Supporting information

Appendix A1: Climate extreme indices calculation

(1) Maximum length of wet spell (CWD)

Maximum number of consecutive days with RR ≥ 1 mm. Let RR_{ij} be the daily precipitation amount on day i in period j. Count the largest number of consecutive days where: $RR_{ij} \geq 1$ mm.

(2) Maximum length of dry spell (CDD)

Maximum number of consecutive days with RR < 1 mm. Let RR_{ij} be the daily precipitation amount on day i in period j. Count the largest number of consecutive days where: $RR_{ij} < 1$ mm.

(3) Simple pricipitation intensity index (SDII)

Let RR_{wj} be the daily precipitation amount on wet days, w (RR ≥ 1 mm) in period j. If W represents number of wet days in j, then $SDII_j = \frac{\sum_{W=1}^{W} RR_{wj}}{W}$

(4) Cold speel duration index (CSDI)

Annual count of days with at least 6 consecutive days when TN < 10th percentile. Let TN_{ij} be the daily maximum temperature on day i in period j and let $TN_{in}10$ be the calendar day 10th percentile centred on a 5-day window for the base period. Then the number of days per period is summed where, in intervals of at least 6 consecutive days: $TN_{ij} < TN_{in}10$.

(5) Warm speel duration index (WSDI)

Annual count of days with at least 6 consecutive days when TX > 90th percentile. Let TX_{ij} be the daily maximum temperature on day i in period j and let $TX_{in}90$ be the calendar day 90th percentile centred on a 5-day window for the base period. Then the number of days per period is summed where, in intervals of at least 6 consecutive days: $TX_{ij} > TX_{in}90$.

(6) Growing season length (GSL)

Annual (1st Jan to 31st Dec in Northern Hemisphere (NH), 1st July to 30th June in Southern Hemisphere (SH)) count between first span of at least 6 days with daily mean temperature TG > 5 ℃ and first span after July 1st (Jan 1st in SH) of 6 days with TG < 5 ℃. Let TG_{ij} be daily mean temperature on day i in year j. Count the number of days between the first occurrence of at least 6 consecutive days with: $TG_{ij} > 5$ °C. and the first occurrence after 1st July (1st Jan. in SH) of at least 6 consecutive days with: $TG_{ij} < 5$ °C.

(7) Number of tropical nights (TR)

Annual count of days when TN (daily minimum temperature) > 20 °C. Let TN_{ij} be daily minimum temperature on day i in year j. Count the number of days where: $TN_{ij} > 20$ °C.

(8) Number of icing days (ID)

Annual count of days when TX (daily maximum temperature) < 0 °C. Let TX_{ij} be daily maximum temperature on day i in year j. Count the number of days where: $TX_{ij} < 0$ °C.

(9) Number of summer days (SU)

Annual count of days when TX (daily maximum temperature) > 25 °C. Let TX_{ij} be daily maximum temperature on day i in year j. Count the number of days where: $TX_{ij} > 25$ °C.

(10) Number of frost days (FD)

Annual count of days when TN (daily minimum temperature) < 0 °C. Let TN_{ij} be daily minimum temperature on day i in year j. Count the number of days where: $TN_{ij} < 0$ °C.

(11) Seasonality index (SI)

Let SI_i be the seasonality index of precipitation/temperature in the i^{th} year; X_{in} be the precipitation/termperature of n^{th} month in the i^{th} year; Ri be the precipitation/temperature of the i^{th} year: $SI_i = \frac{1}{R_i}\sum_{n-1}^{12}\left|X_{in} - \frac{R_i}{12}\right|$

Table A1 Temporal variation trends of WQI, HI, and R based on Mann Kendall test

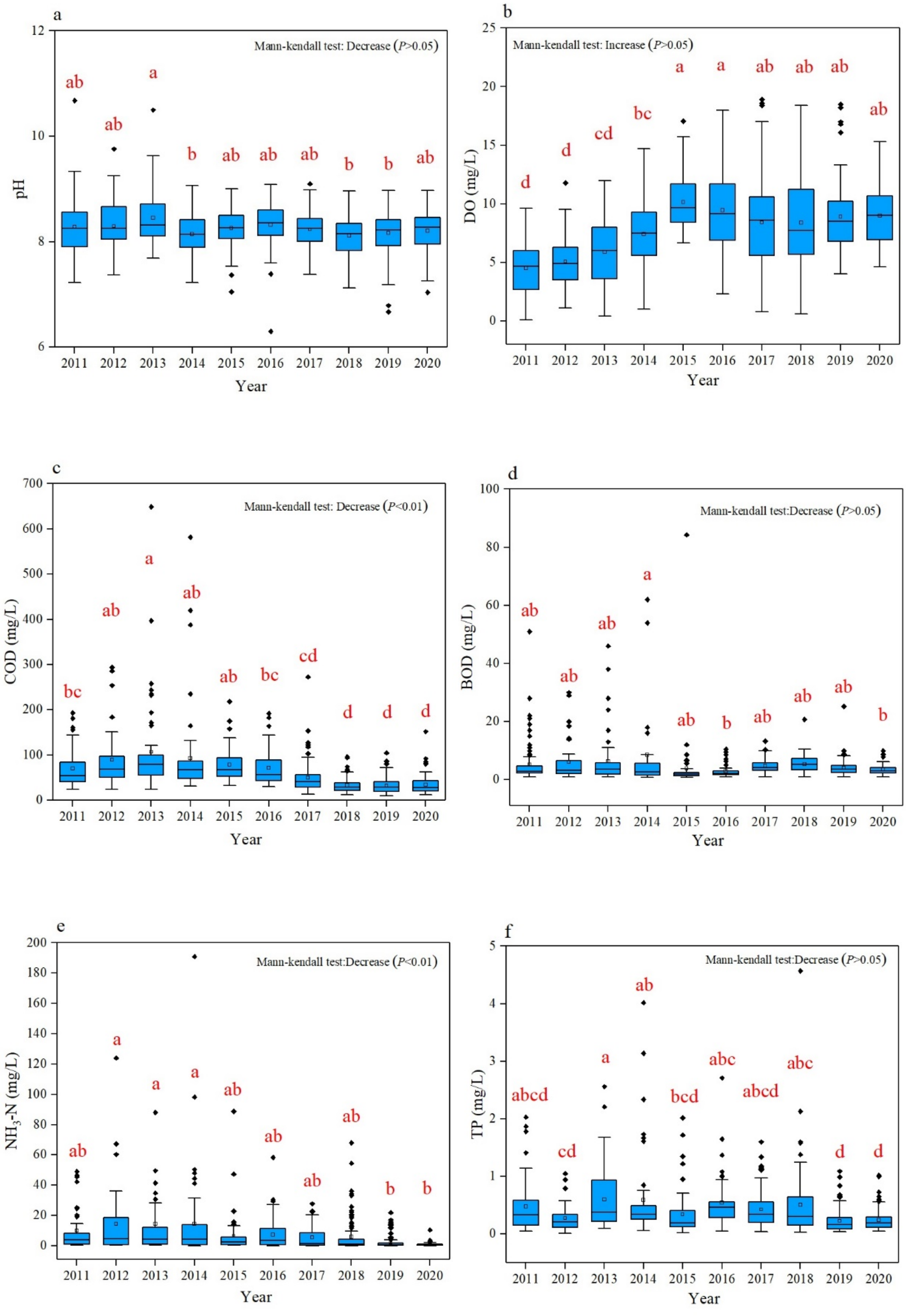
Sampling Sites	WQI	HI	R
S1	decrease**	decrease**	decrease**
S2	decrease*	decrease**	decrease**
S3	decrease*	decrease**	decrease*
S4	decrease*	decrease**	decrease**
S5	decrease**	decrease*	decrease*

