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Eco-hydrological impacts of climate change and human activities on watershed: Cases and implications

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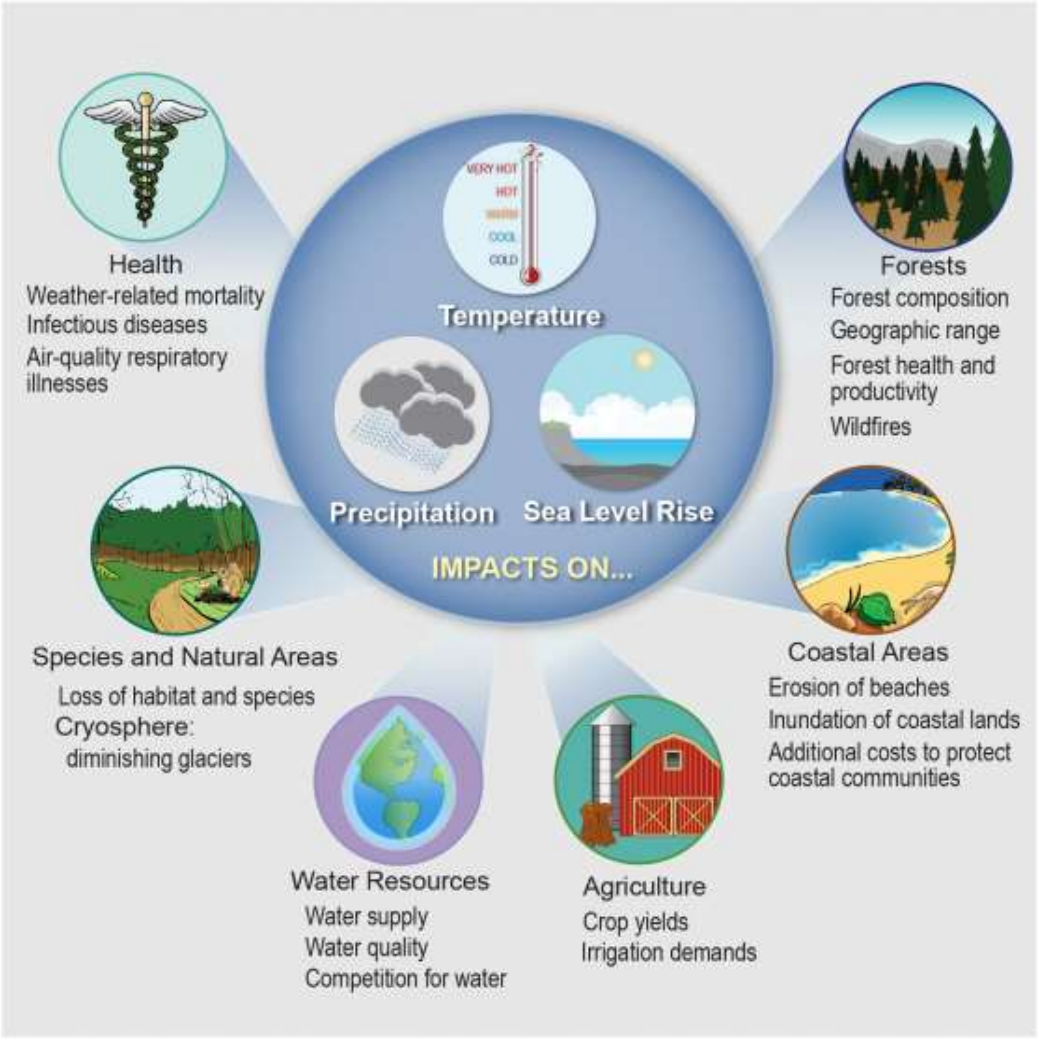
Background

