蘭州大學 LANZHOU UNIVERSITY

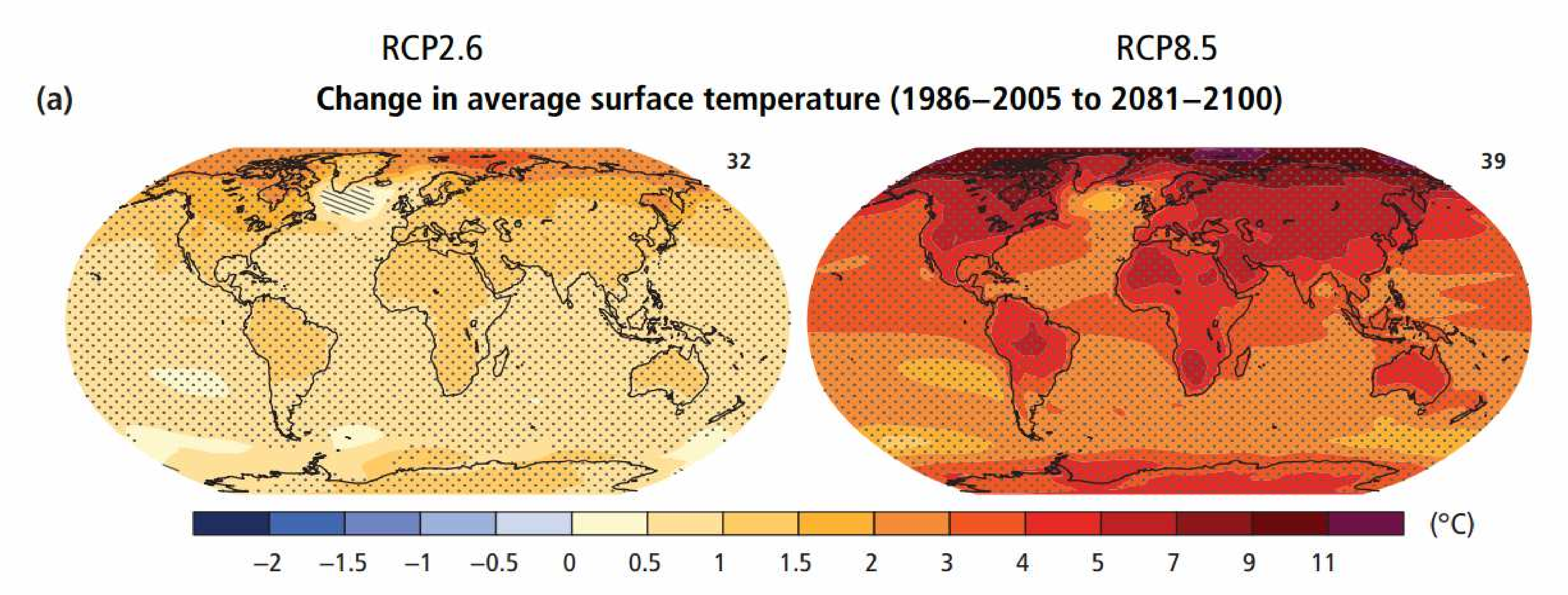
Effect of a thermokarst lake on the water storage capacity in permafrost regions of the Qinghai-Tibet Plateau, China

Yibo Wang[1], Zeyong Gao[2], Zhe Sun[2] and Yan Sun[1]

1. *College of Earth and Environment Sciences, Lanzhou University,*
2. *State Key Laboratory of Frozen Soil Engineering, Northwest Institute of Eco-Environment and Resources, CAS*