S6	/	decrease*	decrease*

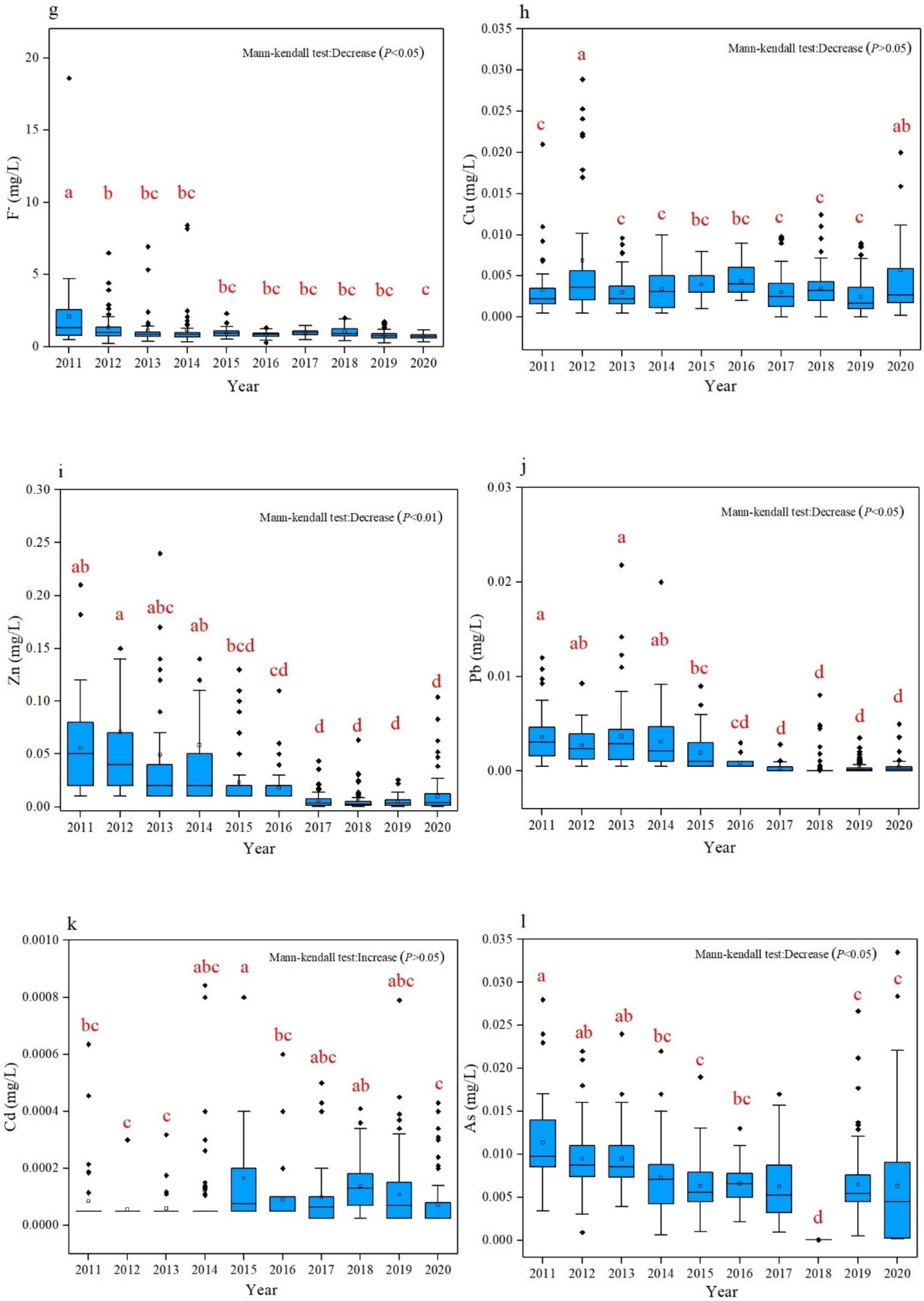
Notes: **indicates *P*<0.01, *indicates *P*<0.05, / indicates *P*>0.05

Table A2. Analysis methods and their resources, equipment, and detection limits for water quality parameters