Potential Effects of Climate Change



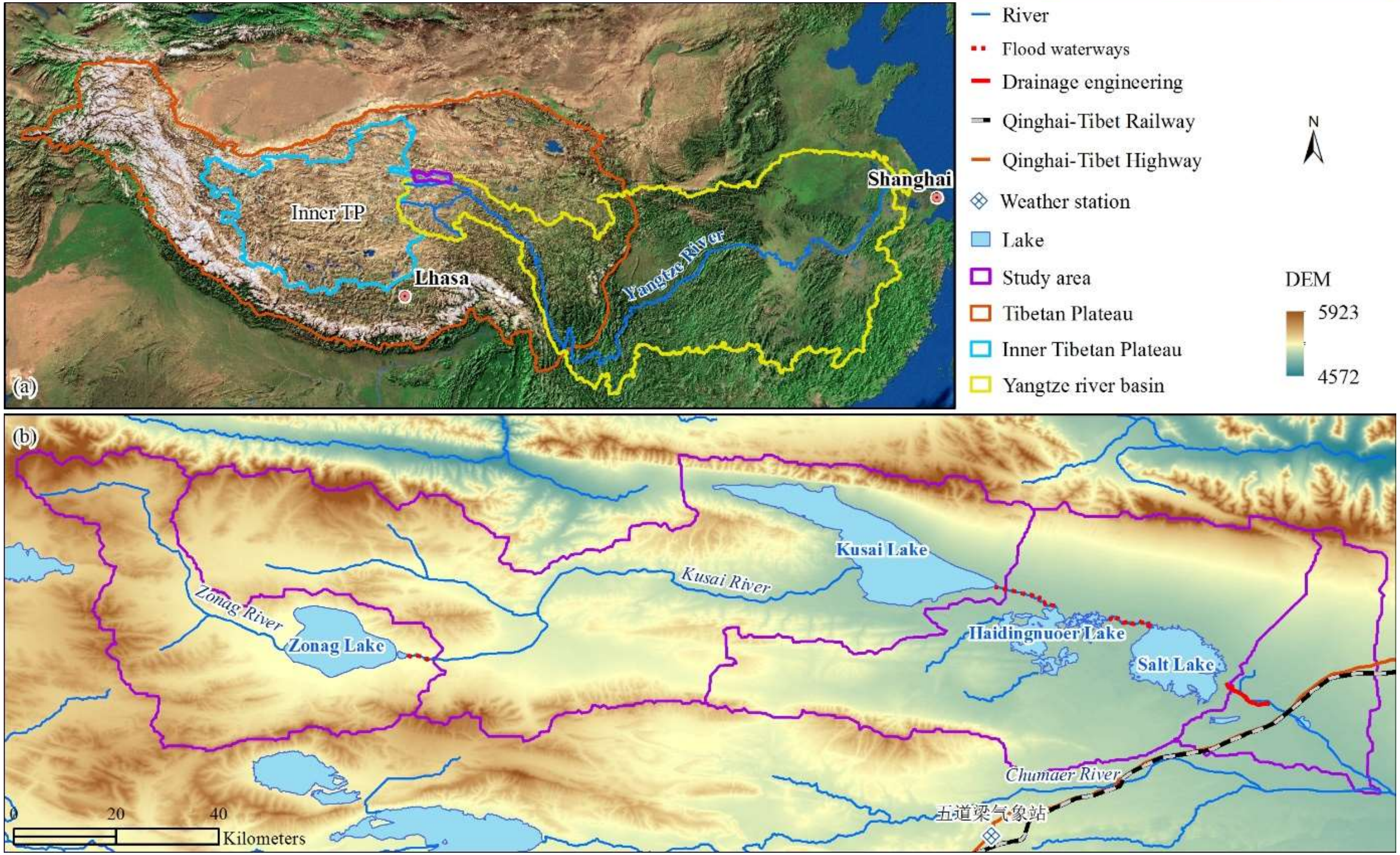
Negative effects

- Rising temperatures
- Melting ice and rising sea levels
- Ocean acidification
- Extreme weather events
- Disruption of ecosystems
- Food and water security
- Health impacts
- Economic consequences
- Displacement and migration
- National security risks

Positive effects

- Agriculture in certain areas
- New shipping routes
- Energy production
- Short-term tourism

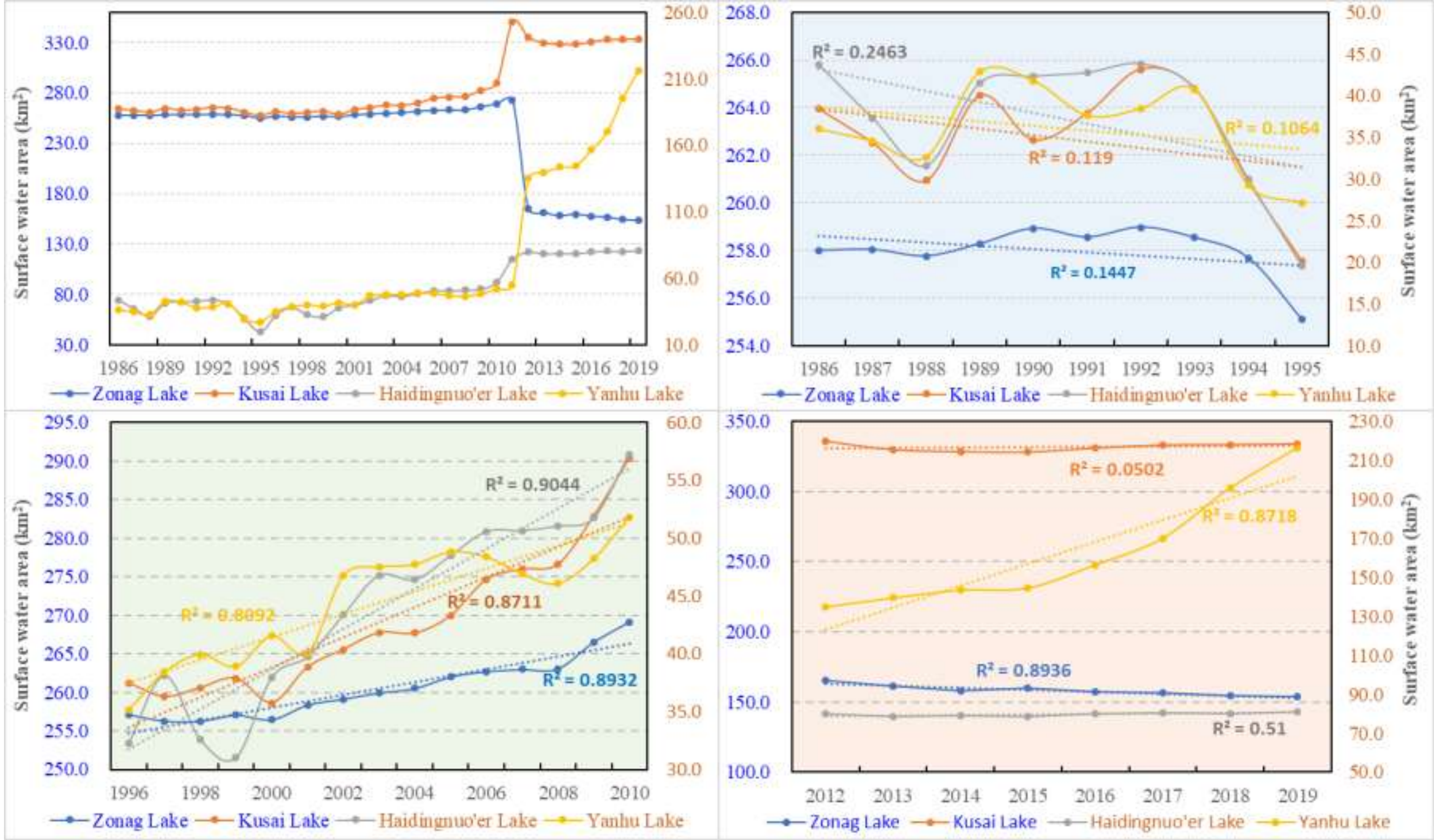
Case I: Negative effects



Drainage basin reorganization and endorheic-exorheic transition triggered by climate change and human intervention

