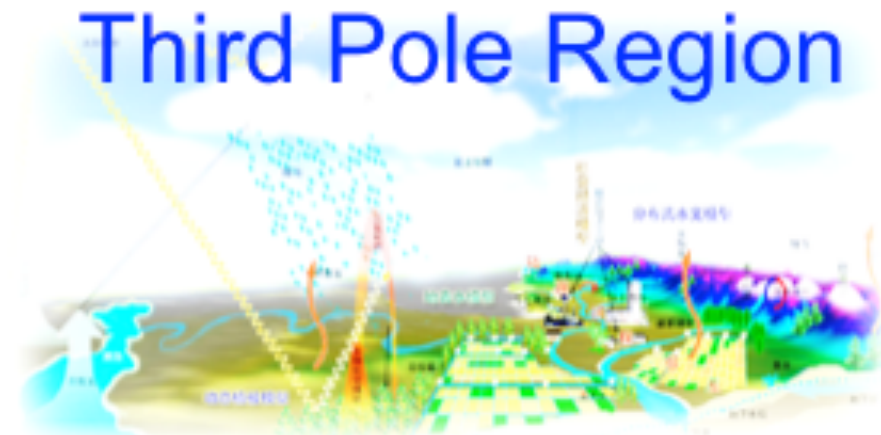


Closing water balance at basin scale in an endorheic river basin in the Pan Third Pole Region



Xin Li

**Institute of Tibetan Plateau Research,
Chinese Academy of Sciences**

May 6-11 2018, Canmore, Canada
2018 GEWEX Open Science Conference

Outline

- Endorheic river basins along the silk road in the Pan Third Pole region and their water use crisis
- Integrated watershed study in the Heihe River Basin
- Closing water cycle in the Heihe River Basin and its Implication for water resource management in arid regions

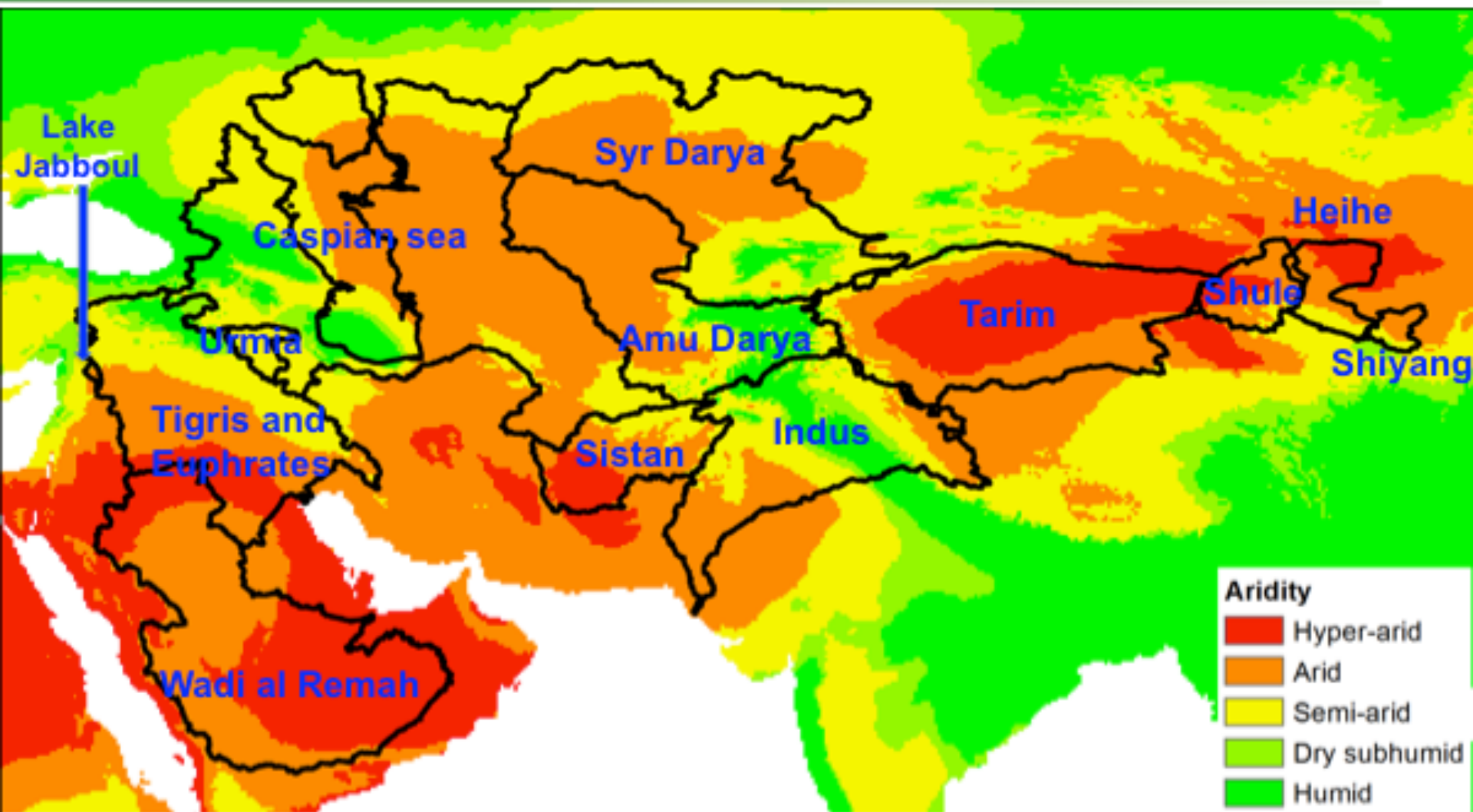
1. Endorheic river basins along the silk road in the Pan Third Pole region and their water use crisis



River basins along the silk road in the Pan Third Pole region

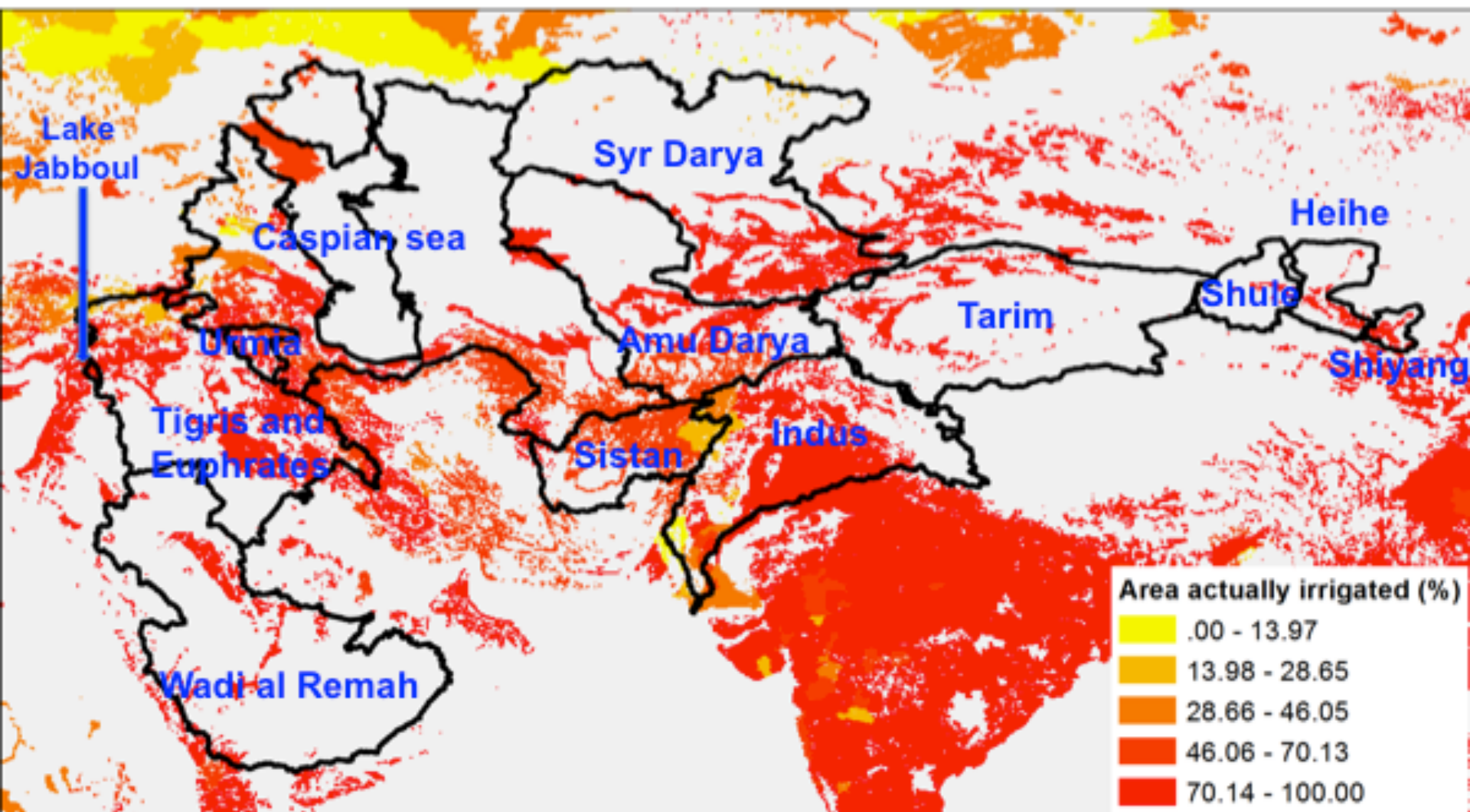


Arid environments

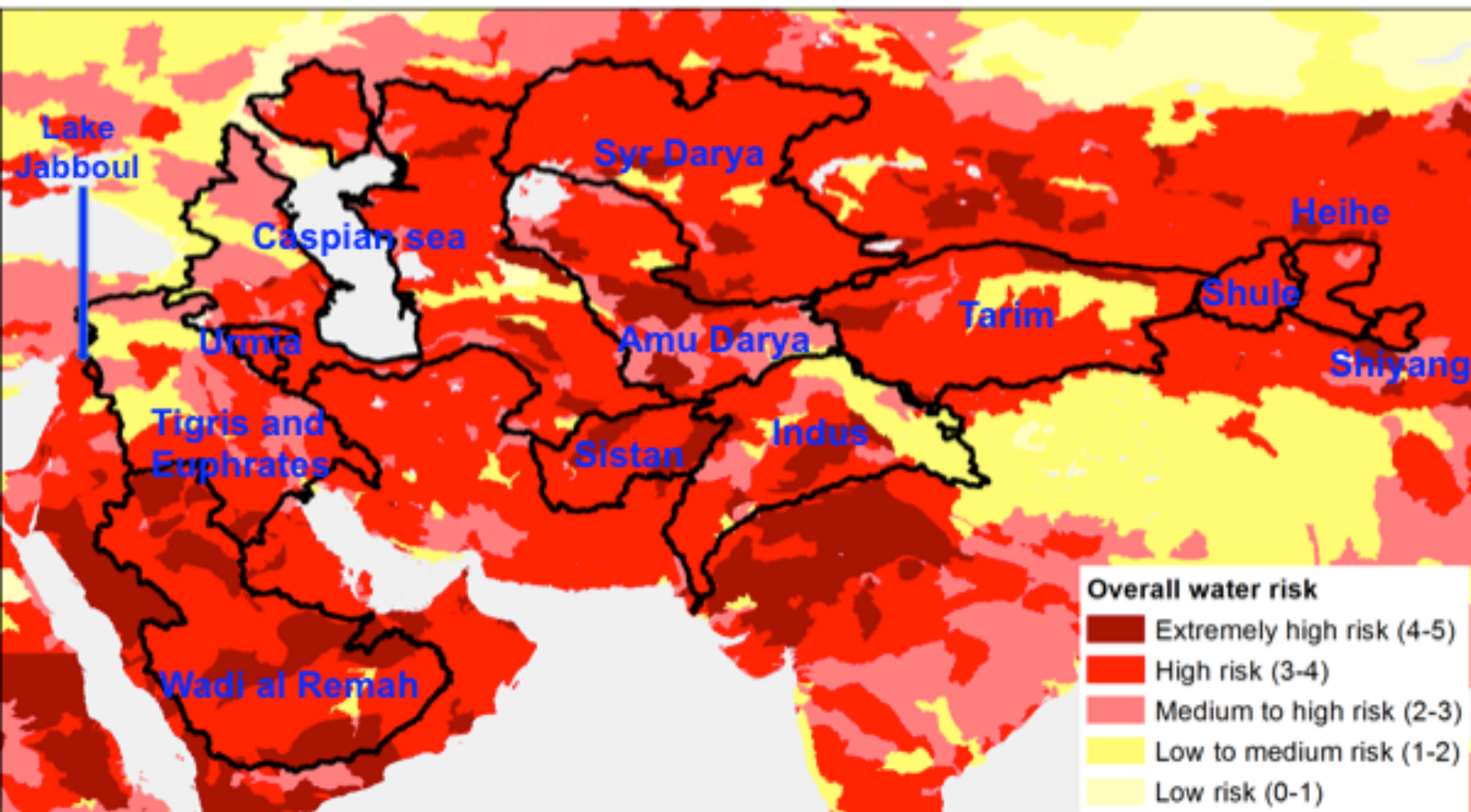


Food and Agriculture Organization of the United Nations. FAO GEONETWORK. Global map of aridity - 10 arc minutes (GeoLayer). (Latest update: 04 Jun 2015) Accessed (6 Mar 2018). URL: <http://data.fao.org/ref/221072ae-2090-48a1-be6f-5a88f061431a.html?version=1.0>

