

**Modeling the Impacts of Climate Change on  
Groundwater Recharge in the  
Gharehsoo Watershed, Iran, from an Ensemble of  
Global Climate Model Projections**

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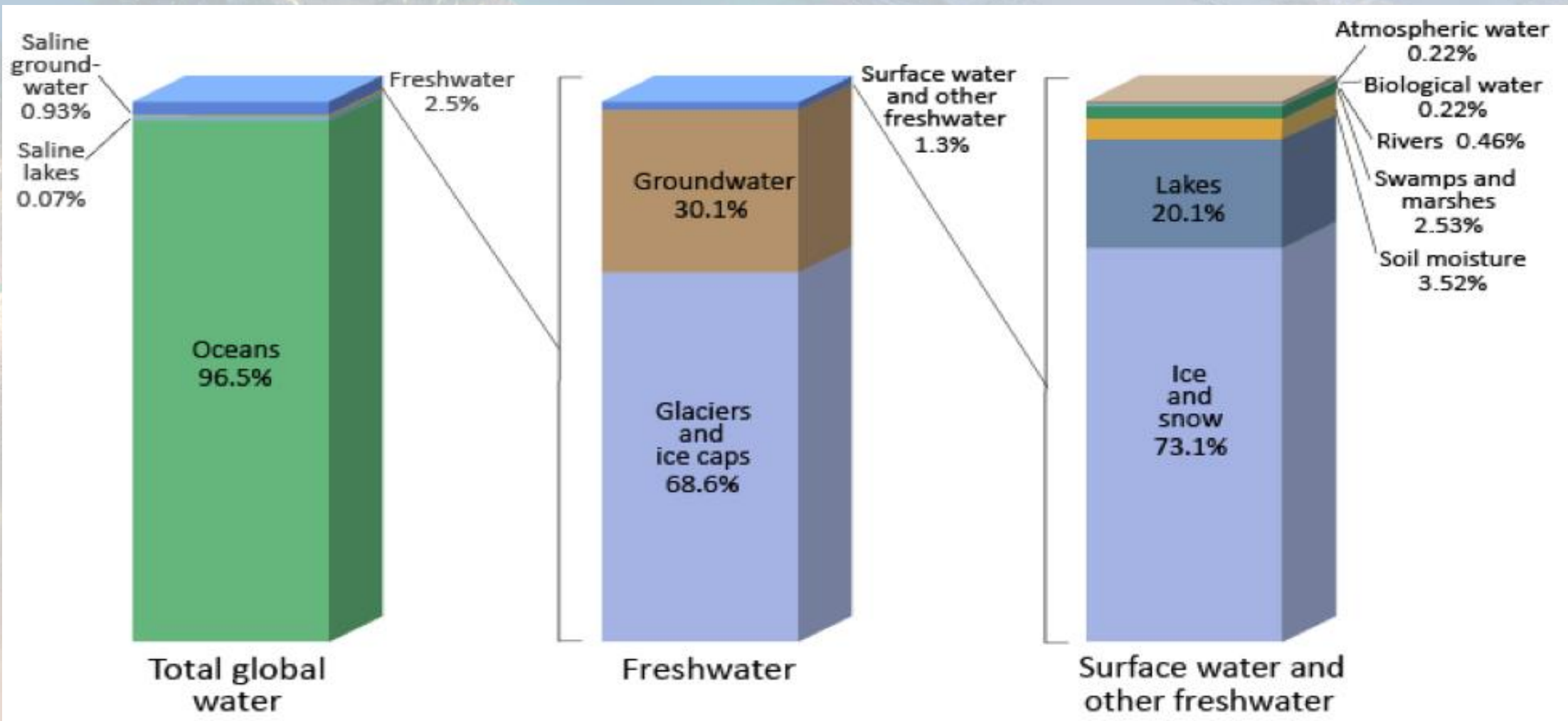
Department of Geohydraulics and Engineering