Lu et al., 2021, Global and Planetary Change

Surface water changes in Zonag Lake and Yanhu Lake drainage basins



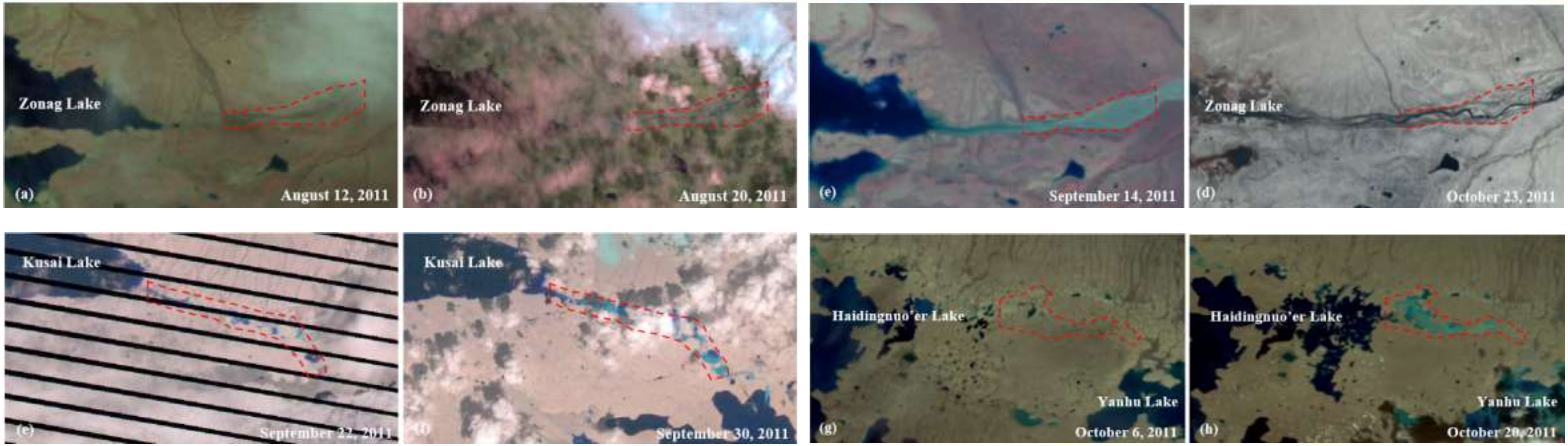
Surface water changes for Zonag, Kusai, Haidingnuo'er, and Yanhu Lakes

The total lake area in this region was relatively stable between 1976 and 1995.

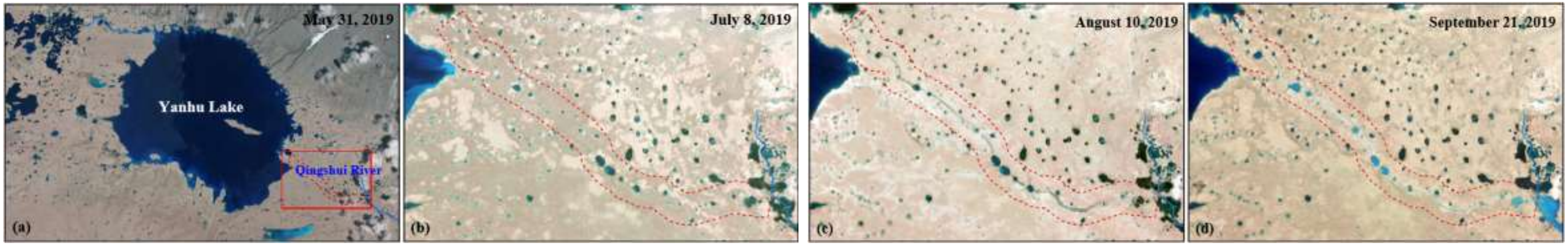
During the period from 1996 to 2010, the area of surface water increased significantly.

From 2011 to 2019, the drainage system completely reorganized.

Drainage basin reorganization and endorheic-exorheic transition



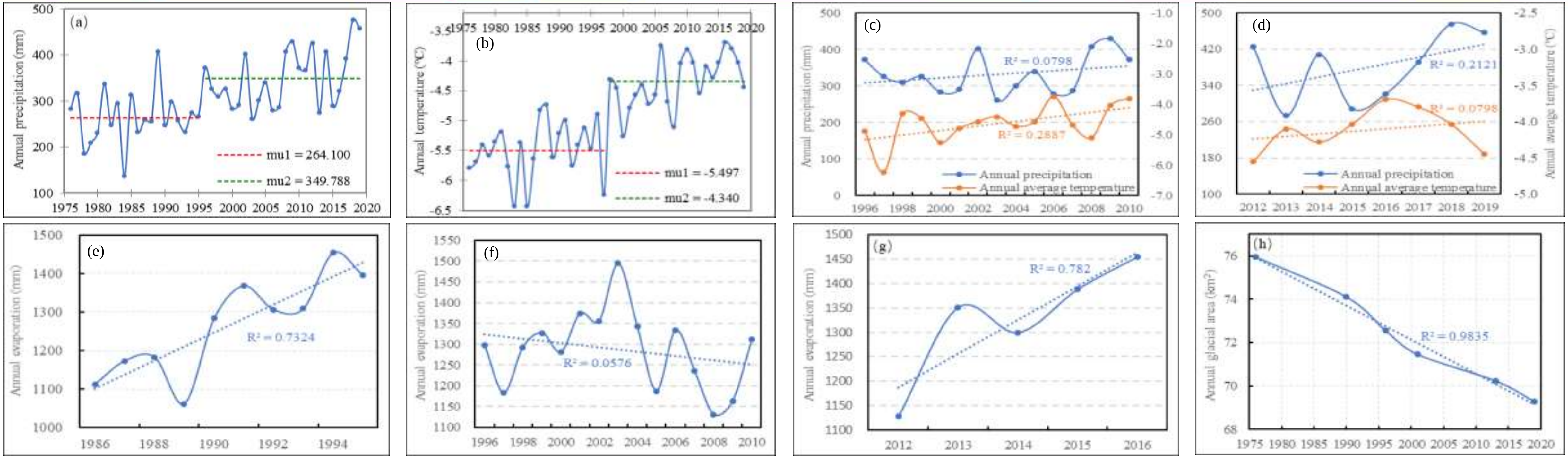
Critical time nodes of the reorganization of the Zonag Lake and Yanhu Lake drainage basins