Overexploitation of water resources for irrigation



Water security in high risk



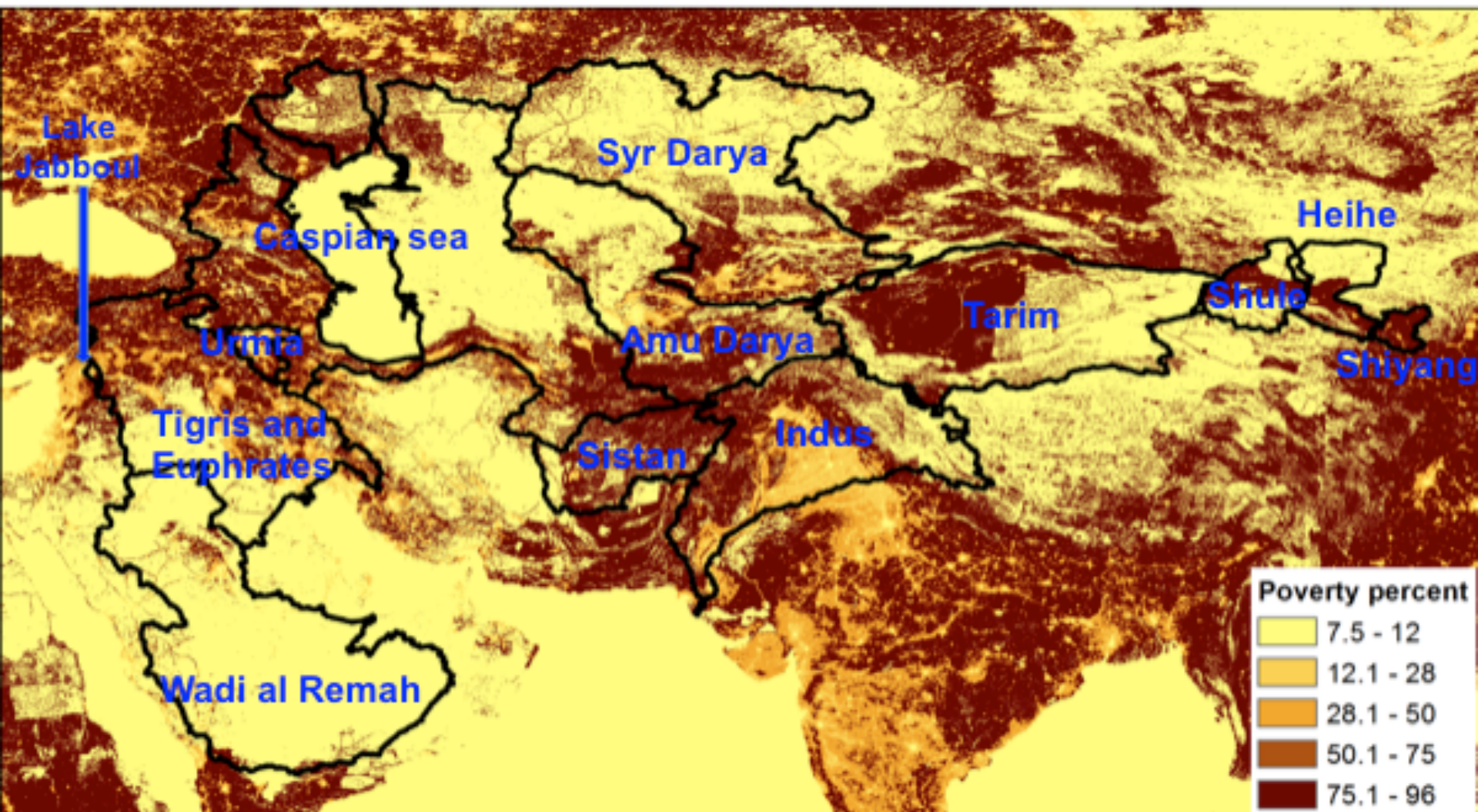
Gassert, F., M. Landis, M. Luck, P. Reig, and T. Shiao. 2014. *Aqueduct Global Maps 2.1. Working Paper*. Washington, DC: World Resources Institute.

Culture diversity: UNESCO world heritage sites



<http://whc.unesco.org/en/interactive-map/>

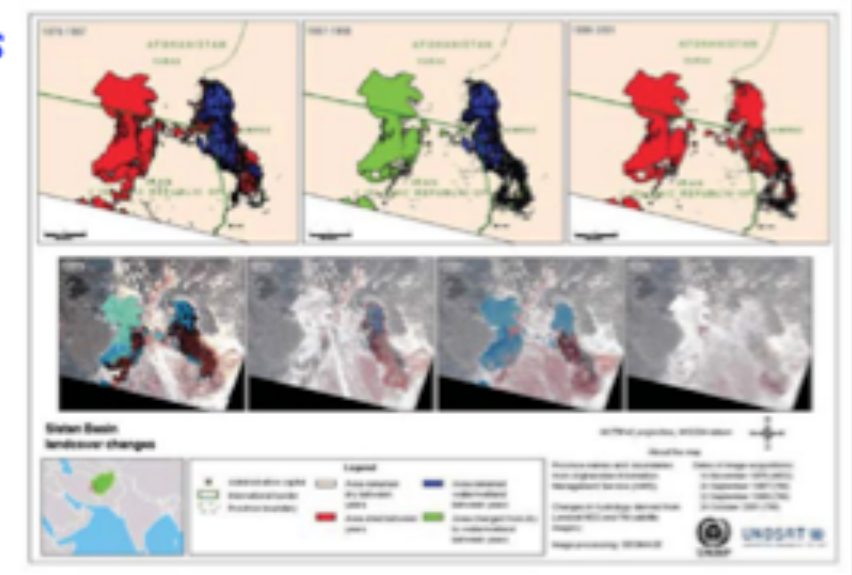
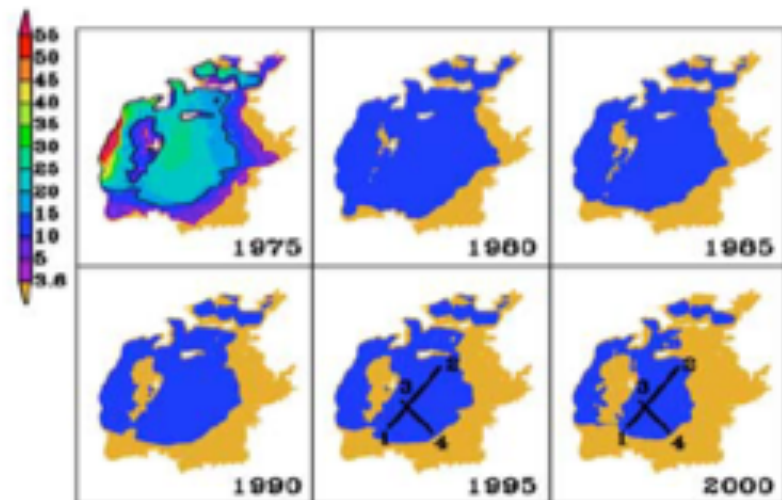
Poverty is a problem



Elvidge C D, Sutton P C, Ghosh T, et al. A global poverty map derived from satellite data. Computers & Geosciences, 2009, 35(8): 1652-1660. https://www.ngdc.noaa.gov/eog/dmsp/download_poverty.html

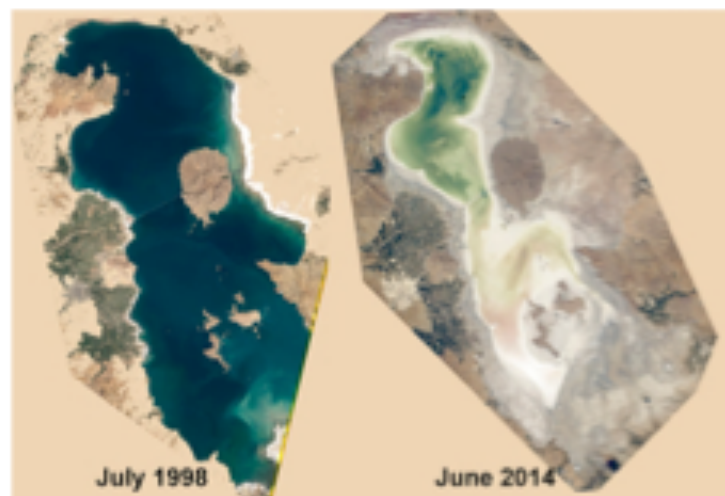
Tragedy of the Commons

Overuse of shared and unregulated resources

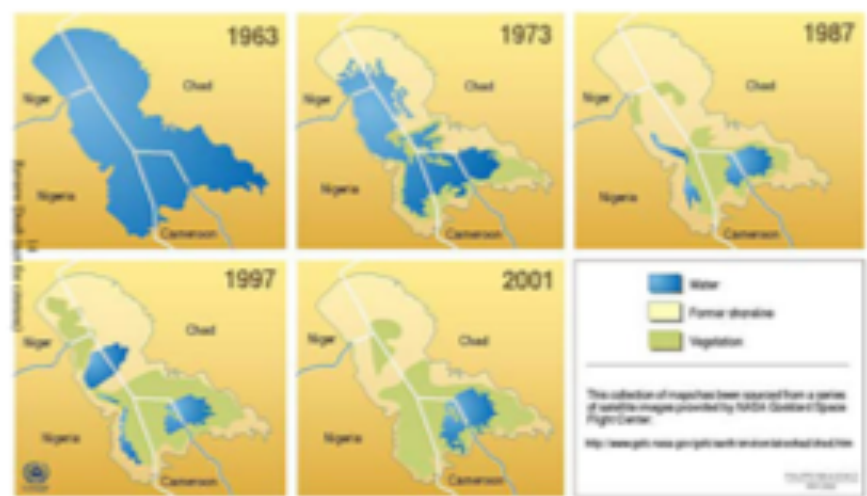


Aral sea ecological tragedy (Klein et al., 2014)

Hamoon lakes, Sistan Basin
(Najafi and Vatanfada, 2011)