Project	Methods	Resources	Equipment	Detection limit
pH	Measured in situ	/	Hach sensION$^+$ (USA)	0
DO	Measured in situ	/	Hach sensION$^+$ (USA)	0 mg/L
COD	Titration	GB 11914-1989	COD digester (KH COD 8Z,China)	5 mg/L
BOD	Dilution and seeding method	HJ 505-2009	Thermostatic incubator	2 mg/L
TP	Spectrophotometry	GB 11893-1989	Spectrophotometer (T6,China)	0.01 mg/L
NH_3-N	Spectrophotometry	HJ 535-2009	Spectrophotometer (T6,China)	0.025 mg/L
F^-	Ion selective electrode	GB/T 7484-1987	Ion meter (PXS-270,China)	0.05 mg/L
As	Fluorescence spectrometry	*Water and Wastewater Monitoring and Analysis Methods (4th Edition)*	Atomic fluorescence spectrometer (AF-630, China)	0.2 μg/L
Hg	Fluorescence spectrometry	*Water and Wastewater Monitoring and Analysis Methods (4th Edition)*	Atomic fluorescence spectrometer (AF-630,China)	0.04 μg/L
Cr^{6+}	Spectrophotometry	GB/T 7467-1987	Spectrophotometer (T6,China)	0.004 mg/L
Cu	FAAS	GB 7475-1987	Atomic absorption spectrometer (L-5000,Japan)	0.001 mg/L
Pb	FAAS	GB 7475-1987	Atomic absorption spectrometer (L-5000,Japan)	0.001 mg/L
Zn	FAAS	GB 7475-1987	Atomic absorption spectrometer (L-5000,Japan)	0.02 mg/L
Cd	FAAS	GB 7475-1987	Atomic absorption spectrometer (L-5000,Japan)	0.0001 mg/L



a
Mann-kendall test: Decrease (P>0.05)
pH
Year
b
Mann-kendall test: Increase (P>0.05)
DO (mg/L)
Year
c
Mann-kendall test: Decrease (P<0.01)
COD (mg/L)
Year
d
Mann-kendall test:Decrease (P>0.05)
BOD (mg/L)
Year
e
Mann-kendall test:Decrease (P<0.01)
NH3-N (mg/L)
Year
f
Mann-kendall test:Decrease (P>0.05)
TP (mg/L)
Year
2011 2012 2013 2014 2015 2016 2017 2018 2019 2020


g
Mann-kendall test:Decrease (P<0.05)
F⁻ (mg/L)
Year
h
Mann-kendall test:Decrease (P>0.05)
Cu (mg/L)
Year
i
Mann-kendall test:Decrease (P<0.01)
Zn (mg/L)
Year
j
Mann-kendall test:Decrease (P<0.05)
Pb (mg/L)
Year
k
Mann-kendall test:Increase (P>0.05)
Cd (mg/L)
Year
l
Mann-kendall test:Decrease (P<0.05)
As (mg/L)
Year

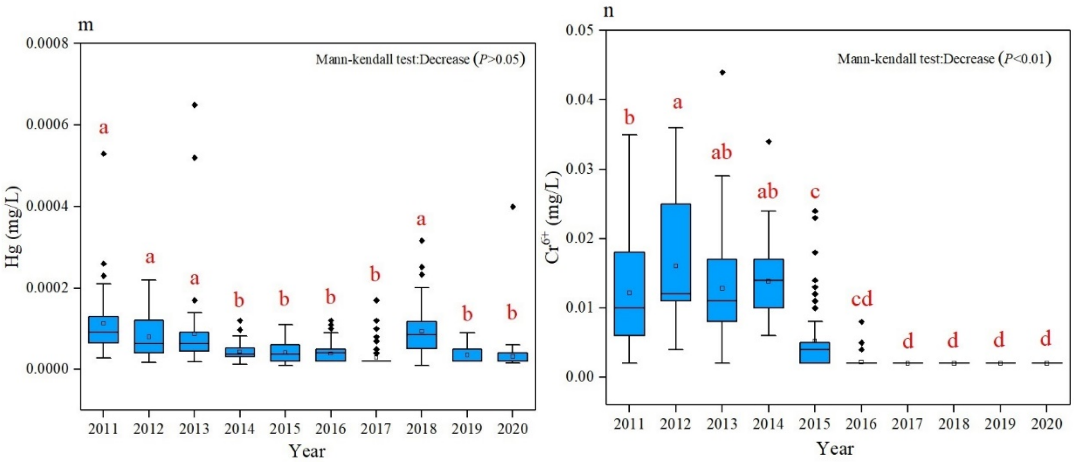
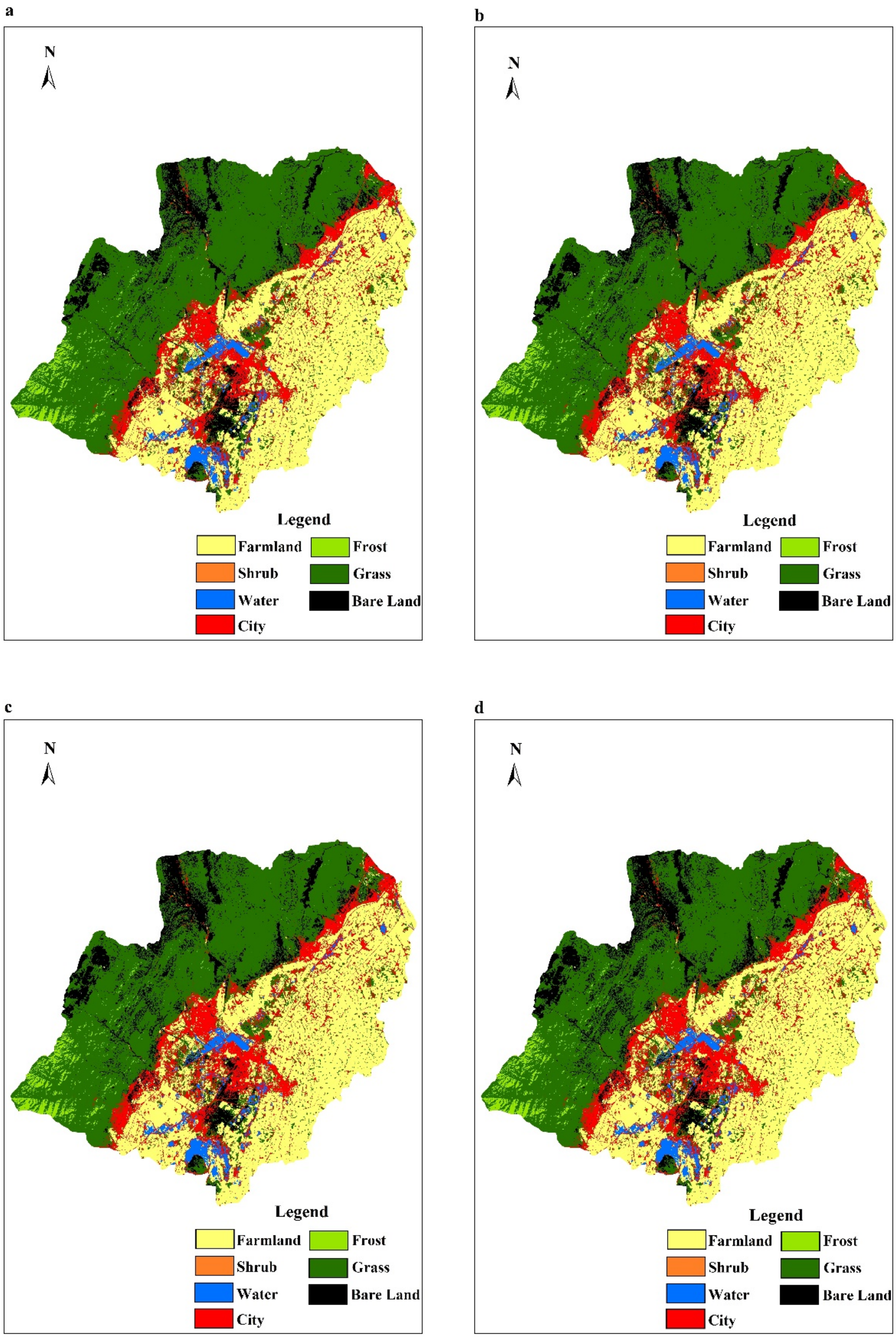