Location of the Yanhu artificial drainage channel and construction milestones in 2019

Processes triggering the hydrological reconfiguration

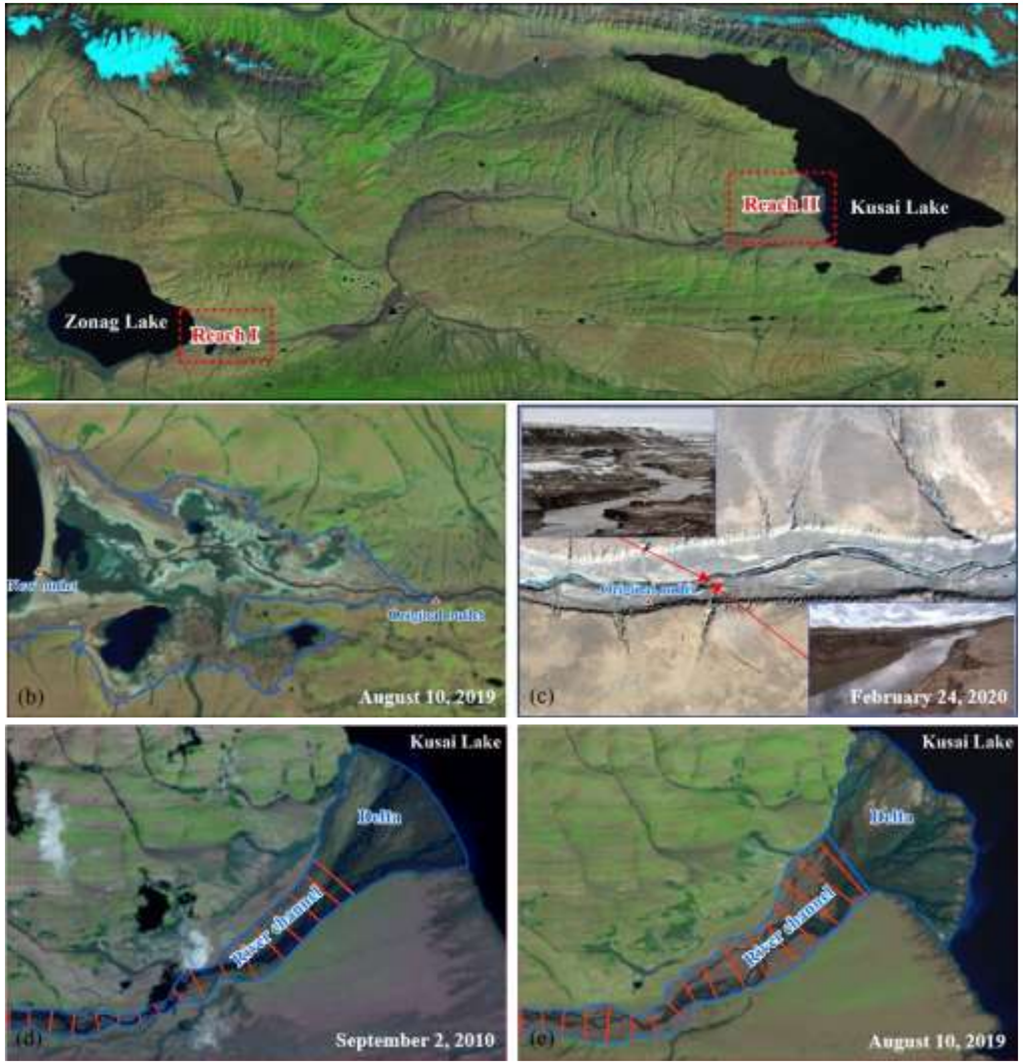
CBAS



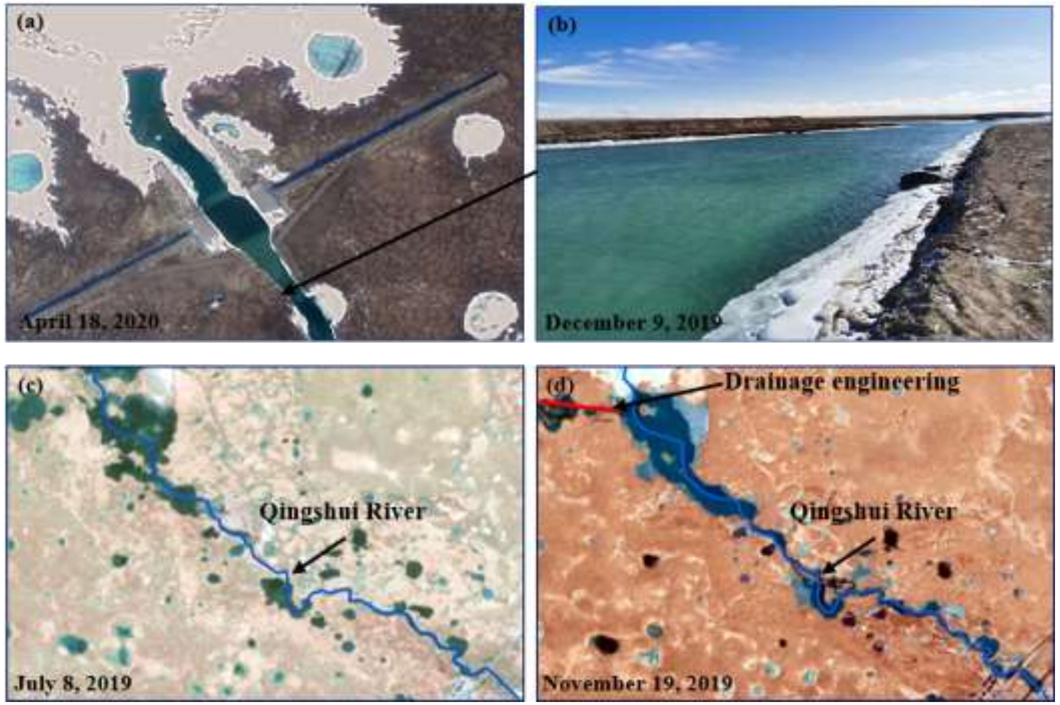
Annual precipitation (a, c, d), average temperature (b, c, d), evaporation (e, f, g), and glacial area (h) from 1976 to 2019