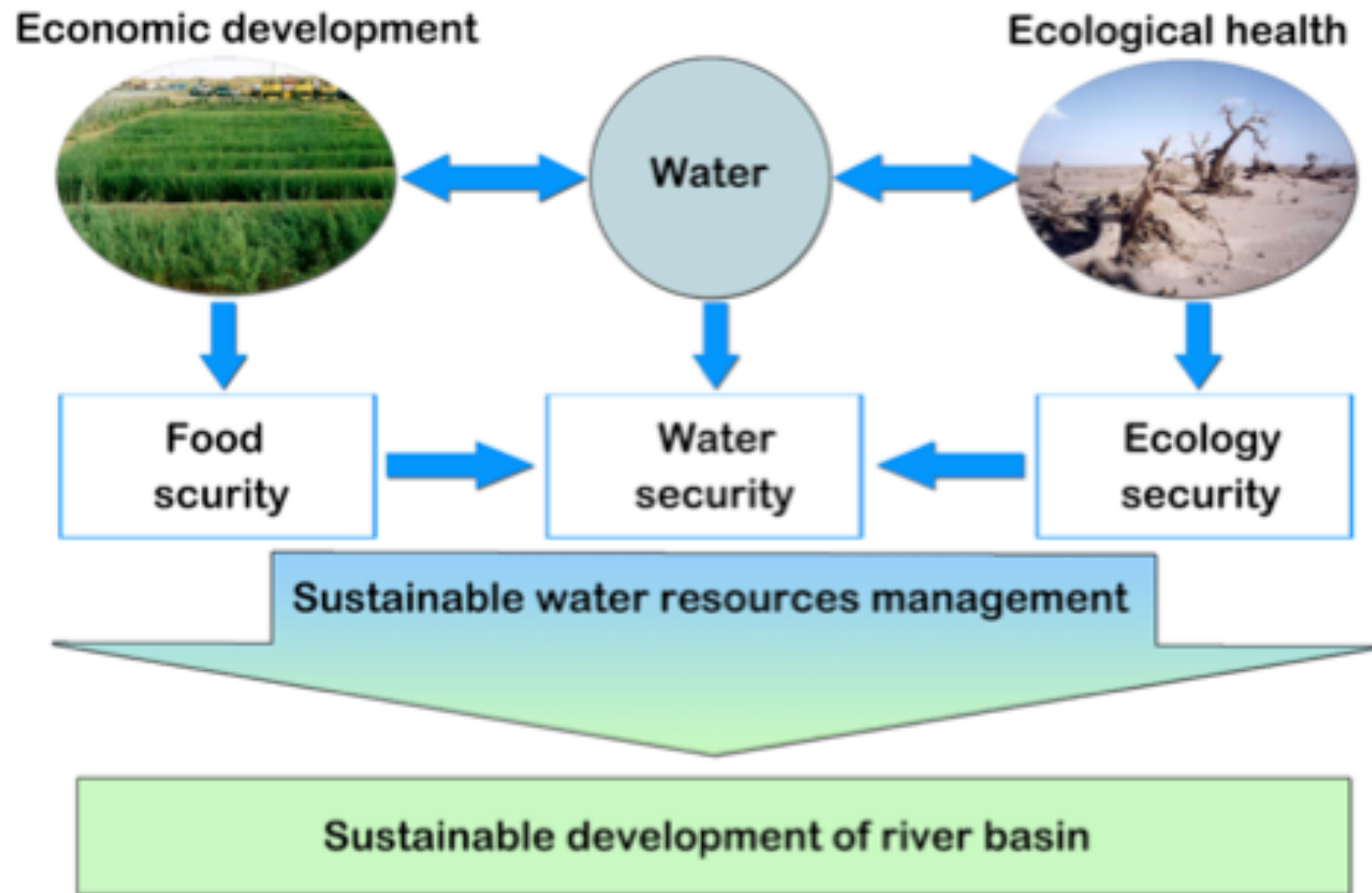


Lake Urmia (Stone, 2015)

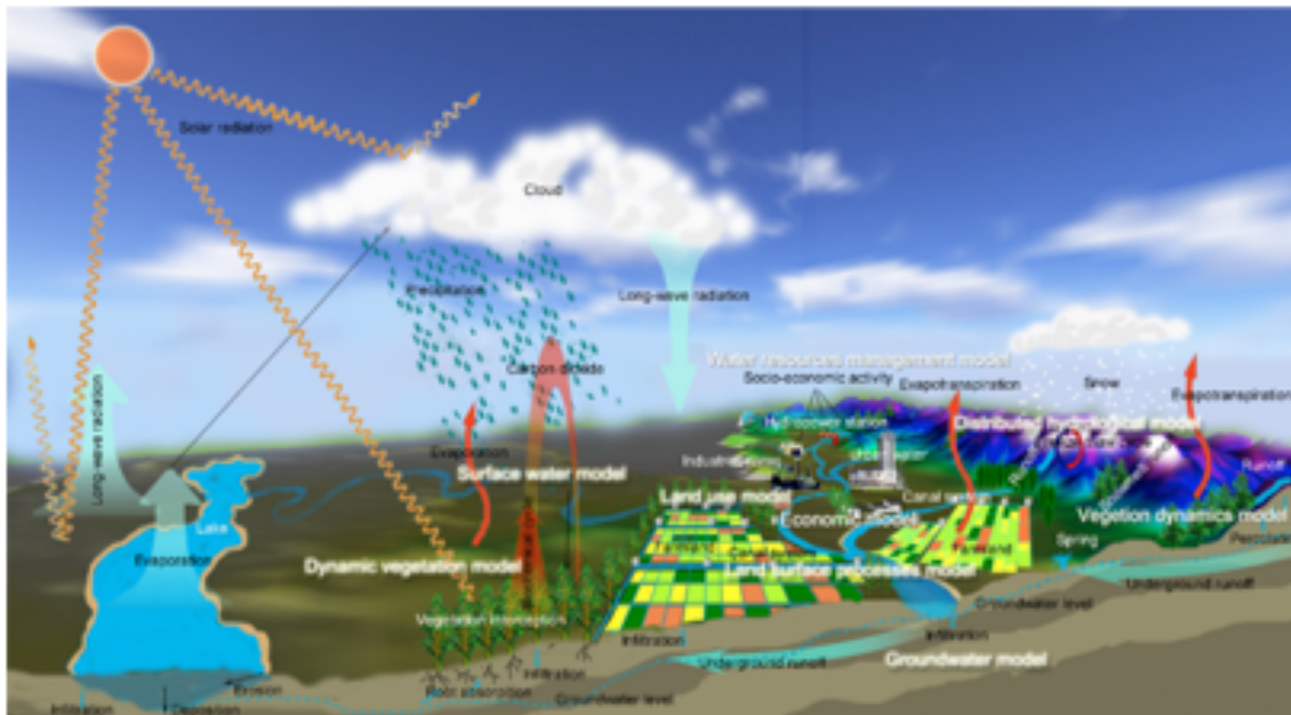


Shrinkage of the Chad Lake (Lemoalle et al., 2012)

How to achieve “Our Common Future” and avoid the “Tragedy of the Commons” on the Silk Road



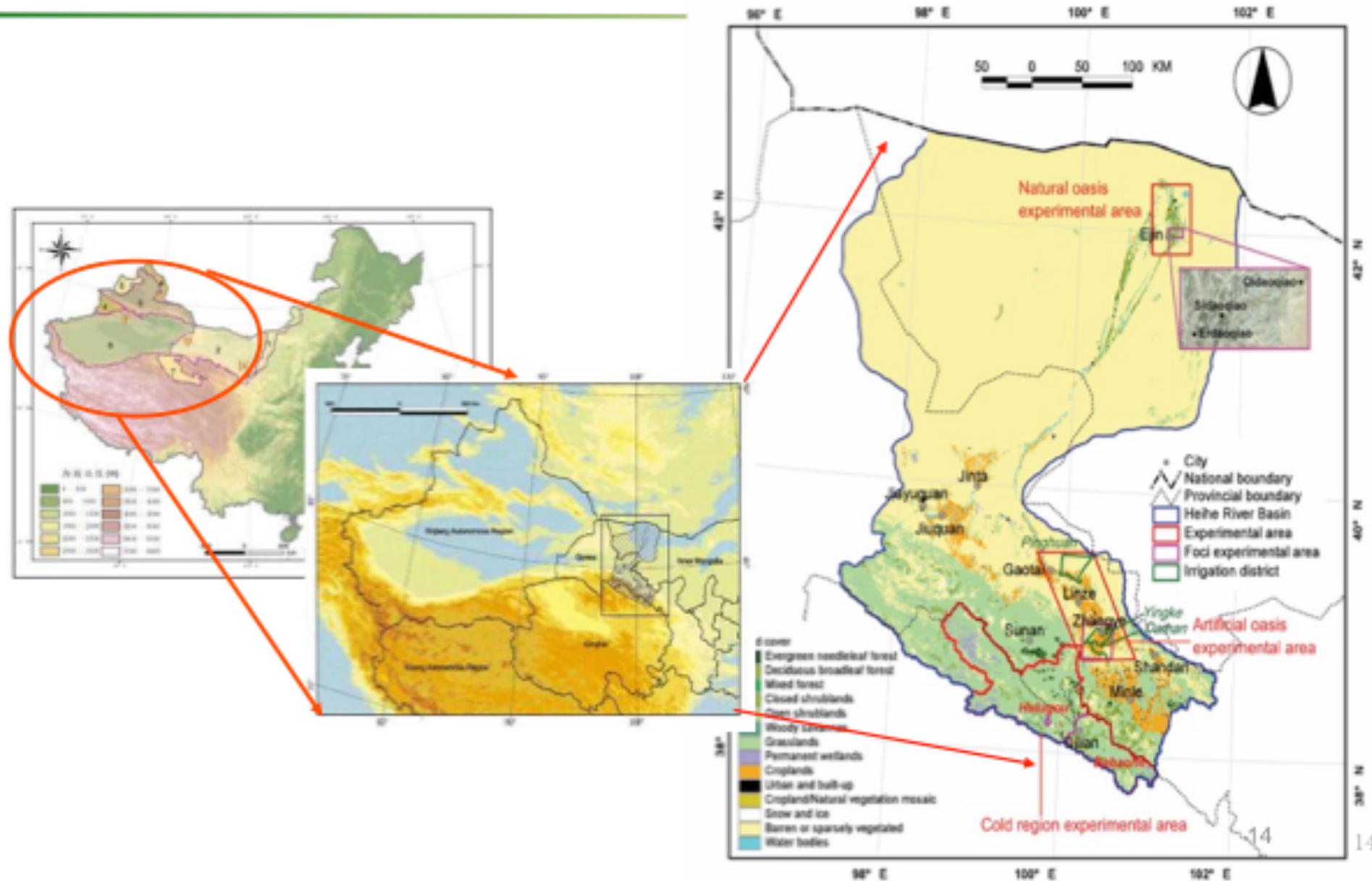
2. Integrated watershed study in the Heihe River Basin



Geographic context of the Heihe River Basin: Mountain cryosphere, oases and deserts



Heihe River Basin: Extremes meet



HRB as an INARCH site

INARCH: International Network for Alpine Research Catchment Hydrology

Canada – Canadian Rockies & Yukon;

USA – Reynolds Creek, Idaho; Senator Beck
Basin, Colorado.

