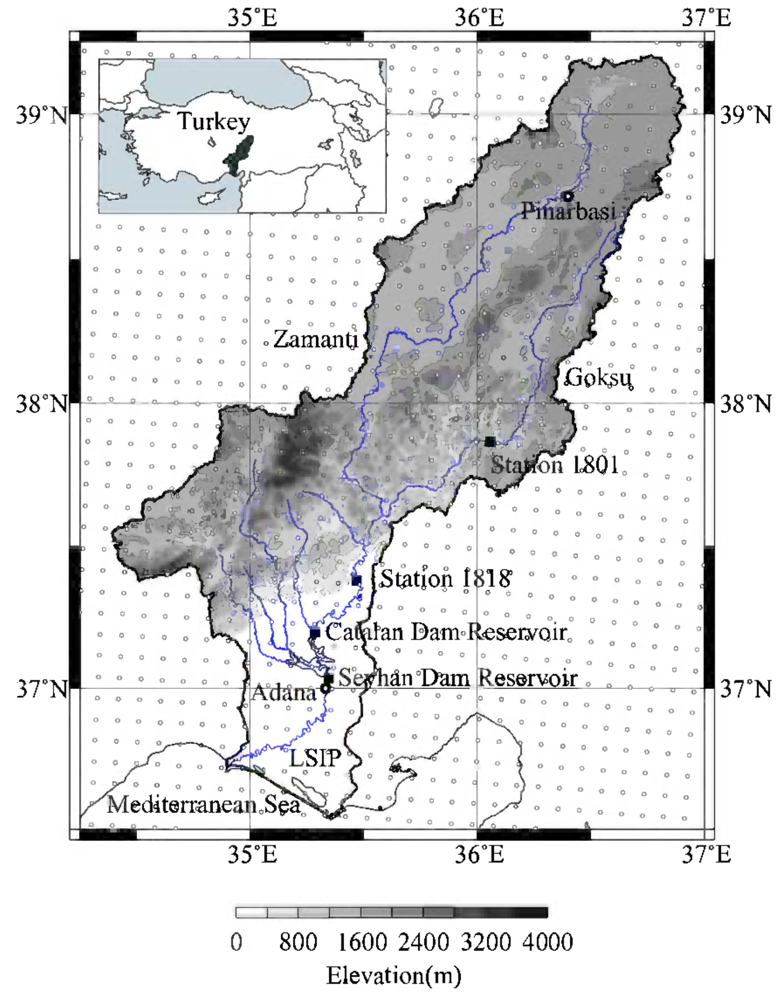


Rainfall

Application of hydrologic models

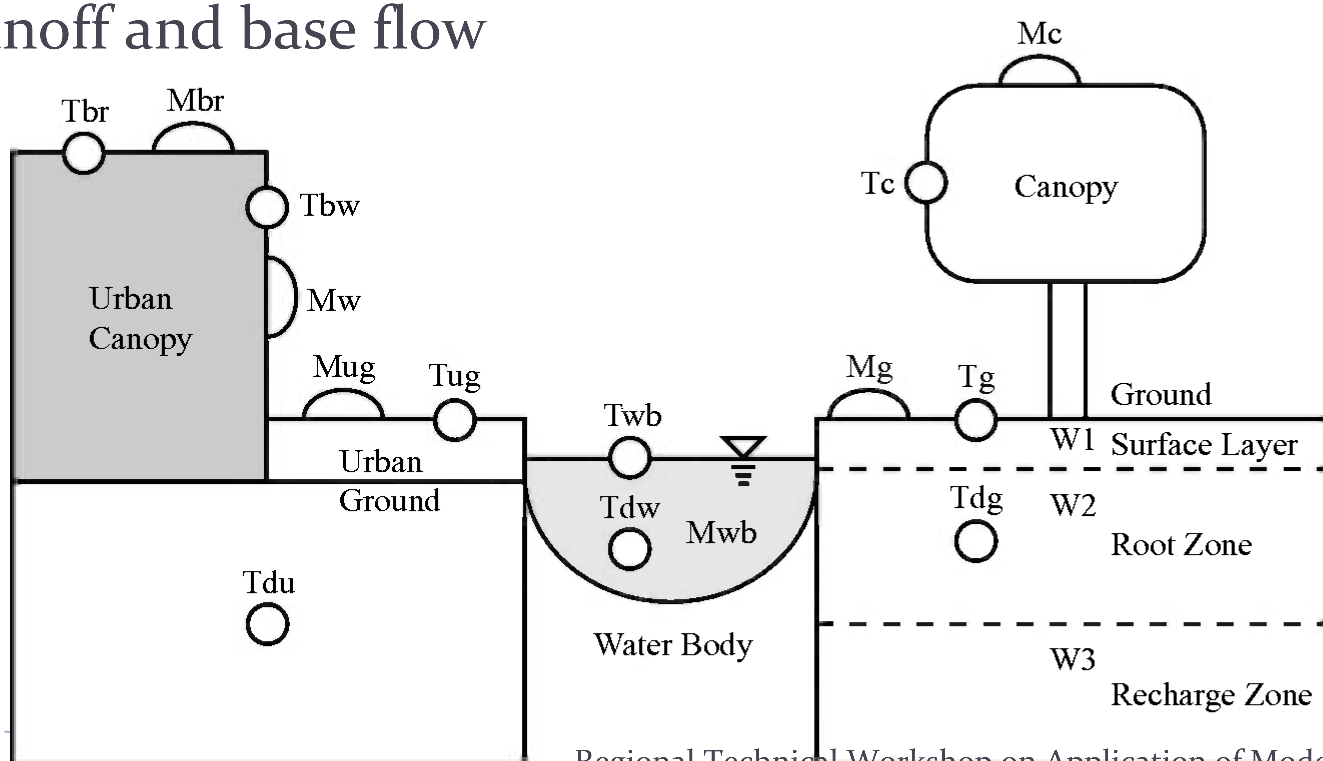
- Simulation region
  - 34.25E–37.0E and 36.5N–39.25N
  - 5-min latitude–longitude spatial resolution (33*33 grids).

- Basin information
  - DEM: Gtopo030
  - land use dataset: LANDSAT
  - Soil (porosity, field capacity, and root zone dept): ECOCLIMAP