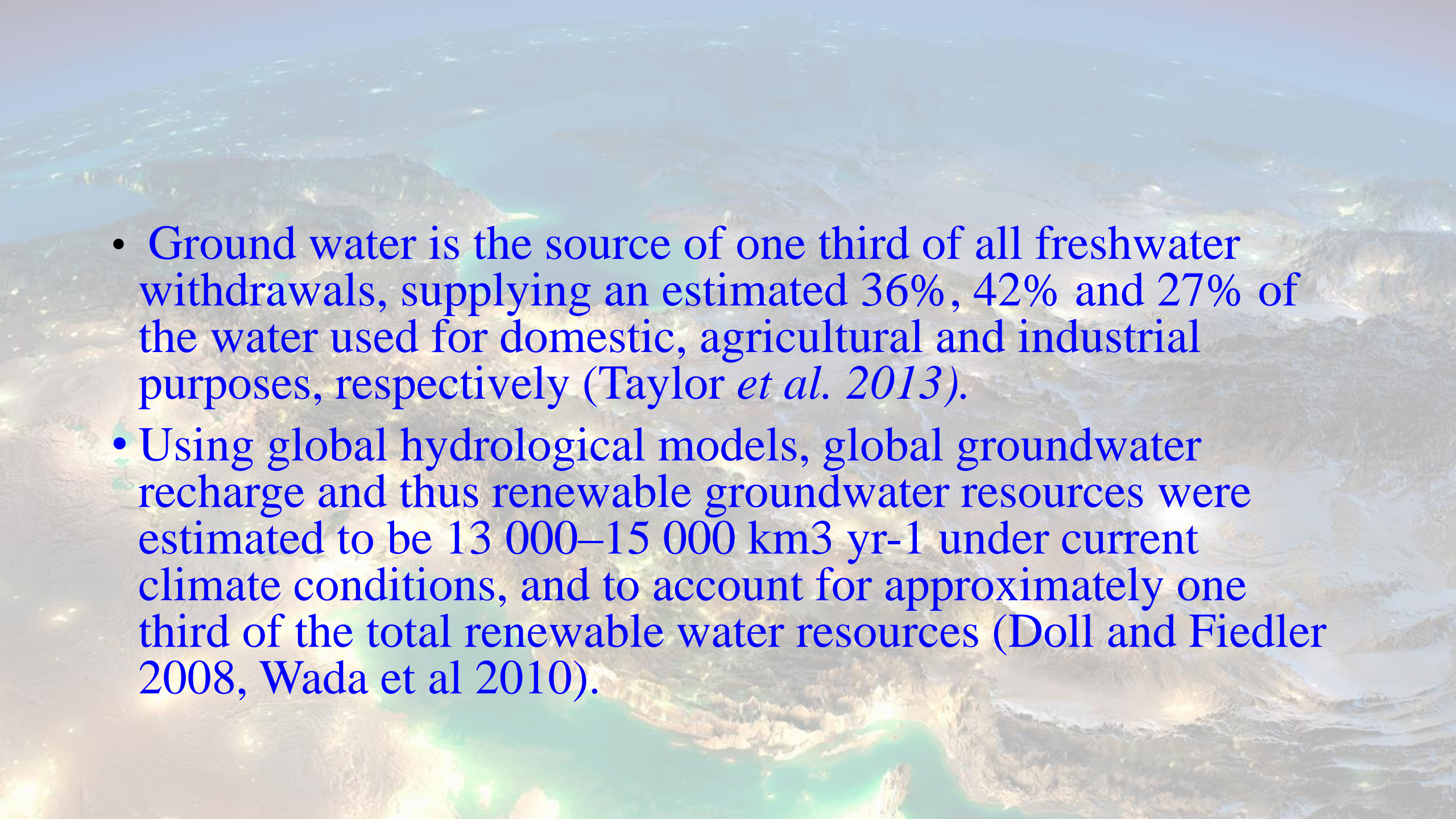
Hydrology, University of Kassel, Germany

# Outline of the presentation

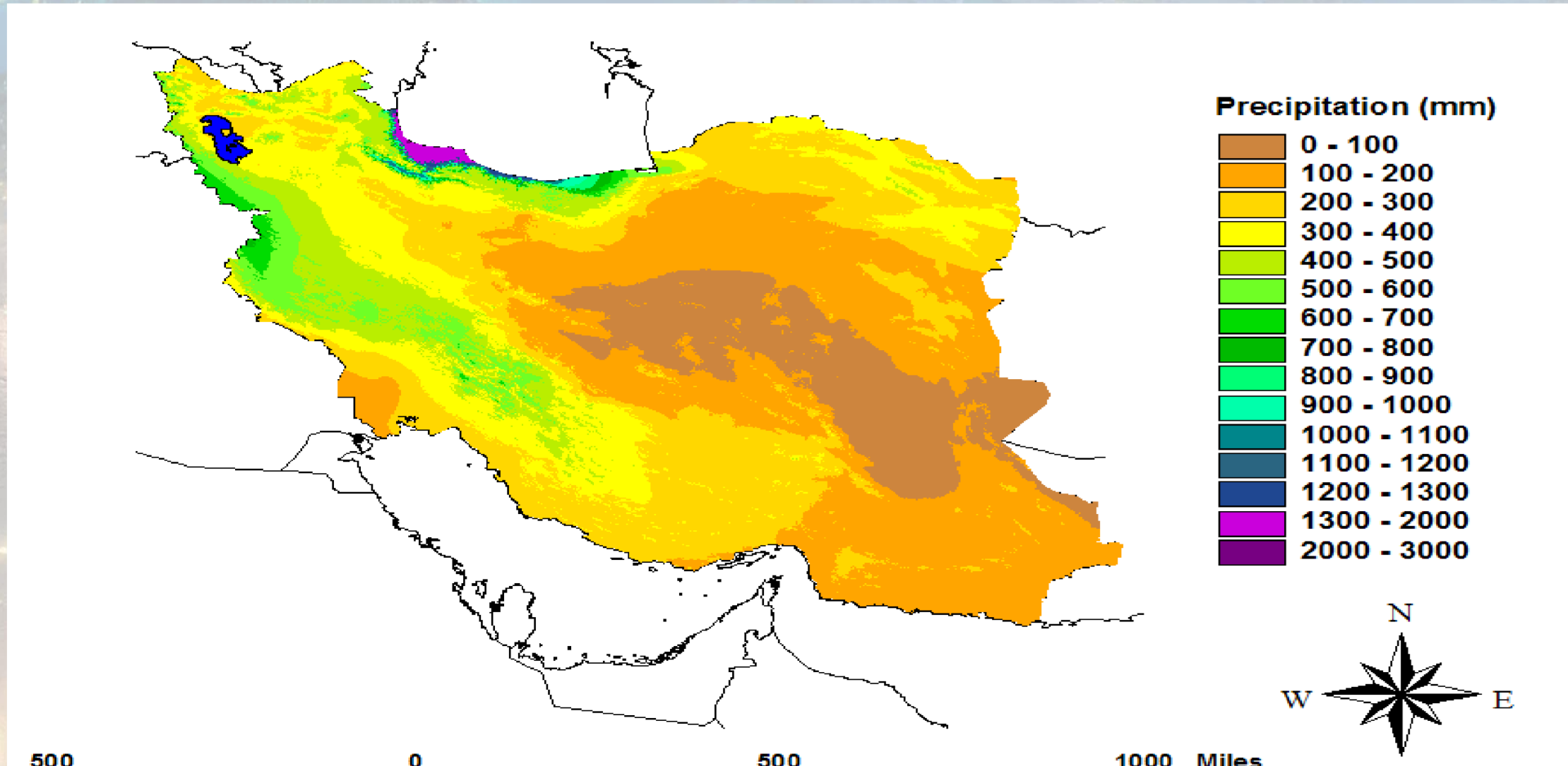
- Groundwater resources conditions in the global scale
- Groundwater resources conditions in Iran
- Climate change and groundwater resources
- Research objectives
- Application area
- Research methodology
- Expected results