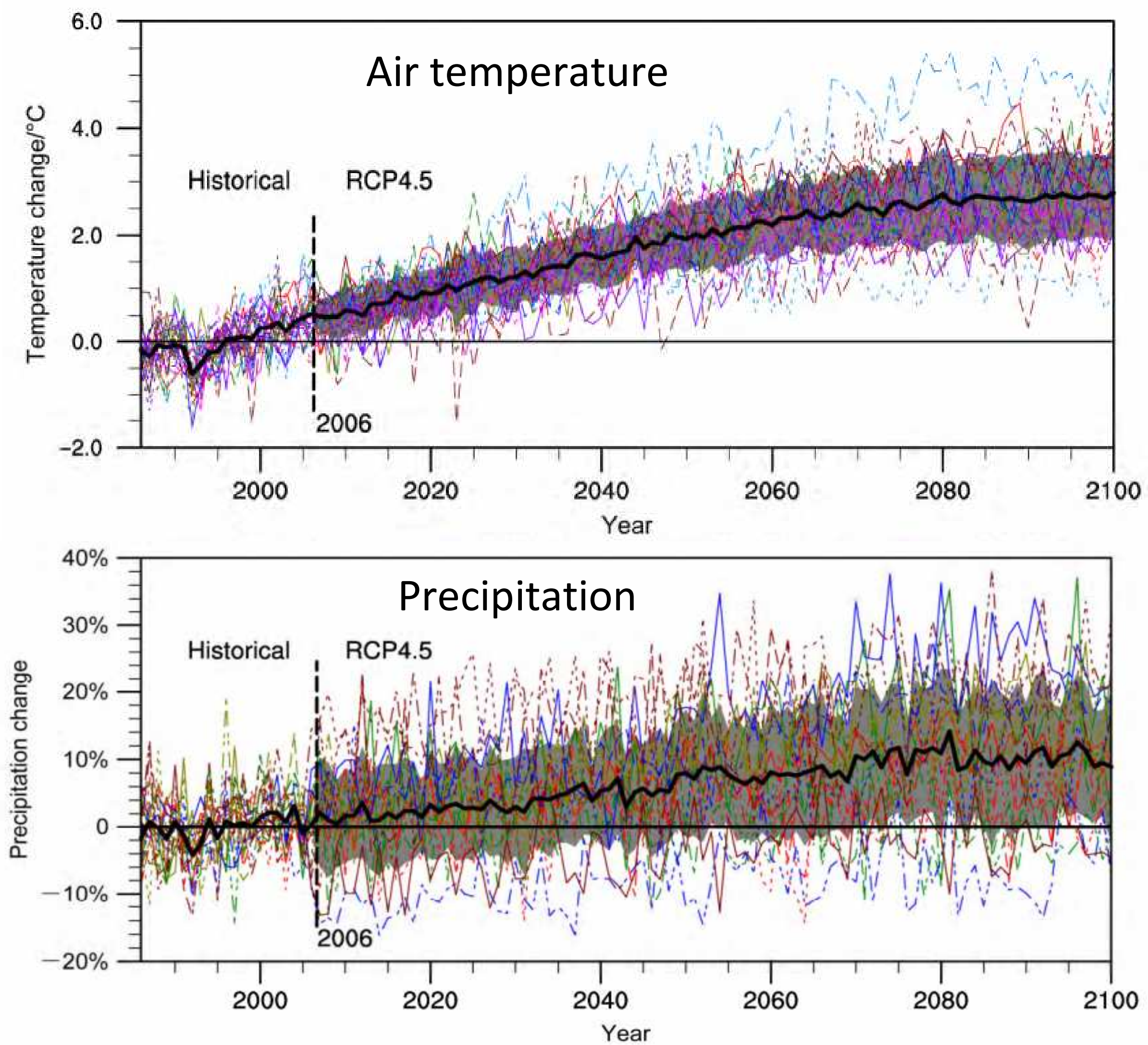
Background

Global climate warming



The increase of global mean surface temperature by the end of the 21st century (2081-2100) relative to 1986-2005 is likely to be 0.3 ℃ to 1.7 ℃ under RCP2.6, 1.1℃ to 2.6 ℃ under RCP4.5, 1.4 ℃ to 3.1 ℃ under RCP6.0 and 2.6 ℃ to 4.8 ℃ under RCP8.5. The Arctic region will continue to warm more rapidly than the global mean (IPCC, 2014)

Background

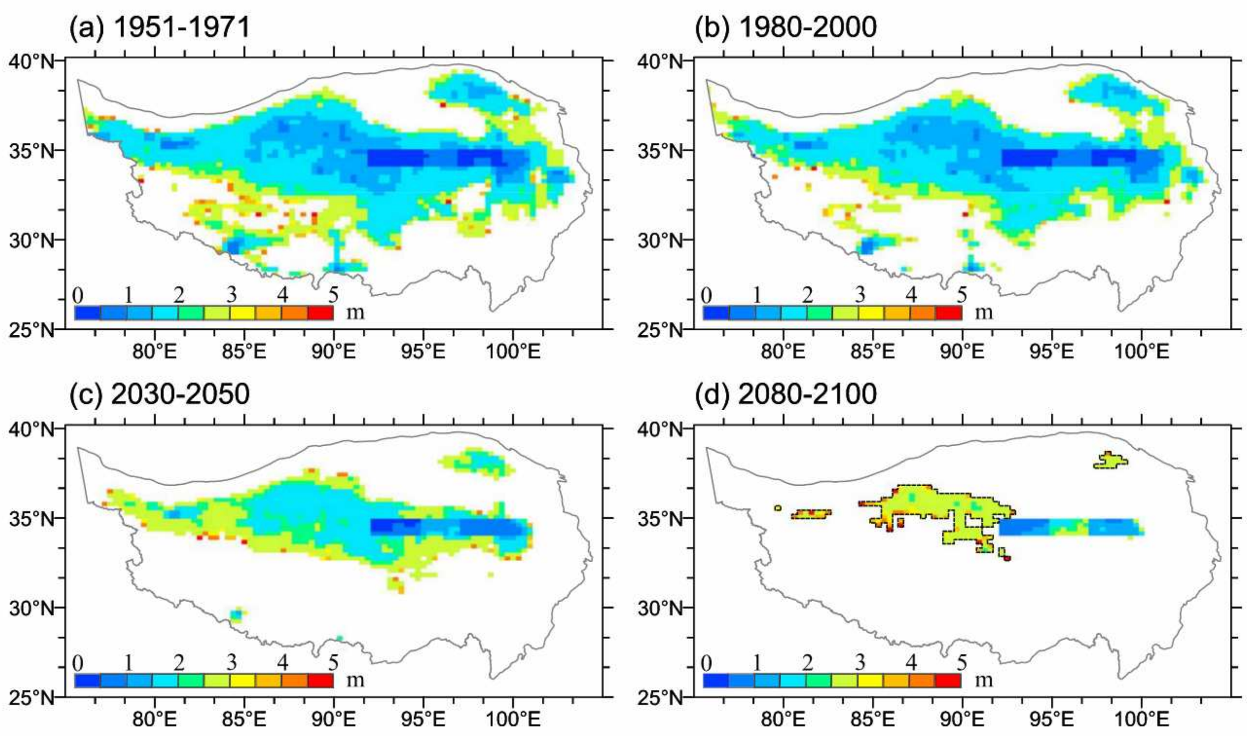


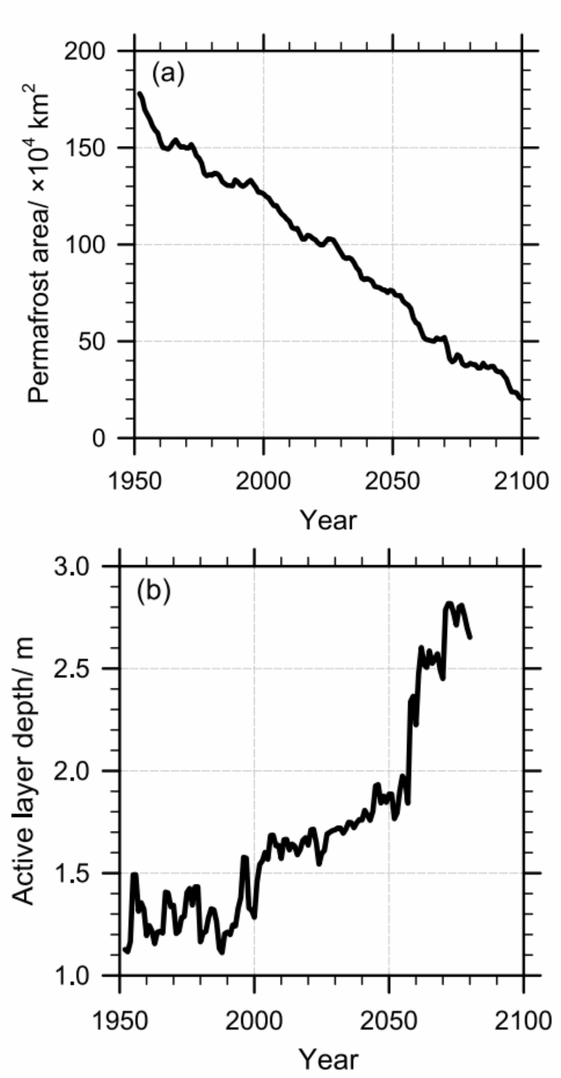
Climate warming and wetting in the Tibetan Plateau:

Regional averaged annual air temperature and precipitation over the Tibetan Plateau during 1986-2100 relative to 1986-2005 as derived from 30 models

Hu et al., 2015

Background

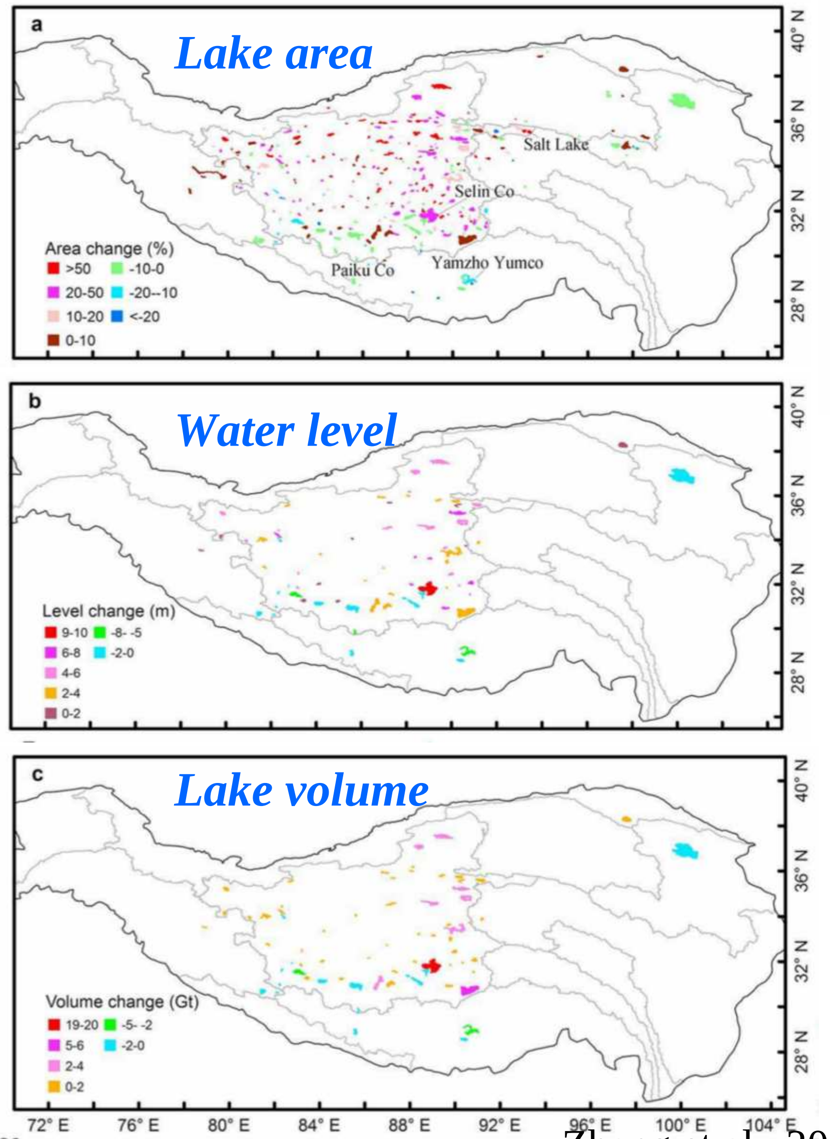




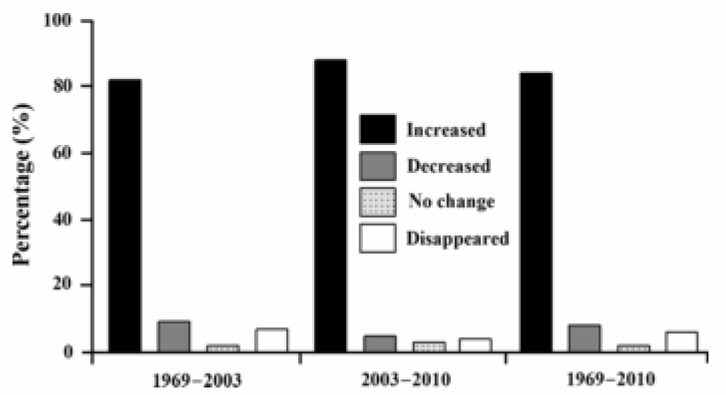
The areas of 126.7×10^4 km^2 is occupied by permafrost, and the near-surface permafrost area is projected to decrease by approximately 39% by the mid-21st century and by approximately 81% by the end of the 21st century (0.58°C per decade over the QTP for the 1980 ~2100 under the A1B greenhouse gas emissions scenario)