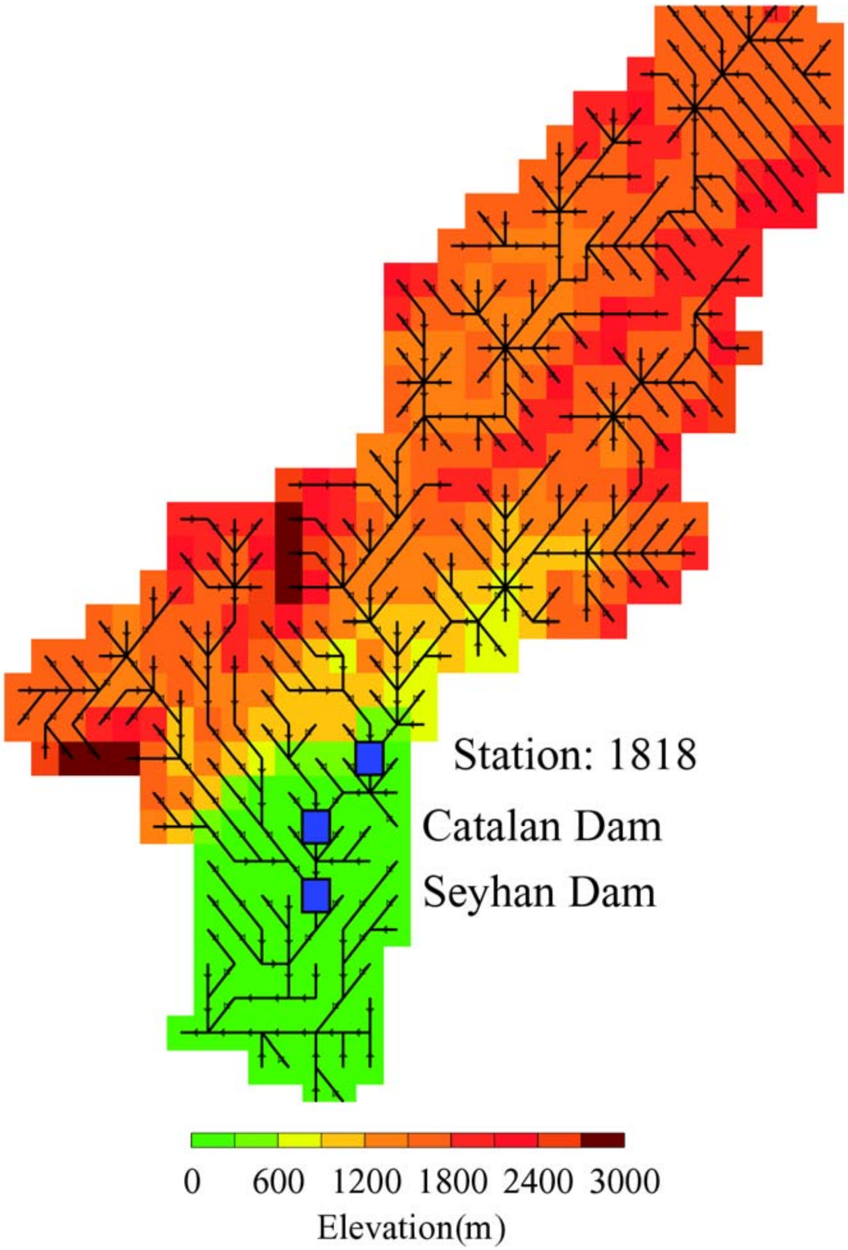
SiBUC

- Simple Biosphere including Urban Canopy（Tanaka and Ikebuchi, 1994） land surface model
  - The SiBUC simulates snow accumulation and melt, soil moisture dynamics and evapotranspiration, and surface runoff and base flow

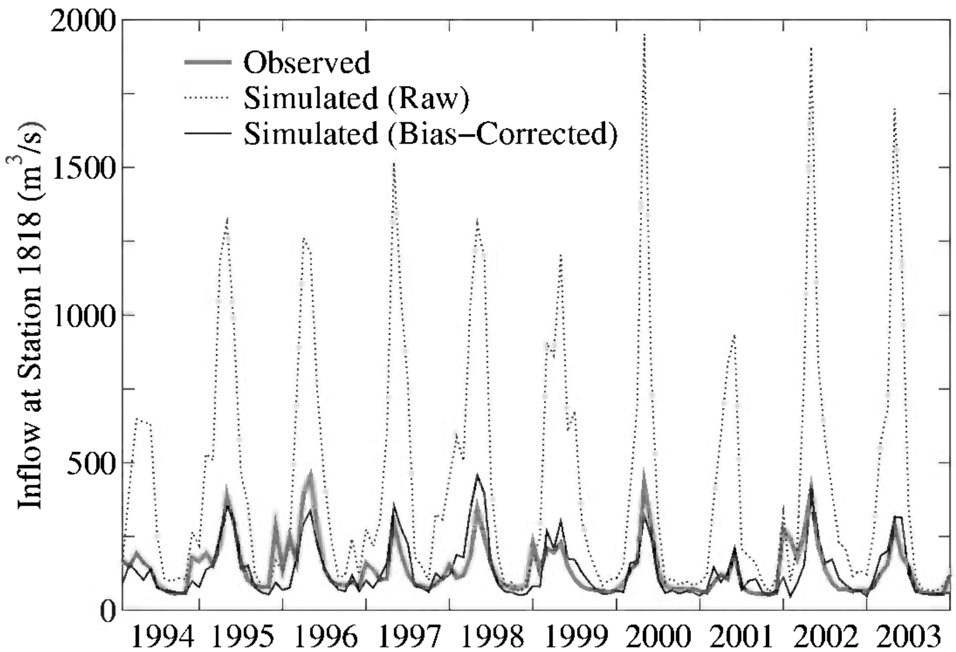


River flow network

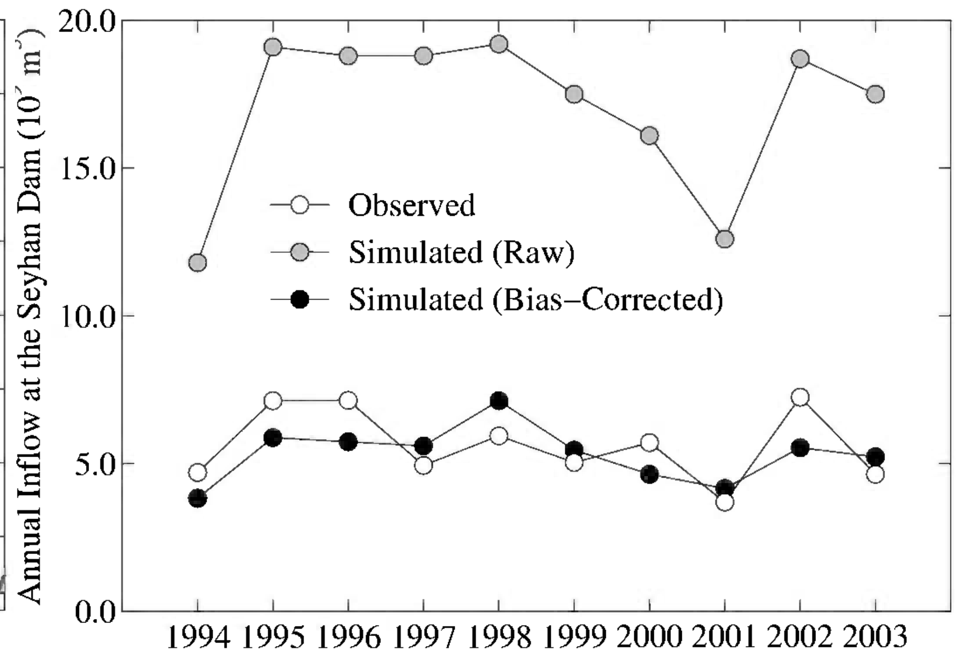
- The simulated surface runoff and base flow in each grid cell were routed using the flow routing network
- The flow direction in each grid cell was defined using a digital elevation model (DEM), and flow routing was performed using the kinematic wave method
- Reservoir model
  - Seyhan: 0.88 billion m3
  - Catalan : 1.6 billion m3