# Groundwater resources conditions in the global scale

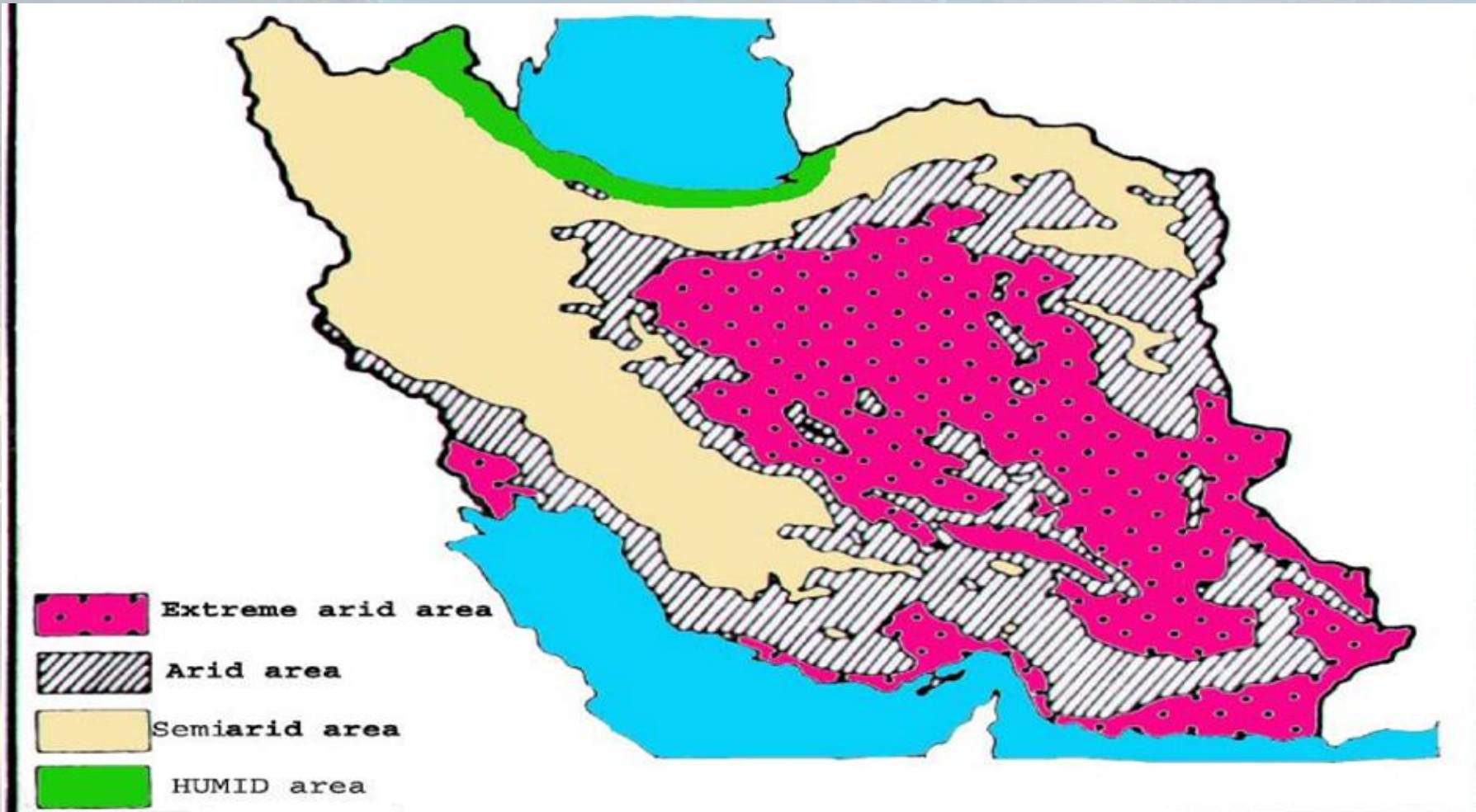


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- An aerial photograph of a mountain range with a river valley. The mountains are covered in green vegetation, and the river valley is a mix of brown and green. The sky is blue with some white clouds.
- Ground water is the source of one third of all freshwater withdrawals, supplying an estimated 36%, 42% and 27% of the water used for domestic, agricultural and industrial purposes, respectively (Taylor *et al.* 2013).
  - Using global hydrological models, global groundwater recharge and thus renewable groundwater resources were estimated to be 13 000–15 000 km<sup>3</sup> yr<sup>-1</sup> under current climate conditions, and to account for approximately one third of the total renewable water resources (Doll and Fiedler 2008, Wada et al 2010).