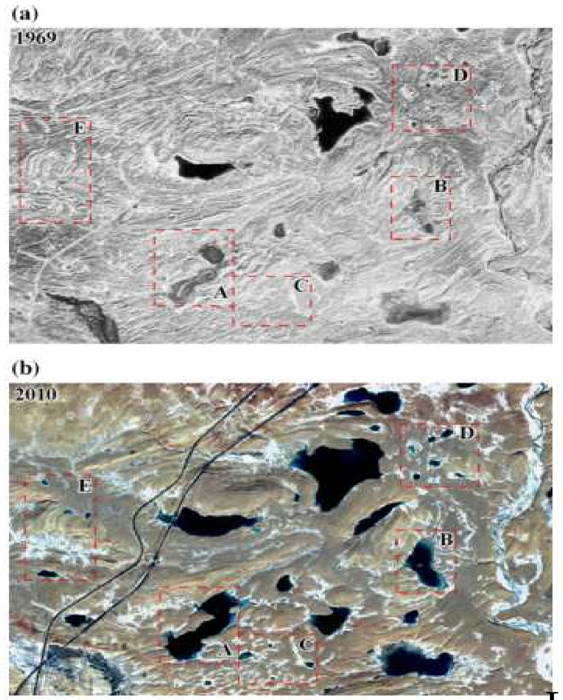
(Guo et al., 2012. JGR)

Background



Zhang et al., 2017

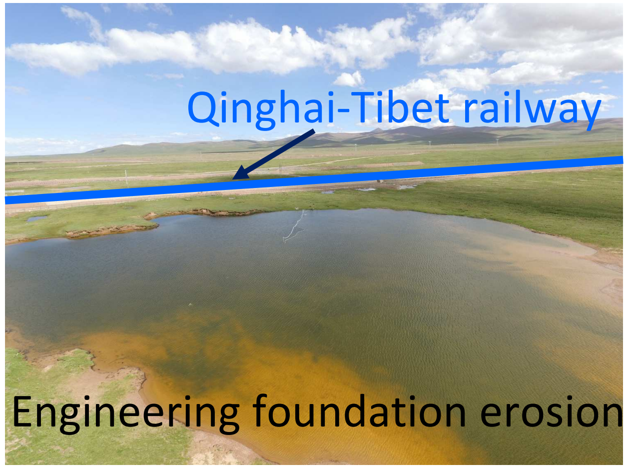


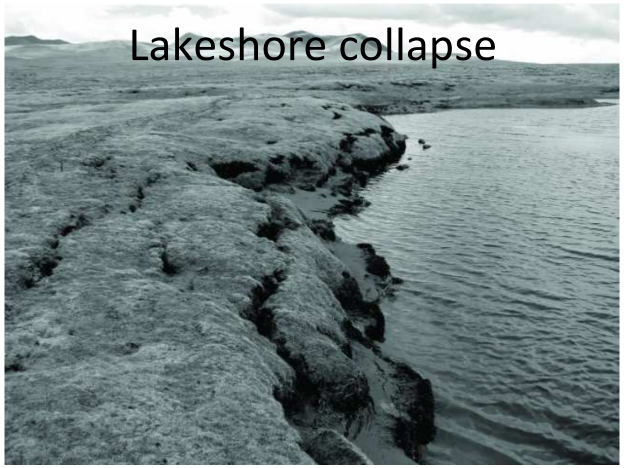


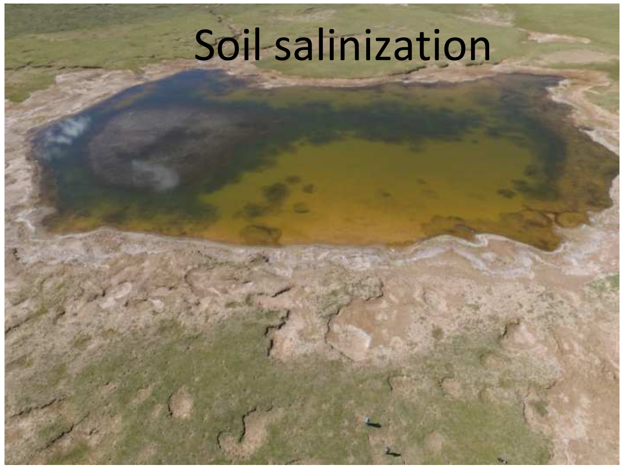
Luo et al., 2015

Background

The environmental and engineering effects of thermokarst lake expanding







Objective

Presently, research aimed at the above issues is mainly focused on:

(1)the development and temporal evolution of thermokarst lakes;

(2)studying the thermal effects on adjacent permafrost;

(3)estimation of carbon release;

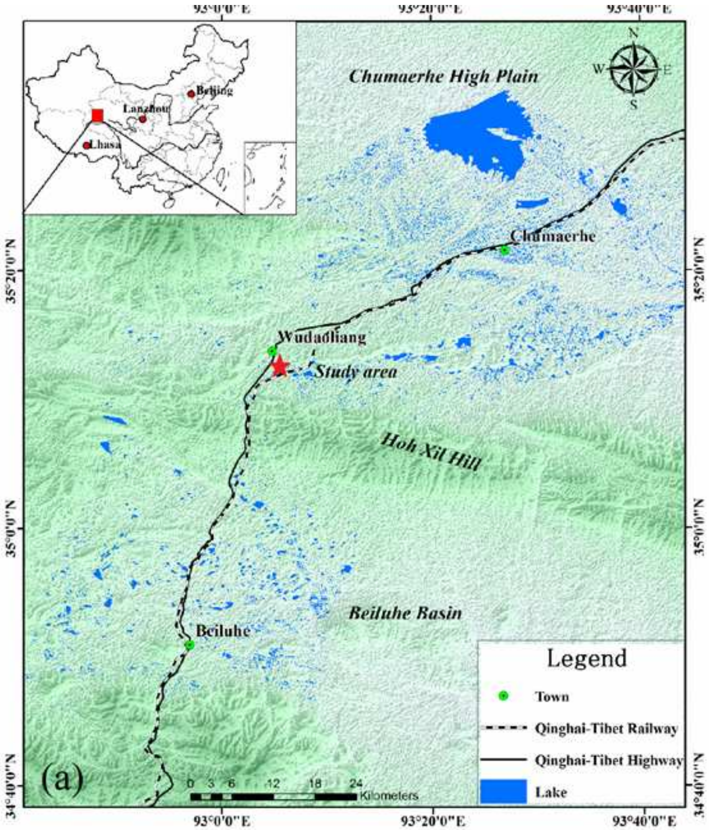
(4)investigation of the involved engineering activities, ecological processes, and environmental changes