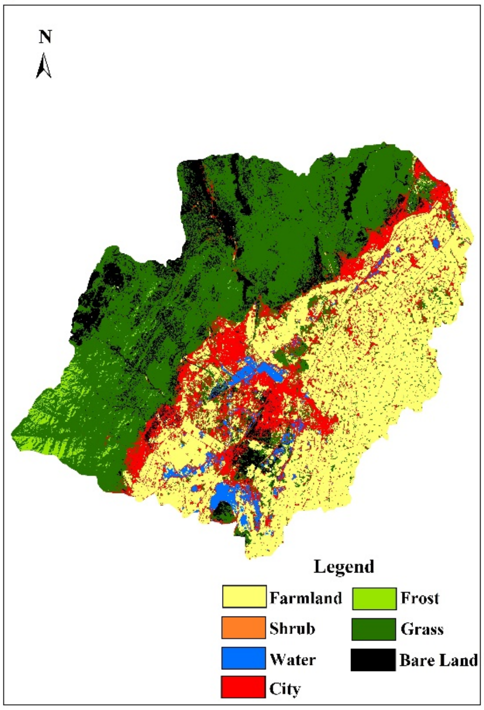
Fig. A1 Water quality indicators in Diannong River (Shizuishan section) from 2011 to 2020. (a) pH, (b) DO, (c) COD, (d) BOD, (e) NH_3-N, (f) TP, (g) F^-, (h) Cu, (i) Zn, (j) Pb, (k) Cd, (l) As, (m) Hg, (n) Cr^{6+}, completely different letters represent significant differences (P<0.05)

Table. A3 Land use in Diannong River (Shizuishan section) basin from 2011 to 2020

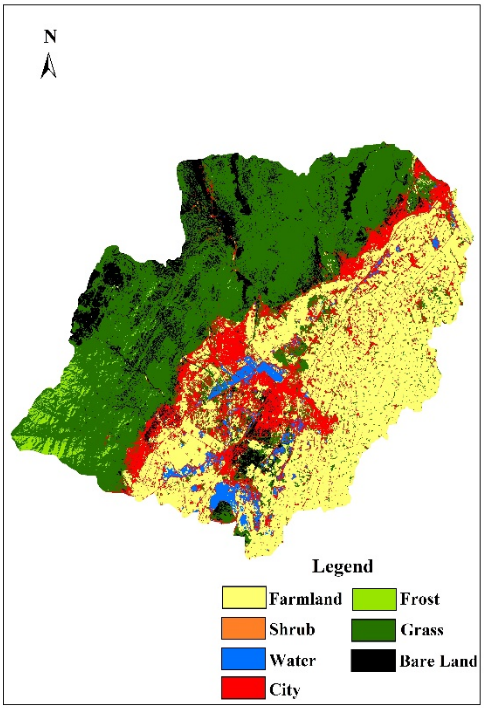
Year	agricultural land	forest	shrub	grassland	waters	naked ground	Impermeable surface
2011	32.32%	1.65%	0.0004%	44.10%	2.33%	8.40%	11.20%
2012	32.13%	1.65%	0.0003%	43.01%	2.33%	9.25%	11.63%
2013	31.98%	1.65%	0.0003%	41.31%	2.33%	10.36%	12.37%
2014	32.00%	1.65%	0.0003%	40.38%	2.33%	11.04%	12.60%
2015	32.23%	1.65%	0.0003%	40.47%	2.33%	10.44%	12.87%
2016	32.35%	1.66%	0.0003%	40.63%	2.36%	9.79%	13.20%
2017	32.62%	1.66%	0.0003%	41.59%	2.32%	8.31%	13.49%
2018	32.84%	1.66%	0.0003%	41.39%	2.28%	8.13%	13.69%
2019	33.10%	1.66%	0.0003%	41.63%	2.23%	7.59%	13.79%
2020	33.14%	1.66%	0.0003%	41.11%	2.12%	7.93%	14.04%


a
N
Legend
Farmland
Frost
Shrub
Grass
Water
Bare Land
City
b
N
Legend
Farmland
Frost
Shrub
Grass
Water
Bare Land
City
c
N
Legend
Farmland
Frost
Shrub
Grass
Water
Bare Land
City
d
N
Legend
Farmland
Frost
Shrub
Grass
Water
Bare Land
City