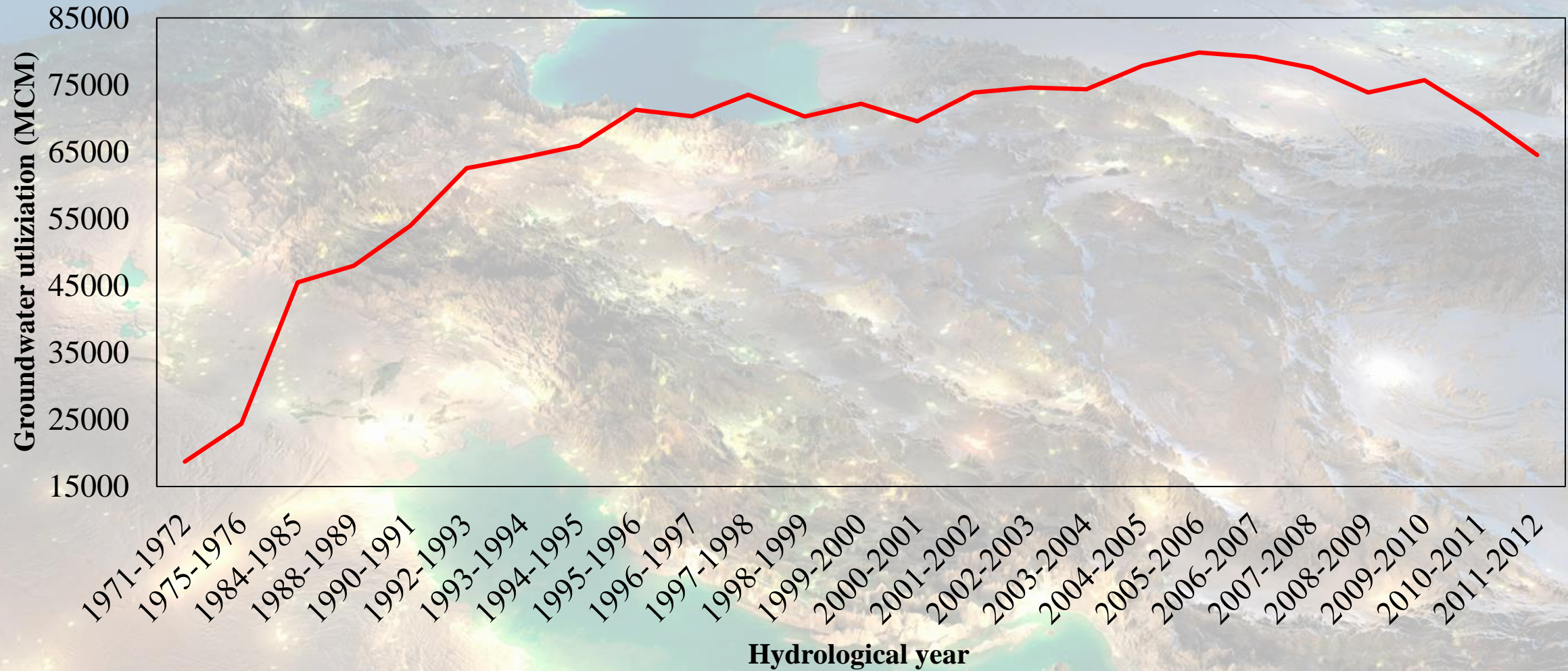
# Groundwater resources condition in Iran