Chile – Upper Maipo & Upper Diguillin River
Basins, Andes,

Germany – Schneefernerhaus & Zugspitze;

France – Arve Catchment, Col de Porte &
Col du Lac Blanc;

Switzerland – Dischma & Weissfluhjoch;

Austria – OpAL Open Air Laboratory, Rofental

Spain – Izaña, Pyrenees;

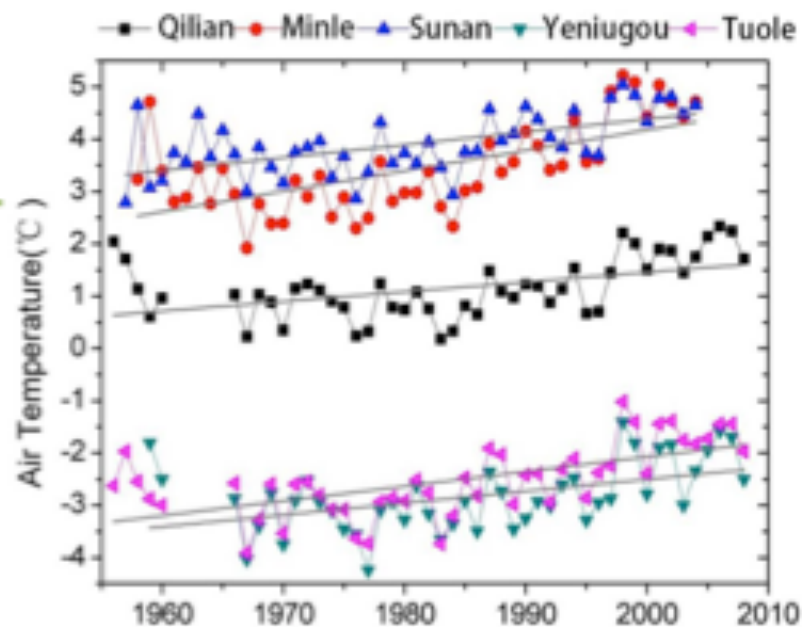
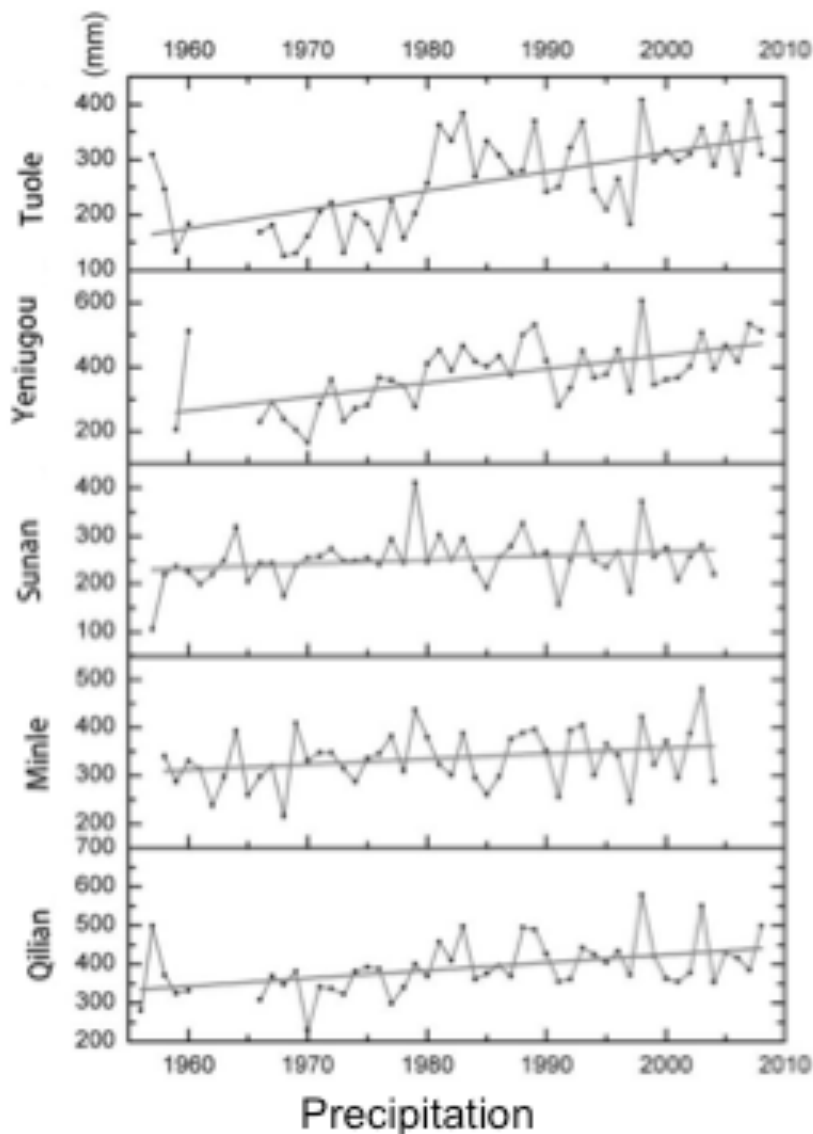
China – Upper Heihe River, Tibetan Plateau,

Nepal – Langtang Catchment, Himalayas

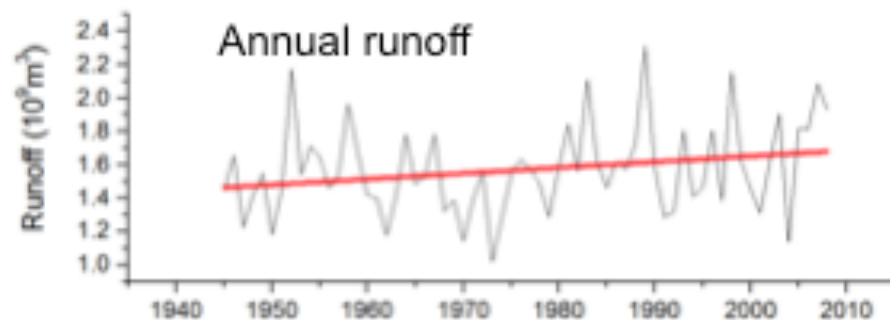


From Prof. John Pomeroy

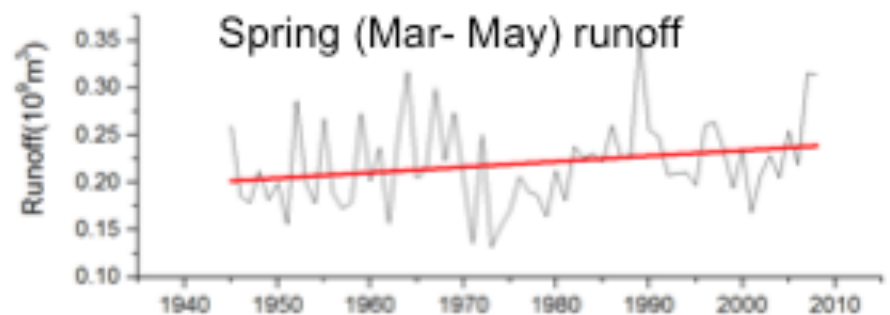
Climate change



Air temperature

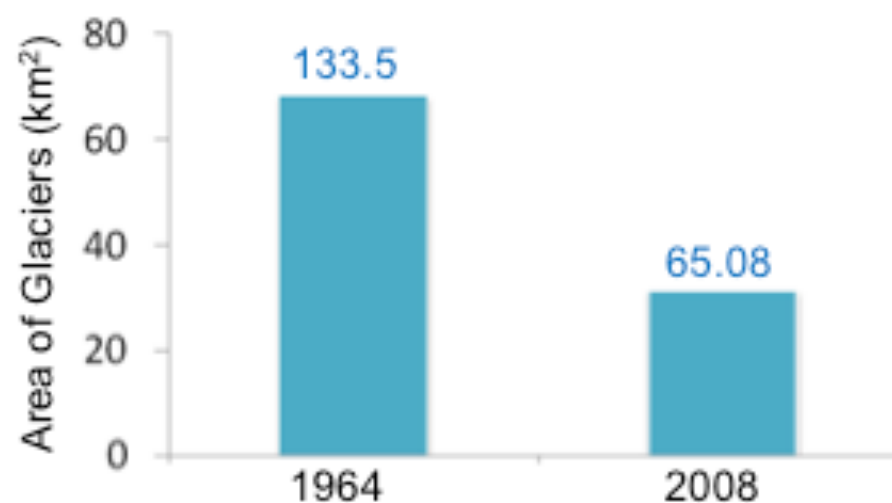
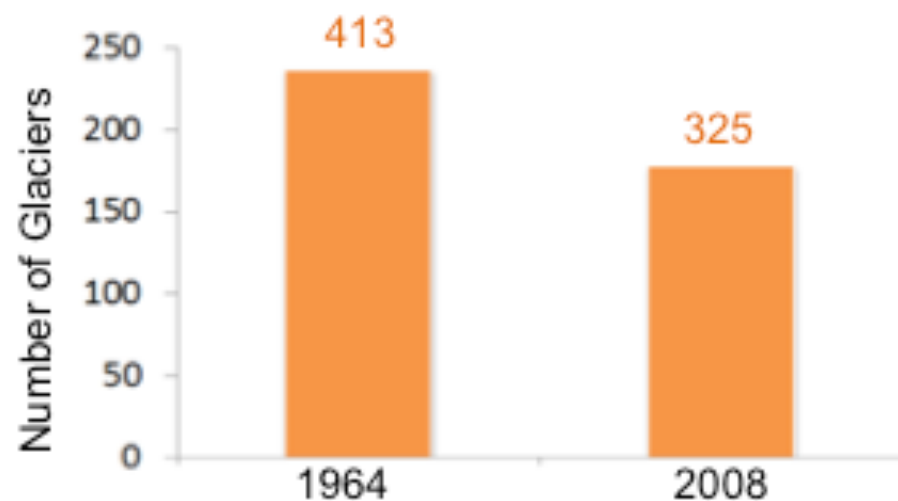
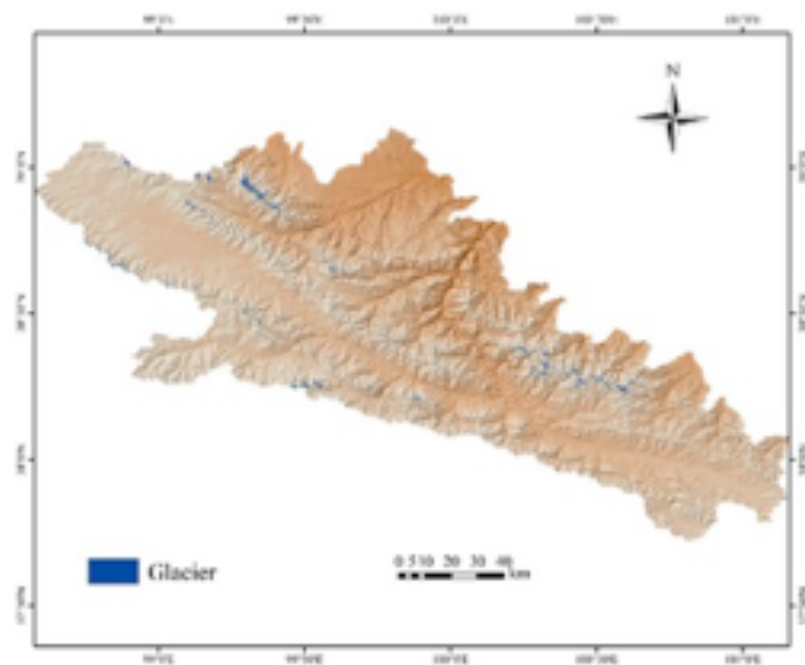


Annual runoff

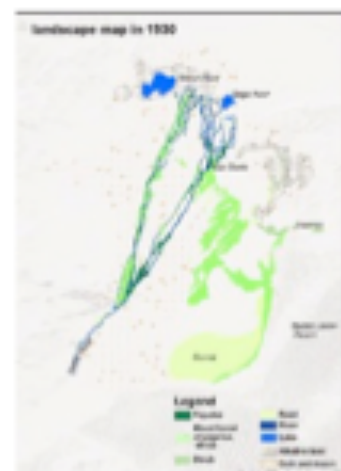


Spring (Mar- May) runoff

Observed cryospheric change: e.g., glaciers



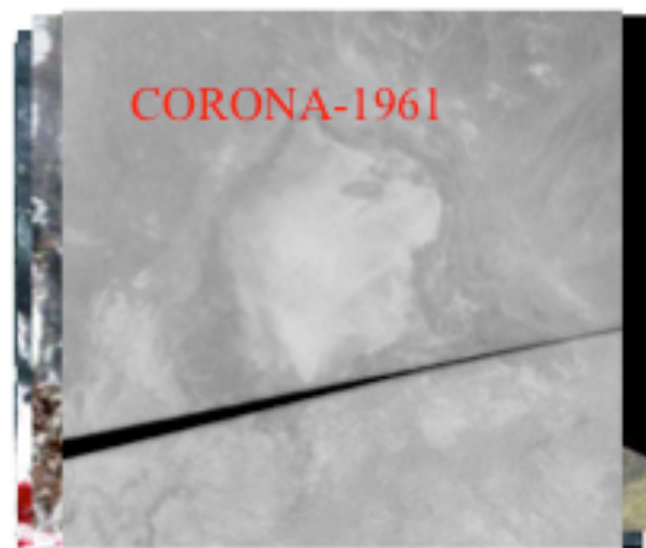
Ecological deterioration in the Heihe River Basin before 2000