- **Between 1986 and 1995, the surface water system was in relative equilibrium.**
- **From 1996 to 2010, the increase in precipitation undermined the hydrological balance, so that the surface water system became unstable.**
- **In 2011, the extreme regional precipitation directly caused the overflow of Zonag Lake and the reconfiguration of the whole watershed.**
- **Between 2012 and 2019, the higher precipitation dominated the change in total water volume in the basin.**

Impacts of the reorganization to water systems of the basin



Geomorphological changes of Zonag Lake outlet channel and Kusai Lake inlet channel and delta from 2010 to 2019

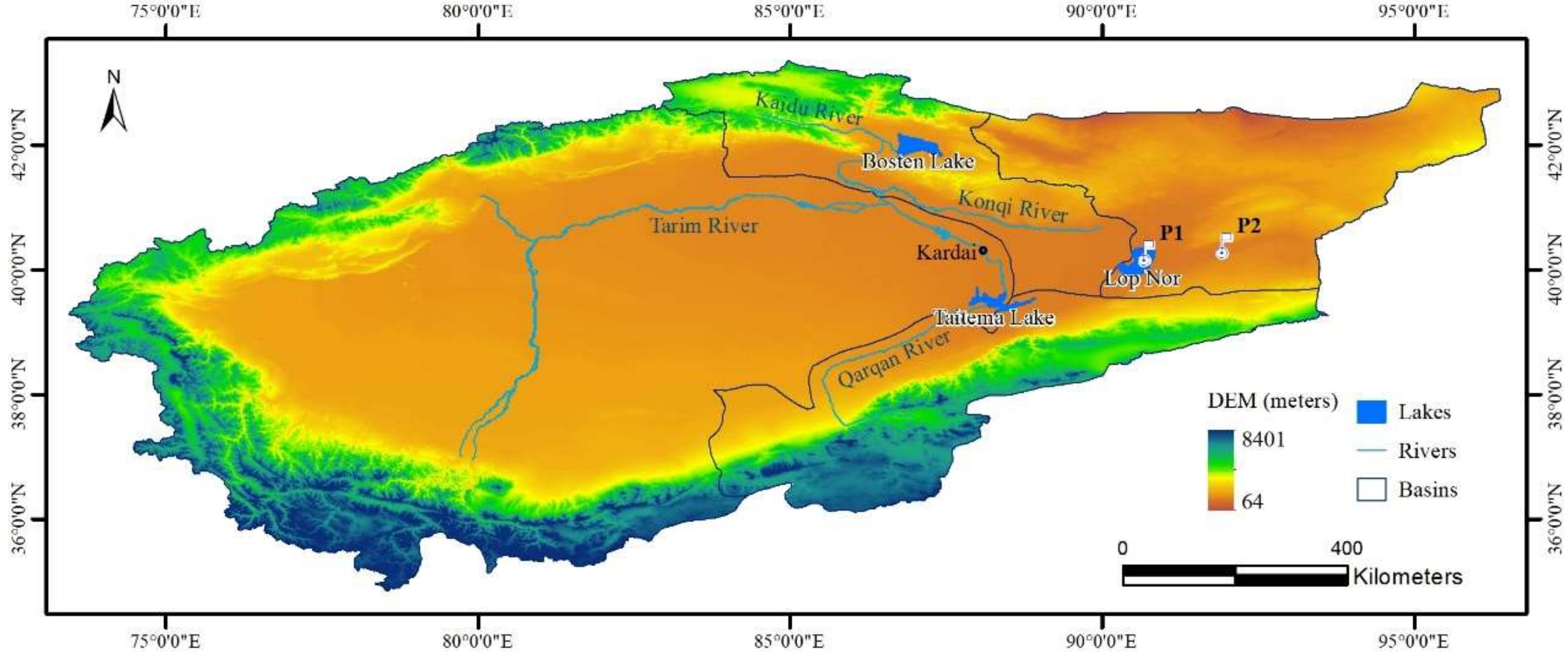


Impact on the Qingshui River volume and channel morphology

Degraded lakebed and surrounding area in Zonag Lake

Case II: Positive effects

Active water management brings possibility restoration to degraded lakes in dryland regions: A case study of Lop Nur, China



Lu et al., 2022, Scientific Reports

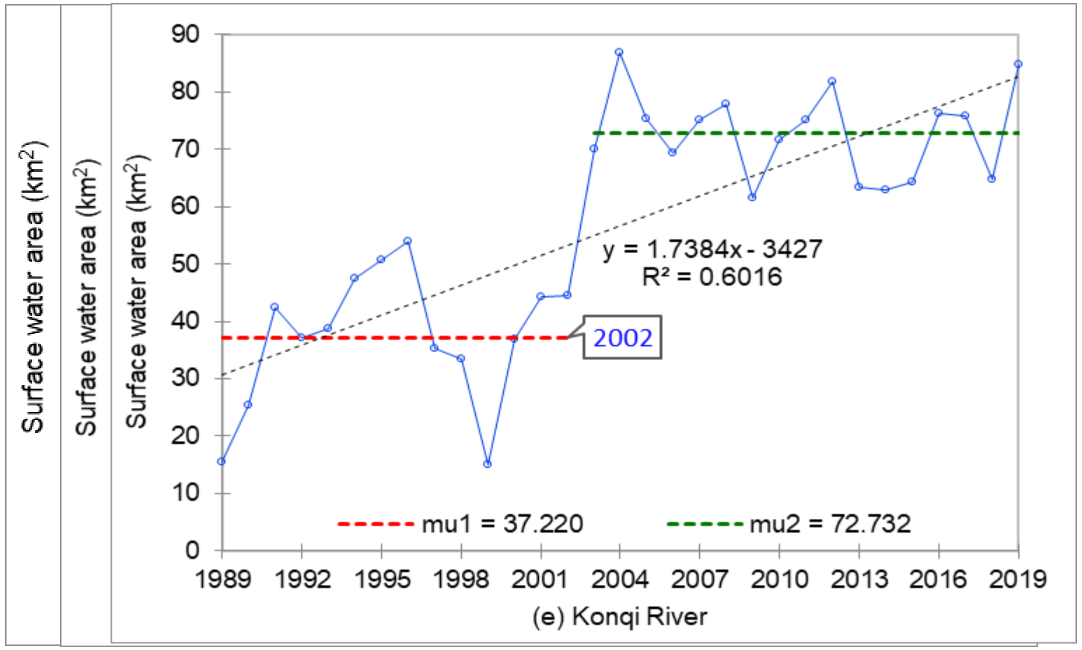
Surface water changes in the Tarim River Basin