# Climate in Iran



# Groundwater exploitation over the time in Iran



# Climate change and groundwater

1- Direct impact

Changes in recharge rate

2- Indirect impact

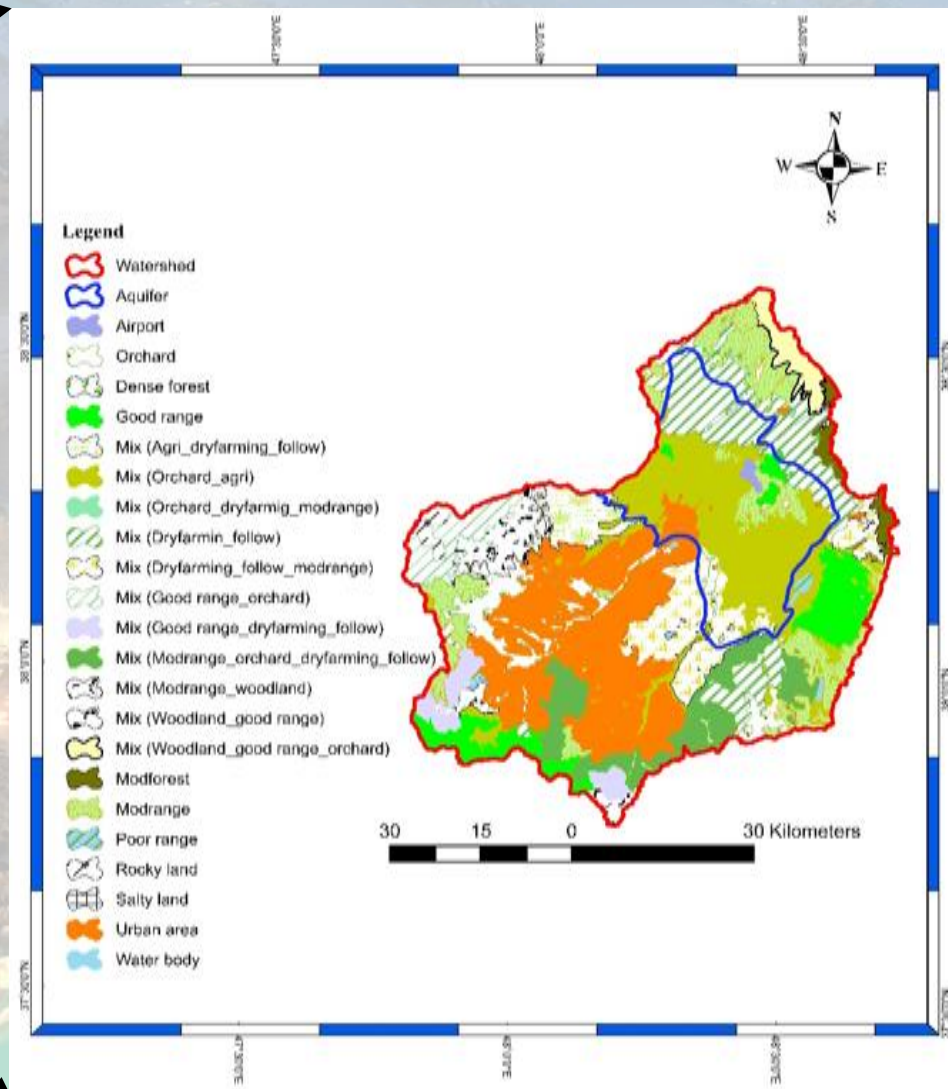
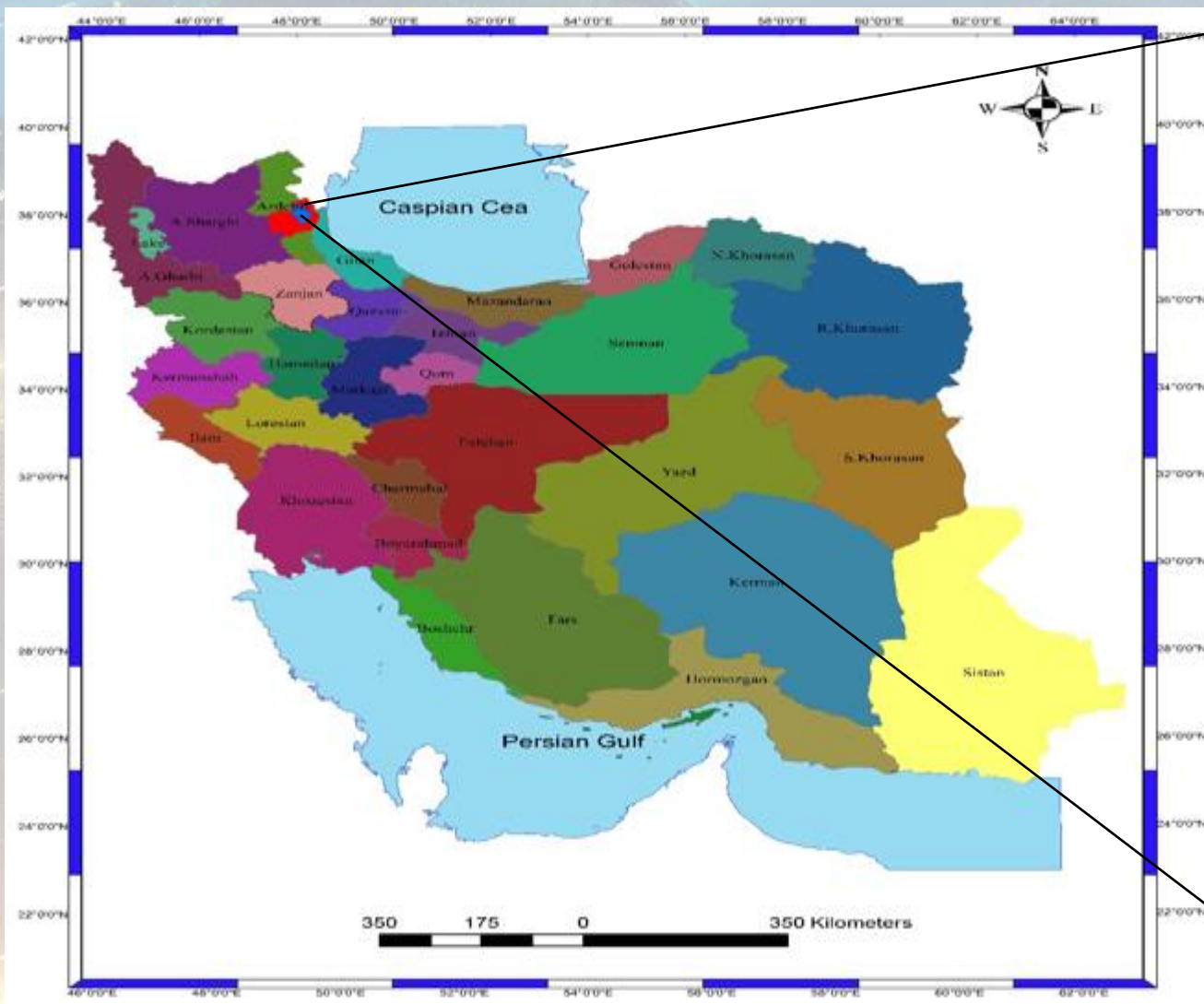
Increasing dependency on groundwater utilization by virtue of surface water scarcity resulted from climate change impacts.