Hydrograph (present)

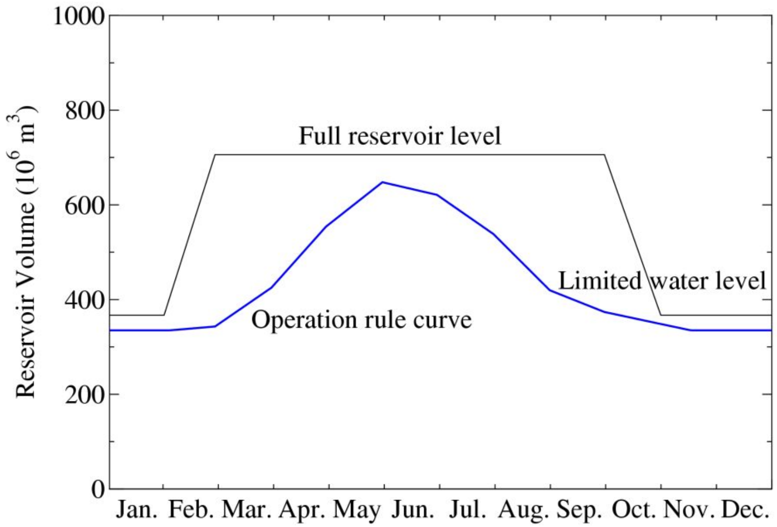


Monthly Runoff



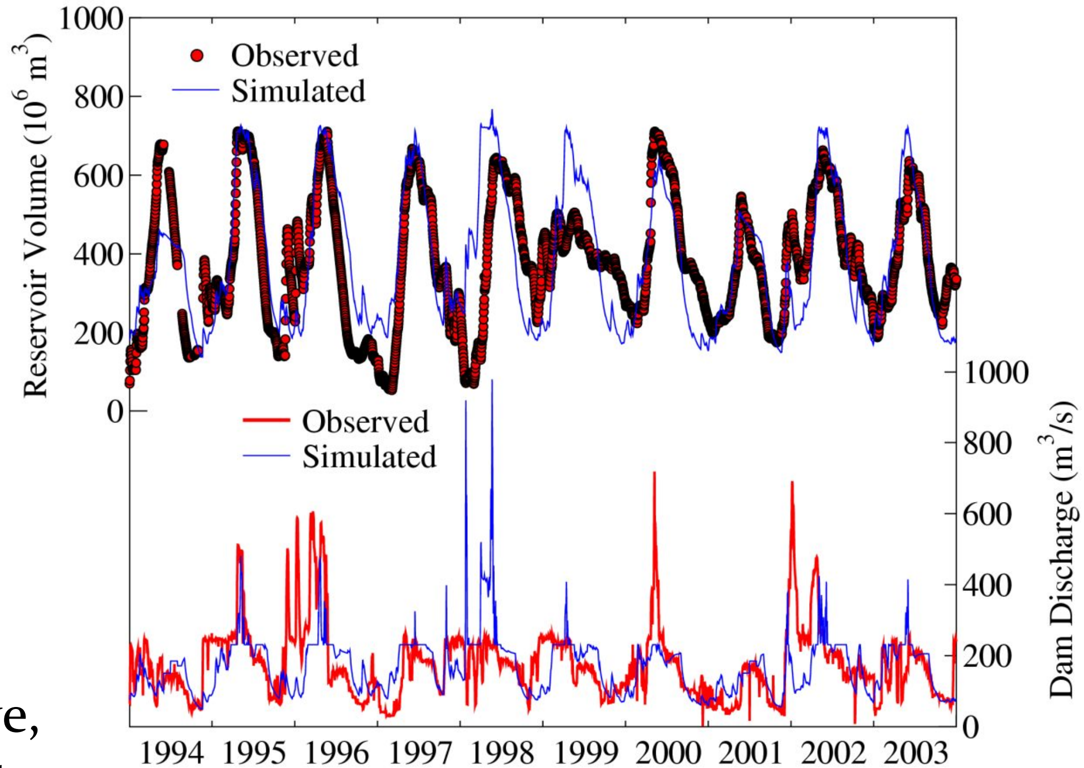
Annual Runoff

Reservoir models



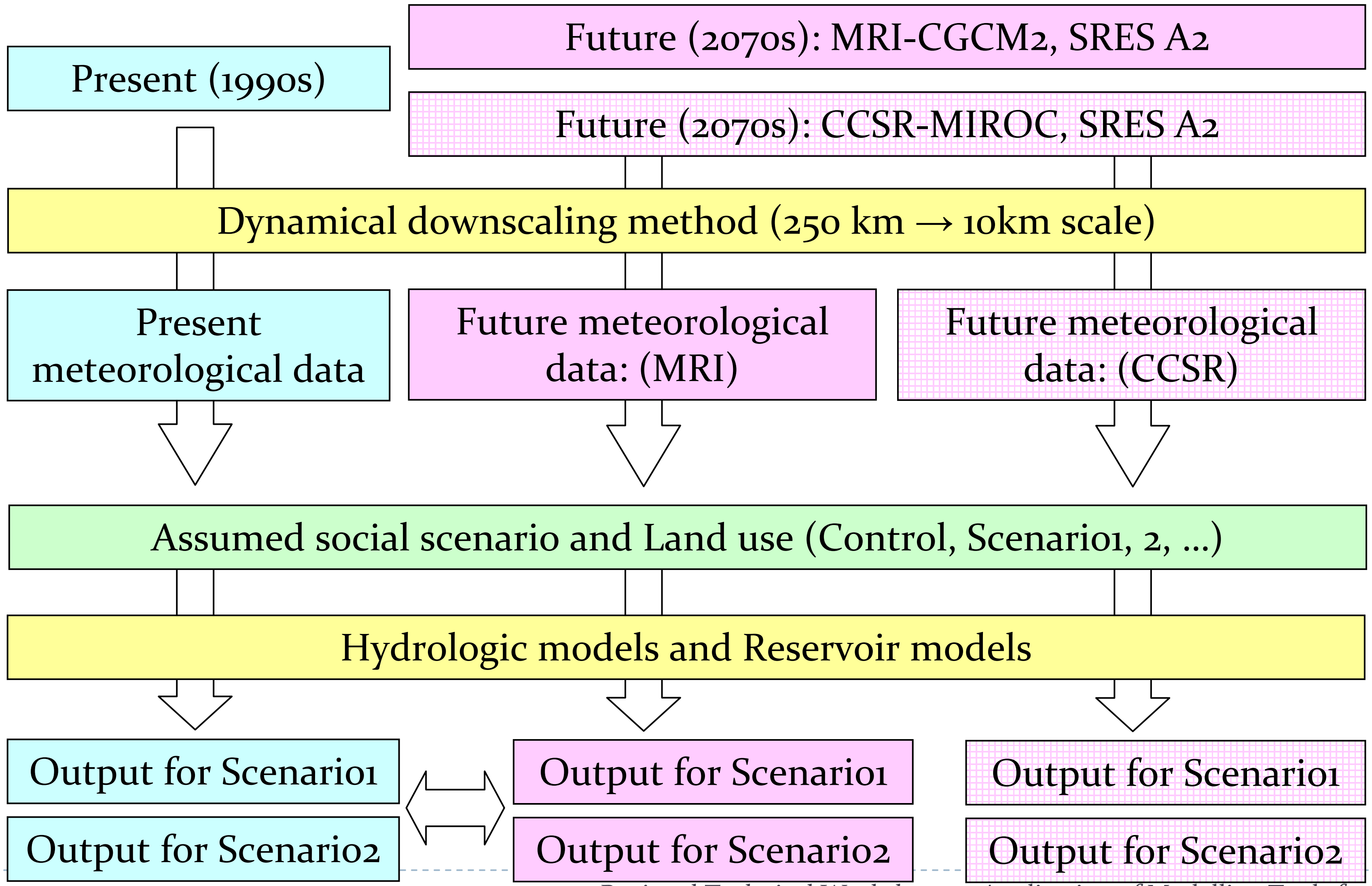
Rule curve