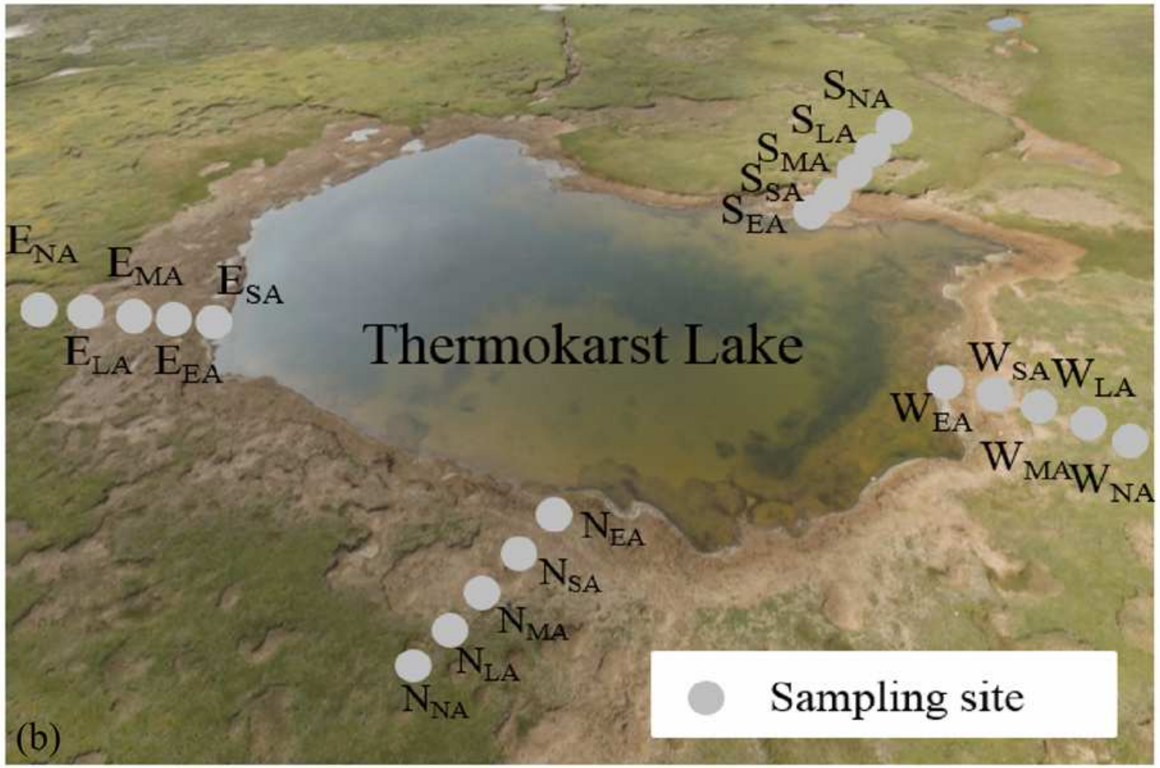
and yet, very few studies have investigated the variations in soil hydrological properties of such affected areas.

Objective

Clarifying the variety and the range of soil hydrological processes in thermokarst affected areas.