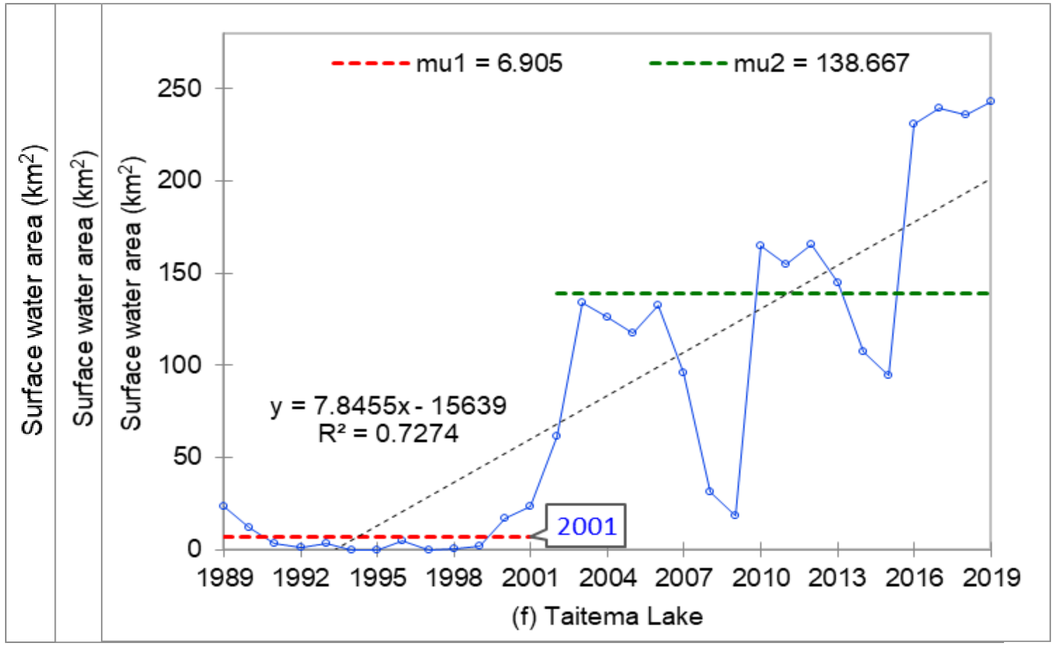
Mann-Kendall (M-K) trend test results of surface water area

	Kendall's tau	p-value (two-tailed)	alpha
Tarim River	0.686	< 0.0001	0.05
Tarim Basin	0.751	< 0.0001	0.05
Kaidu-Konqi River	0.419	0.001	0.05
Qarqan River	0.806	< 0.0001	0.05
Konqi River	0.548	< 0.0001	0.05
Taitema Lake	0.617	< 0.0001	0.05

Pettitt's test results of surface water area

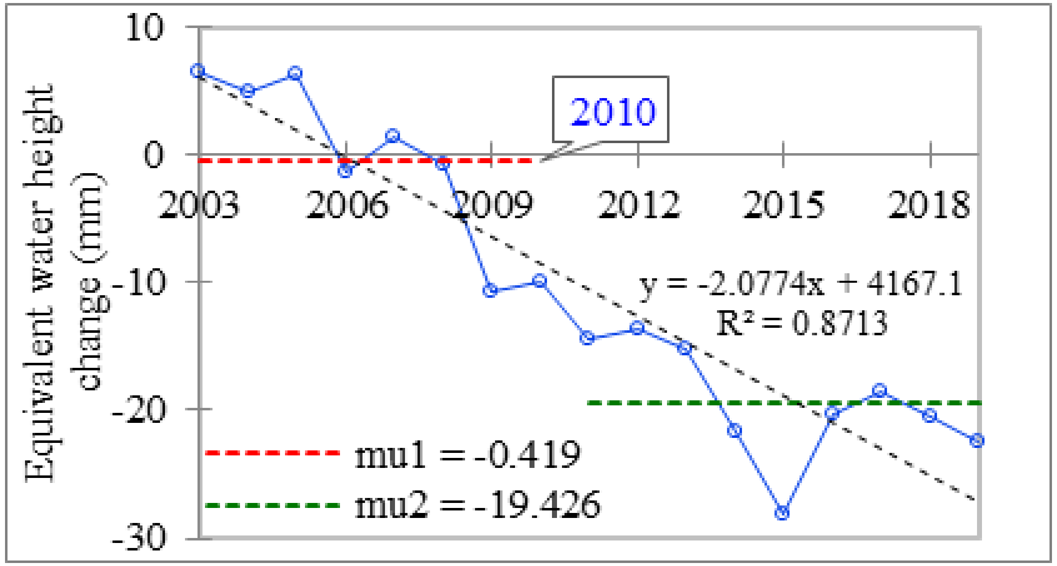
	Change year	p-value (two-tailed)	alpha
Tarim Basin	2004	< 0.0001	0.05
Tarim River	2004	0.000	0.05
Kaidu-Konqi River	1999	< 0.0001	0.05
Qarqan River	2002	< 0.0001	0.05
Konqi River	2002	< 0.0001	0.05
Taitema Lake	2001	< 0.0001	0.05