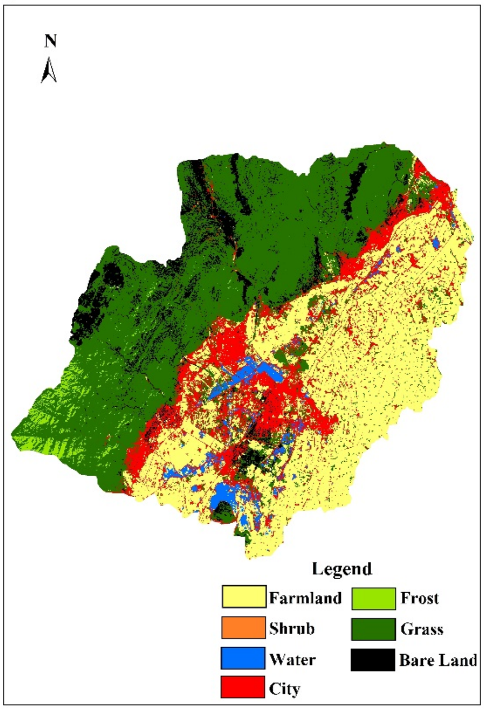
e


N
Legend
Farmland
Frost
Shrub
Grass
Water
Bare Land
City

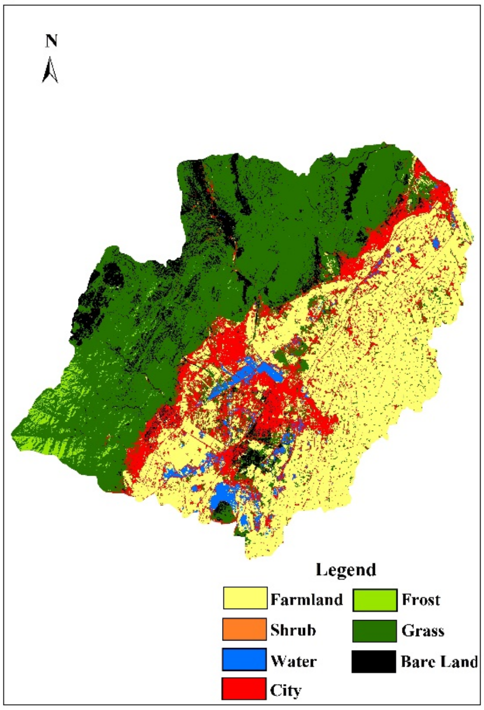
f


N
Legend
Farmland
Frost
Shrub
Grass
Water
Bare Land
City

g


N
Legend
Farmland
Frost
Shrub
Grass
Water
Bare Land
City

h


N
Legend
Farmland
Frost
Shrub
Grass
Water
Bare Land
City

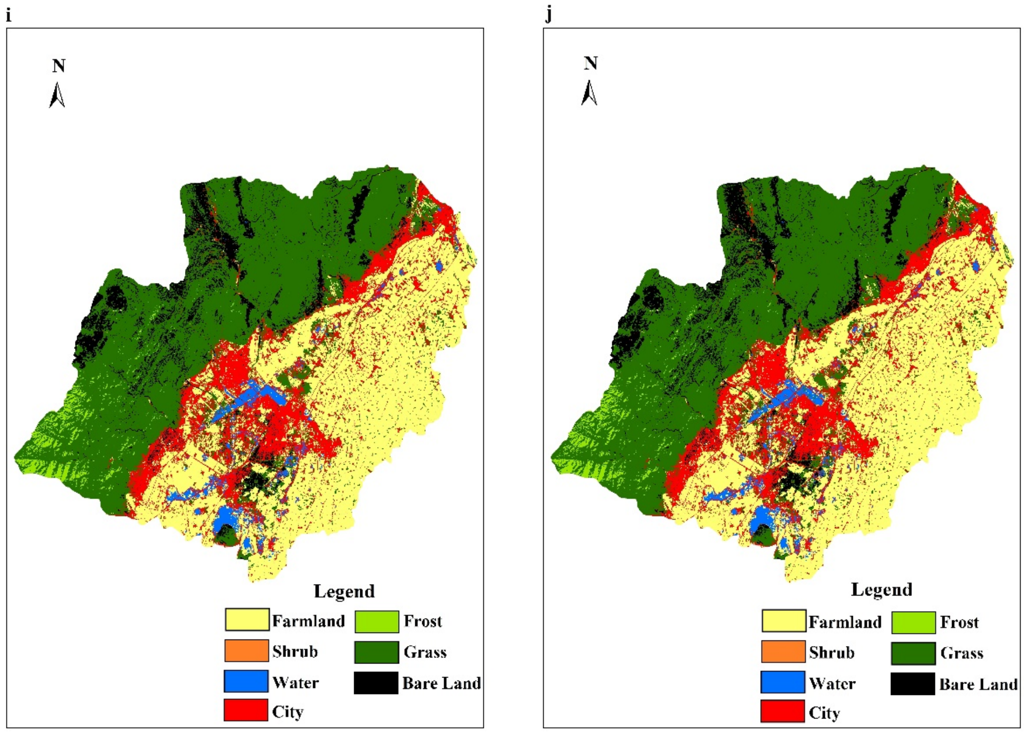


Fig. A2 Land use in Diannong River (Shizuishan section) basin from 2011 to 2020. (a) 2011, (b) 2012, (c) 2013, (d) 2014, (e) 2015, (f) 2016, (g) 2017, (h) 2018, (i) 2019, (j) 2020