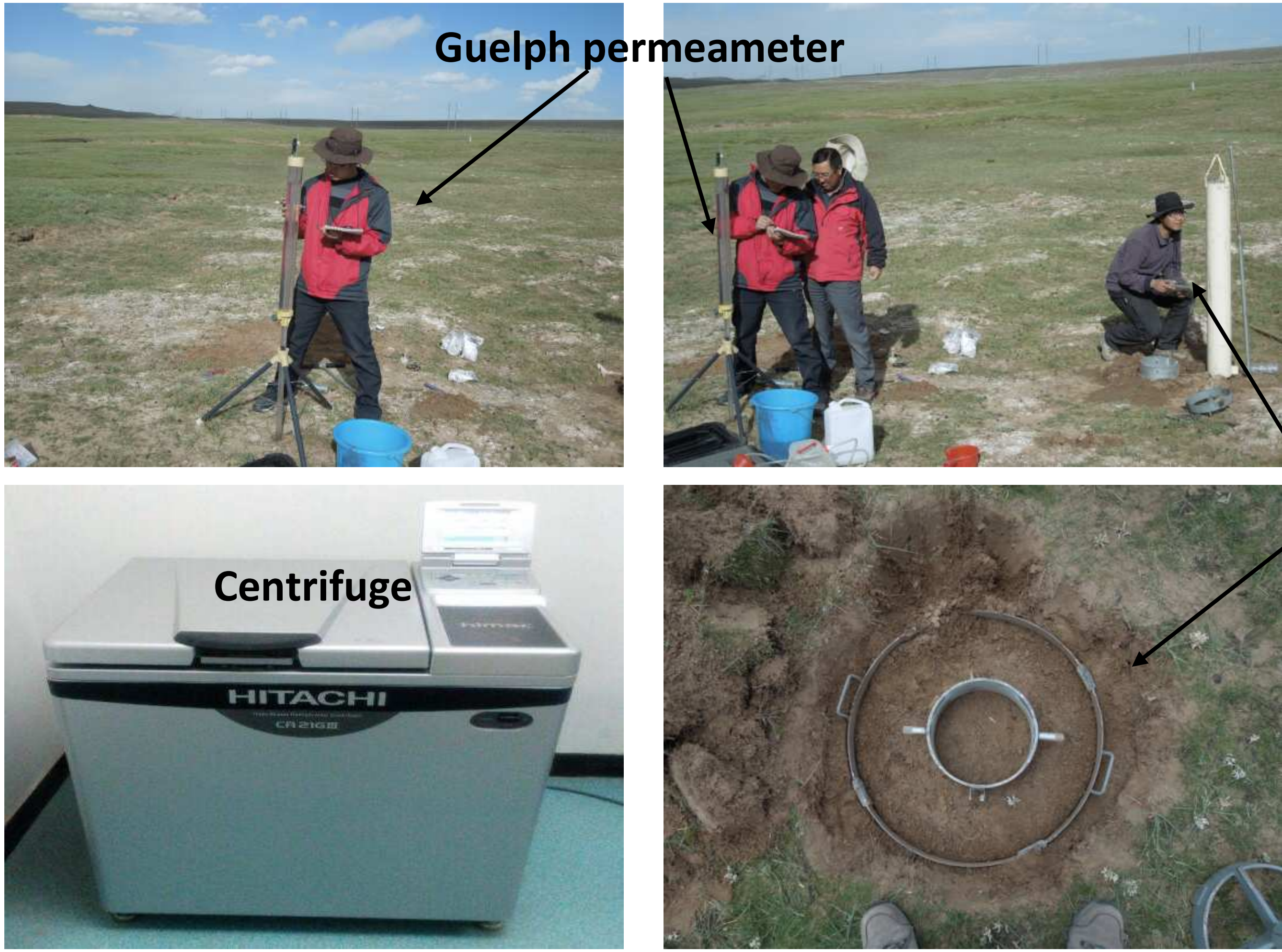
Sampling method





S_L/%	Distance from the lake/m	Impact degree	Best community standards
0±0	3.8±0.4	Extremely affected	$S_L < 20$
24±5.3	7.4±0.9	Severely affected	$30 > S_L \geq 20$
39±6.9	13.1±1.5	Medium-affected	$50 > S_L \geq 30$
68±8.6	20.9±1.7	Lightly affected	$80 > S_L \geq 50$
92±3.1	31.4±1.7	Non-affected	$S_L \geq 80$

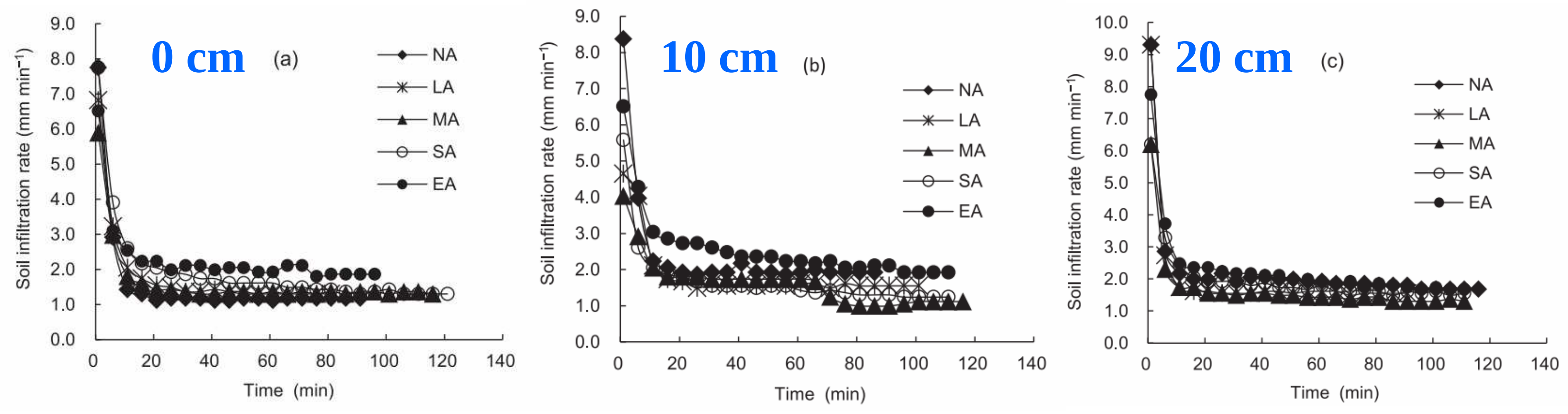
Sampling method



Double-ring infiltrometers

Results

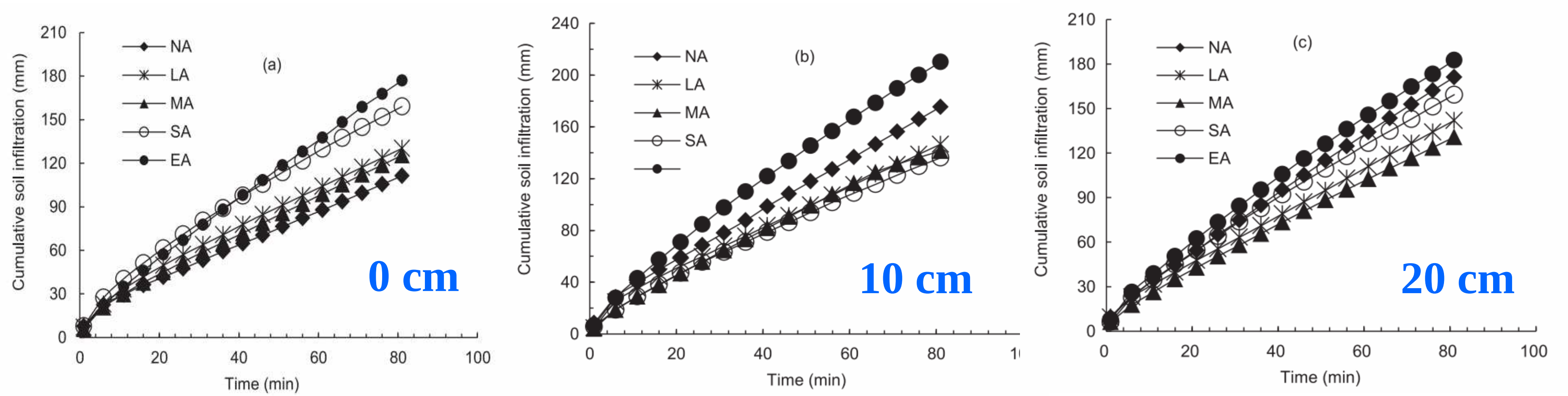
Soil infiltration processes



Initial soil infiltration rates on the surface showed less variability than at depths of 10 and 20 cm in different affected areas, but stable soil infiltration rates on the surface and at 10 cm depth were more volatile than at the 20 cm depth, whereas soil infiltration processes reached the stable state more easily at a depth of 20 cm compared to all other depths.