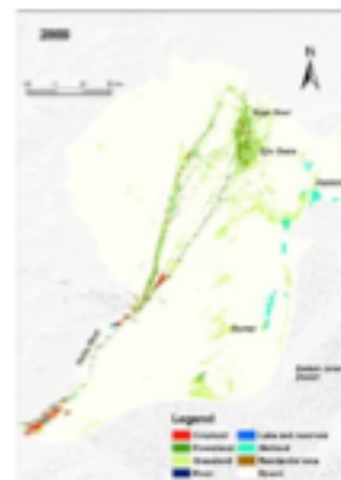
1930s



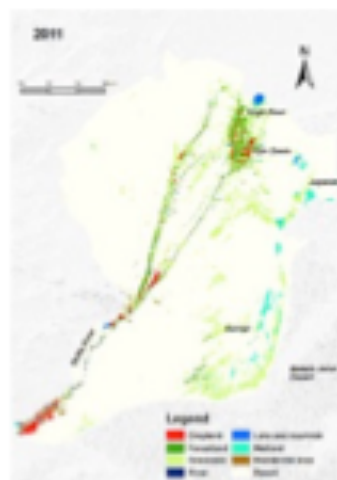
1960s



Drying up of the lake



2000

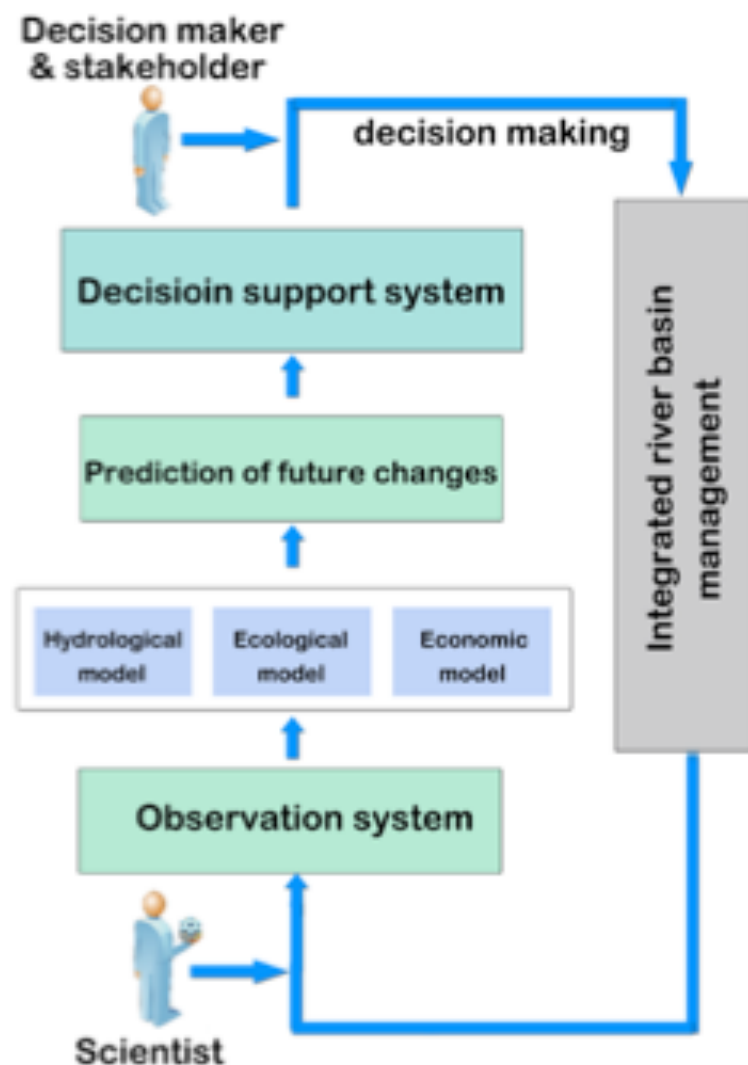
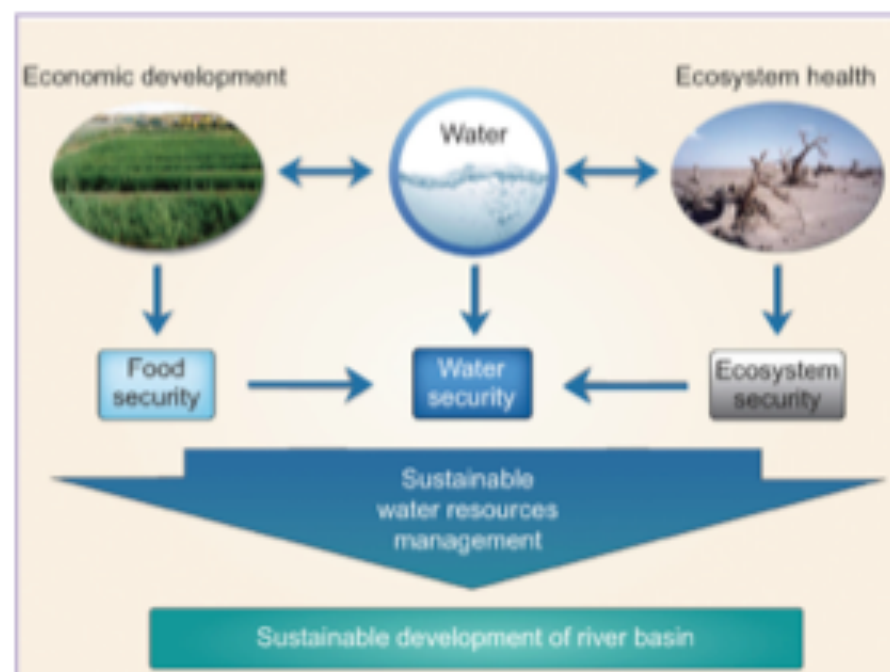


2011

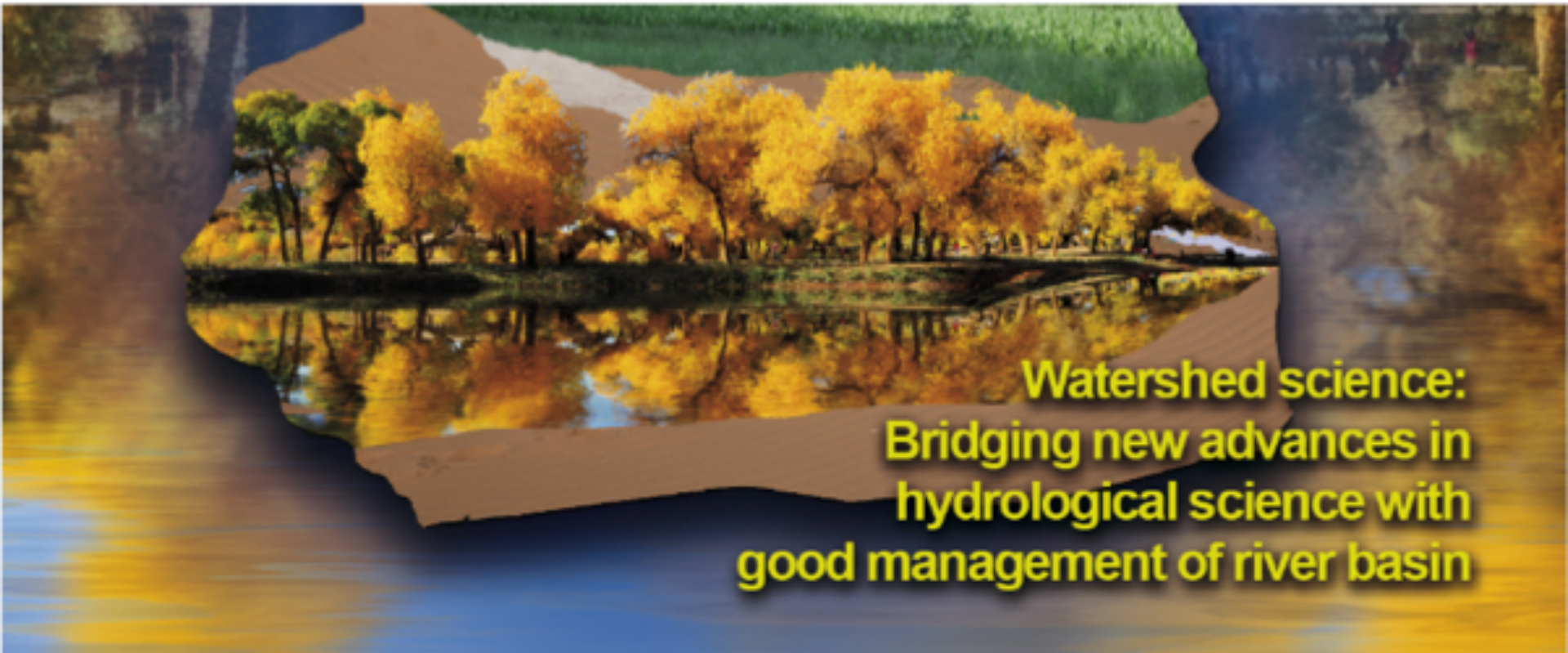


NSFC: Integrated Research on the Eco-Hydrological Process of the Heihe River Basin (2010-2018)

... and to provide fundamental theory and technical support for water security, ecological security, and sustainable development in inland river basins.

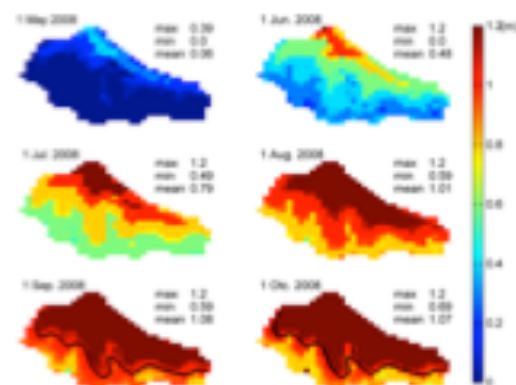
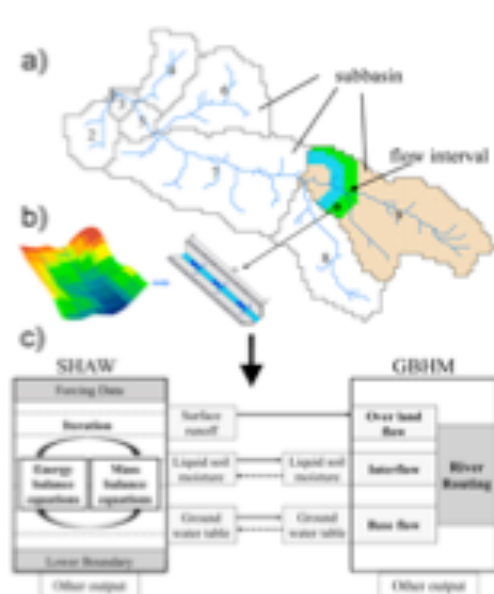