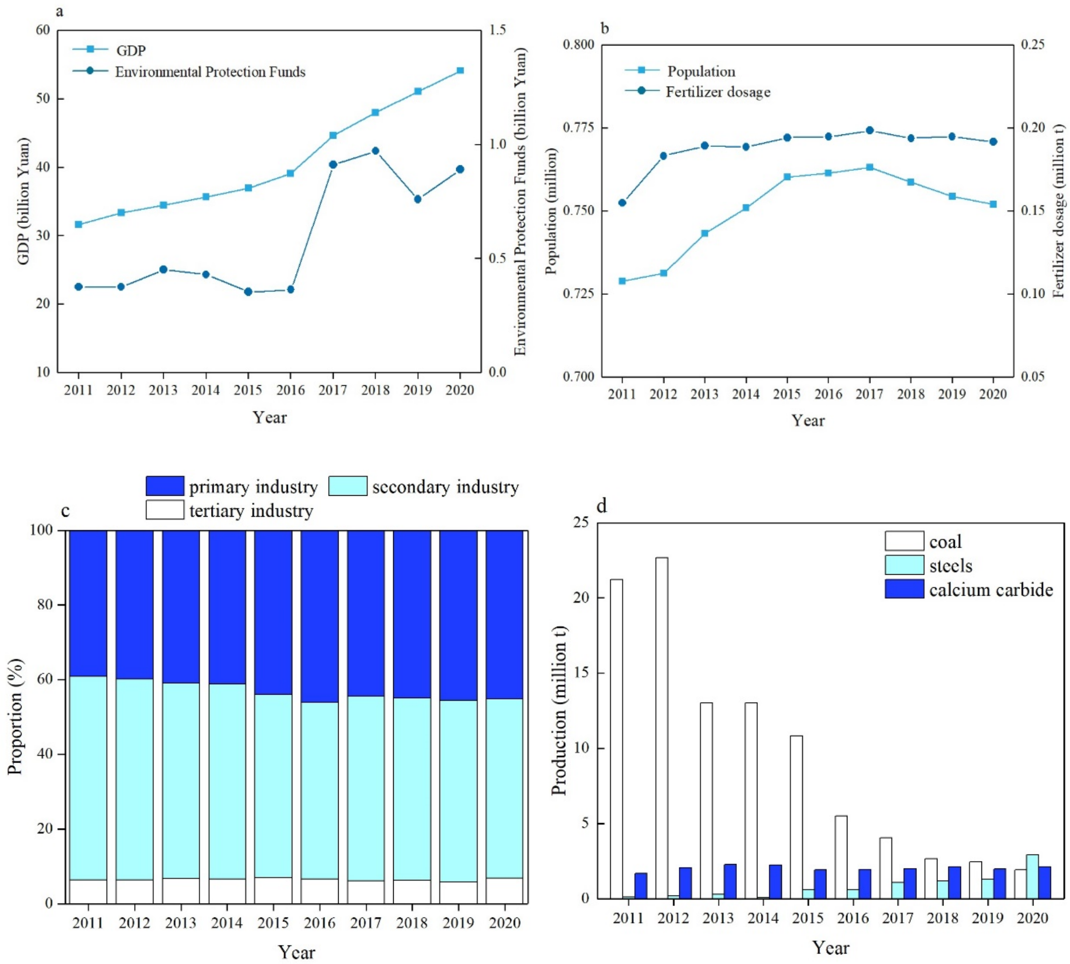


Fig. A3 Socio-economic indicators in Shizuishan City. (a) GDP and environmental protection funds, (b) Population and fertilizer dosage, (c) the proportion of different industries in GDP, (d) the output of main industrial products in Shizuishan

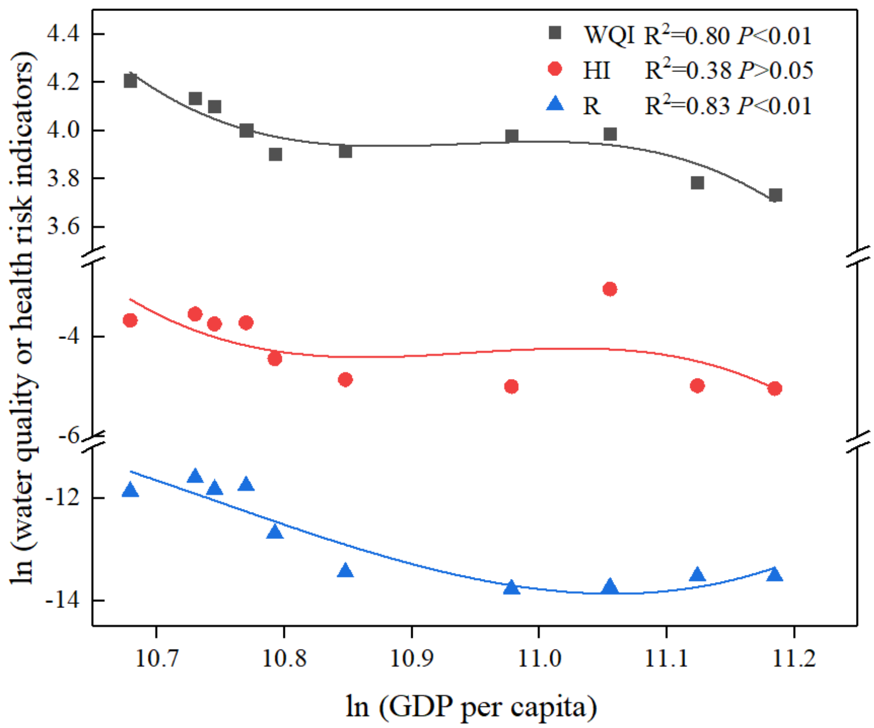


Fig. A4 The environmental Kuznets curve between GDP per capita and WQI, HI, and R