Results

Soil infiltration processes



With the degree of impact intensifying, soil cumulative infiltration underwent an increasing trend on the soil surface; the value of soil cumulative infiltration on EA increased by 59.1% compared with NA, whereas that of MA was slightly lower than LA. At a soil depth of 10 cm, the changing trends of soil cumulative infiltration decreased at first and then increased, the minimum value being 136.09 mm (SA) and the maximum 210.18 mm (EA), an increase of19.8% compared to NA. At the 20 cm soil depth, the changing trend was similar to that at 10 cm, also reaching the minimum value at SA (130.82 mm); no differences in soil cumulative infiltration were found between NA and EA.

Results

Characteristics of soil physical and chemical properties

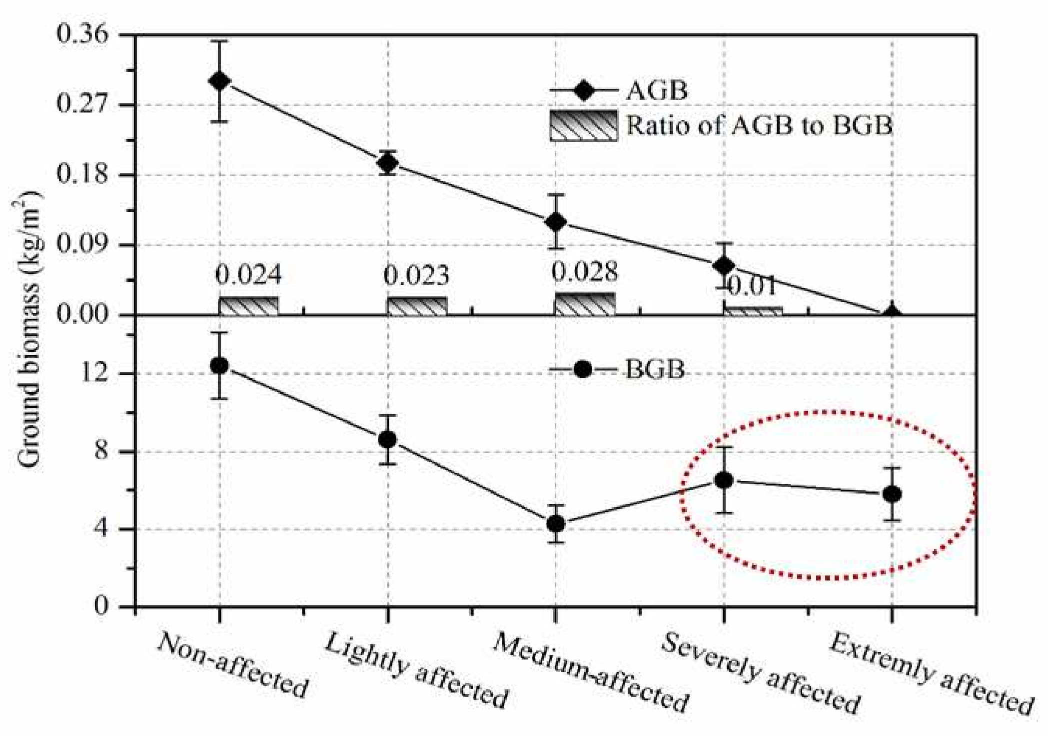
Impact degree	Clay /%	Silt /%	Sandy /%	TP /%	SOM ($g\ kg^{-1}$)	AN ($mg\ kg^{-1}$)	AK ($mg\ kg^{-1}$)	pH
non-affected	4.32±0.33	15.95±1.18	79.74±1.51	50.78±1.79	6.31±0.45	47.54±1.78	84.96±1.79	8.49±0.13
Lightly affected	3.28±0.40	15.16±0.71	81.56±0.47	50.45±2.05	6.25±0.53	44.52±1.55	78.85±2.59	8.46±0.08
Medium-affected	2.39±0.28	15.73±0.76	81.88±0.68	47.71±1.11	6.01±0.56	41.37±1.17	73.12±3.18	8.79±0.07
Severely affected	2.31±0.36	13.64±0.64	84.05±0.99	45.12±0.92	5.26±0.31	30.54±2.77	67.14±2.35	8.73±0.08
Extremely affected	3.34±0.44	15.33±0.63	81.33±0.79	42.36±1.60	7.31±0.18	45.98±1.45	87.36±1.65	8.76±0.06

Values are mean ± standard errors (n=12).

TP: total porosity; SOM: soil organic matter; AN: available nitrogen; AK: available potassium.