## Research objectives

- Prediction of the groundwater recharge and groundwater level and budget accordingly based on climate projections by using coupled modeling SWAT-MODFLOW
- Distinguishing climate change impacts from groundwater over-exploitation impacts
- Evaluation of suitability of SWAT-MODFLOW for climate change studies on groundwater recharge

# Application area

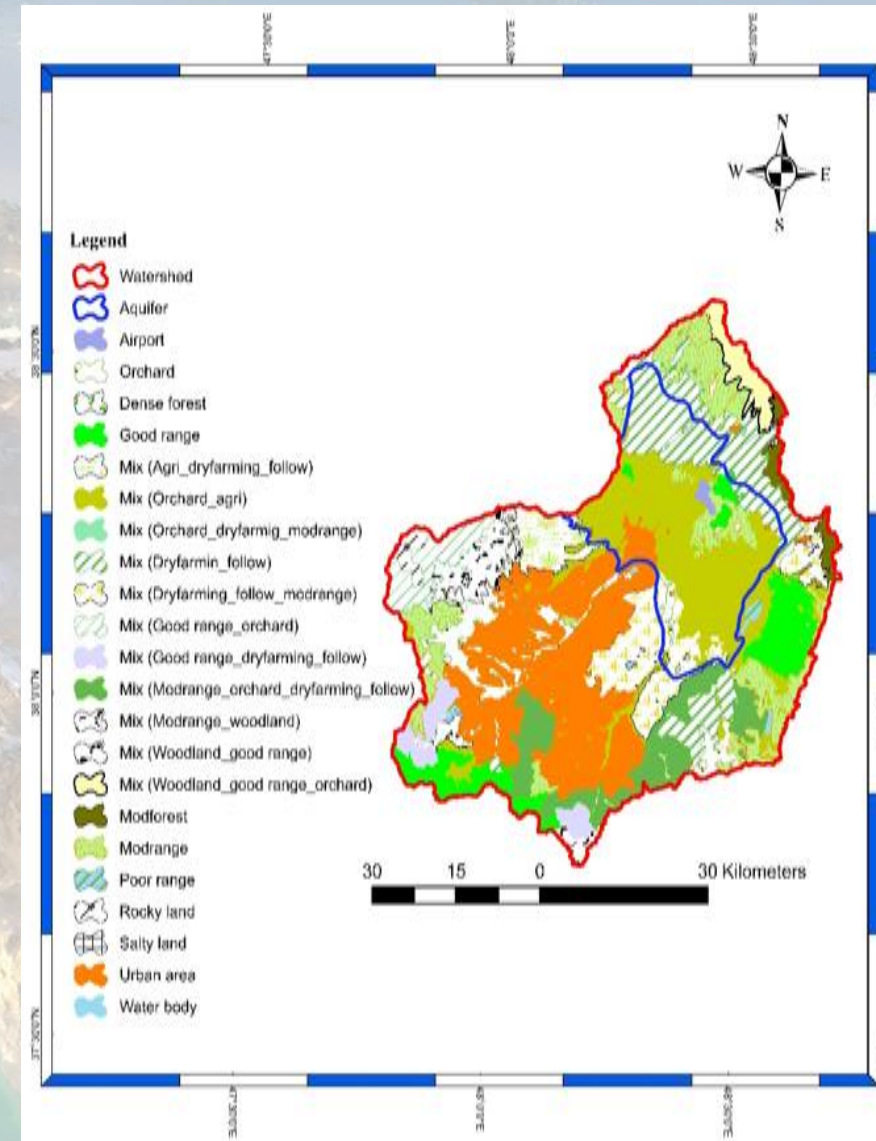
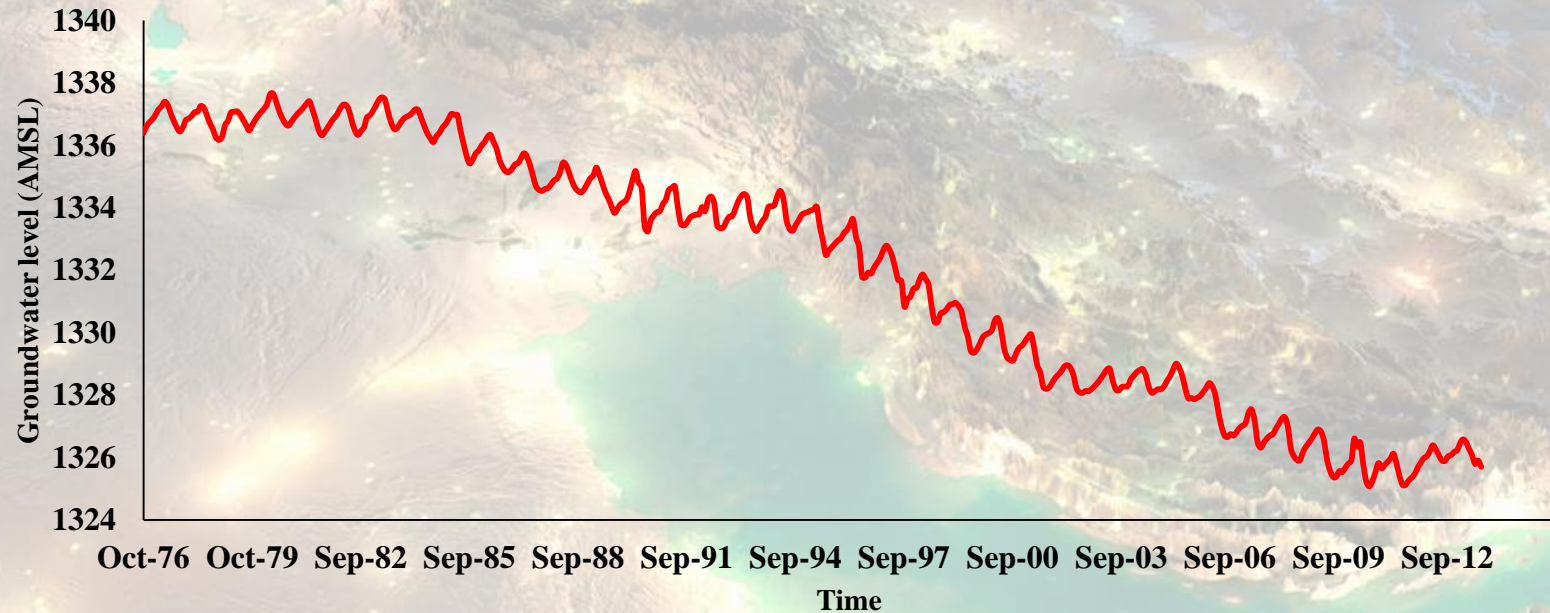