3. Closing water cycle in the Heihe River Basin and its Implication for water resource management in arid regions

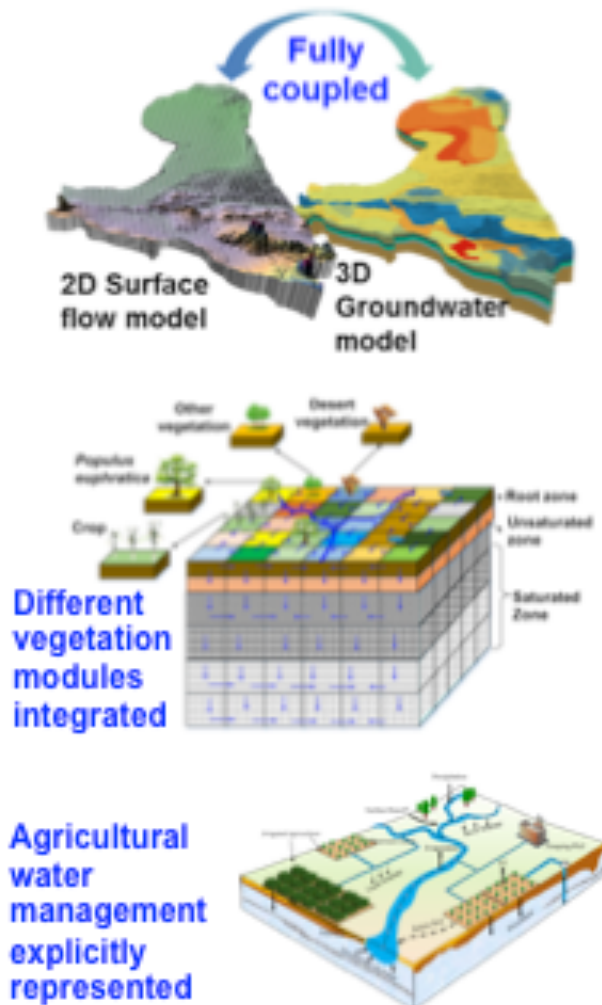


**Watershed science:
Bridging new advances in
hydrological science with
good management of river basin**

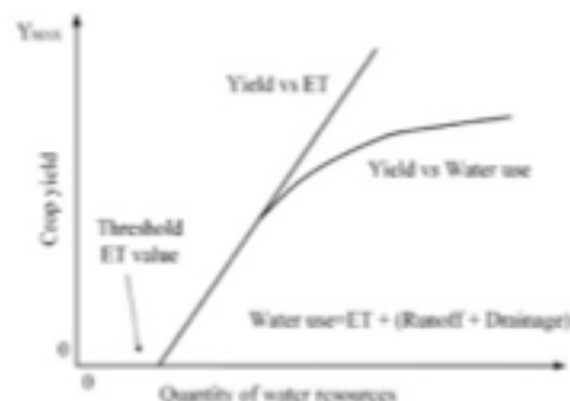
Methods: Integrated watershed system model



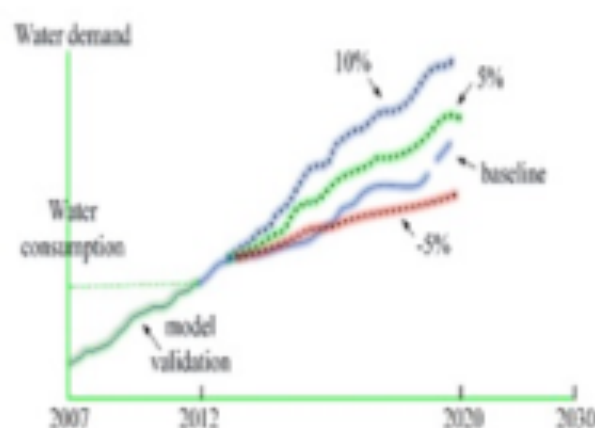
A distributed eco-hydrological model that integrates the glacier, snow, and frozen soil processes (Yang et al., 2015, SCES)



Hydrological-Ecological Integrated watershed-scale FLOW model (HEIFLOW) (Tian et al., 2015 WRR, Yao et al., 2015)

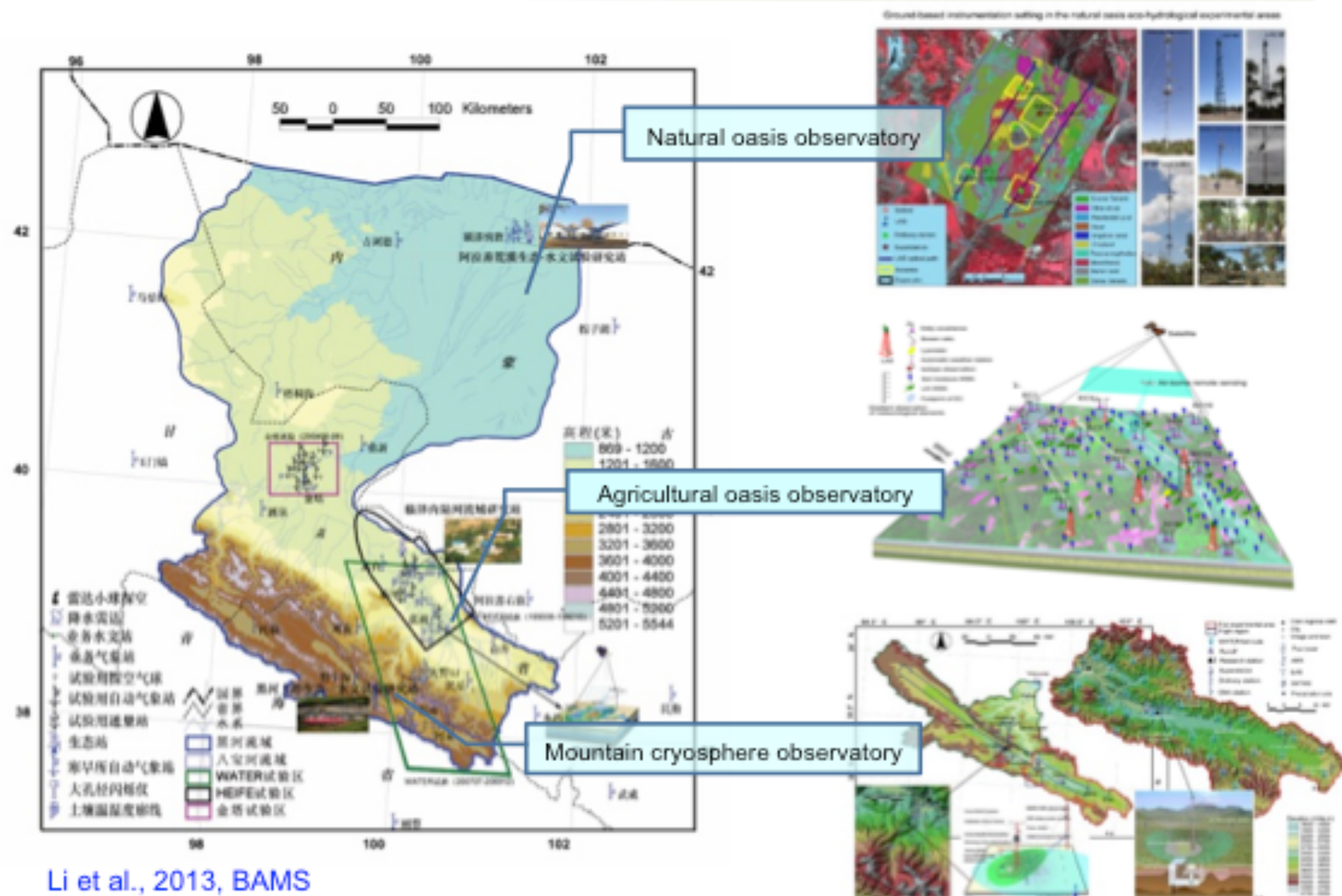


Production function model

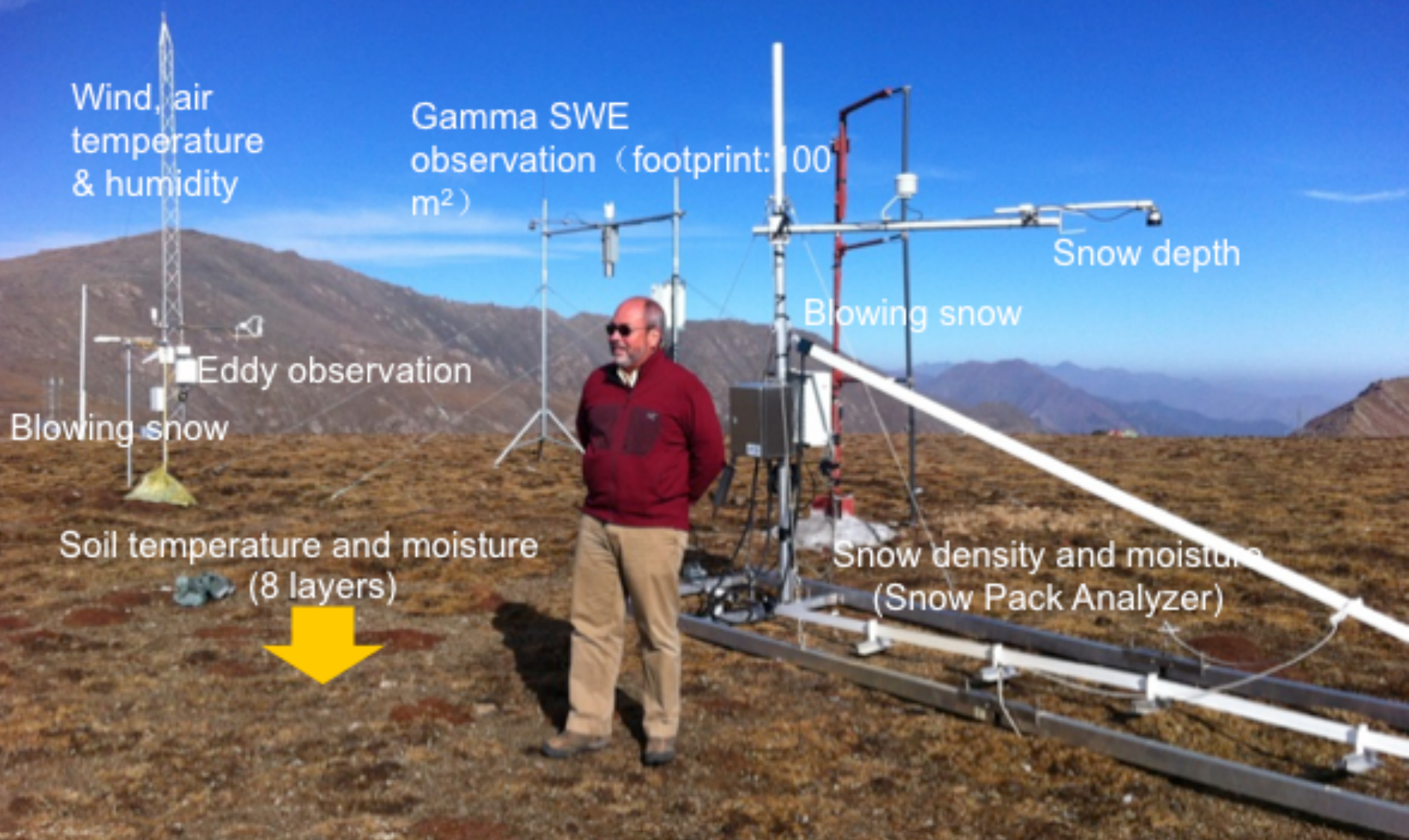


Water Economic System Model (WESM) (Wu et al., 2015, Ecological Modeling)