Water is stored in order to maintain the operation rule curve, and the water is released to meet the demand regardless of the rule curve (Fujihara et al., 2008).

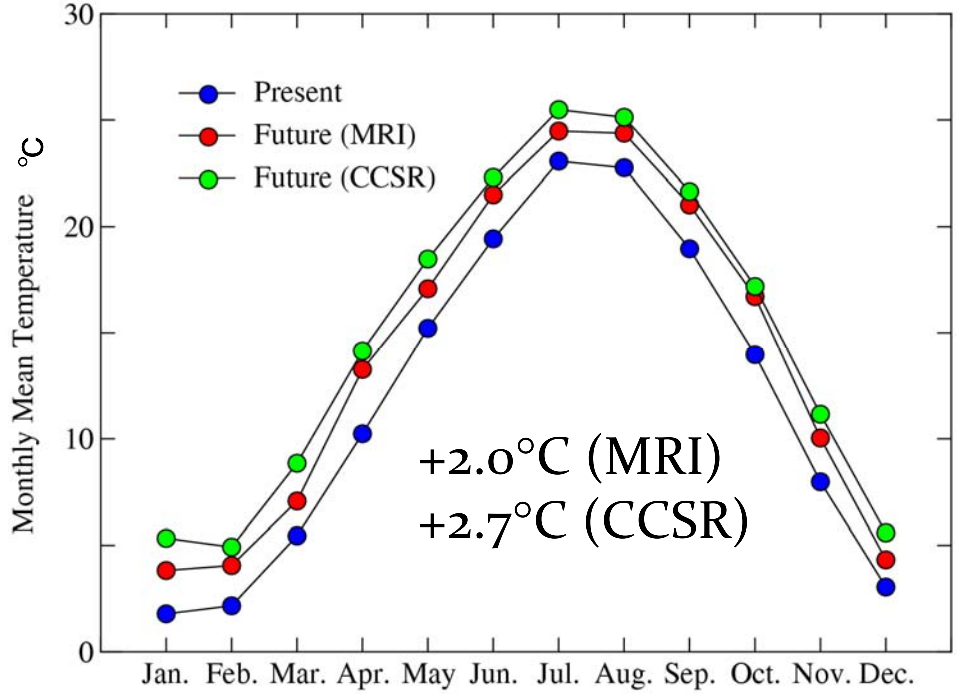


Observed and simulated reservoir volume and discharge (Seyhan)