# Hydroclimatology of Gharehsoo watershed

- Rainfall: Varies from 250 to 500 mm but on average 343 mm per year.
- Temperature: Changes from 4 to 14 on average in different parts of the watershed whereas the average of temperature in the whole area is about 7.4 Centigrade.
- Evaporation from the pan: With respect to the location, it fluctuates from 600 to 1400 mm per year. On average is about 1259 mm per year.

# Hydrogeology of the study area

- Aquifer area: 1000.74 km<sup>2</sup>
- Aquifer recharge~ 149.47 MCM
- Aquifer discharge~ 164.53 MCM
- Groundwater dropping ~0.27 m/yr



# Research methodology

Based on combined MODFLOW-SWAT the following procedure is expected:

- 1-The initial step is to execute and calibrate SWAT based on all available data and obtained simulated groundwater recharge for each HUR (direct recharge and transmission loss from riverbeds).
- 2-The groundwater recharge from SWAT's HRUs are reformatted and feed to MODFLOW cells as the upper boundary condition.
- 3- MODFLOW will be executed and calibrated based on all available data and the adjusted recharge values were extracted from the MODFLOW results.

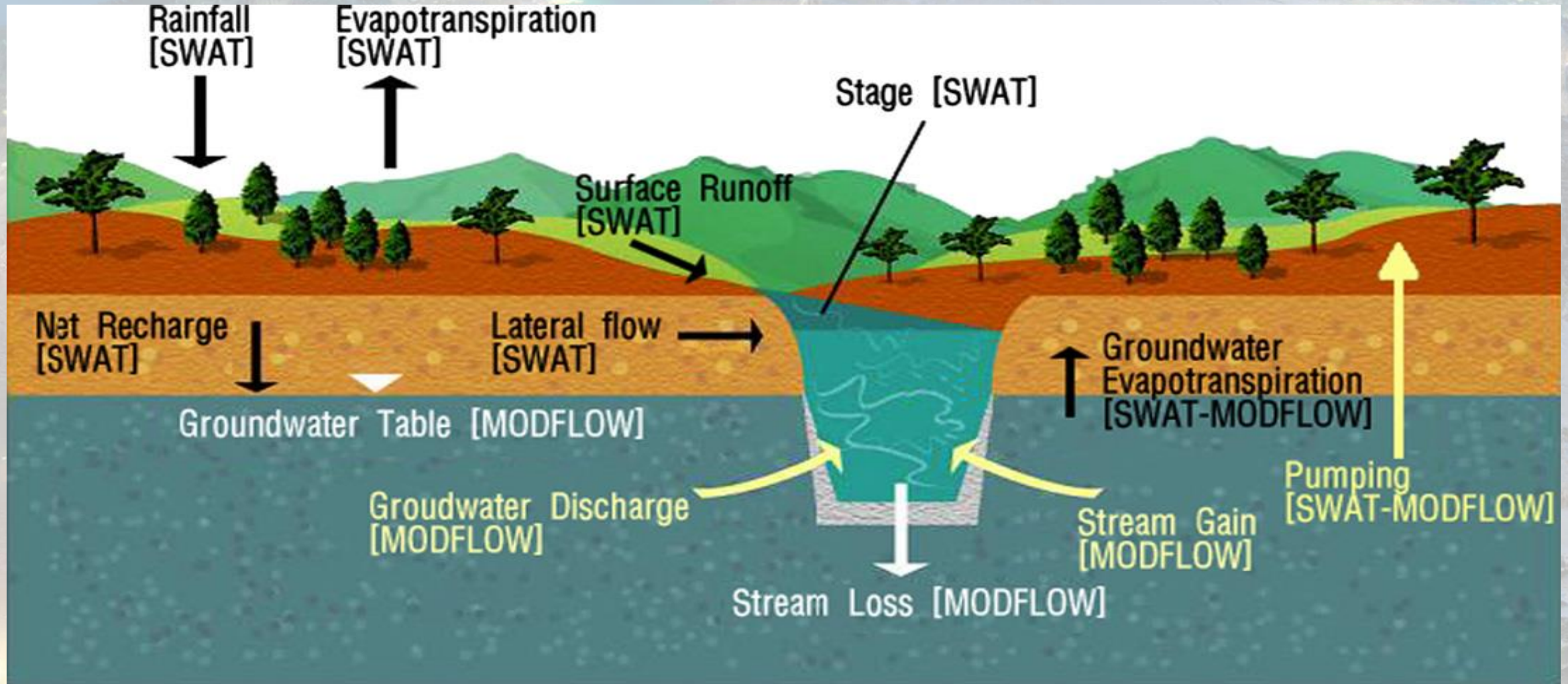
An aerial photograph of a mountainous region. A large river flows through the center, with a lake or reservoir situated in a valley. The terrain is rugged and covered in dense vegetation. The sky is clear and blue.

4- The MODFLOW adjusted-recharge values are sent back to SWAT as observed data.

5-Steps three and four (iteration between SWAT and MODFLOW) are repeated to achieve satisfactory results.

6- As a control, computed recharge rates are checked against the independently estimated annual mean groundwater recharge rates.