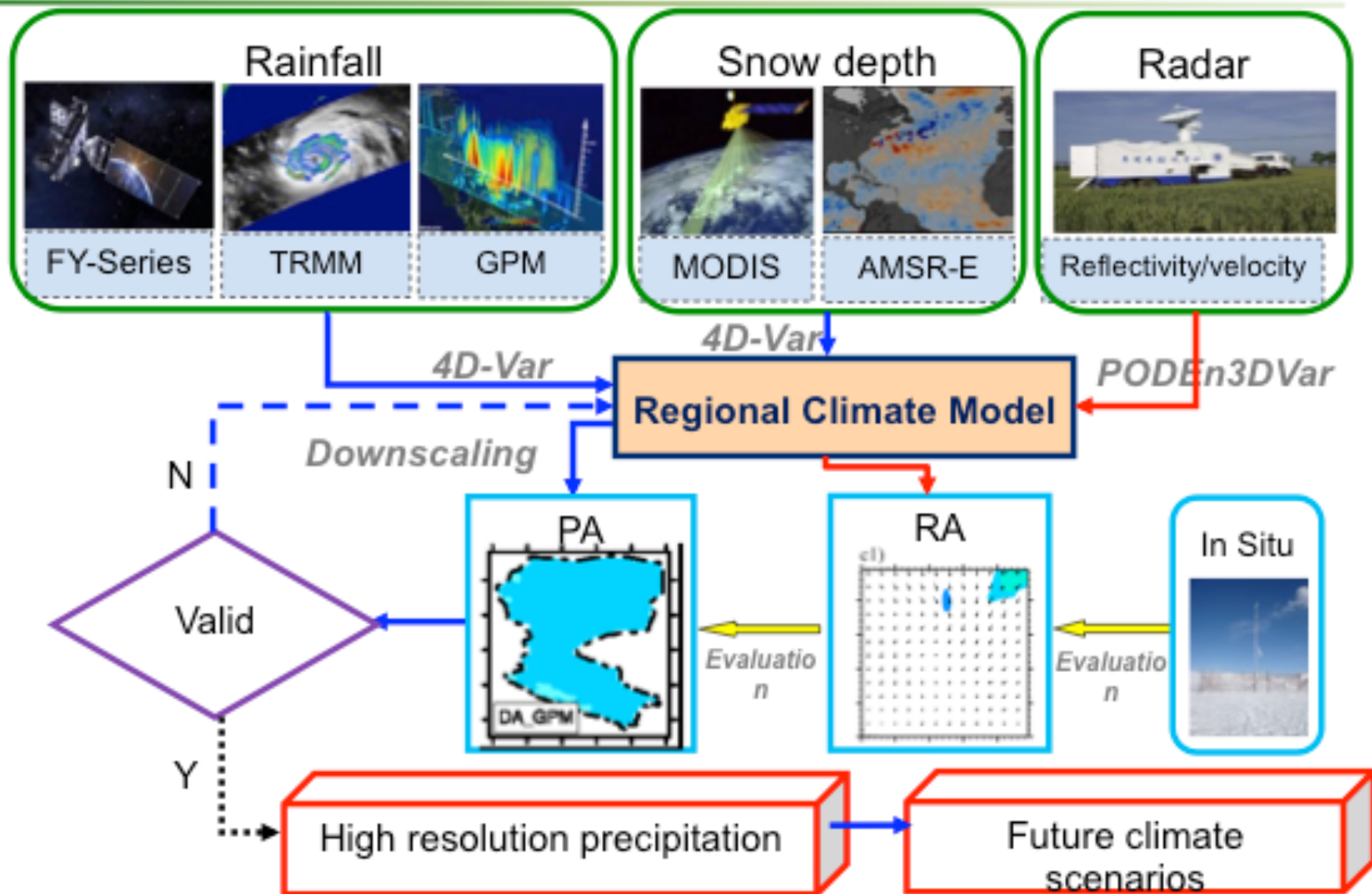
Watershed observation system in the HRB



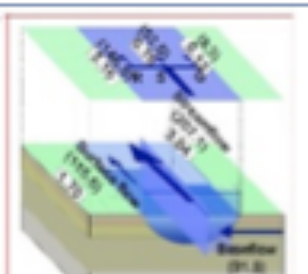
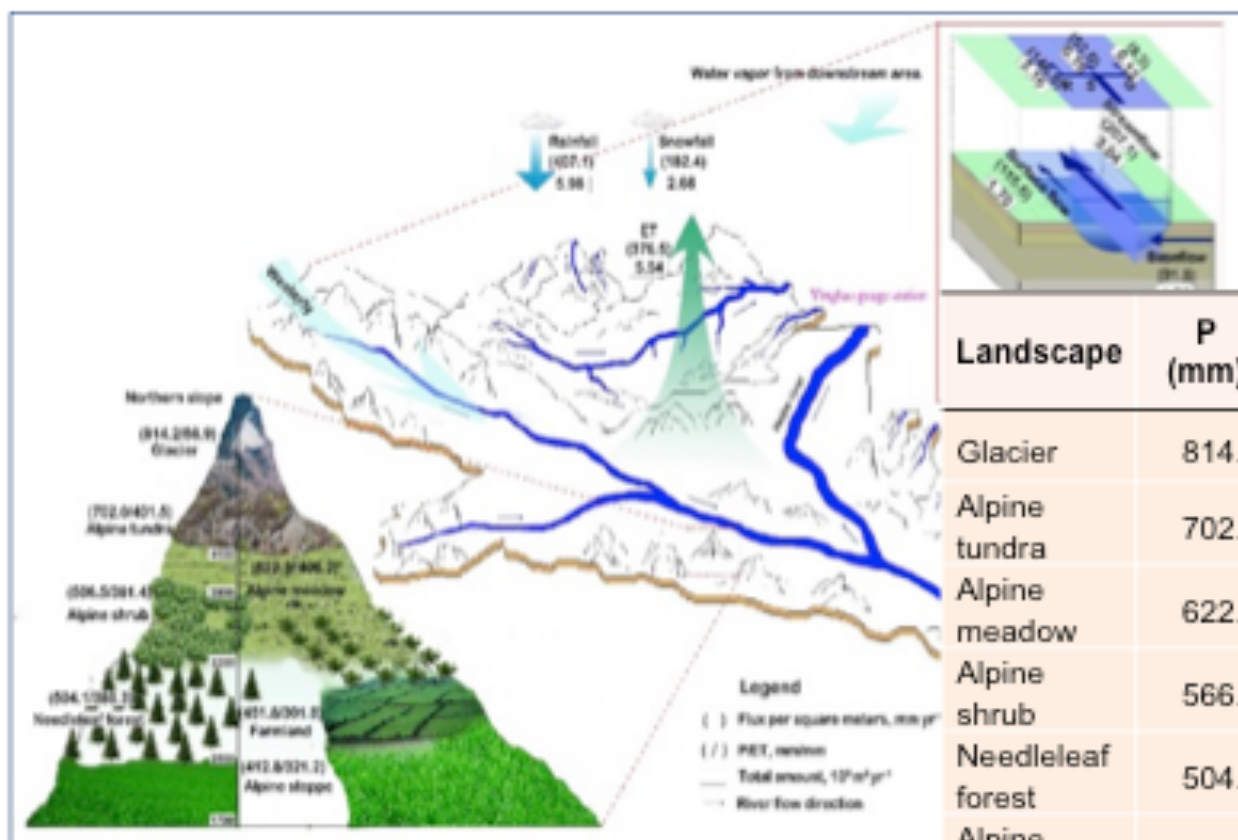
Snow observatory in the upstream of the HRB (4150 m)



Remote Sensing Precipitation Assimilation: High resolution precipitation products

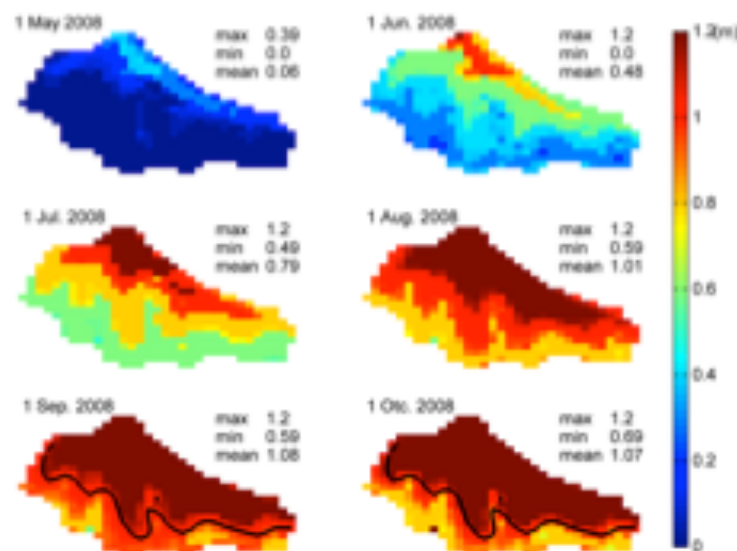
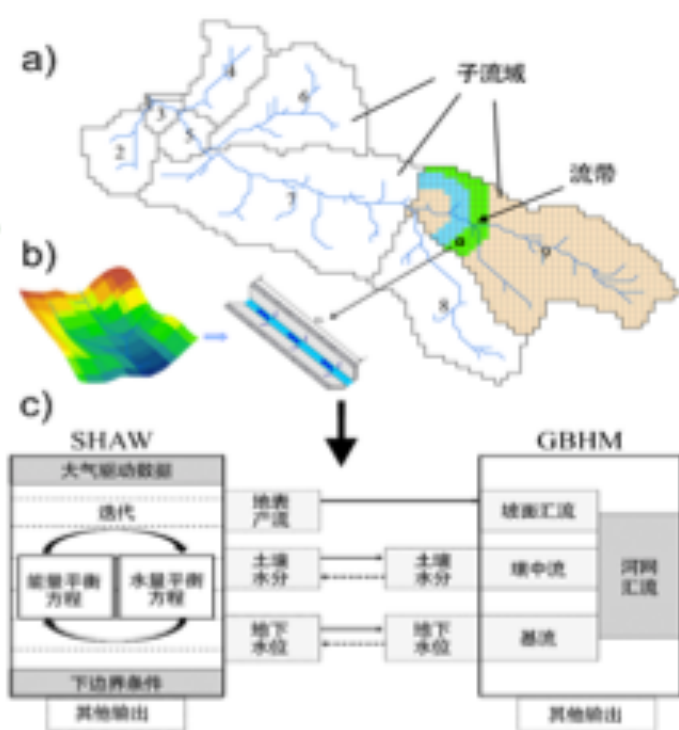


Upstream mountainous area



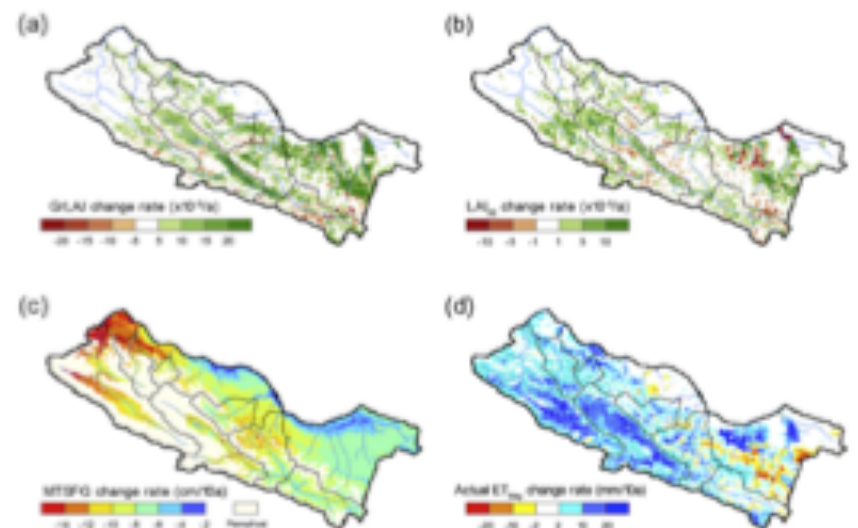
Landscape	P (mm)	ET (mm)	Runoff (mm)	Runoff coefficient	Storage change (mm)
Glacier	814.2	88.9	976.9	1.20	-251.6
Alpine tundra	702.0	401.5	297.7	0.42	2.8
Alpine meadow	622.3	406.2	204.4	0.33	11.7
Alpine shrub	566.5	381.4	179.0	0.32	6.1
Needleleaf forest	504.1	386.3	117.8	0.23	0.0
Alpine steppe	412.8	321.2	88.2	0.21	3.3
Farmland	451.8	301.8	122.6	0.27	27.4
Desert	425.4	257.6	164.6	0.39	3.2
Total	589.5	407.1	207.1	0.35	6.1