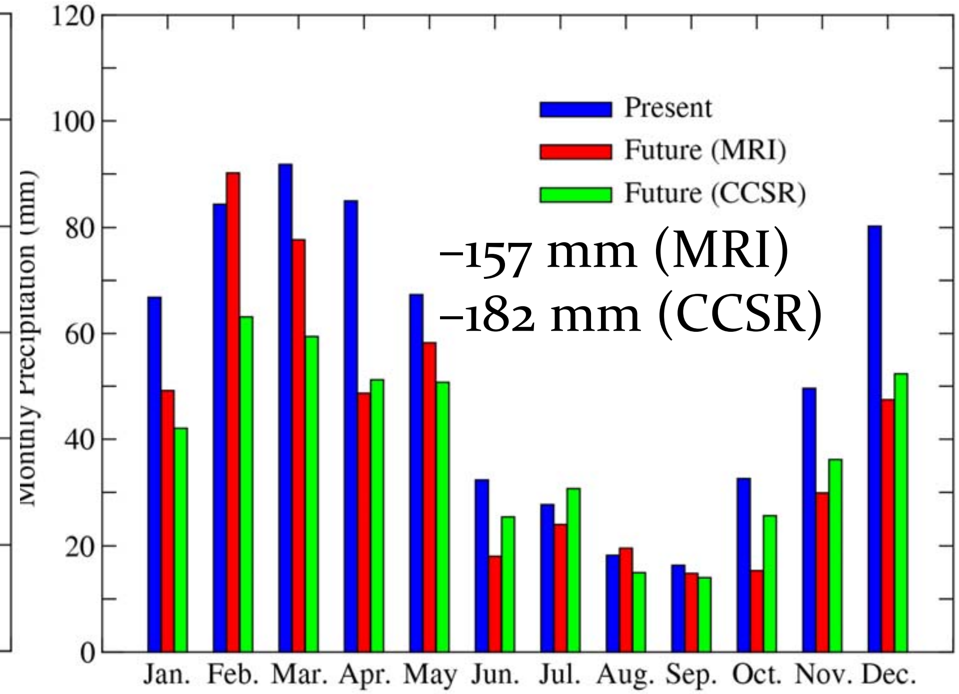
Approach used in this study



Temperature and rainfall changes

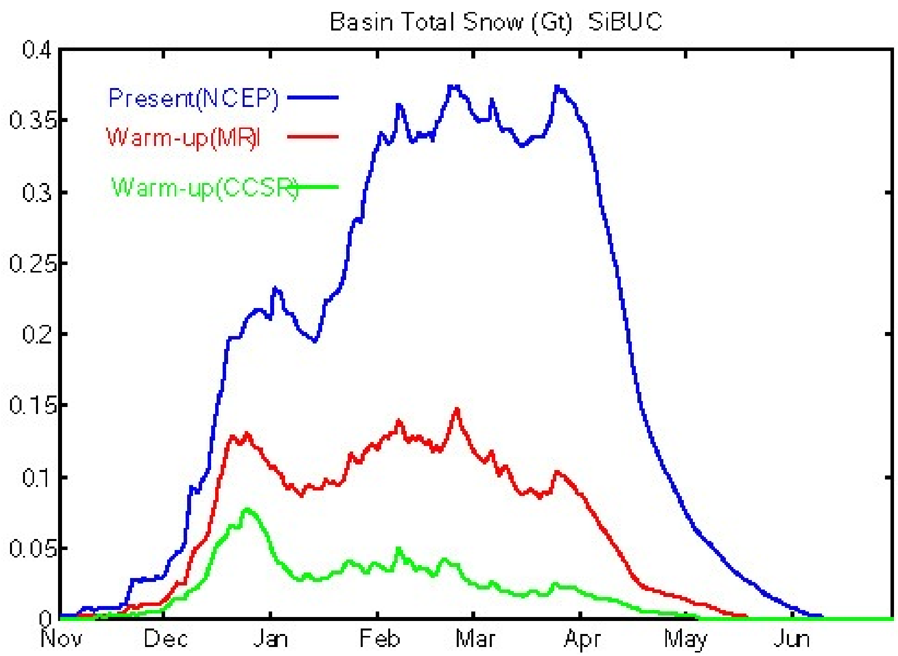


Temperature

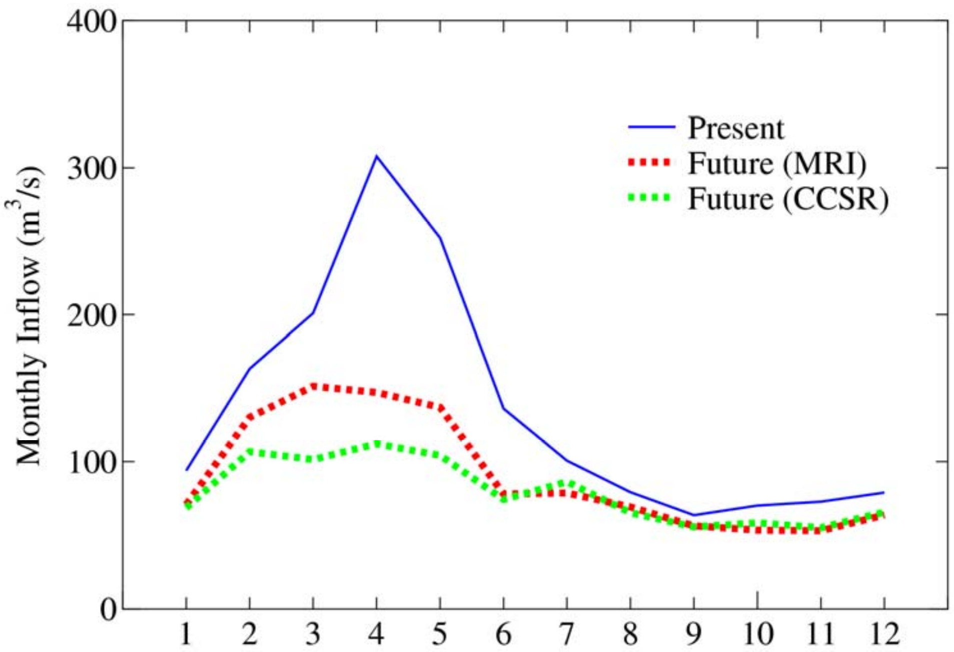


Precipitation

Snow and river flow changes



Snow water equivalent

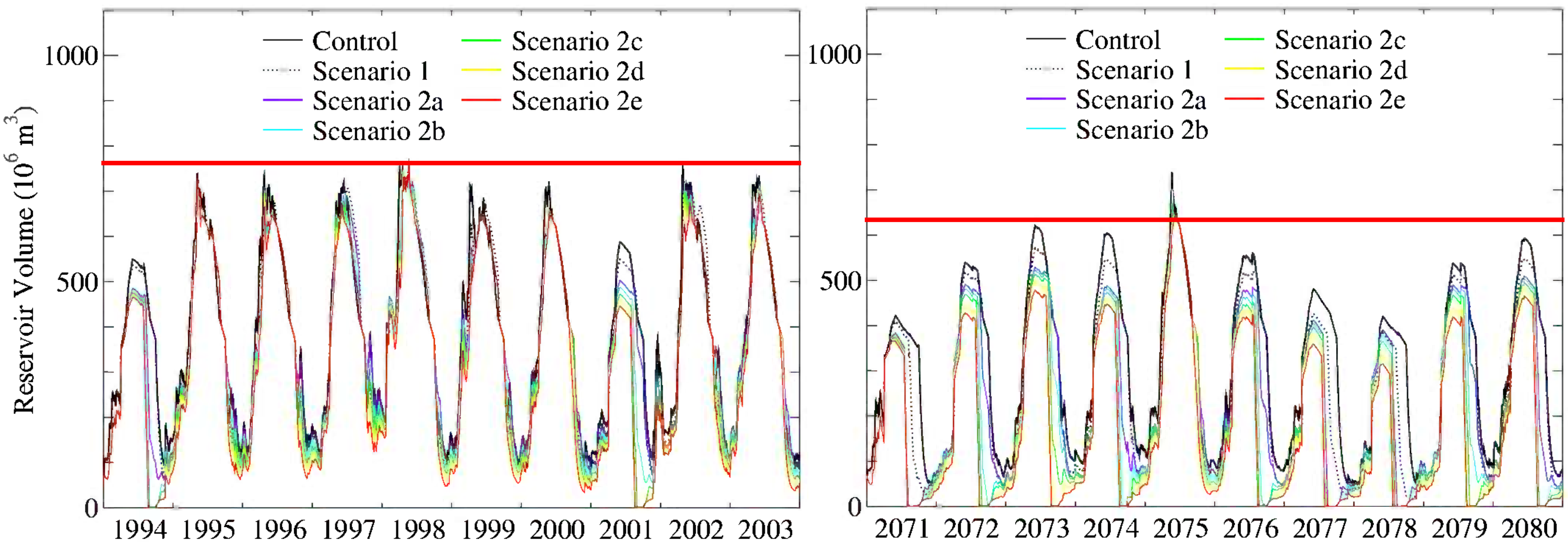


River flow

Water balance

	Precipitation (mm)	Evaporation (mm)	Flow (mm)
Present	634	411	227
MRI-future	476（-25%）	375（-9%）	109（-52%）
CCSR-future	452（-29%）	372（-10%）	89（-61%）