# Schematic diagram of combined surface water and groundwater model (Kim and et al. 2008)



# GCMs and SRES

Considered General Circulation Models:

1- Canadian Global Coupled Model (CGCM 3.1)

2- *Hadley Centre Coupled Model, version 3 (HADCM3)*

Considered SRES:

1- A1B

2- B1

3- A2



An aerial photograph of a mountain range with a river valley. The mountains are brown and rocky, and the river valley is green and lush. The sky is blue with some clouds.

Separation Climate change and variability, lets say drought, impacts from groundwater over- utilization impacts

1- Creating the groundwater hydrographs under both climate change impacts and current utilization of groundwater reserves.

2-Creating the groundwater hydrographs under the current situation of groundwater exploitation (Neglecting the impacts of climate change and variability).

3- Drawing the groundwater hydrographs under climate change impacts (Cutting groundwater pumping as much as the groundwater recharge).

Groundwater dropping as a consequence of over- exploitation effects:

$$D_o = H_t - H_c$$

Where  $D_o$  denotes groundwater dropping due to over- utilization,  $H_t$  shows the main groundwater hydrograph resulted from both over- abstraction and climate change impacts and  $H_c$  is the groundwater hydrograph obtained from climate change impacts.

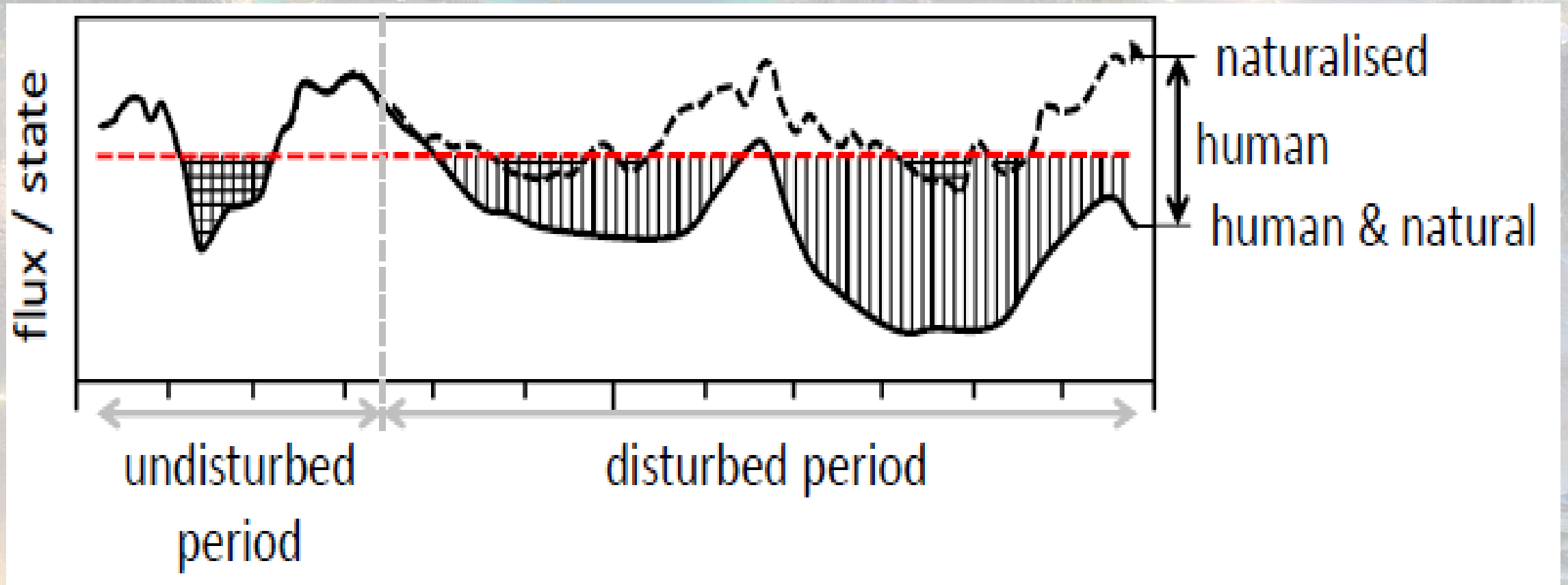
Groundwater dropping in response to climate change impacts:

$$D_c = H_t - H_o$$

Where  $D_c$  denotes dropping with respect to the climate change,  $H_t$  shows the main groundwater hydrograph resulted from both over- abstraction and climate change impacts and  $H_o$  is the groundwater hydrograph obtained from only over- abstraction of the groundwater reserves.

Based on all the time series available, the program for these separations will be provided in R programming language.

Conceptual figure of a system that is affected by both natural and anthropogenic influences (solid line), of which the ‘naturalized situation’ (dashed line) needs to be known to quantify the anthropogenic effect. The red horizontal line indicates a threshold below which the system is negatively impacted. The gridded surfaces indicate anomalies with natural causes (drought) and the vertically-stripped surfaces indicate anomalies with human (water scarcity) causes (Adopted from Van Loon, 2013)



## Expected results

- Groundwater level and budget will be significantly decreasing under all ensemble of climate projections.
- SWAT-MODFLOW is a powerful tool to assess climate change impacts on groundwater resources compared with using only MODFLOW.
- Most of groundwater dropping has been resulted from groundwater over-abstraction rather than drought and climate change impacts.

An aerial photograph of a mountainous region. A river flows through the center, with a large lake or reservoir in the foreground. The terrain is rugged and covered in dense vegetation. The sky is clear and blue.

**Thousands have lived without love,  
not one without water.**

Thank you for your attention