Coupling the frozen soil processes into an ecohydrological model



Spatial and temporal variation of frozen depth

Zhang et al., 2013, HP; Zhang et al., 2017, PPP



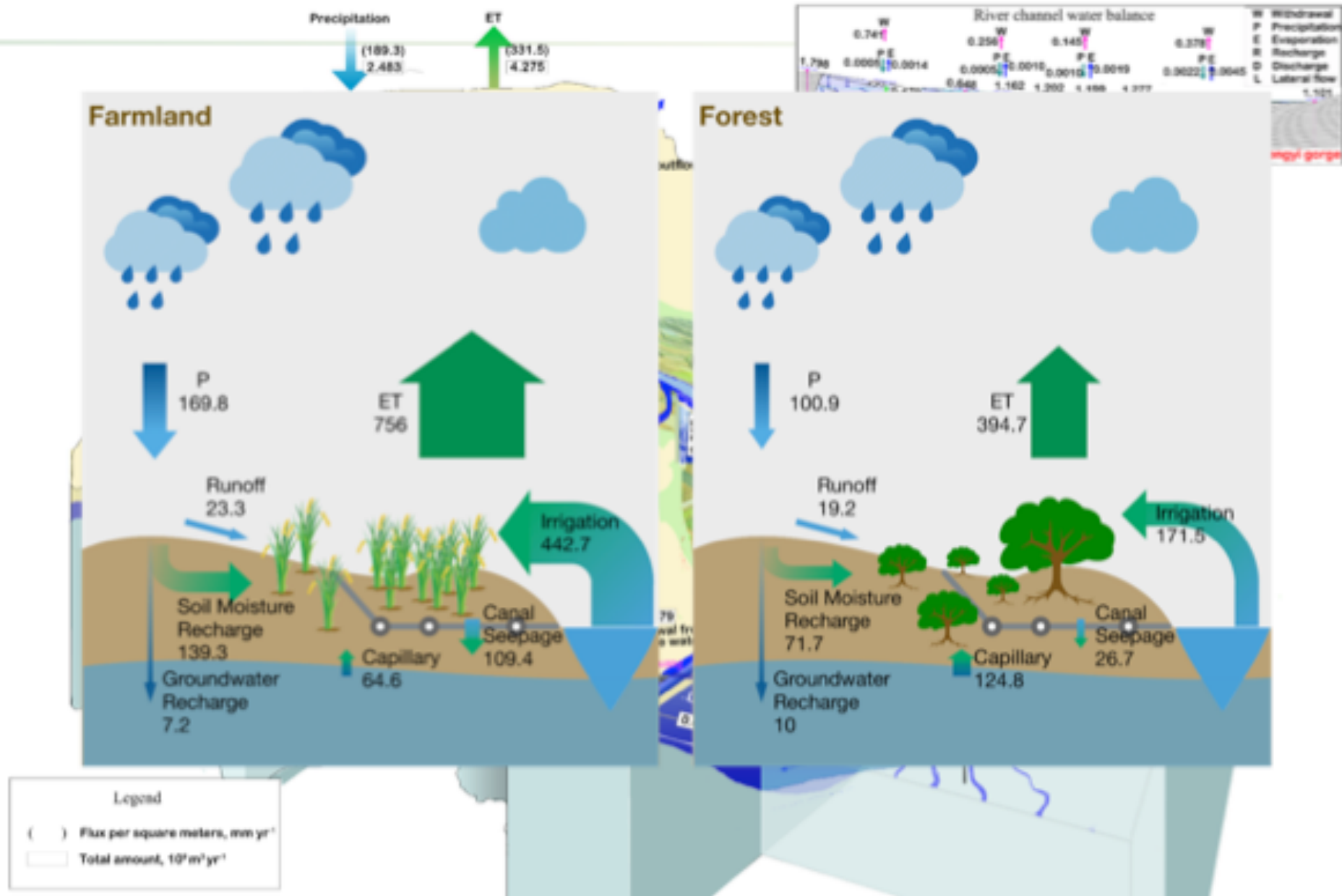
Ecohydrological model: simulation of LAI, maximum frozen depth, and ET



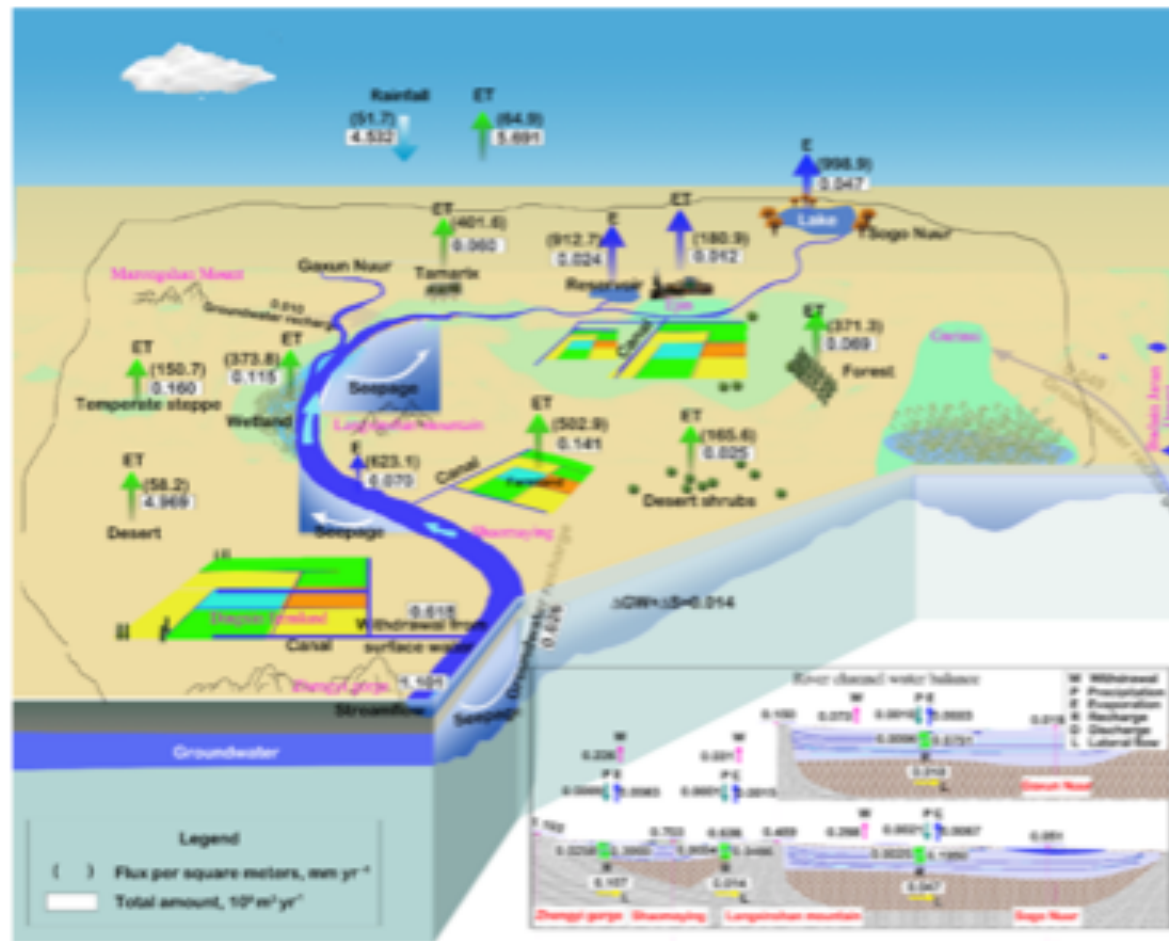
Prediction of the active layer of permafrost

Yang et al., 2015, SCES; Qin et al., 2016, JH

Midstream area



Downstream areas



In terms of the available water, approximately

- 39% is used to sustain the natural oases,
- 4% is used to sustain a terminal lake,
- 9% is used to maintain the streamflow and reservoirs,
- 13% is used for irrigation to support rapidly expanding cropland, and approximately
- 35% of water is lost via ET in the desert.

Policy suggestions: Ecological restoration by the year of 2011

- Policy suggestion on rescuing the Ejin oasis
- Eco-economic development path for the Heihe River Basin
- Virtual water: A new approach for water security in NW China
- Happiness oriented water resources management in Zhangye city



Revival of *Populus euphratica* in the Ejin oasis



Replenished Juyan lake

References

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE
10.1029/2017JD027889

Special Section:
Water and air-plant-human nexus: Modeling and observing complex land-surface systems at river basin scale

Hydrological Cycle in the Heihe River Basin and Its Implication for Water Resource Management in Endorheic Basins

Xin Li^{1,2}, Guodong Cheng^{3,4}, Yingchan Ge⁵, Mengdi Li⁶, Fang Han^{4,5}, Xiaoli Hu⁷, Wei Tian⁸, Yang Tian⁹, Xianbin Fan¹⁰, Yanguan Nian¹¹, Yanlin Zhang¹², Youhua Ren¹³, Yi Zhang¹⁴, Bing Gao¹⁵, Dawen Yang¹⁶, Chunmiao Zheng¹⁷, Ruihong Wang¹⁸, Shaomin Liu¹⁹, and Xining Cai²⁰

¹Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China, ²State Key Laboratory of Tibetan Plateau Earth Sciences, Chinese Academy of Sciences, Beijing, China, ³Institute of Urban Study, Shanghai Normal University, Shanghai, China, ⁴School of Environmental Science and Engineering, Southern University of Science and Technology, Shenzhen, China, ⁵School of Water Resources and Hydropower Engineering, Wuhan University, Wuhan, China, ⁶College of Earth and Environmental Sciences, Lanzhou University, Lanzhou, China, ⁷National Local Joint Engineering Laboratory of Geo-spatial Information Technology, Hunan University of Science and Technology, Xiangtan, Hunan Province, China, ⁸School of Water Resources and Environment, China University of Geosciences, Beijing, China, ⁹State Key Laboratory of Hydroscience and Engineering, Department of Hydraulic Engineering, Tsinghua University, Beijing, China, ¹⁰State Key Laboratory of Earth Surface Processes and Resource Ecology, School of Natural Resources, Faculty of Geographical Science, Beijing Normal University, Beijing, China, ¹¹Yan-Tai-Chao Hydrological Laboratory, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA

Key Points:

- Water balance at different scales of an endorheic basin is closely intertwining an hydrological model and systematic observations
- Climate warming, resulting in greater precipitation, increased, glacier melt, and runoff, elevates water scarcity in Heihe River Basin
- Biological water diversion is positive, but increase of water for agriculture brings unfavorable changes in surface-ground-water interaction

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

COMMENTARY
10.1029/2017JD028154

Special Section:
Water and air-plant-human nexus: Modeling and observing complex land-surface systems at river basin scale

Watershed System Model: The Essentials to Model Complex Human-Nature System at the River Basin Scale

Xin Li^{1,2}, Guodong Cheng^{3,4}, Hui Lin⁵, Xining Cai⁶, Miao Fang⁷, Yingchan Ge⁸, Xiaoli Hu⁹, Min Chen¹⁰, and Waiyue Li¹¹

¹Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China, ²State Key Laboratory of Tibetan Plateau Earth Sciences, Chinese Academy of Sciences, Beijing, China, ³Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China, ⁴Institute of Urban Studies, Shanghai Normal University, Shanghai, China, ⁵Institute of Space and Earth Information Science, Chinese University of Hong Kong, Hong Kong, ⁶Yan-Tai-Chao Hydrological Laboratory, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA, ⁷Key Laboratory of Virtual Geographic Environment, Ministry of Education of China, Nanjing Normal University, Nanjing, China

Key Points:

- A watershed system model should represent the coordination of the watershed air-plant-human nexus
- A new approach to build a scientifically based decision support system can take advantage of surrogate modeling
- Simulation approaches and soft systems methodologies will be critical in future watershed modeling

Abstract Watershed system models are urgently needed to understand complex watershed systems and to support integrated river basin management. Early watershed modeling efforts focused on the

Li, X., Cheng, G. D., Ge, Y. C., Li, H. Y., Han, F., Hu, X. L., et al. (2018). Hydrological cycle in the Heihe River Basin and its implication for water resource management in endorheic basins. *Journal of Geophysical Research: Atmospheres*, 123(2), 890-914.

Li, X., Cheng, G. D., Lin, H., Cai, X. M., Fang, M., Ge, Y. C., et al. (2018). Watershed system model: The essentials to model complex human-nature system at the river basin scale. *Journal of Geophysical Research: Atmospheres*, 123(6), 3019-3034.

Summary

- Climate warming, resulting in greater precipitation, snowmelt, glacier melt, and runoff, alleviates water scarcity in Heihe River Basin.
- Water resource management in the region should be adjusted to adapt to a changing hydrological cycle and economic water use should be reduced. To foster long-term benefits, water conflicts should be handled from a broad socioeconomic perspective.
- Endorheic basins in arid regions are similar in natural geography, climatology, hydrological cycle, and water resource problems. The results in this study could contribute to the understanding of the hydrological cycle in endorheic basins and also provide a useful reference for sustainably exploiting water resources in endorheic basins around the world.