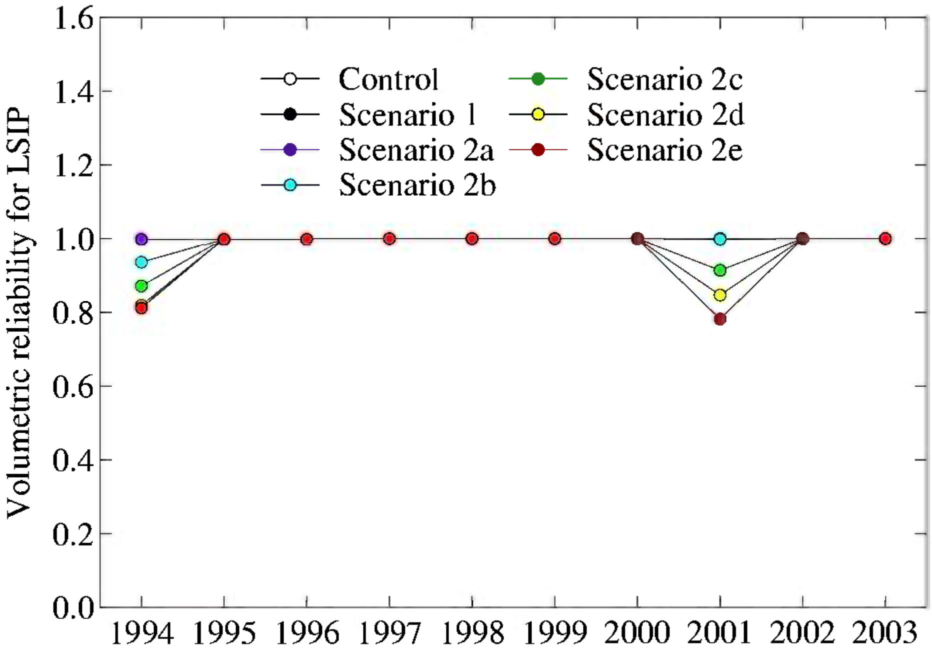
Reservoir models



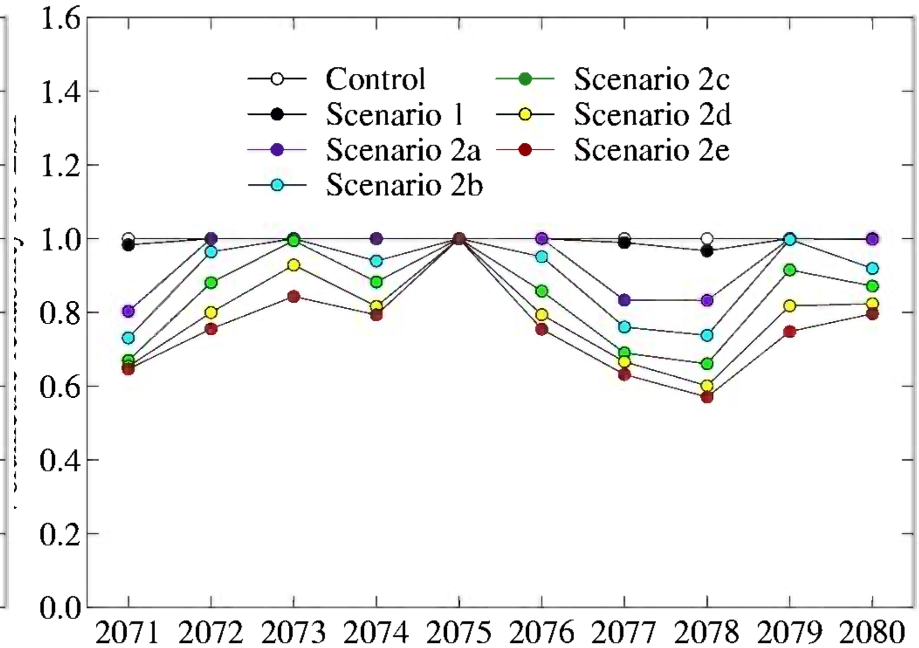
Present

MRI-future

Reservoir reliability = Supply / Demand water



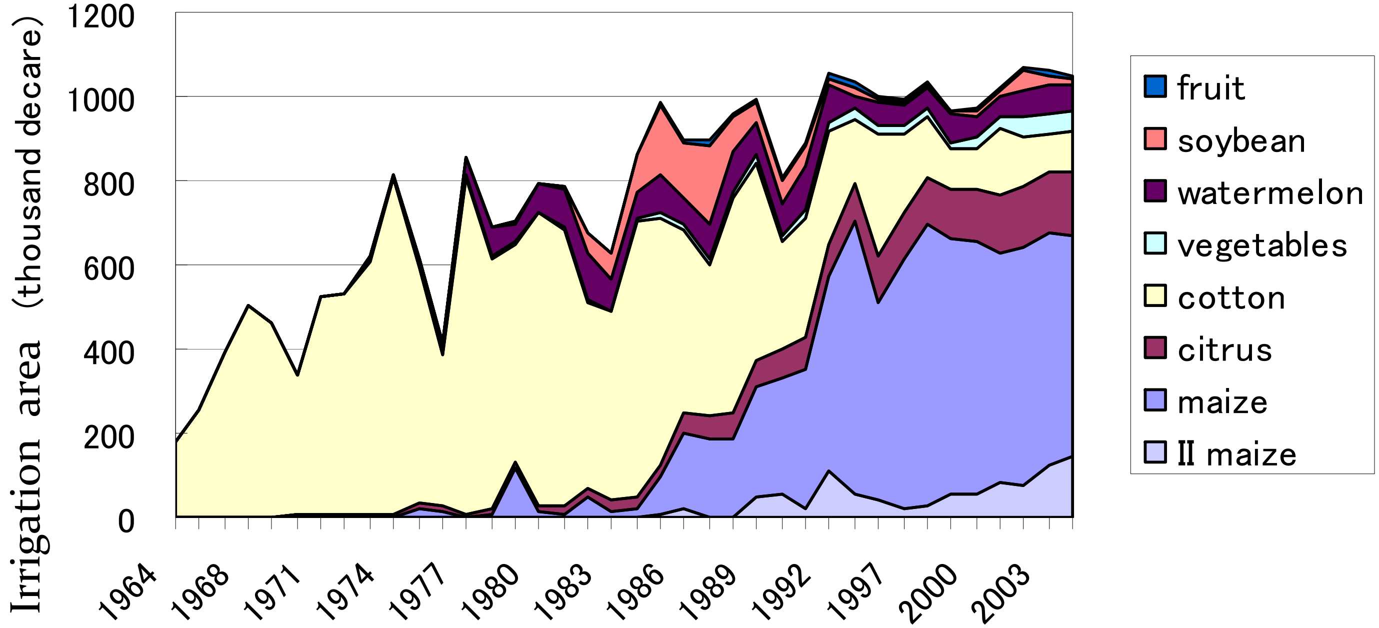
Present

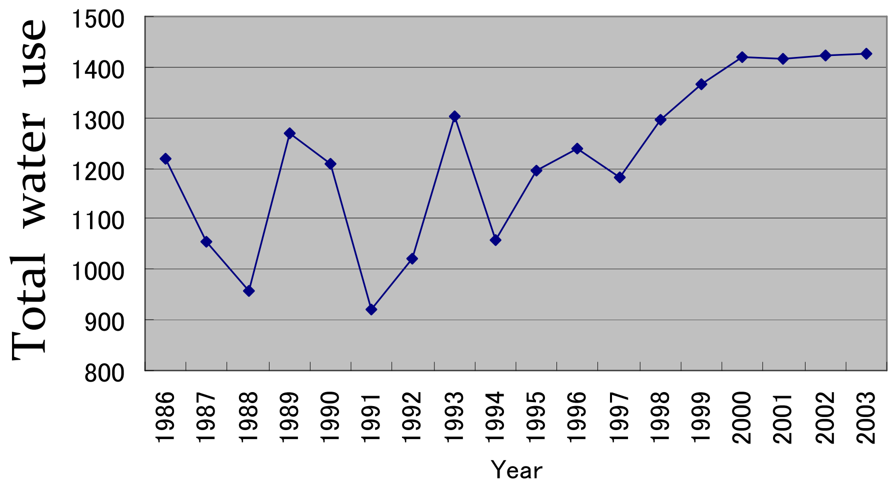


MRI-future

Scenario	Note	Irrigation area (ha)	Water demand (Gm3/y)
Present, Future	Present water use	133,000	1.60
Scenario 1	LSIP IV is completed.	174,000	2.08
Scenarios 2a–2e	LSIP IV and developed irrigated farmlands.	(a) 174,000+20,000	2.32
		(b) 174,000+40,000	2.56

But, can we say scenario 1 is safety in future??