Results

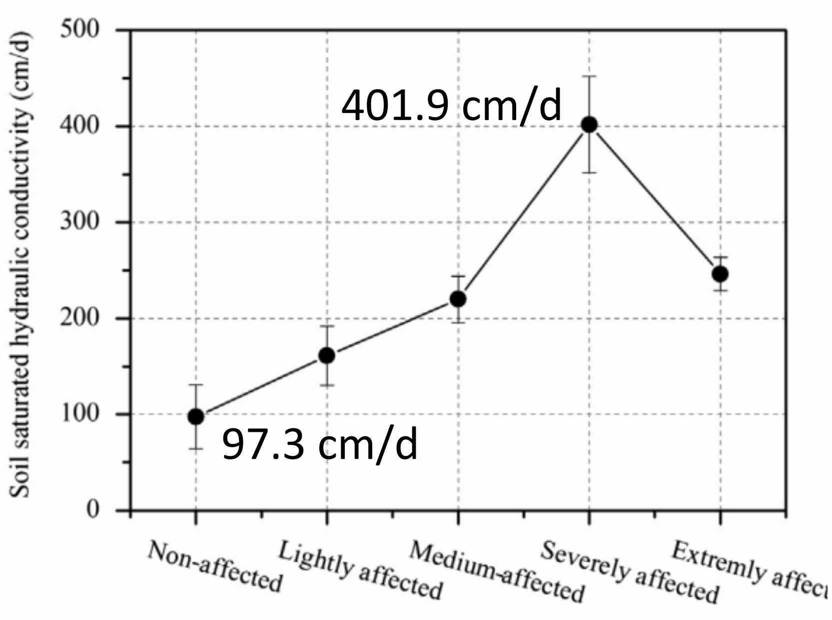
AGB and BGB



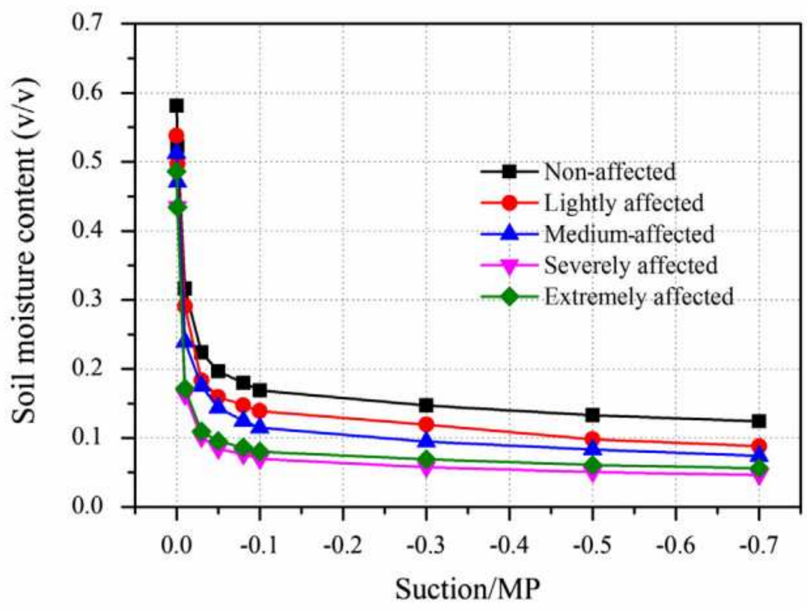
The distribution of above-ground biomass (AGB) and below-ground biomass (BGB) in alpine meadows located in different lake affected areas.

Results

Soil saturated hydraulic conductivity



Soil water retention curves



Compared with the non-affected areas,the Ks values were 1.7- to 4.1-fold higher in the thermokarst lake-affected areas, which indicates that the formation of the thermokarst lake enhanced the soil infiltration capacity;

The soil moisture content decreased from the non-affected areas to extremely affected areas, and then increased slightly in the extremely affected areas, where the soil matric potential ranged from 0 to−0.7 Mpa.

Results

Correlations between soil hydrological properties and environmental factors

The principal component analysis showed that the plant biomass was vital to changes in soil hydrological properties

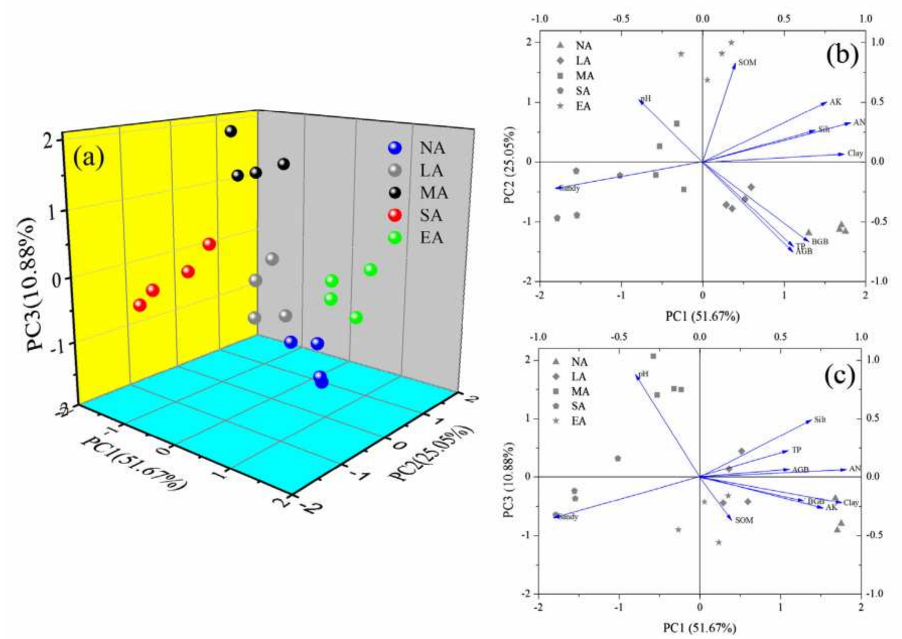


Table 3 Correlation analysis of soil infiltration characteristics and soil physical properties[a)]

Correlation coefficient	Initial *f*	Stable *f*	Cumulative *f*	Soil moisture	Soil bulk density	Clay	Silt	Sand
Initial *f*	1							
Stable *f*	0.425	1						
Cumulative *f*	0.219	0.872**	1					
Soil moisture	0.415	−0.004	−0.04	1				
Soil bulk density	−0.135	0.473*	0.607*	−0.288	1			
Clay	0.160	−0.494*	−0.657**	0.229	0.754**	1		
Silt	0.099	−0.502*	−0.609**	0.195	−0.718**	0.899**	1	
Sand	−0.128	0.498*	0.696**	−0.177	0.754**	−0.947**	−0.900**	1

a) ** A statistical significance at $P \leqslant 0.01$; * a statistical significance at $P \leqslant 0.05$.

Conclusions

1. The formation of a thermokarst lake can lead to the degradation of alpine meadows, accompanied by a change in the soil physiochemical and hydrological properties.
2. The formation of a thermokarst lake will facilitate precipitation infiltrating to deeper layer.
3. The formation of the thermokarst lake enhanced the soil saturated hydraulic conductivity by 1.7- to 4.1-fold, and the greatest value was documented in the severely affected areas.
4. The soil water holding capacity gradually decreased from the non-affected areas to the severely affected areas, but increased slightly in the extremely affected areas.
5. The results of principal component analysis showed that the plant biomass was vital to the changes in soil hydrological properties. Thus, the vegetation might be serving as a link between the thermokarst lake and soil hydrological properties.


Thanks for your attention!