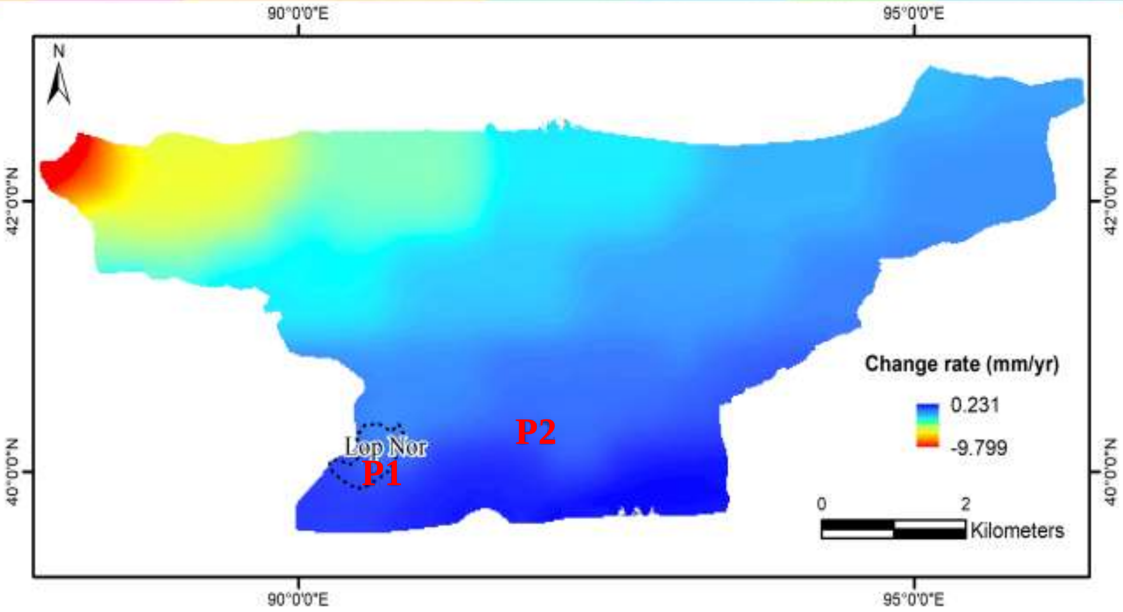




Variation trend and tipping point change of surface water area in the Tarim River Basin and its tributaries from 1989 to 2019

Groundwater changes in the Lop Nur region





Variation trend and tipping point change (a) and spatial change rate (b) of equivalent water height of groundwater in the Lop Nur region from 2003 to 2019

Burial depth of groundwater in central (Fig.1, P1) and east (Fig.1, P2) of Lop Nor region (The photo was taken by the corresponding author on July 27 & 28, 2021).

Impacts of climate change on surface water

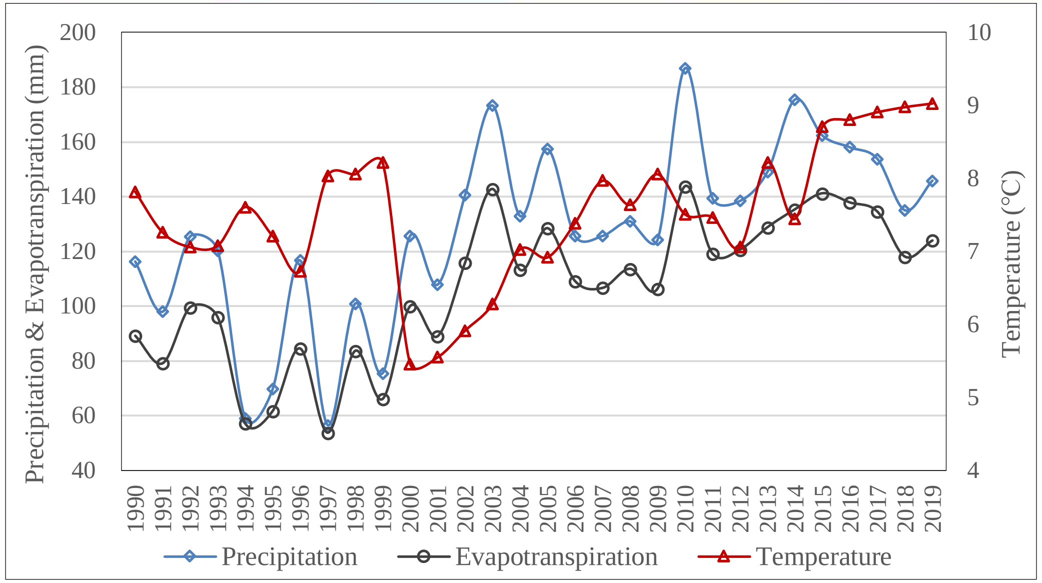
Pettitt's test of the annual precipitation, evapotranspiration, and average temperature

Pettitt's test	Precipitation	Evapotranspiration	Temperature
Change year	2001	2001	2006
p-value (two-tailed)	< 0.0001	< 0.0001	0.005
alpha	0.05	0.05	0.05

Pearson's correlation test results between meteorological elements in the Tarim River Basin and surface water area of each tributary river

Meteorological elements in the basin	Correlation analysis parameters	Surface water area of each river		
		Qarqan River	Kaidu-Konqi River	Tarim River
Annual average temperature	Correlation coefficient	.509**	-.054	.491**
	Significance (bilateral)	.003	.772	.005
	Number of samples	31	31	31
Annual precipitation	Correlation coefficient	.613**	.417*	.490**
	Significance (bilateral)	.000	.019	.005
	Number of samples	31	31	31
Annual evapotranspiration	Correlation coefficient	.696**	.474**	.577**
	Significance (bilateral)	.000	.007	.001
	Number of samples	31	31	31

*Significance level with alpha=0.05, **Significance level with alpha=0.01.