Sugestion1:
Cropping pattern changes should be taken into account from now. Water use is increasing already regardless of climate change

Why water scarcity will not occur despite the impacts of climate change in scenario 1??

- Reservoirs are quite large
  - Seyhan: 0.88 billion m3
  - Catalan : 1.6 billion m3
- Inflow volume
  - Present: 5.5 billion m3
  - Future: 2.64 (MRI), 2.15 (CCSR) billion m3

- Moreover, environmental flow from these reservoirs has not been introduced. They can store the water as possible as they want.
- There is very little flow at the down stream now especially in summer

Sugestion2:
Environmental flow from reservoirs should be taken into account.
Some problems may be already taking place

Snow is key hydrologic variables in the basin

- Future:
  - Impact on snow is large and inflow will decrease in April and May
- Present
  - Snow melt sometimes lead to floods in early spring

- If snow amount is monitored in winter, it is possible to forecast the inflow in spring, and relatively easy to operate reservoirs for flood control and water resources.

- However, precipitation observation system has not been established in the basin

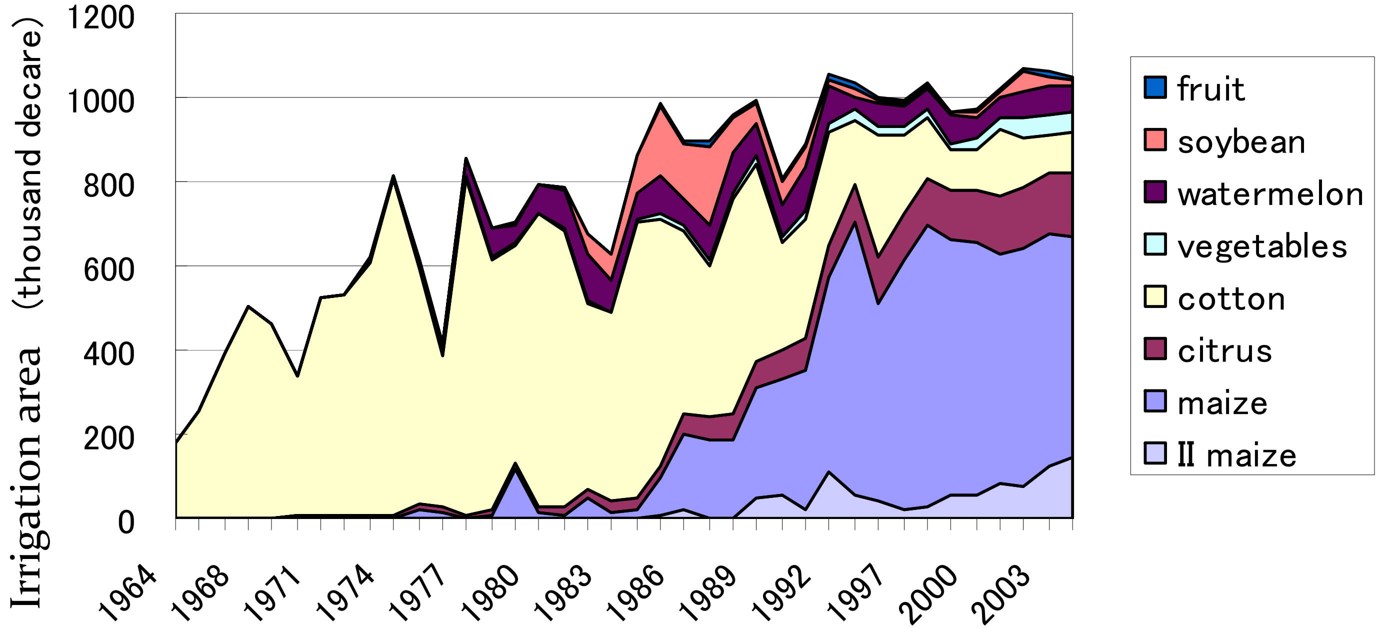
Sugestion3:
Meteorological observation system in mountain area should be developed immediately

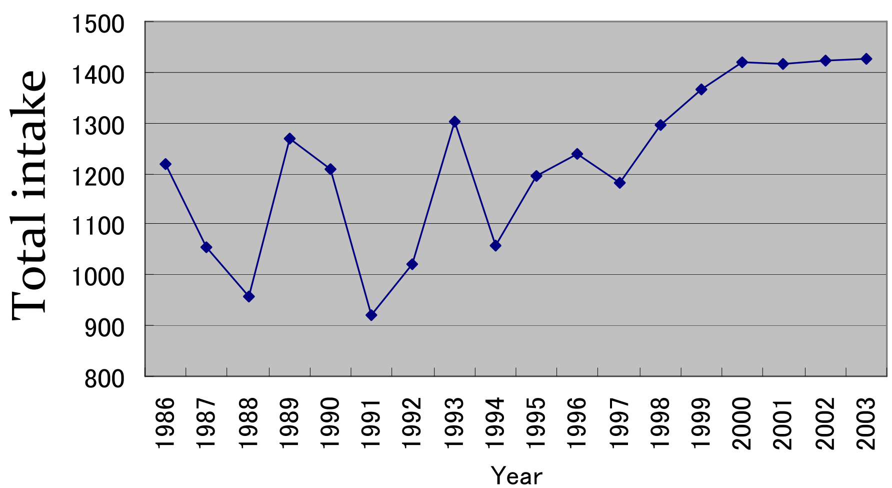
Conclusions

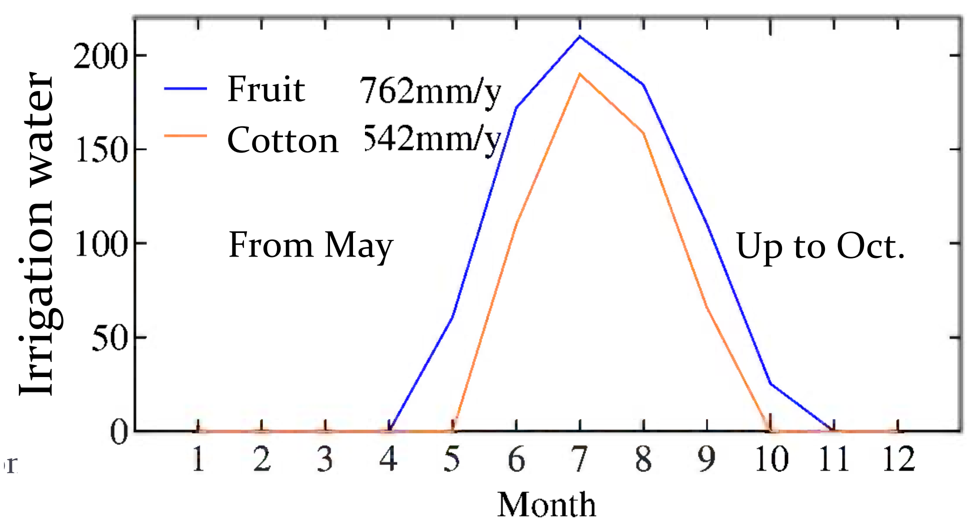
- We developed an approach that uses dynamically downscaled data as inputs to hydrologic simulations and applied it to the Seyhan River Basin in Turkey. We assessed the impact of changes on the water resource systems of the basin.
- Suggestions to the basin
  - Cropping pattern changes should be taken into account from now. Water use is increasing already regardless of climate change
  - Environmental flow from reservoirs should be taken into account. Some problems may be already taking place
  - Meteorological observation system in mountain area should be developed immediately
- CC studies are not only for future problems but also for present (existing) problems

Thank you for your attention!!