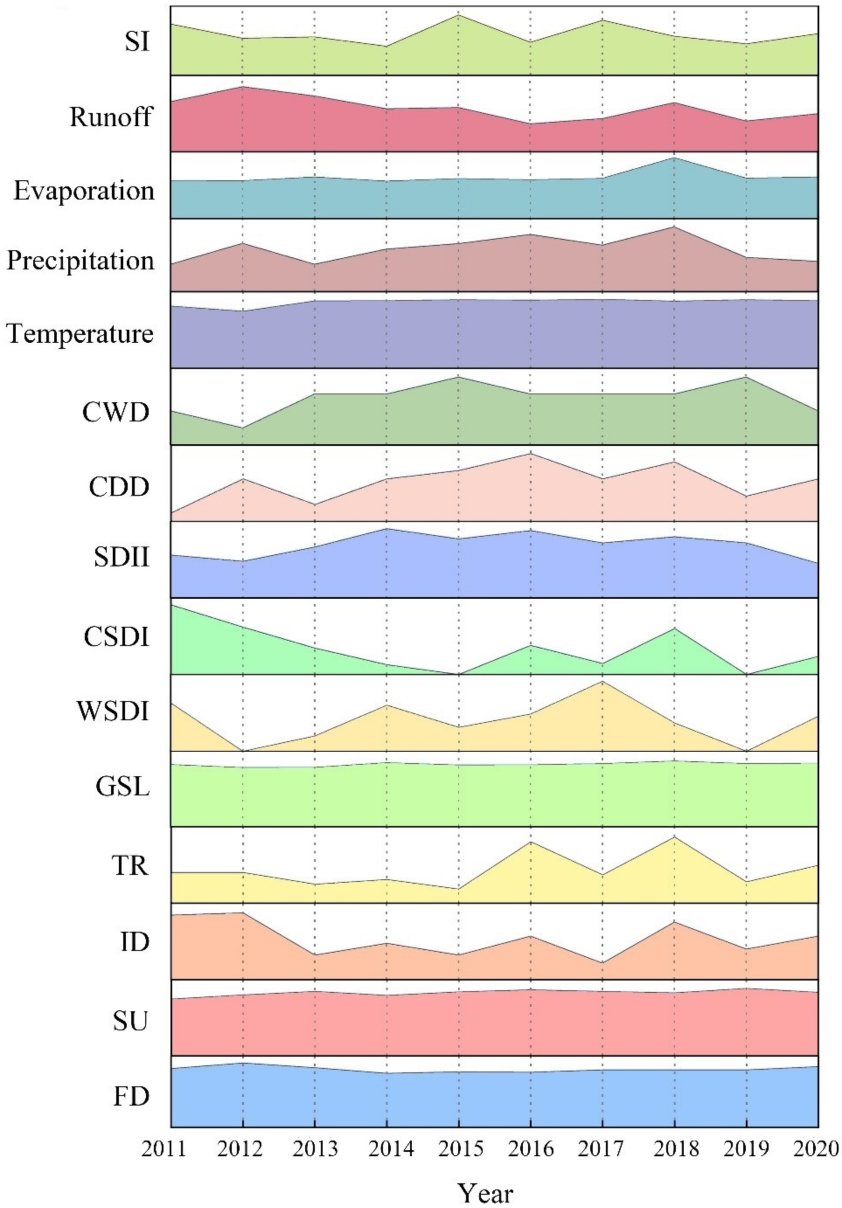


Fig. A5 Climate change indicators and runoff of Diannong river (Shizuishan section) basin from 2011 to 2020