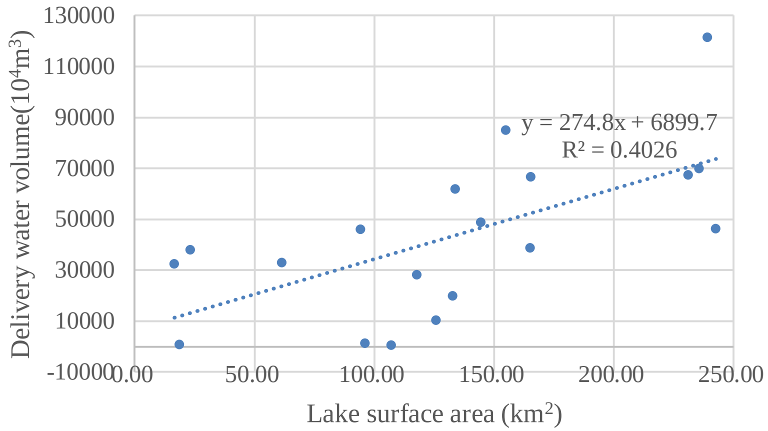


Change trends of annual precipitation, evapotranspiration, and average temperature from 1989 to 2019

Contribution of precipitation (including rainfall and snowmelt) and glacier melt to the surface runoff was 71.8% and 28.2.
The future precipitation and melting water volume of glaciers of the Tarim River basin will increase significantly until about 2050.

Impacts of human activities on surface water

Number of ecological water delivery	Date	Volume(10^4m^3)	Water head reached area
1st	2000-05~2000-07	9923	Kardai
2nd	2000-11~2001-02	22655	Kardai
Phase 1 of the 3rd	2001-04~2001-07	18433	Taitma Lake
Phase 2 of the 3rd	2001-09~2001-11	19790	Taitma Lake
4th	2002-07~2002-11	33129	Taitma Lake
Phase 1 of the 5th	2003-03~2003-07	34028	Taitma Lake
Phase 2 of the 5th	2003-08~2003-11	27997	Taitma Lake
6th	2004-04~2004-06	10527	Taitma Lake
Phase 1 of the 7th	2005-04~2005-06	5236	Taitma Lake
Phase 2 of the 7th	2005-08~2005-11	22997	Taitma Lake
8th	2006-09~2006-11	20098	Taitma Lake
9th	2007-09~2007-11	1411	Kardai
10th	2009-11~2009-12	1027	Kardai
11th	2010-06~2010-11	38952	Taitma Lake
12th	2011-04~2011-11	85211	Taitma Lake
13th	2012-04~2012-11	66716	Taitma Lake
14th	2013-04~2013-10	48800	Taitma Lake
15th	2014-06	727	Taitma Lake
16th	2015-08~2015-11	46128	Taitma Lake
17th	2016-08~2016-10	67611	Taitma Lake
18th	2017-04~2018-01	121461	Taitma Lake
19th	2018-04~2018-11	70006	Taitma Lake
20th	2019-08~2019-12	46482	Taitma Lake
21th	2020-09~2020-11	27934	Taitma Lake
Total		847279	



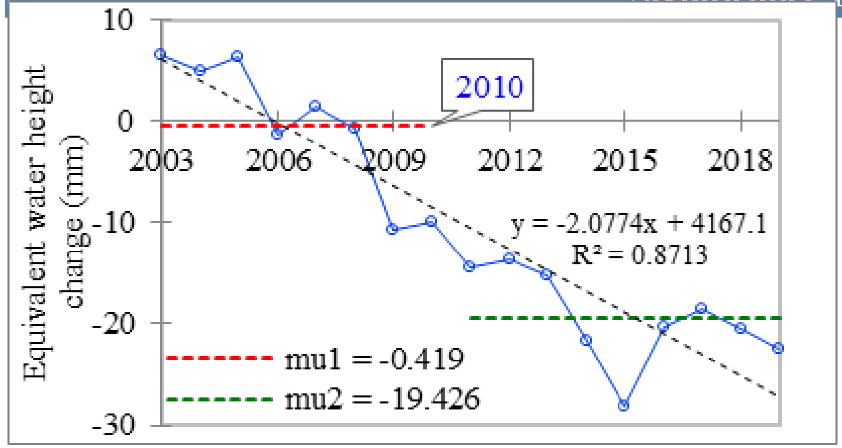
Linear correlation between surface water area of Taitema Lake and the total annual volume of ecological water delivery of Tarim River.

Since 2015, in order to save the Konqi River, water has been diverted from the Tarim River and Bosten Lake from 2016 to 2020, with cumulative water delivery of 1.57 billion m^3, which has rejuvenated hundreds of kilometers of rivers that have been cut off for many years.

Influence of surface water change on groundwater level in Lop Nur

Pearson's correlation between equivalent water height in the Lop Nur region and the water surface area of each tributary river during two periods (2003~2014, 2015~2019)

2003~2014				
		Tarim River	Qarqan River	Kaidu-Konqi River
Equivalent water height in Lop Nur region	Correlation coefficient	-.582*	-.660*	.863**
	Significance (bilateral)	.047	.020	.000
	N	12	12	12
2015~2019				
		Tarim River	Qarqan River	Kaidu-Konqi River
Equivalent water height in Lop Nur region	Correlation coefficient	.978**	.787	.729
	Significance (bilateral)	.004	.114	.163
	N	5	5	5
*Significance level with alpha=0.05, **Significance level with alpha=0.01.				



Before 2015, the annual recharge of groundwater by the rivers upstream of Lop Nur is less than the total evapotranspiration, resulting in the gradual decrease in groundwater. After 2015, the difference between groundwater recharge and regional evapotranspiration gradually decreased, followed by the declining groundwater decrease. Although the groundwater in the area is still decreasing, it has been in a positive recovery state.

Implications from the two case studies

- Climate change may have more positive effects than negative effects on local areas. We should make good use of the opportunities of the climate cycle to repair and restore the ecological environment.

- When responding to and addressing the responsible effects of climate change, engineering measures need to be used carefully, taking into account both short-term impacts and long-term trends.

Adapted from the Fourth National Climate Assessment (2018)

Thanks to your attention!

Dr. Shanlong Lu, Professor, International Coordinator of SDG 6

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