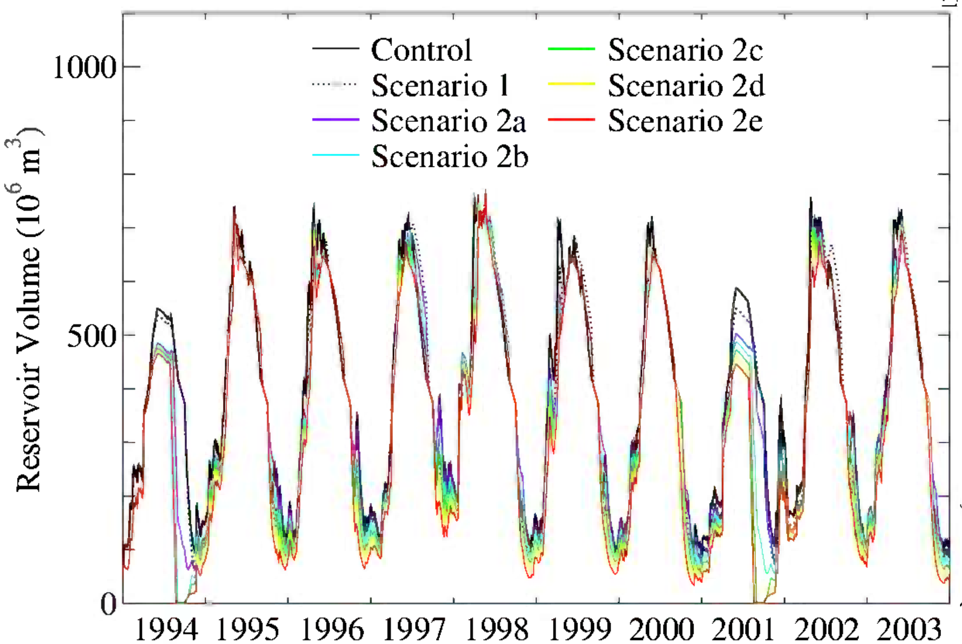
But, can we say scenario 2b (LSIP IV + 40,000 ha) is safety in future??

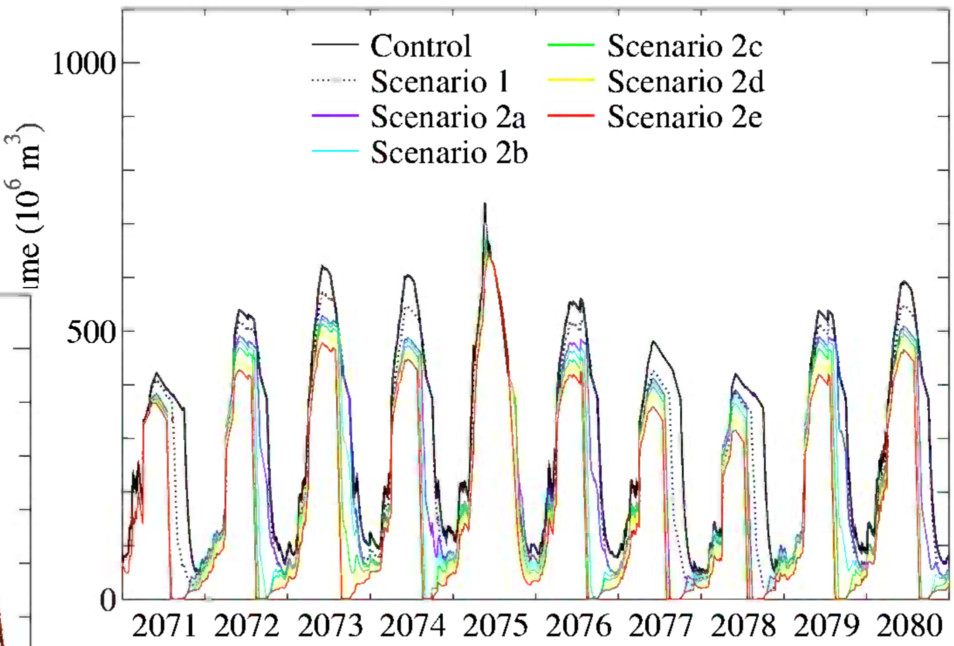


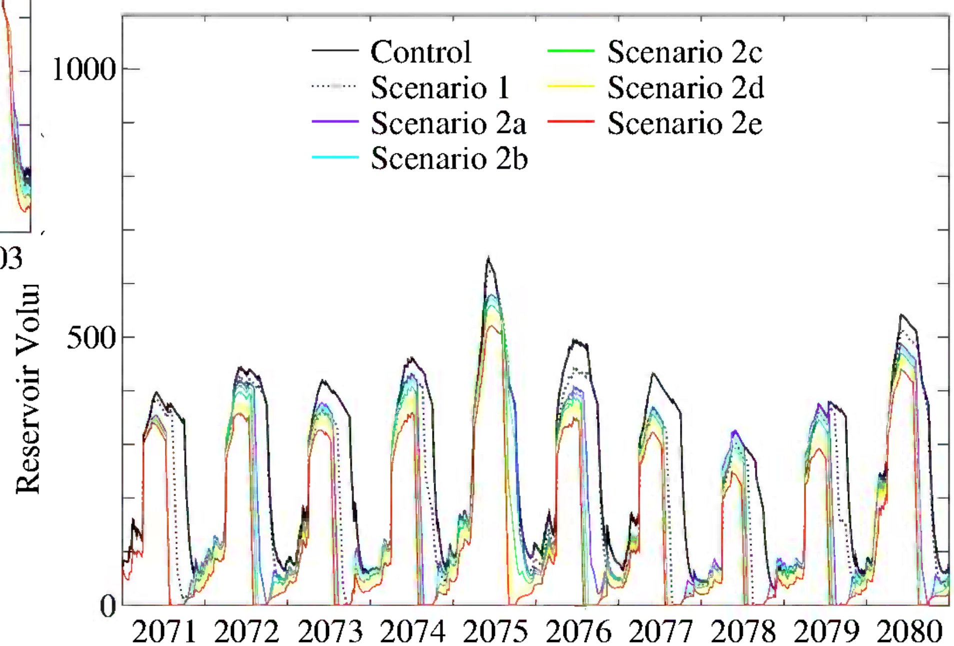




Reservoir volume
Seyhan Dam







Reservoir reliability =Supply / Demand