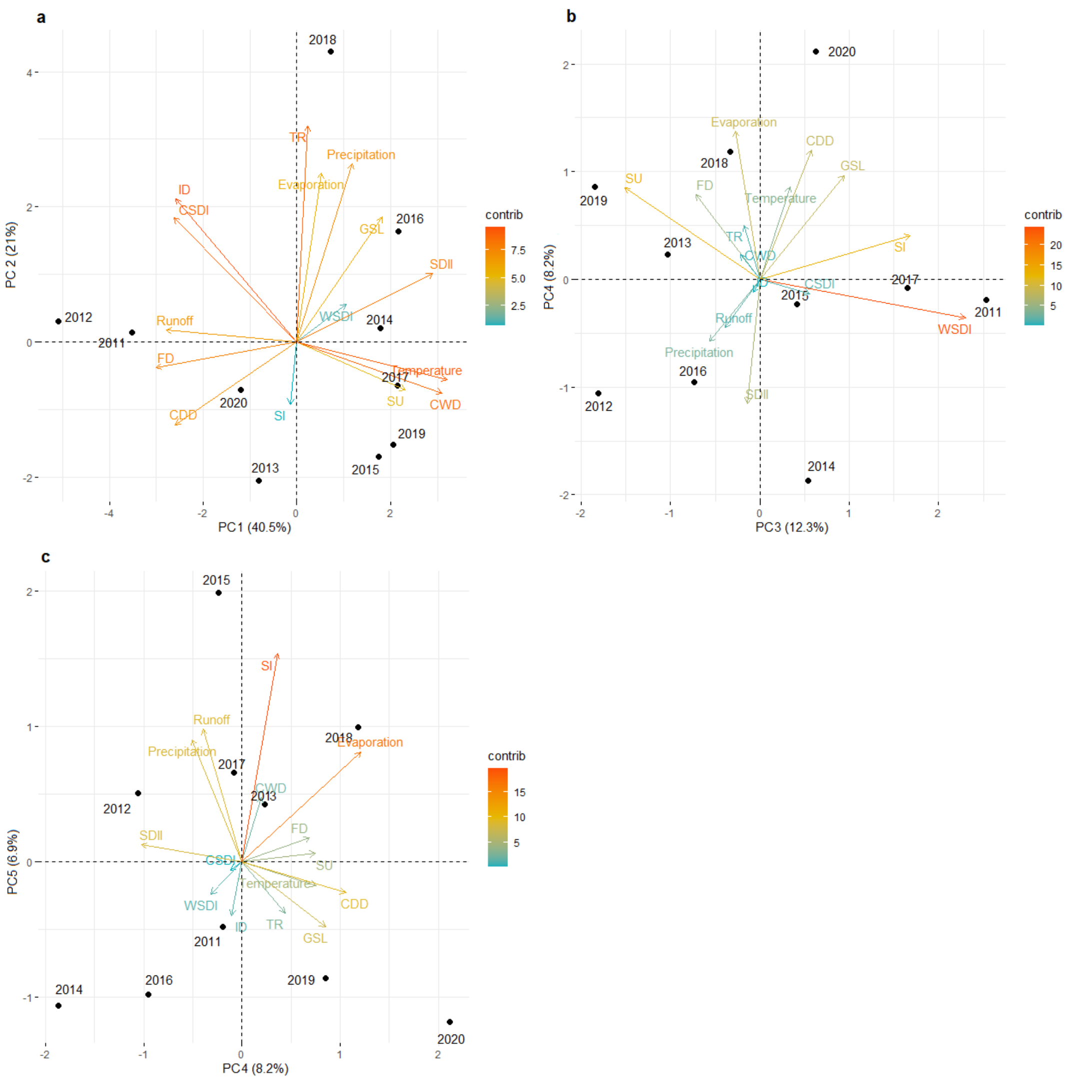


Fig. A6 PCA of climate change and hydrology indicators. (a) PC1 and PC2, (b) PC3 and PC4, (c) PC4 and PC5

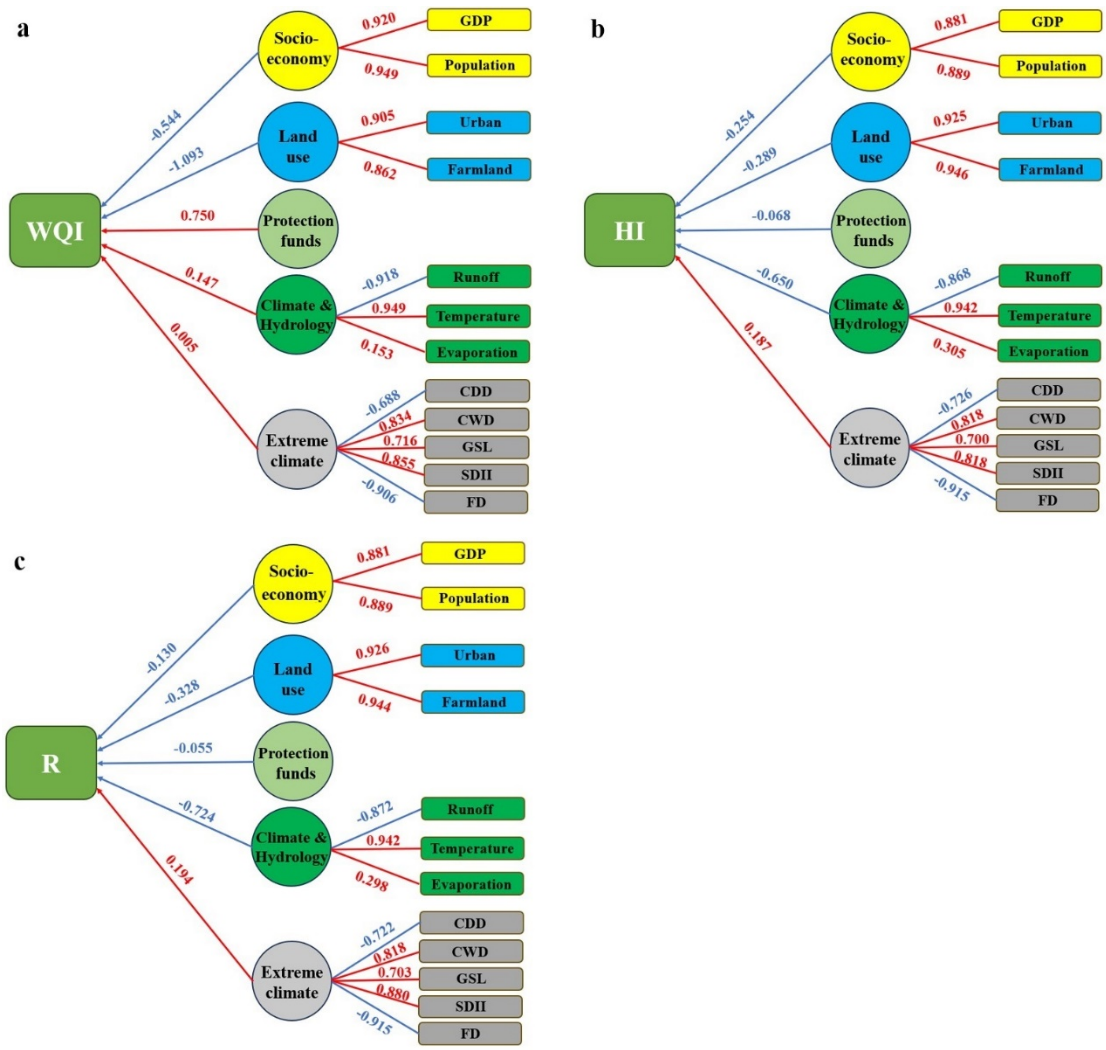


Fig. A6 PLS-PM including all of the parameters. (a) WQI, (b) HI, (c) R

Table A4 The standards of main water quality parameters for drinking water sources (GB 3838-2002, Class III) and irrigation water (GB 5084-2021) in China

Parameters	Standard for drinking water sources (GB 3838-2002, Class III)	Standard for irrigation water (GB 5084-2021)
pH	6~9	5.5~8.5
DO (mg/L)	⩾5	/
COD (mg/L)	20	200
BOD (mg/L)	4	100
NH_3-N (mg/L)	1	/
TP (mg/L)	0.2	/

F^-(mg/L)	1	2
Cu (mg/L)	1	1
Zn (mg/L)	1	2
Pb (mg/L)	0.05	0.2
Cd (mg/L)	0.005	0.01
As (mg/L)	0.05	0.1
Hg (mg/L)	0.0001	0.001
Cr^{6+} (mg/L)	0.05	0.1